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Predictors of indoor exposure to mouse allergen in urban and suburban homes in Boston

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Abstract

Background—Mouse allergen exposure is prevalent among urban children with asthma. Little is known about mouse allergen exposure in children at risk for the development of allergic diseases.

Aims of the study—To assess indoor mouse allergen exposure in early life among children with parental history of asthma or allergies.

Methods—Prospective birth cohort study of 498 children with a history of allergy or asthma in at least one parent living in metropolitan Boston.

Results—Of the 498 participating children, 357 (71.7%) resided outside the city of Boston and 439 (90.7%) lived in households with incomes >$30 000. Mouse allergen was detected in 42% of the homes of study participants. In a multivariate analysis adjusting for sex, income, and endotoxin, black race [odds ratio (OR) = 3.0; 95% confidence interval (CI) = 1.3–6.6, $P = 0.009$], signs of mice in the home at age 2–3 months (OR = 3.0; 95% CI = 1.6–5.6, $P = 0.0006$), and kitchen cockroach allergen levels ≥0.05 to <2 U/g (OR = 1.8; 95% CI = 1.1–3.2, $P = 0.02$) were associated with detectable mouse allergen in the kitchen. In this model, living in a single detached house was inversely associated with detectable kitchen mouse allergen levels (OR = 0.4; 95% CI = 0.2–0.6, $P = 0.0001$).

Conclusion—Infants with a parental history of asthma or allergies are commonly exposed to mouse allergen in their homes. Among infants at high risk for atopy, predictors of increased mouse allergen levels included black race, reported mice exposure, and moderate levels of cockroach allergen.

Keywords

mouse allergen; indoor allergens; childhood asthma; environment

Abbreviations

MUP, mouse urinary protein; NPV, negative predictive value; OR, odds ratio; PPV, positive predictive value

Studies have shown that exposure to mouse allergen in inner-city homes (1–5) and perhaps suburban homes (6) is prevalent and potentially important. To date, there are no published studies evaluating the prevalence of exposure to mouse allergen in urban and suburban home

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environments of infants who are at risk for developing asthma and allergies but who have not yet developed atopic disease.

The Home Allergens and Asthma Study is a prospective birth-cohort study of children in the Boston area with a parental history of asthma or allergies. In this report, we examine the prevalence of mouse allergen exposure in these homes and the relation among socioeconomic factors, housing characteristics, and indoor exposure to mouse allergen in this cohort.

Materials and methods

The study included 498 infants with a parental history of allergy or asthma. The screening and recruitment of families have been described elsewhere (7).

A trained research assistant made a home visit when the child was 2–3 months of age and administered a questionnaire to the parent regarding home characteristics, environmental exposures, and demographics. The study was approved by the Institutional Review Board of the Brigham and Women's Hospital in Boston.

Definition of predictor variables

Sociodemographic variables included the child's sex and race, household income; maternal education, and residence within Boston city limits. Variables related to family history included maternal history of asthma and paternal history of asthma. Variables related to the home environment included parental report of signs of mice, and/or cockroach, type of dwelling, age of house >50 years old, presence of any pets in the home when the child was 2–3 months old, presence of carpet in any room, reported cleaning of any room ≥1 time per week, presence of forced air heating, presence of air conditioning, reported history of water damage in the home during the past year, presence of a vacuum cleaner in the home, and smoke exposure.

Analysis of house dust samples

Methods of collecting dust samples and processing and assaying of allergens have been detailed previously (7–11). Dust samples were collected when the infant was 2–3 months old from the bedroom, kitchen, and living room and analyzed for endotoxin and the following allergens: dust mite, cat, dog, and cockroach. Dust samples were also analyzed for the major mouse allergen, mouse urinary protein (MUP) in the kitchen and living room using a competitive enzyme-linked immunosorbent assay to determine the concentration of MUP in μg/g of dust (Greer Laboratories, Lenoir, NC).

Statistical methods

The univariate analysis of the relation between predictor variables and detectable levels of mouse allergen employed 2 × 2 tables for categorical variables and *t*-tests for continuous variables. Formulas for positive predictive value (PPV) and negative predictive value (NPV) were as follows: PPV = (true positive results × 100)/(true positive + false positive results); NPV = (true negative results × 100)/true negative + false negative results) (12) using reported exposure as the predictive test and detectable MUP as the standard. Stepwise logistic regression was used to develop the multivariate models. An indicator variable for missing values allowed us to control for the missing values in our models. Variables included in the final models satisfied a change-in-estimate criterion [≥10% in the odds ratio (OR) estimate] or were significant at the $P < 0.05$ level.

Results

Most of the participants were white and lived in suburban households with annual incomes of at least $30 000 (Table 1). There were no significant differences between children with and without complete data on mouse allergen levels except for age of the house (>50 years old *vs* ≤ 50 years old).

The MUP was detectable in the kitchen or the living room in 42% of homes analyzed; 31.65% of kitchens and 33.25% of living rooms. The levels of MUP in the kitchen and living room dust samples were correlated ($R = 0.42$ Spearman correlation coefficient, $P < 0.0001$).

Median MUP levels were higher in homes with reported mice exposure ($P < 0.01$). However, reported exposure of mice was not an accurate predictor of detectable MUP levels. The PPV (12) of reported mice exposure for detecting MUP in either the kitchen or the living room was 64.47% and the NPV of reporting no mice exposure for not detecting MUP in either the kitchen or the living room was 50.33%.

Race, household income <$30 000, signs of mice in the home, signs of cockroach in the home, maternal education less than college graduation, and residing in a home within Boston city limits were associated with detectable kitchen MUP (Table 2). Living in a single detached home and having a vacuum cleaner were associated with lower odds of having detectable kitchen MUP. Indicators of lower socioeconomic status (e.g. household income <$30 000, maternal education less than college graduation) were associated with increased median kitchen MUP levels (data not shown).

Similar results were obtained for the univariate analysis of the relation among sociodemographic factors, housing characteristics, and detectable living room MUP. Black race, annual household income <$30 000, maternal education less than college graduation, living outside of Boston City, report of signs of mice, report of signs of cockroach, and having a vacuum cleaner were associated with detectable living room MUP. There was no significant association between any of the other demographic or housing characteristics and detectable MUP in the kitchen or living room.

Endotoxin levels were not correlated with MUP levels in either the kitchen or the living room (kitchen $R = -0.02$, $P = 0.78$; living room $R = -0.04$, $P = 0.39$). Table 3 summarizes the relations among the levels of other allergens, endotoxin, and detectable MUP levels in the kitchen. Levels of cockroach allergen (*Bla g 1 or 2*) ≥0.05 μg/g were associated with detectable kitchen MUP levels. Dog allergen levels (*Can f 1*) of ≥20 to <200 μg/g and endotoxin levels in the second quartile were inversely associated with detectable kitchen MUP levels. There were no significant associations between either dust mite allergen or cat allergen and detectable MUP in the kitchen. There were also no significant associations between any of the allergens or endotoxin and detectable MUP in the living room (data not shown).

Table 4 shows the multivariate analysis of the relationship between the variables of interest and detectable levels of mouse allergen in the kitchen of the homes of participating children. After adjustment for sex, household income, and endotoxin levels, predictors of detectable mouse allergen included black race, report of signs of mice in the home in the previous year, and kitchen levels of cockroach allergen ≥0.05 to <2 U/g. Living in a single detached home was inversely associated with detectable kitchen MUP. Adjusting for maternal education, and other housing/socioeconomic factors did not significantly change our results.

Discussion

In our cohort, MUP was detected in more than 42% of the homes studied. This is surprising, considering that a significant proportion of children in our study live in suburban and relatively affluent areas. These findings suggest that indoor exposure to mouse allergen is common among children at high risk for atopy who live in urban and suburban communities.

As expected, the prevalence of exposure to mouse allergen in inner-city homes is generally higher than that in primarily suburban environments such as metropolitan Boston (1,3,5). Recent studies support our findings that mouse allergen may be present environments outside of the inner-city (6,13).

Although we found a significant association between reported exposure to mice and detectable levels of mouse allergen, many homes with no reported mice exposure had detectable levels of mouse allergen. In studies conducted in children living in the inner-city, reported mice exposure was also related to higher levels of mouse allergen (1,3) but reported exposure alone was not always predictive of mouse allergen levels. These findings suggest that actual MUP levels should be measured for studies of the relation between indoor mice exposure and allergic diseases.

In our study, we found a correlation between mouse allergen levels measured in the kitchen and the living room. Other studies report similar findings (2,5) suggesting that mouse allergens may be widely disseminated in some homes infested with mice. In addition, our study suggests that while factors associated with lower socioeconomic status (such as race, cockroach allergen levels, and living in a nondetached home) may be associated with a higher prevalence of detectable mouse allergen, but that mouse allergen is not limited to inner-city environments.

We did not find a significant correlation between levels of mouse allergen and endotoxin levels in our study. None of the other studies of mouse allergen reported endotoxin in their analysis. We also found no association between detectable MUP and cat or dust mite allergen. Only one inner-city study suggested that the reported absence of a cat was related to levels of mouse allergen (5).

Conclusions

We found that indoor exposure to mouse allergen is common among children living in urban and suburban areas in Boston who have parental history of asthma or allergies. In these children, black race, reported signs of mice exposure, living in a single detached home, and moderate levels of cockroach allergen were predictors of the presence of mouse allergen.

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Table 1

Characteristics of children in the cohort (n = 498)[†]

Variable	No. (%) of subjects with measurement of mouse allergen in kitchen (n = 376)	No. (%) of subjects without measurement of mouse allergen in kitchen (n = 122)	Total (%) (n = 498)
Race			
White	281 (74.73)	94 (77.05)	375 (75.30)
Black	48 (12.77)	12 (9.84)	60 (12.05)
Hispanic	21 (5.59)	7 (5.74)	28 (5.62)
Asian/others	26 (6.91)	9 (7.38)	35 (7.03)
Male sex	203 (53.99)	65 (53.28)	268 (53.82)
Household income[*]			
<$30 000	37 (10.11)	8 (6.78)	45 (9.30)
$30 000–$49 999	62 (16.94)	26 (22.03)	88 (18.18)
≥$50 000	267 (72.95)	84 (71.19)	351 (72.52)
Maternal education less than college graduate	82 (21.81)	23 (18.85)	105 (21.08)
Boston City *vs* other	112 (29.79)	29 (23.77)	141 (28.31)
Maternal history of asthma	117 (31.12)	35 (28.69)	152 (30.52)
Paternal history of asthma[*]	93 (25.20)	23 (19.01)	116 (23.67)
Signs of mice in home at age 2–3 months (past 12 months)	74 (19.68)	29 (23.77)	103 (20.68)
Signs of cockroach in home at age 2–3 months (past 12 months)[*]	39 (10.40)	12 (9.84)	51 (10.26)
Detached house	201 (53.46)	65 (53.28)	266 (53.41)
House >50 years old[*]	239 (72.64)	62 (60.19)	301 (69.68)[‡]
Dog in home at age 2–3 months	63 (16.76)	16 (13.11)	79 (15.86)
Cat in the home at age 2–3 months	73 (19.41)	31 (25.41)	104 (20.88)
Any pets	129 (34.31)	42 (34.43)	171 (34.34)
Clean kitchen >1 week	305 (81.12)	101 (82.79)	406 (81.53)
Forced air heating[*]	79 (21.53)	33 (27.73)	112 (23.05)
Air conditioning	249 (66.22)	91 (74.59)	340 (68.27)
Water damage in past year[*]	133 (35.85)	34 (28.33)	167 (34.01)
Have a vacuum cleaner	352 (93.62)	120 (98.36)	472 (94.78)

[*] Information missing on household income (n = 14), paternal history of asthma (n = 8), signs of cockroaches in the home (n = 1), house >50 years old (n = 66), number with forced air heating (n = 12), water damage in past year (n = 7).

[†] Mouse urinary protein analysis was performed after additional funding was obtained and only 376 kitchens and 421 living rooms had adequate dust samples for analysis.

[‡] $P < 0.05$ for comparison between groups.

Table 2

Housing characteristic and demographic predictors of detectable kitchen levels of mouse allergen

Covariate	No. (%) with detectable† MUP (*n* = 119)	No. (%) with nondetectable MUP (*n* = 257)	OR (95% CI)	*P*-value
Race				
White	71 (59.66)	210 (81.71)	1.00	—
Black	30 (25.21)	18 (7.00)	4.93 (2.60–9.38)	<0.0001
Hispanic	9 (7.56)	12 (4.67)	2.22 (0.90–5.48)	0.09
Asian/other	9 (7.56)	17 (6.61)	1.57 (0.67–3.70)	0.30
Household income				
≥$50 000	65 (57.02)	202 (80.16)	1.00	—
$30 000–$49 999	25 (21.93)	37 (14.68)	1.56 (0.91–2.67)	0.10
<$30 000	24 (21.05)	13 (5.16)	2.88 (1.44–5.76)	0.003
Maternal education < college graduate	36 (30.25)	46 (17.90)	1.99 (1.20–3.30)	0.007
Boston city *vs* other	50 (42.02)	62 (24.12)	2.28 (1.44–3.62)	0.0004
Signs of mice at age 2–3 months (past 12 months)	37 (31.09)	37 (14.40)	2.68 (1.59–4.52)	0.0002
Signs of cockroach at age 2–3 months (past 12 months)*	21 (17.80)	18 (7.00)	2.87 (1.47–5.63)	0.0015
Detached house	41 (34.45)	160 (62.26)	0.32 (0.20–0.50)	<0.0001
House >50 years old*	66 (70.21)	173 (73.62)	0.85 (0.50–1.43)	0.53
Dog at age 2–3 months	15 (12.61)	48 (18.68)	0.63 (0.34–1.17)	0.14
Cat at age 2–3 months	20 (16.81)	53 (20.62)	0.78 (0.44–1.37)	0.38
Clean kitchen ≥1/week	100 (84.03)	205 (79.77)	1.34 (0.75–2.38)	0.33
Have vacuum cleaner	102 (85.71)	250 (97.28)	0.17 (0.07–0.42)	<0.0001

* Information missing on household income (*n* = 10), signs of cockroaches at age 2–3 months (*n* = 1), house >50 years of age (*n* = 47).

† Lower limit of detection was 0.25 μg/g of dust.

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Table 3

Relationship of detectable levels of mouse allergen in kitchen to levels of other allergens and endotoxin

Covariate	No. (%) with detectable† MUP (*n* = 119)	No. (%) with nondetectable MUP (*n* = 257)	OR (95% CI)	*P*-value
Bla g 1 or 2 in kitchen* (U/g)				
<0.05	44 (36.97)	149 (57.98)	1.00	—
≥0.05 to <2	51 (42.86)	88 (34.24)	1.96 (1.21–3.18)	0.006
≥2	24 (20.17)	19 (7.39)	4.28 (2.15–8.52)	<0.0001
Der p 1 or Der f 1* in living room (μg/g)				
<0.05	9 (7.56)	14 (5.47)	1.00	—
≥0.05 to <2	55 (46.22)	117 (45.70)	0.73 (0.30–1.79)	0.49
≥2 to <10	33 (27.73)	54 (21.09)	0.95 (0.37–2.44)	0.92
≥10	22 (18.49)	71 (27.73)	0.48 (0.18–1.27)	0.14
Fel d 1, home max (μg/g)				
<1	41 (34.45)	83 (32.30)	1.00	—
≥1 to <8	50 (42.02)	105 (40.86)	0.96 (0.58–1.60)	0.89
≥8	28 (23.53)	69 (26.85)	0.82 (0.46–1.46)	0.50
Can f 1* (μg/g) in living room				
<20	91 (88.35)	168 (77.42)	1.00	—
≥20 to <200	3 (2.91)	21 (9.68)	0.26 (0.08–0.91)	0.03
≥200	9 (8.74)	28 (12.90)	0.60 (0.27–1.31)	0.20
Endotoxin (range, EU/mg)*				
1st quartile (2.14–52.48)	26 (26.80)	46 (21.30)	1.00	—
2nd quartile (52.50–80.00)	16 (16.49)	63 (29.17)	0.45 (0.22–0.93)	0.03
3rd quartile (80.48–123.19)	26 (26.80)	52 (24.07)	0.89 (0.45–1.73)	0.72
4th quartile (125.61–713.20)	29 (29.90)	55 (25.46)	0.93 (0.48–1.80)	0.84

*Information missing on kitchen levels of cockroach allergen (*n* = 1), living room levels of dust mite allergen (*n* = 1), living room levels of dog allergen (*n* = 56), and living room levels of endotoxin (*n* = 63).

†Lower limit of detection was 0.25 μg/g of dust.

Table 4

Multivariate analysis for predictors of detectable mouse allergen in the kitchen*

Covariate	Model OR (95% CI)	*P*-value
Race (white)		
Black	2.95 (1.32–6.60)	0.009
Hispanic	0.97 (0.31–3.06)	0.96
Asian/other	1.71 (0.69–4.24)	0.25
Signs of mice at age 2–3 months (no)		
Yes	3.00 (1.60–5.60)	0.0006
Detached house (no)		
Yes	0.35 (0.20–0.60)	0.0001
Cockroach allergen, kitchen (<0.05 U/g)		
≥0.05 to <2 U/g	1.84 (1.08–3.15)	0.02
≥2 U/g	2.15 (0.91–5.09)	0.08

* Model adjusts for sex, household income, and endotoxin levels.