
Parent report of pests and pets and indoor allergen levels in inner-city homes

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Background: Guidelines recommend allergen avoidance for patients with allergic asthma, but direct measurements of home allergen levels are not available to most physicians. Parent report of indoor allergen exposure is a potentially convenient and inexpensive surrogate measure of exposure, although validity of parent report to estimate indoor allergen levels is not well established.

Objective: To determine if parent-reported pest and pet exposures can identify patients with clinically relevant allergen exposure.

Methods: Parents of 300 inner-city children completed a survey about pests (cockroaches and mice) and furred pets (dogs and cats). Settled dust samples were obtained for *Blatella*, *Mus mus*, *Canis*, and *Felis* from kitchens and bedrooms.

Results: Parent reports were associated with clinically relevant levels of *Blatella*, *Mus mus*, *Canis*, and *Felis* ($P < .001$ for all). For example, when parents reported cockroaches were present, 86% of homes had settled dust *Blatella* levels of 1 U/g or higher, and when they reported mice were present, 90% had *Mus mus* levels greater than 500 ng/g. Report of pets was also predictive of clinically meaningful allergen levels. Parent-reported absence of pets provided assurance that allergen levels were below relevant thresholds (negative predictive value, 80%–98%). However, parent-reported absence of pests did not provide assurance of low levels of these allergens (negative predictive value, 38%–75%).

Conclusions: Since direct measurement of indoor allergens is not always feasible, especially in the inner city, parent report of pests and pets may be sufficient to recommend environmental control practices for sensitized children. Negative parent reports of pests are not sufficient evidence of low pest allergen exposure.

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INTRODUCTION

Exposure to indoor allergens from cockroaches, mice, and furred pets can contribute substantially to asthma morbidity among sensitized children.¹ In the inner city, where asthma morbidity is particularly high, many homes have significant exposure to certain indoor allergens that can worsen asthma.^{2–6} Several studies, including those performed in inner-city homes, have reported that environmental interventions can decrease indoor allergen levels and improve asthma-related morbidity.^{7–9} As a result of this evidence, national and international asthma guidelines recommend determination of allergen exposure and reduction of these exposures as a part of asthma management.¹

Studies have shown that individuals with asthma who are exposed to allergens to which they are sensitized have more severe disease.^{10–12} Ideally, a physician should have sufficient information regarding allergen exposure during a clinic visit

to provide appropriate recommendations regarding allergen avoidance strategies. Although sensitization can be easily determined by the physician, measurements of indoor allergen levels require additional resources. For example, home allergen evaluation requires procurement of dust samples and a laboratory with the capabilities to process and analyze the dust samples for allergen content. Although there are commercially available home test kits that provide semiquantitative exposure levels for dust mite allergen, there are no such home tests available for pest or pet allergen evaluation. As a result, home allergen analysis is rarely available to physicians to guide treatment recommendations. A simple and practical method of determining potential exposure could be asking the parent about the home environment, but there is relatively little available information about the validity of such reports in inner-city homes. The purpose of this study was to determine if caregiver report of pests (cockroaches and mice) and furred pets (cats and dogs) provides sufficient information on which to base environmental control recommendations.

METHODS

Study Participants

We enrolled children who were between 2 and 6 years old and were residents of 9 contiguous zip codes in inner-city Baltimore, Maryland. Children with and without asthma were identified from a random sample of children with a health

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care encounter in the previous 12 months at Johns Hopkins Community Physicians or Bayview Pediatrics, the 2 health care centers that provide most of the care to residents in these zip codes. A more extensive description of methods used in this study, the Baltimore Indoor Environmental Study of Asthma in Kids (BIESAK), has been described elsewhere.^{13–15}

Eligibility criteria for children with asthma included (1) caregiver report of physician-diagnosed asthma, (2) symptoms or use of asthma medications within the last 6 months, and (3) at least 1 health care encounter coded for asthma within the last 12 months (*International Classification of Diseases, Ninth Revision*, 493.xx). All control subjects had (1) at least 1 non-asthma-related health care encounter within the last 12 months and (2) a caregiver report of never having physician-diagnosed asthma.

Participants were recruited between September 2001 and December 2003. All potential subjects received an initial mailing describing the study. Study staff then contacted parents by telephone, and a screening survey was administered to determine eligibility. Written informed consent was obtained from the parent or legal guardian. The Johns Hopkins Medical Institutional Review Board approved the study protocol.

Data Collection

An interviewer-administered questionnaire was used to evaluate household demographics, housing characteristics, and indoor environmental exposures. Parent report of environmental exposures (pests [cockroaches and mice] and pets [dogs and cats]) was evaluated using a standardized survey with closed-ended questions. Parents were asked whether the specific exposure was currently (within the previous month) present in the child's home. For example, parents were asked, "Have you seen cockroaches in your home indoors within the previous month?"

Atopic status was determined by skin prick testing (Multi-Test II; Lincoln Diagnostics, Decatur, Illinois) to 14 aeroallergens: American and German cockroach, dust mite mix, cat, dog, mouse, rat, 3 pollens, and 3 molds. A positive skin test result was defined as a wheal size of at least 2 mm greater than the negative control. Children without asthma did not undergo allergy skin testing because testing in nondiseased children was not allowed by the Johns Hopkins University Institutional Review Board.

Measurement of Allergen Levels in Settled Dust

Household dust samples were collected from the child's bedroom and kitchen on an unwoven fabric collector inserted into the nozzle of a typical portable vacuum cleaner, using established methods.¹⁶ An aqueous extract of 100 mg of the sieved dust (<300 μ m) specimen was prepared in 2 mL of borate-buffered saline. The extracts were stored at -30°C until they were assayed for cat (Fel d 1), dog (Can f 1), cockroach (Bla g 1), and mouse (Mus m 1), using antibody-based enzyme-linked immunosorbent assay.^{17–20} The results are expressed in micrograms per gram of dust or in units per

gram of dust (for Bla g 1). The limits of detection of the assay were 50 ng/g (Fel d 1 and Can f 1), 2 ng/g (Mus m 1), and 1 U/g (Bla g 1).

Statistical Analysis

Continuous variables were compared using the 2-tailed *t* test or Kruskal-Wallis test, and differences for categorical variables were determined by the Pearson χ^2 or Fisher exact test as appropriate. Sensitivity and specificity were calculated using a standard approach.²¹ Positive predictive values (PPVs) and negative predictive values (NPVs) were calculated because these values have important clinical relevance. PPV represents the probability that a home would have an allergen level above a critical value when the parent reports the presence of the pest or pet. NPV represents the probability that a home would have an allergen level below a critical value when a parent reports the absence of the pest or pet. Because clinicians may have different thresholds for allergen levels at which they would recommend remediation, we considered multiple thresholds for each allergen, including levels above detection and higher threshold levels (2 levels for each allergen) thought to be clinically relevant, based on prior literature. For most of the allergens, the lower threshold levels selected have been associated with an increased risk of allergic sensitization and the higher threshold levels have been associated with asthma symptoms.^{22–25} All analyses were performed with StataSE statistical software, version 8.0 (College Station, Texas). A 2-tailed $P < .05$ was considered statistically significant.

RESULTS

Respondents

Three hundred individuals with ($n = 150$) and without ($n = 150$) asthma were enrolled in the study. The mean age of the study participants was 4.4 years, 91% were African American, and 80% were from single-parent homes. Nearly all participants (90%) had public or no health insurance, and 74% of those who responded to the questionnaire were from homes with annual household incomes of less than \$25,000 per year, reflecting a poor inner-city population (Table 1). We found no significant differences in respondent characteristics between participants with asthma and those without asthma, except that boys were slightly more common among patients with asthma (58%) compared with patients without asthma. Of the children with asthma, 69% were atopic, and sensitization to cockroach was common (43%). Sixty-nine percent of respondents were skin test sensitive to 1 of the studied allergens (14% were sensitized to 1 allergen, 35% were sensitized to between 2 and 4 allergens, and 20% were sensitized to 5 or more). (Table 2).

Indoor Environmental Exposures

Parents reported many relevant exposures, including mice in 65%, cockroaches in 45%, cats in 24%, and dogs in 16% of homes. We found no statistically significant differences between the exposures reported in the homes of children with

Table 1. Child and Caregiver Characteristics (N = 300)

Characteristics	Participants, % ^a
Age, mean (range), y	4.4 (2–6)
Male sex	50.0
Race	
Black	90.2
White	5.7
Other	4.1
Primary caregiver	
Birth mother	85.9
Grandmother	6.4
Birth father	2.7
Other	5.0
Employment	
Work full-time	34.3
Unemployed	21.9
Homemaker	18.2
Work part-time	12.5
Other	13.1
Household income (annual)	
<\$25,000	43.5
\$25,000–\$50,000	11.4
>\$50,000	3.7
Not reported	41.4
Health insurance	
Private	10.8
Public	87.4
Self-pay	1.8

^a Data are percentage of study participants unless otherwise indicated.

Table 2. Allergic Sensitization Status (Patients With Asthma Only) (n = 150)

Skin test sensitivity	Participants, %
German or American cockroach	43
Mouse	17
Rat	25
Cat	30
Dog	9
Dust Mite	25

asthma and those without asthma. Reported household exposures were also similar between atopic and nonatopic patients with asthma. Parents who reported the presence of cockroach or mice and owning a cat or dog had substantially higher levels of Bla g 1, Mus m 1, Fel d 1, and Can f 1, respectively, compared with those who reported the absence of these exposures (all $P < .001$) (Fig 1).

Positive Predictive Values

When a parent reported the presence of one of the studied pests or pets, the likelihood was very high that the respective allergen would be detected in the home (PPV, 86% to 100%) (Table 3). As expected, the PPV was lower as successively higher exposure threshold values were examined. Parental

report of cockroach, mouse, or cat were associated with values of these allergens exceeding clinically relevant thresholds (PPV >80% at the lower threshold and PPV >70% at the higher one) in at least 1 room. For dog allergen, although parent report was strongly predictive of a detectable level (>90%), it was only modestly predictive of the lower clinically relevant threshold (PPV, 58% to 62%) and not highly predictive of the highest studied threshold (PPV, 36%).

Negative Predictive Values

The reported absence of the furred pets and pests varied in the ability to ensure low exposure levels. For dogs and cats, the reported absence was helpful in excluding clinically relevant levels of Can f 1 (NPV $\geq$ 95%) and Fel d 1 (NPV $\geq$ 80%), respectively (Table 3). When parents reported the absence of cockroaches, Bla g 1 levels were less than clinically relevant thresholds for most children's bedrooms (NPV, 58% to 75%) and even less predictive of low levels in the kitchen (NPV, 38% to 57%). Mouse allergen (Mus m 1) was so ubiquitous in the study homes and present at such high levels that parent report of the absence of mice could not ensure levels below clinically relevant thresholds (NPV, 37% to 55%).

Sensitivity and Specificity

When a level of the respective allergen in the home exceeded the clinically relevant threshold, it was likely that the parent reported that the pests or pets were present (sensitivity, 60% to 90% for pets and 56% to 75% for pests). Specificity ranged from 86% to 95% for pets and 49% to 74% for pests above the clinically relevant thresholds (Table 4).

DISCUSSION

This study showed that simple questions about the home environment can provide valuable information to guide treatment recommendations for inner-city children. These findings are important because health care providers must be able to gauge when home environmental control measures are needed to decrease indoor allergen levels and improve asthma-related morbidity among inner-city children. In the absence of costly home allergen assessments, simple predictive methods are needed.

We found that parent report of pests or furred pets in the home was often predictive of allergen levels exceeding clinically important thresholds. For example, when a parent reported cockroaches in the home, allergens in at least 1 room usually exceeded the clinically relevant thresholds (PPV, 72% to 86%). Most children with parental report of mice, similar to those with parental report of cockroach, had values of mouse allergen in at least 1 room exceeding the clinically relevant thresholds (PPV, 78% to 90%). Our study supports previous findings that parent report of mouse exposure was strongly predictive of clinically relevant mouse allergen levels.¹⁴ Report of mouse exposure may be particularly important because a level of Mus m 1 greater than 500 ng/g has been associated with asthma morbidity.²⁶

In our study, when parents reported the absence of cockroaches, Bla g 1 levels tended to be below clinically relevant

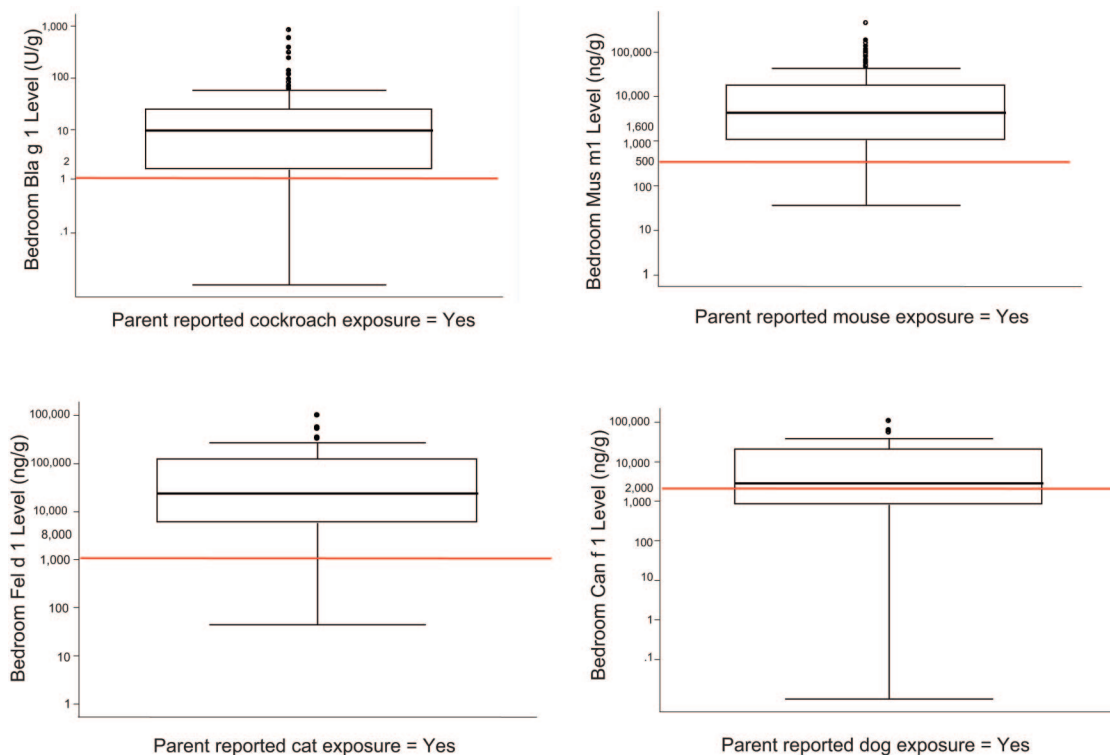


Figure 1. Allergen levels exceeding a clinically relevant threshold (represented by red line) when a parent reported the presence of 1 of the studied pests or pets. Values above this level may be associated with increased risk of sensitization and/or morbidity. Boxes show interquartile range; heavy, dark lines are median values. Whiskers represent the closest value within 1.5 times the interquartile range.

Table 3. Predictive Values of Parent-Reported Pests and Pets for Measured Allergen Concentration Thresholds

	Allergen concentration threshold ^a					
	Low		Medium		High	
	PPV	NPV	PPV	NPV	PPV	NPV
Cockroach (Bla g 1)						
Kitchen (n = 262)	91	32	86	38	72	57
Bedroom (n = 283)	86	44	73	58	53	75
Mouse (Mus m 1)						
Kitchen (n = 256)	100	0	90	38	78	49
Bedroom (n = 279)	100	0	84	37	68	55
Cat (Fel d 1)						
Kitchen (n = 262)	97	34	84	92	55	98
Bedroom (n = 282)	100	9	89	80	74	95
Dog (Can f 1)						
Kitchen (n = 260)	92	71	62	96	36	97
Bedroom (n = 282)	96	36	58	95	36	98

Abbreviations: PPV, positive predictive value; NPV, negative predictive value.

^a Threshold levels are Bla g 1, 1 U/g (low), 2 U/g (medium), 8 U/g (high); Mus m 1, 2 ng/g (low), 500 ng/g (medium), 1,600 ng/g (high); Fel d 1, 100 ng/g (low), 1,000 ng/g (medium), 8,000 ng/g (high); Can f 1, 78 ng/g (low), 2,000 ng/g (medium), 10,000 ng/g (high).

thresholds for most children's bedrooms; however, most kitchens still had levels above the clinically relevant thresholds (NPV, 38% to 57%). Similar to our study, in a study of allergic/asthmatic families in Boston, report of cockroaches

predicted high (≥ 2 U/g) cockroach allergen (Bla g 2), but many homes (48%) in which cockroaches were not reported still had detectable cockroach allergen.²⁷ In our study as well, parent report of the absence of mice could not ensure levels

Table 4. Sensitivity and Specificity Values of Parent-Reported Pests and Pets for Measured Allergen Concentration Thresholds

	Allergen concentration threshold ^a					
	Low		Medium		High	
	SE	SP	SE	SP	SE	SP
Cockroach (Bla g 1)						
Kitchen (n = 262)	56	78	56	74	61	69
Bedroom (n = 283)	57	78	60	71	65	65
Mouse (Mus m 1)						
Kitchen (n = 256)	66	-	74	66	75	53
Bedroom (n = 279)	64	-	70	56	73	49
Cat (Fel d 1)						
Kitchen (n = 262)	34	97	84	93	90	86
Bedroom (n = 282)	27	100	60	95	84	91
Dog (Can f 1)						
Kitchen (n = 260)	36	98	71	93	74	90
Bedroom (n = 282)	22	98	68	92	84	89

Abbreviations: SP, specificity; SE, sensitivity.

^a Threshold levels are Bla g 1, 1 U/g (low), 2 U/g (medium), 8 U/g (high); Mus m 1, 2 ng/g (low), 500 ng/g (medium), 1,600 ng/g (high); Fel d 1, 100 ng/g (low), 1,000 ng/g (medium), 8,000 ng/g (high); Can f 1, 78 ng/g (low), 2,000 ng/g (medium), 10,000 ng/g (high).

below clinically relevant thresholds (NPV, 37% to 55%) either. These findings suggest that if a parent reports the absence of mouse infestation, it cannot be assumed that children are not exposed, and efforts should be made to directly evaluate the allergen levels. Another study found that reported presence of cockroaches predicted allergen levels above the higher threshold (8 U/g) (sensitivity, 78%) but was a relatively poor measure of allergen exposure above the limit of detection and the lower threshold (sensitivity, 56% and 68%, respectively).²⁸ In general, the sensitivities in our study were similar to those found in other studies, but specificities were substantially lower.

In the case of furred pets, report of a cat in the home is strongly predictive of cat allergen levels greater than 2 ng/g (PPV, 84% to 89%) and modestly predictive of levels greater than 8 ng/g (PPV, 55% to 74%). Parent report of a dog in the home does not predict high allergen levels as strongly as parent report of a cat in the home (PPV, 36% to 62%). Report of a dog in the home is only modestly predictive of a dog allergen level greater than 2 µg/g and is poorly predictive of a level greater than 8 µg/g. The reason for the difference in PPVs for reported cat and dog is not clear but is possibly due to differences in the habits of dogs and cats. For example, a dog may be kept outdoors most if not all of the time, whereas a cat may be indoors most or all of the time.

When parents reported the absence of dogs, Can f 1 levels were less than the clinically relevant thresholds for almost all of the children's bedrooms and kitchens (NPV, 95% to 98%). For cats, NPVs were also very high at the clinically relevant thresholds in kitchens (NPV, 92% to 98%) and slightly lower in children's bedrooms (NPV, 80% to 95%). Many studies have shown that cat and dog allergens are virtually ubiquitous and are present in homes in which there are no pets.²⁹ In our study, when parents reported that there were no pets, many homes (29% to 91%) had detectable levels, but very few had

levels that exceeded clinically relevant thresholds (2% to 20%).

In general, these findings suggest that asking a parent about pets in the home can provide important information about levels of pet allergen in the home and that this information can help inform environmental control practice recommendations. In the case of a dog, if the patient has intermittent asthma or the dog is kept outdoors exclusively, then finding the dog a new home may not be a first-line recommendation. On the other hand, if the dog-sensitized patient requires substantial medication to control his or her asthma or has difficult-to-control asthma, then even relatively low levels of dog allergen may be an important contributor, and removal of the dog may be a first-line recommendation. Thus, we advocate that clinicians carefully titrate their recommendation to the entire clinical scenario and not rely exclusively on estimated allergen levels. For example, a cat-sensitized patient with asthma should be counseled to find the cat a new home because reporting a cat in the home is strongly predictive of high levels of cat allergen. On the other hand, report of a dog in the home suggests that the patient is more likely than not to have clinically relevant dog allergen levels. In this situation, other clinical information may matter more in making recommendations to the dog-sensitized patient about the dog. If the patient has intermittent asthma or the dog is kept outdoors exclusively, then finding the dog a new home may not be a first-line recommendation. On the other hand, if the dog-sensitized patient requires substantial medication to control his or her asthma or has difficult-to-control asthma, then even relatively low levels of dog allergen may be an important contributor, and removal of the dog may be a first-line recommendation.

Our study had several limitations. The study participants represent an inner-city population of low socioeconomic status in Baltimore City. Our results may not be able to be

extrapolated to other regions of the country or to patients from different socioeconomic backgrounds. In addition, PPVs and NPVs are highly dependent on prevalence, and this study was performed in inner-city Baltimore, where cockroach and mouse allergen are detectable in almost all homes; therefore, the PPVs may be higher than in other settings. We have reported sensitivity and specificity also, which are not affected by study-specific prevalence of the exposure.

This study confirms that inner-city children whose parents report the presence of pests or pets in the home are very likely to be exposed to levels of allergen that are known to exacerbate asthma. When children are known to be IgE sensitized to one of these allergens, families should be counseled to take steps to reduce the allergen levels in their homes, using methods that have previously been shown to be effective. For example, Morgan et al⁹ demonstrated that allergen levels in inner-city homes can be successfully reduced by using a multifaceted, home-based, environmental intervention program, when tailored to the sensitizations and exposures of individual children. Our findings suggest that in addition to assessing allergic sensitization status in all patients with asthma, clinicians should also ask parents about pest sightings, pest infestation, and ownership of pets. Our study found that clinically relevant levels of dog or cat allergen, although they cannot be completely excluded, are unlikely in the inner city when parents report not having household pets. Although we selected threshold allergen levels based on previously published reports, there are some important points that should be understood about these threshold levels. First, these thresholds are derived from epidemiologic data and are therefore most applicable to populations and less so to any given individual patient. Second, whereas the use of thresholds may suggest that there is a "safe" level of allergen, such safe levels have not been established. The thresholds are derived from epidemiologic studies that have demonstrated risks associated with higher levels of allergen. To our knowledge, no studies to date have proven that certain low levels of allergen cannot promote disease or exacerbation of existing disease. Individual response to allergen, or combinations of them, likely is very complex, with individual patients having widely varying degrees of clinical sensitivity to an allergen. Exposure-response relationships, derived from population level data, may not be helpful in all cases for gauging the extent of a patient's clinical response to a given allergen level.

This study also found that children whose parents report that there are no cockroaches or mice may still be exposed to clinically important levels of these allergens, and only quantification of allergen levels in dust samples from the home will provide the clinician with accurate information about pest allergen exposure. For a clinician in the inner city, being able to estimate the probability that a patient has clinically relevant allergen exposure (by knowing the PPVs and NPVs) is critical to being able to implement environmental control practices recommended by guidelines.¹

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