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Original article

Monthly measurements of indoor allergens and the influence of housing type in a northeastern US city

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Key words: allergens; cat; cockroach; dust mite; seasonal variation.

Background: We examined seasonal variation of dust-mite (Der f 1 and Der p 1), cat (Fel d 1), and cockroach (Bla g 1) allergens in Boston, while adjusting for other covariates. Limited data are available on seasonal patterns of indoor allergen concentrations for different geographic regions in the USA. Understanding within-home seasonal variation of allergens is important epidemiologically and clinically.

Methods: From June 1995 to June 1996, dust samples were vacuumed monthly from the bed, bedroom floor, and kitchen of 20 homes. Indoor temperatures were measured monthly and used in calculating relative and absolute humidity. Monthly home characteristics questionnaires were completed by an adult resident of each home. Dust samples were assayed by enzyme-linked immunosorbent assays.

Results: Der f 1 and Der p 1 in beds and floors peaked in the autumn months, Fel d 1 peaked in winter and spring, and Bla g 1 was highest in summer. Dust-mite allergen concentrations were 1.9–2.4 times higher in autumn than spring, but the levels in beds were 19–31 times higher in houses than those in apartments. Although Fel d 1 levels in beds were 2.4 times higher in spring than summer, homes with cats had levels 224 times higher than those without cats. Similarly, Bla g 1 levels in kitchens were 2.1 times higher in summer than winter, but apartments had levels five times higher than those of houses.

Conclusions: Sampling season is a source of within-home dust-mite, cat, and cockroach allergen variation in the northeastern USA. However, the influence of housing type and owning a cat far outweighed the seasonal variation of these indoor allergens.

The views expressed in this paper are those of the authors and not necessarily those of the Food and Drug Administration.

Abbreviations: SD: standard deviation; ELISA: enzyme-linked immunosorbent assay; A_w : water activity; mAb: monoclonal antibody; BSA: bovine serum albumin; PBS: phosphate-buffered saline; T: Tween 20 solution; BBS: borate-buffered saline; LOD: limit of detection.

Several epidemiologic studies have investigated the association between allergen levels in homes and childhood asthma (1–5). Exposure assessment in many of these studies has relied upon cross-sectional sampling of dust to estimate allergen exposure. Definition of geographically specific patterns of indoor allergen concentrations would enable investigators to assess the extent to which the season of home sampling might influence the ability to compare exposure between homes. Identification of such seasonal patterns would reveal the timing of peak allergen levels and the season-dependent ranges of allergen levels that might be found within homes. An understanding of the timing of peak indoor allergen levels might also be useful to clinicians in advising sensitized patients.

In the four studies that have reported seasonal variation of dust-mite allergens in house-dust samples, dust-mite populations reached a peak in the summer, with dust-mite allergen concentrations peaking later in the autumn (6–9). In a Swedish study, the highest levels of cat allergen were during the period of October through December (8). However, these studies have been limited to climates different from the northeastern USA, and their sample sizes were limited by either a small number of homes studied or by few repeated sampling measurements. The objective of this study was to examine seasonal variation of dust-mite, cat, and cockroach allergens in the Greater Boston area, while adjusting for certain housing characteristics.

Material and methods

Study cohort

Twenty homes were selected on the basis of

- 1) proximity to the city of Boston
- 2) no use of acaricides
- 3) the assumption that occupants would not change residence during the year of follow-up
- 4) willingness of the resident to help with sample collection.

An adult resident of each home gave informed consent to be included in this study. All participants were Harvard

School of Public Health faculty, students, staff, or friends thereof.

Questionnaires

In each of the 20 homes from the greater Boston area, residents were asked to complete a brief home characteristics questionnaire for each month of sampling (from June 1995 through June 1996). Questions regarding floor surfaces that were vacuumed, layers and type of bedding, number of pillows on the bed, and whether or not the windows were open at the time of sampling were included. At the end of the study, a comprehensive home characteristics questionnaire was administered which inquired about building structure, type of heating, home dampness, and the presence of visible fungi, as well as other factors such as type of floor covering, presence of pets, and frequency of cleaning. Home characteristics of the study cohort are presented in Table 1.

Temperature and relative humidity measurements

On each sampling occasion, wet-bulb and dry-bulb temperatures were recorded with a Microscanner D-501 (Exergen Corporation, Newton, MA, USA) in the bedroom approximately 5–8 cm above the floor, and these measurements were used in calculating relative humidity. Absolute humidity was calculated from dry-bulb temperature and relative humidity with a psychrometric chart. Surface temperatures from the bed and the bedroom floor were obtained with the same instrument in order to calculate an approximation of water activity in these locations. Water

Table 1. Home characteristics of study cohort

Characteristic	Houses (n=7)	Apartments (n=13)
One or more cats present (n)	4	2
Report of cockroaches in past 12 months (n)	0	7
Carpeting in bedroom (n)	6	9
Location of bedroom (n)		
Basement	0	2
Ground level	0	1
First story	7	3
Second story	0	3
Third story	0	2
Fourth story	0	1
Sixth story	0	1
Air conditioner in living room or bedroom (n)	2	2

activity (A_w) represents the amount of water at a surface that is available to dust mites and other microorganisms and is comparable to relative humidity at the surface. A_w was calculated with surface temperature by assuming that the absolute humidity just above a given surface was equivalent to the absolute humidity at the surface, and that water vapor in air was the only water source.

Dust collection

Dust samples were collected by the same person (either a resident of the home or a technician) each month for 13 months. Persons collecting dust samples were trained to follow a standardized protocol. A Eureka Mighty-Mite II canister vacuum cleaner (Model 3621, Eureka Co., Bloomington, IL, USA) was modified to collect dust in a 19×90-mm cellulose extraction thimble (Whatman International, Ltd, UK). All surfaces that could contact the thimble, possibly causing cross-sample contamination, were cleaned with isopropanol between each sample collection. Separate dust samples were collected from the bed, bedroom floor, and kitchen according to the following standardized protocols. All layers of bedding, including mattress and pillows, were vacuumed for 5 min. A separate thimble of dust was collected from the bedroom floor by vacuuming 2 m² of the floor adjacent to the bed for 5 min. In kitchens, the floor was vacuumed for 5 min, concentrating on edges by cabinets, inside cabinets under the sink, and around the refrigerator. If a rug was present in the bedroom or kitchen, at least 1 min was devoted to sampling the rug. After sampling, each thimble was sealed in a plastic bag and returned to the laboratory the same day for sifting and weighing.

Dust extraction and allergen analysis

Each dust sample was sieved through a 425-μm mesh, the fine dust was weighed, and a portion was extracted in borate-buffered saline (BBS), pH 8.5 (25 mg/ml), for 2 h at room temperature (10). Dust extracts were serially diluted in phosphate-buffered saline (PBS) with 1% bovine serum albumin (BSA) and 0.05% Tween 20 (BSA-PBS-T), pH 7.4. Two-site monoclonal antibody (mAb) immunoassays for Der p 1, Der f 1, and Fel d 1, and a mAb/polyclonal immunoassay for Bla g 1 were used (Indoor Biotechnologies, Clwyd, UK) (10–12). However, the reactions were not stopped with sodium azide, and optical density was measured at 15-s intervals for a total of 5 min with a CERES900C microtiter plate reader (Bio-tek Instruments,

Winooski, VT, USA). Allergen concentrations were reported in μg/g of dust except for Bla g 1 which was reported in units/g (U/g) of dust. Bedroom dust samples were analyzed for the already mentioned allergens except for Bla g 1. Kitchen dust samples were analyzed only for Bla g 1.

Statistical analysis

Allergen concentrations, temperature, and humidity measurements were analyzed as continuous variables. Allergen measurements below the limit of detection (LOD) were assigned a value of half the LOD for the specific allergen. Normality of these data was tested with a Wilks-Shapiro test statistic. When data were not normally distributed, they were log-transformed and tested again for normality. Home characteristics were dichotomized. When a home characteristic changed, the change was incorporated into the data analysis. Sampling seasons were categorized as winter (November–March), spring (April–May), summer (June–August), and autumn (September–October), according to Boston's climate.

Seasonal variation in Der f 1, Der p 1, Fel d 1, and Bla g 1 was assessed with a repeated measures analysis (13). Repeated measures analysis takes into account the correlation between repeated measurements from each home. Linear mixed effects models were fit for each allergen with a random effect for each home and fixed effects for the following covariates: temperature (air and surface of bed and floor), relative humidity, absolute humidity, water activity of bed and floor, season, type of building (i.e., house vs apartment), and presence of a cat. Variables with statistical significance were chosen for the final models. When multiple variables were predictive of allergen levels, the difference between −2 log-likelihood estimates was compared to a chi-square distribution to test whether the multivariate model was significantly better than the univariate model. Mixed effects models were also created to test differences in temperature, relative humidity, and absolute humidity between apartments and houses. All data were analyzed with SAS statistical software (SAS Institute, Cary, NC, USA) (14).

Results

Temperature and humidity

Average ambient indoor temperature and relative humidity for each sampling month are shown in Fig. 1. Apartments

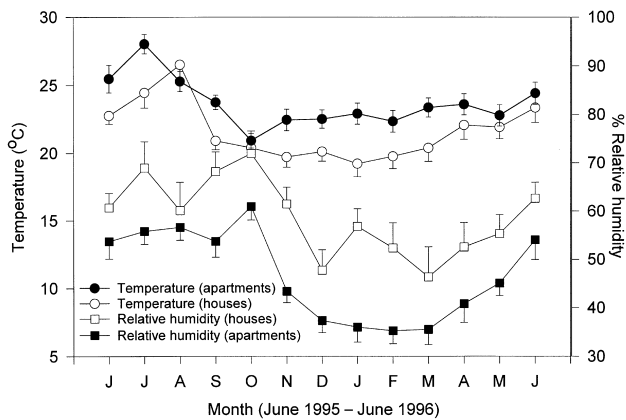


Figure 1. Indoor temperature and humidity averages for each sampling month.

tended to have hotter and drier interiors than those of houses during all seasons. These differences were most pronounced during winter. The mean ambient temperature in apartments during winter months, 23°C, was significantly higher than that in houses, 20°C, with a *P* value from a mixed effects model of 0.0060. Absolute humidity (6.6 g/kg) and relative humidity (38%) in apartments during winter months were lower than the respective humidities in houses: 7.8 g/kg and 53% (*P*=0.0842 and *P*=0.0005). Apartments experienced a greater decrease in relative humidity from October to November than did houses: 61% to 43% vs 72% to 62%. Average relative humidity remained below 40% for four winter months in apartments, but rarely fell below 40% for any month in houses.

Allergens

Figs. 2–5 illustrate the monthly variations in allergen levels from June 1995 through June 1996. Overall, type of building

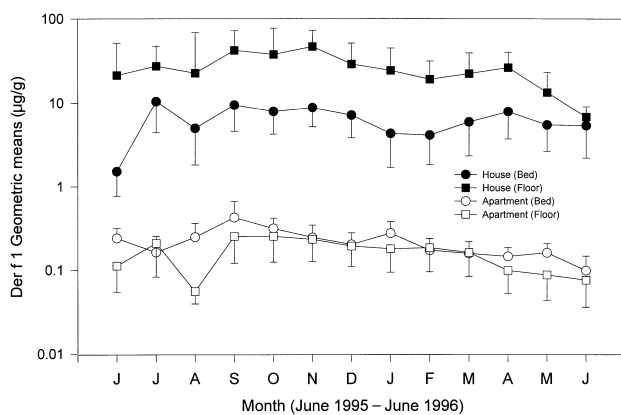


Figure 2. Der f 1 concentrations in bed and floor dust of houses and apartments. Bars represent one standard error from geometric mean.

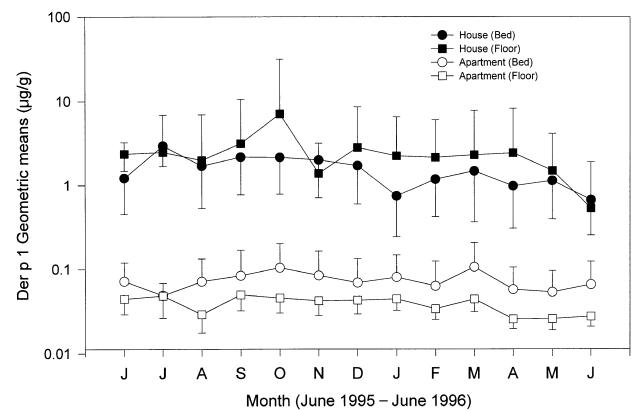


Figure 3. Der p 1 concentrations in bed and floor dust of houses and apartments. Bars represent one standard error from geometric mean.

predicted average concentrations of dust-mite and cockroach allergens, while presence of one or more cats predicted average concentrations of cat allergen. These primary factors far outweighed seasonal effects. However, within each of these major categories, seasonal patterns were observed. Other categorical variables such as presence of carpeting, type of bedding, and report of cockroaches were not significant predictors of allergen levels in our study.

Dust-mite allergen

Der f 1 and Der p 1 levels increased from August to peak in September and October, then decreased through June (Figs. 2 and 3). However, many of the standard error bars overlap because the graphical display of mean level of allergen does not adjust for correlation within each home. Adjusting for correlation within home, dust-mite allergen levels in the bed were 1.8 to 2.2 times higher in autumn than the referent season, spring (Table 2). Similar increases of 1.9 and 2.4 were observed for levels of Der p 1 and Der f 1 in floor dust.

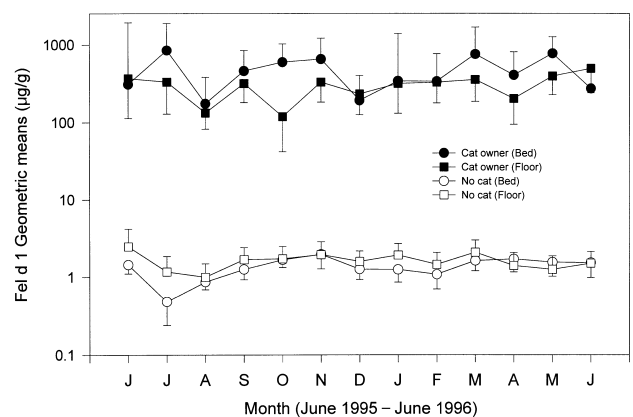


Figure 4. Fel d 1 concentrations in bed and floor dust of homes with and without cats. Bars represent one standard error from geometric mean.

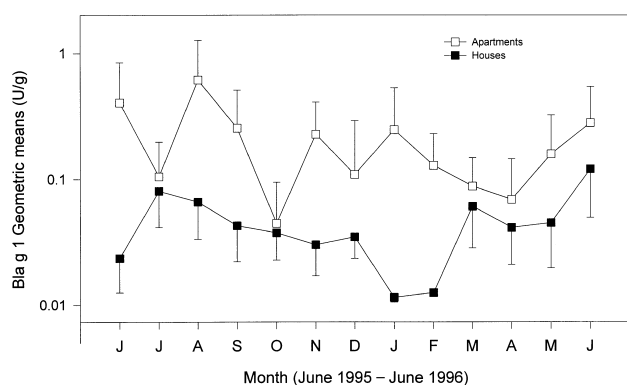


Figure 5. Bla g 1 concentrations in kitchens of houses and apartments. Bars represent one standard error from geometric mean.

Increased ambient and surface temperatures at the time of dust collection were also independent predictors for lower levels of Der p 1 (beds and floors) and Der f 1 (floors). However, none of the humidity or water activity measurements were significantly associated with any of the simultaneous allergen measurements. When winter surface temperatures were averaged for each home, increases in this variable were significantly associated with decreases in both dust-mite allergens in bed dust samples. Similar results were found for both dust-mite allergens in floor dust. Increases in average winter relative humidity and absolute humidity

were associated with increases in Der f 1 and Der p 1 in bed and floor dust, although the relationship between winter absolute humidity and Der p 1 levels did not reach statistical significance.

In univariate analyses, the strongest predictor for dust-mite allergen concentration was type of building, with levels in beds 19–31 times higher in houses than those in apartments (Table 2). In floor dust samples, levels of Der p 1 and Der f 1 in houses were 56 (95% CI 11–292) and 148 (95% CI 24–919) times higher, respectively, than those in apartments. Multivariate models that include building type, season, and average surface temperature during winter are presented in Table 3. When average indoor winter surface temperature rather than temperature at time of sample collection was used in predicting Der p 1 in bed dust, the model was significantly improved over that using building type alone to predict Der p 1 levels in the bed. The parameter estimate for building type decreased from 19.5 to 1.1 and was no longer significant. The inclusion of mean indoor winter temperature in the models for Der f 1 in bed dust and Der p 1 in floor dust also tended to decrease the parameter estimates for building type. Thus, in the final multivariate models, we adjusted for this potential confounder even when it was not statistically significant.

Table 2. Univariate models for dust-mite allergens (Der f 1 and Der p 1) in beds

Predictors	Ratio of predictor to reference category or level with 95% confidence interval*	
	Der f 1	Der p 1
Season		
Spring	Reference	Reference
Summer	0.9 (0.7–1.2)	1.4 (1.0–2.0)
Autumn	1.8 (1.3–2.5)‡	2.2 (1.5–3.2)‡
Winter	1.2 (0.9–1.5)	1.4 (1.0–1.9)
Home type		
Apartment	Reference	Reference
House	30.9 (9.2–104.1)‡	19.5 (2.5–152.6)‡
Absolute humidity (g/kg)†	0.9 (0.8–1.1)	0.9 (0.7–1.0)
Relative humidity (%)†	1.0 (0.9–1.2)	1.1 (0.9–1.3)
Ambient temperature (°C)†	0.9 (0.8–1.0)	0.8 (0.7–1.0)‡
Surface temperature (°C)†	0.9 (0.8–1.1)	0.8 (0.7–0.9)‡
Water activity†	1.0 (0.9–1.2)	1.1 (0.7–1.6)
Average winter absolute humidity (g/kg)†	3.7 (1.3–10.0)‡	1.5 (0.4–6.3)
Average winter relative humidity (%)†	6.8 (4.1–11.3)‡	5.3 (1.9–14.4)‡
Average winter surface temperature (°C)†	0.2 (0.1–0.4)‡	0.1 (0.0–0.2)‡

*Ratios and 95% confidence intervals in this table were back-transformed to original scale instead of log-scale.
†Ratios and 95% confidence intervals were estimated for interquartile range (25th–75th percentile) change in predictor variable.
‡P<0.05.

Table 3. Multivariate models for dust-mite allergens

Predictors	Ratio of predictor to reference category or level with 95% confidence interval*			
	Bed dust samples		Floor dust samples	
	Der f 1	Der p 1	Der f 1	Der p 1
Home type				
Apartment	Reference	Reference	Reference	Reference
House	10.9 (2.5–47.5)‡	1.1 (0.2–6.6)	130.3 (11.7–1452.1)‡	12.9 (2.0–83.3)‡
Season				
Spring	Reference	Reference	Reference	Reference
Summer	0.9 (0.7–1.2)	1.4 (1.0–1.9)	1.2 (0.8–1.6)	1.2 (0.8–1.6)
Autumn	1.8 (1.3–2.5)‡	2.2 (1.5–3.2)‡	2.4 (1.6–3.5)‡	1.9 (1.4–2.8)‡
Winter	1.2 (0.9–1.5)	1.4 (1.0–1.9)‡	1.8 (1.3–2.5)‡	1.5 (1.1–2.0)‡
Average surface temperature during winter (°C)†	0.6 (0.4–1.0)‡	0.3 (0.2–0.5)‡	0.9 (0.5–1.9)	0.5 (0.3–0.9)‡

*Ratios and 95% confidence intervals in this table were back-transformed to original scale instead of log-scale.
† Ratios and 95% confidence intervals were estimated for interquartile range (25th–75th percentile) change in predictor variable.
‡ $P < 0.05$.

Cat allergen

Spring and autumn levels of cat allergen in bed dust samples were 1.8 and 1.7 times higher, respectively, than the levels in summer, adjusting for presence of a cat in the home. The strongest predictor of cat allergen levels was presence of a cat in the home (Table 4), although cat allergen was detectable in all 14 homes without cats. The addition of the variable, season, did not significantly improve prediction of Fel d 1 in floor dust. Cat allergen measurements were not significantly associated with temperature or humidity measurements.

Table 4. Univariate models for cat allergen (Fel d 1) in beds and on floors

Predictors	Ratio of predictor to reference category with 95% confidence interval*	
	Fel d 1 in bed	Fel d 1 on floor
Season		
Spring	2.4 (1.6–3.6)†	1.3 (0.9–2.0)
Summer	Reference	Reference
Autumn	2.1 (1.4–3.3)†	1.3 (0.9–1.8)
Winter	1.7 (1.2–2.4)†	1.7 (1.3–2.3)†
Cats in home		
No	Reference	Reference
Yes	223.6 (100.1–499.5)†	137.0 (63.8–294.2)†

*Ratios and 95% confidence intervals in this table were back-transformed to original scale instead of log-scale.
† $P < 0.05$.

Cockroach allergen

Bla g 1 levels were twice as high in summer than in winter, but there was little difference in spring or autumn compared to winter. Cockroach allergen levels were most strongly associated with building type, with houses having lower Bla g 1 levels than apartments (Table 5). Cockroach allergen

Table 5. Univariate models for cockroach allergen (Bla g 1) in kitchens

Predictors	Ratio of predictor to reference category or level with 95% confidence interval*
Season	
Spring	1.0 (0.5–1.8)
Summer	2.1 (1.2–3.6)‡
Autumn	0.9 (0.5–1.8)
Winter	Reference
Home type	
Apartment	Reference
House	0.2 (0.1–0.8)‡
Absolute humidity (g/kg)†	1.0 (1.0–1.0)
Relative humidity (%)	1.0 (0.7–1.4)
Ambient temperature (°C)	1.1 (1.2–1.5)‡

*Ratios and 95% confidence intervals in this table were back-transformed to original scale instead of log-scale.
† Ratios and 95% confidence intervals were estimated for interquartile range (25th–75th percentile) change in predictor variable.
‡ $P < 0.05$.

levels were not significantly associated with temperature or relative humidity measurements.

Of the 11 homes with a maximum Bla g 1 measurement of ≥ 2 U/g, nine also had a minimum value below the limit of detection sometime during the year. Only four of these 11 homes had a yearly average Bla g 1 of ≥ 2 U/g. Conversely, of 18 homes with at least one month of nondetectable Bla g 1, nine had at least one measurement of Bla g 1 ≥ 2 U/g. Although all but one home had at least one month with detectable Bla g 1 in the kitchen, none of the homes were highly infested.

Within-home vs between-home variability

Season was a weaker predictor of allergen levels than other factors such as “presence of a cat” for Fel d 1 and “building type” for dust-mite and cockroach allergen. These other factors were, for the most part, sources of between-home variation, whereas season was a source of within-home variation. Fig. 6 displays the distribution of Der f 1 in the bed, by home. This plot shows that variability between homes was larger than that within homes. The distributions were similar for dust-mite allergens in other locations. Specifically, the between-home standard deviations were 7.4, 25.2, 48.3, and 45.3 $\mu\text{g/g}$, respectively, for Der p 1 and Der f 1 in the bed, and Der p 1 and Der f 1 in the floor. Within-home standard deviations were 2.5, 5.4, 6.9, and 16.0 $\mu\text{g/g}$, respectively. Between-home standard deviations were 1238 and 1124 $\mu\text{g/g}$, respectively, for Fel d 1 in bed and floor dust samples, whereas within-home standard deviations were 145 and 102 $\mu\text{g/g}$, respectively. Between-home standard

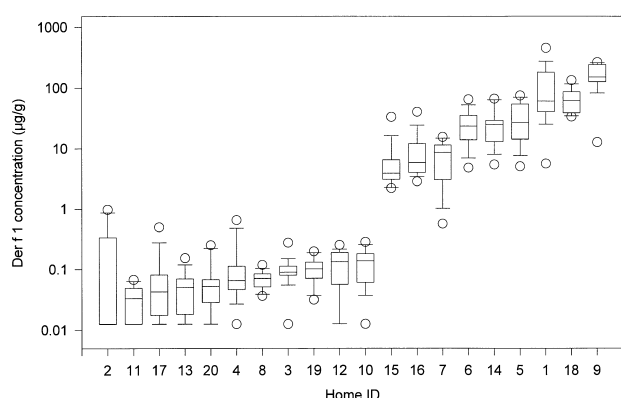


Figure 6. Der f 1 concentrations in bed dust, by home identification (ID). Bottom, middle, and top lines of each box represent 25th, 50th (median), and 75th percentiles of each home's Der f 1 concentration in bed dust. Bottom and top bars indicate 10th and 90th percentiles. Circles represent outliers.

deviation of Bla g 1 in the kitchen was 1.2 U/g, and within-home standard deviation was 1.3 U/g.

Discussion

In this northeastern US study, Der f 1 and Der p 1 levels were highest in autumn and decreased through spring. The observation of an increase in dust-mite allergen levels during autumn agrees with other studies from the USA and Japan (6, 7, 9). Dust-mite populations are reportedly cyclic, with a summer peak and a winter low. The lag in peak allergen levels behind the peak in dust-mite populations has been attributed to persistence of allergen in the environment even after the dust mites have died. Season is a surrogate measure for a combination of climatic factors that appear to affect dust-mite populations. Temperature alone, as a continuous linear variable, did not predict dust-mite allergen levels in our models as well as the variable, season. However, average winter temperature and humidity measurements were strong predictors of dust-mite allergen concentrations in bed-dust samples, even though these averages were obtained from only five spot measurements from November through March. These winter conditions may affect each home's baseline dust-mite population and are important in adjusting for the modeling of seasonal variation.

In our study, the strength of the associations between type of building and dust-mite allergen levels far outweighed the seasonal associations. Studies in The Netherlands and Denmark have also demonstrated higher levels of dust-mite allergens in houses than in multistory apartments (15–17). However, the type of building was no longer a significant predictor of Der p 1 in the bed when average winter surface temperature was placed in the model. For Der p 1 on the floor and Der f 1 in the bed, the effect-estimates for type of building remained significant, but were reduced in magnitude when average winter surface temperature was added to the models. Thus, type of building explained some additional variation in dust-mite allergen levels that average winter surface temperature could not explain. As shown in laboratory studies, the combined effect of temperatures greater than 15°C and A_w of 0.45–0.55 (microenvironmental RH of 45–55%) decreases the survival of dust mites (18). As temperature increases, dust mites require a higher A_w to survive (18–20). In particular, *Dermatophagoides pteronyssinus* has been shown to be more sensitive than *D. farinae* to heat as a stressor (19). It is biologically plausible that average winter surface temperature had a greater effect on

D. pteronyssinus, and this subsequently led to the lower level of Der p 1 allergen in apartments. However, the effect of small temperature changes (increase or decrease of 2–4°C in the range of ambient temperatures of 15–25°C) on dust-mite populations is currently unknown.

As has been previously reported, the major controlling factor for levels of cat allergen in residences is presence or absence of a cat (8, 21). When we adjusted for the presence of a cat, a weak, but significant seasonal pattern in Fel d 1 levels was observed. The Fel d 1 levels in beds were lowest in the summer months. In homes with cats, cat-allergen levels never fell below 1 µg/g, a level which has been associated with sensitization to cat allergen (22). However, all “non-cat” homes had detectable cat allergen, and many had maximum levels exceeding 1 µg/g.

Factors that might control seasonality of cat-allergen levels remain obscure. We speculate that this pattern is associated with fur shedding cycles. The peak cat-allergen months reported for Sweden were October through December (8). The authors ascribed the increase to cats spending more time inside during the colder months, a fact which could explain why Fel d 1 in floor dust was highest during the winter in our study.

The presence of Fel d 1 in homes without cats was probably dependent upon factors such as family members and friends with cats visiting the home or residents visiting places that had high levels of cat allergen. Seasonal variation in these noncat homes could be explained in the same way; during peak seasons, more allergen in the “source” homes would be available for transport to, and deposition in, the noncat homes.

The highest levels of Bla g 1 were recovered in June and August. Mollet et al. also found that Bla g 2, another *Blattella germanica* allergen, peaks in August, and suggested that cockroach allergen levels lag approximately 2 months behind the peak in the cockroach population (23). The authors attribute the lag to the accumulation of dead bodies, cast skins, and feces that have significant amounts of allergen (24, 25). Studies investigating the persistence of cockroach allergen in dust are needed to confirm these hypotheses.

Mean levels of Bla g 1 were higher in apartments than in houses. The higher frequency of cockroach infestation in apartments is often attributed to the difficulty of exterminating populations in an entire building. Infestations can

easily spread from one apartment to another. Moreover, apartments with occupants who do not want their area sprayed might harbor cockroach populations that can readily migrate to other apartments.

The between-home range of cockroach allergen levels was limited in this sample, which did not include heavily infested homes. The observation that within- and between-home variability was similar may apply only to a relatively low range of exposures. Other locations in the homes were not sampled and assayed for Bla g 1; however, the feeding location of cockroaches is usually the kitchen, and we speculate that observed seasonal variation will mirror variation in other locations with similar food sources.

The observed seasonal patterns in dust-mite, cat, and cockroach allergens indicate overall trends that one might expect of homes in a temperate climate; however, individual homes in other regions may have different seasonal patterns. The sample size of 20 homes (i.e., 260 home visits) was sufficient to show statistically significant seasonal variation of all measured allergens. For logistical reasons, many of the homes were sampled by a resident. Because the aim of our study was to identify season trends in allergen concentrations per gram of dust, the consistency of the same person sampling the home each month and the adjustment for this factor in our statistical models should have minimized the effects of individual sampling techniques.

Although the presence of a cat was the strongest predictor of high cat-allergen concentrations in house dust, and living in an apartment was the strongest predictor of having low dust-mite and high cockroach allergen levels, the knowledge of seasonal variation improves the exposure estimate for these allergens. This more precise estimation of peak, average, and season-specific allergen exposure may be useful in the assessment of associations between allergen exposure and the development or exacerbation of asthma. However, clinicians and researchers alike should realize that other factors can have a greater impact than season on allergen levels in dust reservoirs.

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