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Prevalence of Indoor Allergen Exposures among New Orleans Children with Asthma

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ABSTRACT *Studies of inner-city asthmatic children have shown significant regional variation in dust allergen exposures. The home environment of asthmatic children in the Gulf South region of the USA has not been characterized. This study describes indoor dust allergen levels in the homes of 86 asthmatic children in New Orleans and explores regional variability in dust allergen exposure. Data were used from baseline home visits of children in the New Orleans Healthy Homes Initiative. Interview, visual observation, and environmental dust sampling data of 86 children between 4 and 17 years of age were analyzed. Seventy-seven percent of households had moderate (>2.0–9.9 μg/g) or high (≥10.0 μg/g) levels of either Der p 1 or Der f 1 dust mite allergen and 56.6% had moderate (>2.0–8.0 U/g) or high (>8.0 U/g) levels of cockroach allergen (Bla g 1). The prevalence of high (>10 μg/g) levels of dog (Can f 1) allergen was 26.5%, and few households (6.0%) had high cat allergen (Fel d 1) levels (>8.0 μg/g). Households with average humidity levels >50% were three times more likely to have elevated dust mite levels (odds ratio=3.2; 95% confidence interval=1.1, 9.3; p=0.03). Home ownership and education level were inversely associated with cockroach and dust mite allergen levels, respectively. Our findings reinforce the evidence of regional variability in dust allergen exposure levels. Asthmatic children living in the Gulf South are exposed to multiple indoor allergen exposures and live in a highly allergenic environment.*

KEYWORDS *Child health, Asthma, Allergens, Environmental health, Dog allergen, House dust*

Abbreviations: NOHHI – The New Orleans Healthy Homes Initiative; ICAS – Inner City Asthma Study; DACI – Dermatology, Allergy and Clinical Immunology Reference Laboratory; CI – Confidence Interval; IOM – Institute of Medicine

INTRODUCTION

Asthma is the most common chronic disease in childhood. It affects more than one in five children in many poor neighborhoods, and non-Hispanic black children living in inner cities have the highest reported prevalence.[1–4] There has been an

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increase in asthma prevalence, despite a reduction in outdoor air pollutant levels, leading researchers to focus on the home environment as a key risk factor for the development and exacerbation of asthma.[5] It is postulated that more time spent indoors translates into prolonged exposure to indoor allergens, which may exacerbate asthma, particularly among sensitized individuals.[6]

Allergen exposure is dependent on many factors, including local climatic conditions.[7–9] The Inner City Asthma Study (ICAS) characterized the home environment of asthmatic children in seven low-income urban areas in the USA.[10] An important finding was that indoor allergen levels and skin test reactivity among inner-city asthmatics vary significantly by geographic location. Northeastern homes (New York and the Bronx) had the highest concentration of cockroach allergen, whereas homes in the South (Dallas) and Northwest (Seattle) had high levels of dust mite allergens.[9,11] Because regional differences in allergen exposure levels can contribute to varying sensitization profiles among asthmatic children, it is important to describe allergen exposure profiles of homes located in geographic areas with distinctive climatic conditions.

The home environment of asthmatic children living in urban areas of the U.S. Gulf South and the factors associated with elevated allergen levels has not been described. The semitropical climate, with high humidity and lack of winter frost, may increase the risk of multiple allergen exposure.[8,12] To fill the data gap on exposure to home dust allergens in asthmatic children living in the Gulf South, we measured level of dust mite (Der p 1, Der f 1), cockroach (Bla g 1), dog (Can f 1), and cat (Fel d 1) allergen in homes of children with asthma living in inner-city New Orleans.

METHODS

Participants and Study Design

The New Orleans Healthy Homes Initiative was a randomized intervention trial aimed at reducing allergen exposure, asthma morbidity, and lead burden in children ages 4–17 years living in inner-city New Orleans. Eligibility criteria included having no plans to relocate within 7 months of enrollment in the study, medical record evidence of physician-diagnosed asthma, and a positive skin test for any indoor allergen (pet dander, dust mite, cockroach, or mold). This cross-sectional analysis characterizes the baseline prevalence of dust allergen levels in the child's primary residence.

Children were recruited from 15 March 2004 to 30 June 2005 through targeted radio and newspaper advertising and during routine clinic visits to the Medical Center of Louisiana New Orleans Asthma and Allergy Clinic, Tulane Allergy Clinic, Children's Hospital, and Louisiana State University Health Sciences Center Lions Clinic. At the time of the study, these clinics served the majority of inner-city New Orleans residents. Parental informed consent was obtained, and upon completion of the baseline home visit, 86 children were enrolled in the study.

The baseline home visit included an interviewer-administered questionnaire on sociodemographic factors and home characteristics. Vacuum dust samples, home temperature, and relative humidity was measured, and evidence of mold, moisture, and cockroach/rodent infestation was recorded as part of a systematic, visual observation. In situations with multiple eligible children in a household, only one

child was enrolled in the study. For children recruited from clinics, the child presenting with symptoms was enrolled in the study. For children recruited from the community, one eligible child per household was randomly selected for inclusion. The study received approval from the Institutional Review Board of the Tulane University Office of Human Research Protection.

Environmental Sampling and Measurements

Five vacuum dust allergen samples were taken from each household from 8 April 2004 through 30 July 2005. Samples were taken from the living room floor and upholstery, child's bedroom floor and bed, and kitchen floor using separate dust collection bags [Dermatology, Allergy and Clinical Immunology Reference Laboratory (DACI) Baltimore, MD] attached to a Kenmore® (12-amp, high-efficiency particulate air-filtered, canister) electric-powered portable hand-held vacuum cleaner with optional wand extension. Trained environmental health paraprofessionals vacuumed each sample area for 5 min. The vacuum cleaner hose and headpiece was wiped clean and gloves were replaced after each sample was collected to prevent contamination. The selection of sample areas and the overall sampling process followed a standardized protocol.[13] Samples were kept in separate bags after collection, labeled and mailed to the appropriate laboratory. Samples were analyzed for dust mite (Der p 1 and Der f 1), cat (Fel d 1), dog (Can f 1), and German cockroach (Bla g 1) allergens. Temperature and relative humidity were measured at the time of dust sample collection using a BK Precision® thermo-hygrometer in the living room, kitchen, and child's bedroom.

Environmental Sample Analysis

Environmental dust samples were sent to Aerotech P&K Microbiology Services (Cherry Hill, NJ) (54.3% samples) and the Johns Hopkins University DACI (Baltimore, MD) (45.7% samples) for analysis. At the DACI laboratory, the aeroallergens in sieved reservoir dust were extracted [100 mg in 2 ml of phosphate-buffered saline (PBS)–5% bovine serum albumin] and quantified using a monoclonal antibody-based two-site immunoenzymetric assay. All monoclonal antibody reagents and allergen standards were purchased from Indoor Biotechnology (Charlottesville, VA, USA). The Aerotech P&K laboratory extracted sieved dust samples (100 mg in 2 ml) in PBS, pH 7.4 with 0.05% Tween 20 (PBS-T), and mixed end over end for 2 h on an orbital rotator at room temperature. The samples were then centrifuged for 20 min at 2,500 rpm at 4°C, and the supernatants were used for detection of Der p 1, Der f 1, Can f 1, Fel d 1, and Bla g 1 by ELISA method.

Both laboratories reported values below the laboratory detection levels. P&K reported "below detection limit" and "minimum quantification limit (MQL)," and DACI laboratory reported values less than the minimum detection limit for the given quantity. We assigned half of the MQL values to P&K laboratory samples; half of the highest minimum detection limit value was assigned to samples from the DACI laboratory as per instruction by the service provider (personal communication; May 2006).

Statistical Analysis

Based on the literature, lower and upper cut-off points for dust allergens were set at >2 and ≥10 μg/g for Der p 1 and Der f 1; ≥1 and >8 μg/g for Fel d1; ≥2 and >10 μg/g for Can f 1; and >2 and >8 U/g for Bla g 1.[9,14,15] Average household relative humidity was calculated by taking an average of baseline relative humidity levels in the

kitchen, living room, and bedroom. Descriptive statistics were performed to examine frequencies of study variables. Chi-square tests were used to examine differences in allergen exposure by levels of relative humidity (≤50 and >50%) and other pertinent household characteristics. Odds ratios, 95% confidence intervals (CIs), and exact p values were reported for bivariate analysis. All analyses were performed using SAS® software (version 9.1, SAS Institute, Cary, NC, USA).

RESULTS

Of 116 eligible children, 86 (74%) were enrolled in the study. After acquiring informed consent, 16 families could not be contacted to schedule the baseline home visit, 12 refused to participate (e.g., busy schedule, family medical emergencies), one mother refused to have blood drawn on her child, and one family moved.

Complete sociodemographic characteristics of the study population are described in Table 1. The majority of the study sample was African American (97.7%)

TABLE 1 Sociodemographic characteristics of study population (*N*=86)*

Variable	*n* (%)
Sex	
Female	30 (35.3)
Male	55 (64.7)
Race	
African American	84 (97.7)
White	2 (2.3)
Age in years	
4 to 11 years	63 (73.3)
6 to 17 years	22 (26.7)
Other asthmatic children in household	
Yes	20 (23.3)
No	66 (76.7)
Health insurance	
Private	3 (5.5)
Medicaid	52 (94.5)
Home ownership	
Owner	31 (36.0)
Renter	55 (64.0)
Employment	
Yes	60 (69.8)
No	26 (32.2)
Education level of primary caregiver	
Less than high school graduate	4 (4.7)
High school graduate and some college	63 (73.3)
College graduate or more	18 (20.9)
Refused to answer	1 (1.2)
Annual household income	
Less than $10,000	51 (60.0)
$10,000 to $15,000	12 (14.1)
$15,001 to $25,000	10 (11.8)
$25,001 to $50,000	8 (9.4)
Refused to answer	4 (4.7)

*Some variables do not add up to 86 due to missing data

and male (64.7%), and most children were between the ages of 4 and 11 years. In most homes the primary caregiver was employed, and 94% had at least a high school education. Average household income for 74% of the families was less than $15,000. Results from the survey questionnaire on home environment and residential characteristics are described in Table 2. The average relative humidity (%) was between 51 and 53%. Twenty four percent of children were exposed to environmental tobacco smoke, defined as having one or more regular smokers smoking inside the house. Visual observation by health paraprofessionals found evidence of cockroaches/rodents (e.g., eggs, droppings) in 17 out of 86 homes. Whereas very few households had evidence of visible mold (7%) or standing water (5%), some were found to have water damage, moisture, and leaks (13%).

Environmental dust results from kitchen floors, living room floor and upholstery, and child's bedroom floor and bed were available for analysis in 83 of the enrolled households. The prevalence of households having moderate and high

TABLE 2 Residential characteristics of the study population (*N*=86)

Variable	Mean (±SD)
Temperature (°F)	
Kitchen	73.6 (11.1)
Living room	73.1 (11.4)
Bedroom	73.3 (11.2)
% Relative humidity	
Kitchen	73.3 (11.2)
Living room	51.7 (11.0)
Bedroom	51.5 (10.8)
Number of rooms in household	6.6 (2.1)
	N (%)
Total number of people in household	
Less than 5	64 (74.4)
5 or more	22 (25.6)
Smoking inside the house	
None	65 (74.4)
1 to 3 people	19 (22.1)
4 or more	2 (2.3)
Pets (cat, dog, bird, rodent)	
None	63 (73.3)
Single	14 (16.3)
Multiple	9 (10.4)
Evidence or water damage, moisture, or leaks	
Yes	11 (13.4)
No	71 (86.6)
Visible evidence of mold	
Yes	6 (7.1)
No	79 (92.9)
Presence of standing water	
Yes	4 (4.7)
No	82 (95.3)
Evidence of cockroach or rodents	
Yes	17 (20.2)
No	67 (79.8)

levels of allergens in at least one of these samples (Table 3) was estimated. We found that 77.1% of households had >2.0 μg/g of either dust mite allergen (Der p 1 or Der f 1) and 56.6% had >2.0 U/g of cockroach allergen (Bla g 1). Dog allergen levels (Can f 1) ≥2.0 μg/g were found in 55.4% of households. Among the five indoor allergens, cat allergen (Fel d 1) levels were the lowest.

Average household humidity greater than 50% was associated with >2.0 μg/g of either Der p 1 or Der f 1 dust mite allergen (odds ratio=3.2; 95% CI=1.1, 9.3; *p* value=0.03) but was not associated with any other dust allergen (Table 4). Homeownership was associated with low levels of Bla g 1 (odds ratio=2.61; 95% CI=1.03, 6.6; *p* value=0.04), and households where research staff reported seeing evidence of cockroaches during home visits were significantly more likely to have Bla g 1 levels above 8.0 U/g in the kitchen (OR=14.0 95% CI=3.3, 59.5 *p* value=<0.001). Homes in which the primary caretaker had at least some college education were less likely to have Der p 1 levels >2.0 μg/g (odds ratio=0.28; 95% CI=0.10, 0.75; *p* value=0.01). Household income and the number of people living in the household were not associated with dust allergen levels.

DISCUSSION

Previous research has shown substantial regional variability in home dust allergen levels among asthmatic children living in U.S. inner cities.[9] Whereas a number of studies have been published which describe the urban and suburban environments of asthmatics living in the densely populated northeast areas of the USA, there has been little data published on home dust allergen levels of asthmatic children living in urban areas of the Gulf South.[9,14] Climatic conditions in this region of the country are distinguished by high temperature and year-round elevated humidity, creating a damp environment suitable for allergen growth. The Institute of

TABLE 3 Distribution of allergen levels in the household floor, bed, and upholstery (*N*=83)

Allergens	*n* (%)
Der p 1 (μg/g)	
>2.0	38(45.8)
≥10.0	15(18.1)
Der f 1 (μg/g)	
>2.0	49(59.0)
≥10.0	13(15.7)
Either dust mite (μg/g)	
>2.0	64(77.1)
≥10.0	27(32.5)
Fel d 1 (μg/g)	
1.0–8.0	8(9.6)
>8.0	5(6.0)
Can f 1 (μg/g)	
2.0–10.0	24(28.9)
>10.0	22(26.5)
Bla g 1 (U/g)	
>2.0	47(56.6)
>8.0	28(33.7)

TABLE 4 Unadjusted association between average household humidity and dust allergen levels (*N*=83)

Allergens	>50% humidity [*n* (%)]	OR (95% CI)	*p* value
Either dust mite		3.2 (1.1, 9.3)	0.03[a]
≤2.0 μg/g	7 (14.6)		
>2.0 μg/g	41 (85.4)		
Fel d 1		0.6 (0.2, 1.8)	0.32
<1.0 μg/g	42 (87.5)		
≥1.0 μg/g	6 (12.5)		
Can f 1		1.4 (0.6, 3.4)	0.46
<2.0 μg/g	20 (41.7)		
≥2.0 μg/g	28 (58.3)		
Bla g 1		1.0 (0.4, 2.5)	0.97
≤2.0 U/g	21 (43.8)		
>2.0 U/g	27 (56.3)		

[a]Statistically significant (p value<0.05)

Medicine concluded that a damp indoor environment is related to asthma exacerbation and increased morbidity, acting primarily through the proliferation of moisture-sensitive allergens.[16]

Our findings revealed a highly allergenic home environment. Seventy-seven percent of children were exposed to two or more indoor allergens above established cutpoints, and 43.4% were exposed to three or more allergens (data not shown). Over a quarter of homes had moderate or high exposure to three of four dust allergens tested (dust mite, cockroach, and dog). Our data show that asthmatic children in New Orleans may be exposed to a greater number of allergens at moderate to high levels compared to asthmatic children living in other inner cities and to the general population. Of particular note is the rate of exposure to high levels of cockroaches and dust mites (Table 5).

Findings from ICAS established that the homes of inner-city asthmatics living in the Northeast have a higher concentration of cockroach allergen (specifically New York, where 62.2% of homes had levels >2 U/g) than any other region, likely because of the high number of children living in high-rise apartments where cockroach extermination is difficult.[9] In our study, where no child lived in a high-rise apartment, 56.6% of the homes had cockroach allergens above 2 U/g and one third of the households had levels >8 U/g. Home humidity level was not associated with the presence of cockroach allergens and of the various household characteristics measured only home ownership was associated with cockroach allergens, and the association was weak. This leads us to conclude that the high rate of cockroach allergen is related to features of the general ambient, rather than the home, environment.

Dust mites were also a pervasive allergen. Seventy-seven percent of New Orleans homes had levels >2 μg/g of dust mite allergen. Considering a cutpoint of 10 μg/g, the prevalence of residential dust mite exposure was 32.5%. These levels are substantially higher than those found both in the homes of asthmatics in the ICAS sample and levels in beds in the general population.[2,9] Our findings support an association between high humidity and dust mite exposure, suggesting that an intervention that reduces home humidity levels may be warranted. New Orleans

TABLE 5 Comparison of home allergen levels (%) between New Orleans and other cities

Allergens	New Orleans (*n*=83)	Dallas[a] (*n*=135)	Seattle[a] (*n*=127)	Boston[a] (*n*=119)	Bronx[a] (*n*=134)	Chicago[a] (*n*=141)	Tucson[a] (*n*=140)	New York[a] (*n*=141)
Either dust mite, >2.0 μg/g	77.1	69.9	65.1	39.8	21.4	16.7	24.5	8.2
Fel d 1, >8.0 μg/g	4.8	1.6	32.8	14.0	12.4	5.9	5.8	12.6
Can f 1, >10.0 μg/g	25.3	9.7	25.4	9.1	17.5	7.7	19.9	13.8
Bla g 1, >2.0 U/g	56.6	47.7	7.6	36.8	54.3	55.1	11.0	62.2

[a]Gruchalla et al. (2005)[9]

has a humid environment with an average morning relative humidity of 88%.[17] Our dust mite findings may have been a conservative estimate of home allergen exposure because potentially relevant species of dust mites were not sampled. Research has shown that, in addition to Der p 1 and Der f 1, the dust mite *Euroglyphus maynei* is prevalent in humid climates and is a cause of allergen sensitization around the world.[18,19] *Euroglyphus maynei* is a primary source of T cell sensitization and is present in levels that cause sensitization in temperate climates. It is often found in high concentration in beddings, providing a pathway for exposure.[20,21] A study conducted in New Orleans and seven other geographic areas of the USA found that, in New Orleans, *E. maynei* was prevalent in 31% of sampled homes. It was also found in a significant number of homes in Galveston, TX, and Delray Beach, FL, suggesting an affinity for southern climates.[22] Further research is needed to establish whether *E. maynei* species of house dust is a significant source of home allergen exposure in New Orleans homes.

A quarter of homes had levels of dog (Can f 1) allergen >10.0 μg/dl comparable to the highest ICAS site—Seattle. Fifty-four percent of homes with dog allergen levels >10.0 μg/dl reported currently having a dog. Although five homes had cat allergen levels above 8.0 μg/dl, only one of those homes reported currently having cats. Cat allergen levels in homes without cats ranged from 8.0 to 1,474 μg/dl. These findings suggest that allergens from previous pets still lingered in the home or were being tracked in from outdoors. Whereas levels of cat and dog allergens were comparable to levels found in the homes of other inner-city asthmatics, they were lower than levels present in the general population. Approximately one-third (34.7%) of homes in the National Survey of Lead and Allergens in Housing study had dog allergens >10.0 μg/dl, and 34.9% of homes had detectable cat allergen levels above 8.0 μg/dl.[23]

In addition to the climatic disposition, indoor allergen exposure also depends on socioeconomic and sociodemographic factors.[7] The demographic characteristics of our study population are similar to those in the ICAS study; however, the majority of our sample was African-American and had a lower annual income—despite a similar educational level.[10] The majority of families reported receiving an asthma management plan, home cleaning advice, and advice on trigger avoidance from their medical provider. Furthermore, most families reported taking steps to reduce home allergen levels by ceasing to smoke, attempting to eliminate pests, and vacuuming regularly (data not shown). Despite these efforts, home dust allergen levels were very high. A combination of an environment conducive to allergen growth and poverty may be a plausible explanation for these findings. Approximately 70% of caregivers were employed, but the majority of families had annual incomes of <$15,000. Few families reported using mattress covers or air filters, and few reported removing carpets or drapes (data not shown). A lack of resources could be the primary barrier to purchasing allergen avoidance supplies. Kitch et al. reported that, in the greater Boston area, low family income was associated with greater risk of exposure to high levels of cockroach allergen and a lower risk of dust mite allergen exposure in the home.[24] In our sample of low-income families, both dust mite and cockroach were prevalent household allergens.

Asthmatic children in New Orleans are at high risk of exposure to multiple indoor allergens. Overall, our study homes showed higher levels for three out of four allergens, namely, dust mites, cockroach, and dog dander, compared to all ICAS sites. Compared to the general population, levels of cockroach and dust mite allergens were consistently higher, yet levels of cat and dog allergens were lower.

Our findings reinforce evidence of substantial regional variability in the indoor allergen levels of asthmatic children. In an ideal situation, allergen avoidance advice should be tailored to a child's specific home environment. However, individual home allergen testing is not feasible in the clinical setting, making regional exposure data an important resource for clinicians. This study fills a data gap on the home exposure profile of asthmatic children in the Gulf South region of the USA.

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