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Mouse and cockroach exposure in rural Arkansas Delta region homes

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ABSTRACT

Background: Home characteristics and aeroallergen exposure in rural US children with asthma are poorly described.

Objective: To examine the relationship between cockroach and mouse allergen concentrations and home characteristics of children with asthma in the rural Arkansas Delta.

Methods: The home environments of rural children with asthma were examined using home environment questionnaire and home inspection. Bedroom and kitchen dust was analyzed for cockroach and mouse allergen concentrations.

Results: The median age of participants was 9 years, and 84% were African American. Most participants (78%) resided in single-family homes. Evidence of cockroaches was detected in 13% of homes and evidence of rodents was detected in 23% of homes. Detectable Bla g 1 was found in 58% of kitchens and 43% of bedrooms, Bla g 2 was detected in 37% of kitchens and 28% of bedrooms, and Mus m 1 was found in 81% of kitchens and 97% of bedrooms. Evidence of cockroaches in any room was associated with Bla g 1 concentrations of ≥ 2 U/g (odds ratio 21.71, 95% confidence interval 4.26–118.39) and Bla g 2 concentrations of ≥ 2 U/g (odds ratio 21.90 95% confidence interval 4.30–138.91). Multifamily vs single-family dwellings were more likely to have Bla g 2 concentrations of ≥ 2 U/g (odds ratio 3.52, 95% confidence interval 1.0–11.82). Home characteristics were not associated with Mus m 1.

Conclusion: Mouse and cockroach allergens were detected in most rural homes; however, concentrations were relatively low compared with those previously reported in inner-city homes. Few home characteristics predicted allergen concentrations. Further studies are needed to establish clinically relevant associations that might place rural children with asthma at risk for poor clinical outcomes.

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Introduction

Previous investigations have explored the relationship among indoor allergen exposure, allergen sensitization, and asthma morbidity in urban and suburban children,^{1–3} and increased asthma morbidity has been linked to environmental exposure to indoor allergens among patients who are sensitized.^{2,4–6} Home environmental exposure to cockroach and mouse allergens has been cited as a relevant contributor to allergic sensitization and significant morbidity in urban and suburban children.^{2,7–10} Matsui et al⁹ reported that inner-city children who were sensitized and exposed to

high levels of mouse allergen were more likely to have asthma symptoms, including slowed activity, cough, exercise-induced symptoms, night-time awakenings, and rescue medication use compared with children who were not exposed to high levels. Other investigators also have shown that in inner-city children with asthma, those who were allergic to cockroach allergen and exposed to high concentrations had an increased frequency of asthma-related health problems, including more hospitalizations per year, increased number of unscheduled medical visits for asthma, and more days of wheezing, missed school days, and nights with lost sleep.^{1,11}

The National Survey of Lead and Allergens in Housing study showed that the presence of cockroaches and rodents in the home predicted high allergen burden.² Home characteristics, including exposed food, plumbing leaks, and dirty pots, have been shown to be associated with increased allergen concentrations in suburban homes.¹² Socioeconomic factors, population density, and location also have been associated with allergen concentrations in homes.^{13–15} In these studies, several home characteristics have been consistently associated with increased aeroallergen concentrations,

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and several intervention strategies have been designed to decrease the allergen burden in the homes of patients with asthma residing in inner-city and densely populated regions; however, investigations of home characteristics and home allergen exposure in rural US children with asthma are lacking. An increased asthma prevalence in pediatric patients with asthma living in rural Arkansas has been described, as has an increased morbidity in children living in rural vs urban regions of Arkansas.^{16–18} In these prior studies, the lifetime prevalence of provider-diagnosed asthma was 20% in predominately low-income, African American rural school children in the Arkansas Delta, and caregivers have reported high rates of rescue medication use and health care use for asthma. The present study examined the relationship between cockroach and mouse allergen concentrations and home characteristics in the homes of children with asthma who live in the rural Delta region of Arkansas.

Methods

Study Population

For this cross-sectional investigation, 116 participants 4 to 17 years old with current asthma were recruited from public school districts in the Mississippi River Delta region of Arkansas; however, 21 participants did not have a home inspection and were not included in the final analysis. The final dataset includes 95 children with home inspection data and dust analysis. The Lower Mississippi Delta region, one of the poorest, most medically underserved regions of the United States, includes the geographic regions of Arkansas, Louisiana, and Mississippi that are contiguous with the Mississippi River. Participants for the present study were recruited from public schools in Eudora, Lake Village, Marvell, Elaine, and Dumas in the Arkansas Delta region. These small towns are located in counties where 40% of families with children 5 to 17 years old lived below the 2006 poverty line.¹⁹ Students attended consolidated school districts that were predominantly African American—1,034 of 1,552 (67%) in Dumas, 989 of 1,288 (77%) in Lake Village and Eudora, and 507 of 564 (90%) in Marvell and Elaine—and at least 78% of students met federal free or reduced lunch guidelines.²⁰ All students in participating school districts received written information about the research study and caregivers of potentially eligible participants were asked to contact study personnel if they were interested in participating in the research study. Other recruiting measures included informational meetings and flyers at school or community venues, such as Parent–Teacher Association meetings, community health fairs, and school events. In this cross-sectional investigation, all enrolled children met the minimum criteria for asthma according to the National Asthma Education and Prevention Program guidelines and reported taking prescribed controller and/or rescue asthma medications in the 6 months before enrollment. All study procedures were approved by the institutional review board at the University of Arkansas for Medical Sciences (Little Rock), and all participants gave written informed consent.

Study Procedures

Home environment questionnaire

Using an interview format and home inspection, the authors conducted a cross-sectional investigation to assess home characteristics, cleaning practices, and home allergen exposure to cockroach and mouse allergens. The caregiver primarily responsible for the child's health care and medications was interviewed. During a structured, face-to-face interview, caregivers reported general home characteristics (age of home, number of rooms in home, etc), household laundry and cleaning routines, and household pet and/or farm animal exposure. Child and caregiver sociodemographic variables were obtained.

Home inspection

A home inspection administered by a trained environmental technician was conducted at each participant's home to record housing conditions. Inspection of the kitchen, living or television room, child's bedroom, and general home features were documented. A home inspection was conducted to document specific structural factors, including primary sources of heat and air, evidence of smokers in the homes, indoor plumbing and moisture leaks, overflowing trash, exposed food, mildew, evidence of pests, presence of carpeting, and presence or absence of allergy-proof covers on the child's bed.

Aeroallergen assessment

Bedroom dust samples were collected using a hand-held vacuum (model C2094, Hoover, Glenwillow, Ohio) and a Mitest dust collection kit (Indoor Biotechnologies, Charlottesville, Virginia) from the child's bedroom according to published methods. Dust was analyzed by the Dermatology, Allergy, and Clinical Immunology Laboratory at Johns Hopkins University (Baltimore, Maryland) for allergen content by a 2-site monoclonal-based enzyme-linked immunosorbent assay for Bla g 1, Bla g 2, and Mus m 1 allergens.²¹ Bla g concentrations were reported as units per gram of dust, and Mus m 1 concentrations were reported as micrograms per gram of dust. Allergen concentrations were measured in bedroom and kitchen settled dust specimens.

Bedroom allergen exposure was examined in the context of previously established cutoffs. For sensitization risks, Mus m 1 concentrations of $\geq 1.6 \mu\text{g/g}$ and Bla g 1 or Bla g 2 concentrations of $\geq 2 \text{ U/g}$ were examined. For morbidity risks, Mus m 1 concentrations of $\geq 8 \mu\text{g/g}$ and Bla g 1 or Bla g 2 concentrations of $\geq 8 \text{ U/g}$ were examined.

Statistical Methods

Summary statistics, ie, median, lower and upper quartiles for continuous variables, and frequency and percentage for categorical variables, are presented for all demographics, risk factors, and kitchen and bedroom allergen levels. The association between home characteristics and detection, sensitization, and asthma morbidity levels of Mus m 1, Bla g 1, and Bla g 2 allergens in the bedroom and kitchen were studied. Overall home characteristics considered included single-family vs multifamily homes and evidence of smokers. Bedroom characteristics considered included wall-to-wall carpeting in the bedroom, stuffed toys on the bed, and a mattress or a pillow not encased. Kitchen characteristics, such as dirty pots on the stove, exposed food, overflowing trash, plumbing leaks, and a greasy stove, were considered. In addition to these, evidence of cockroaches, mice or rats, dogs, cats, and indoor moisture or leaks in the home, bedroom, and kitchen were considered.

The Fisher exact test was used to test for the association between allergen levels of Bla g 1, Bla g 2, and Mus m 1 and dichotomized home characteristics. The effect of home characteristics on ordinal allergen levels of Bla g 1, Bla g 2, and Mus m 1 (0, below level of detection; 1, above level of detection and below sensitization risk cutoff; 2, above sensitization risk cutoff and below morbidity risk cutoff; 3, above morbidity risk cutoff) were analyzed using ordinal logistic regression. Effects were summarized as odds ratios (ORs) and exact 95% confidence intervals (CIs). All tests conducted were 2-sided assuming a significance level of 5%. The data analysis was generated using SAS/STAT 9.3 (SAS Institute, Cary, North Carolina).

Results

Study Population and General Home Characteristics

The study population consisted of 95 pediatric patients with asthma (median age 9 years) from the Delta region of Arkansas (Table 1). Fifty-seven percent of patients were male, 84% were African American, and 92% had a state-issued health insurance

Table 1
Demographic characteristics of study population^a

Age (y), median (25th, 75th percentiles)	9 (7, 12)
Sex, n (%)	
Male	54 (56.8)
Female	41 (43.2)
Race, n (%)	
African American	80 (84.2)
White	15 (15.8)
Insurance type, n (%)	
ARKids First ^b	62 (65.3)
Medicaid	25 (26.3)
Private	8 (8.4)
Household income, n (%)	
>\$20,000	21 (23.86)
≤\$20,000	67 (76.14)
Maternal education, n (%)	
Grade <9	4 (4.4)
≥ grades 9–11	16 (17.6)
High school graduate	29 (31.9)
≥ some college	42 (45.2)
BMI (kg/m ²), median (25th, 75th percentiles)	19.7 (16.4, 26.0)

Abbreviation: BMI, body mass index.

^aData missing for some participants.^bARKids First is the state child health insurance program in Arkansas.

program (Medicaid or State Child Health Insurance Plan). Most (76%) had an annual household income lower than or equal to \$20,000, and 45% of participants' mothers reported education beyond high school. Only 22% lived in multifamily (apartment, duplex, etc) dwellings (Table 2). There were smokers in 25% of homes. On general home inspection, evidence of live or dead cockroaches in any room was detected in 13% of homes, and evidence of rodents in any room was detected in 23% of homes (Table 2). Specific home characteristics that have been associated with increased allergen exposure were prevalent in the bedrooms and kitchens of participants. In participant bedrooms, 60% had wall-to-wall carpeting and 29% had stuffed toys on the participant's bed. None of the participants had encased mattresses or pillows. In participant kitchens, moisture leaks (32%), dirty pots on the stove (28%), exposed food (44%), and overflowing trash (8%) were detected (Table 2).

Table 2
Home risk factor characteristics (n = 95)

General	
Type of dwelling	
Apartment/duplex/semidetached	21 (22.1%)
Single-family or mobile home	74 (77.9%)
Smokers in home	24 (25.3%)
Evidence of cockroaches	12 (12.6%)
Evidence of rodents	22 (23.2%)
Dogs in the home	12 (12.6%)
Cats in the home	7 (7.4%)
Evidence of moisture or leaks	37 (39.0%)
Bedroom	
Wall-to-wall carpeting	57 (60.0%)
Stuffed toys on bed ^a	27 (28.7%)
Mattress/pillow not encased ^a	94 (100%)
Evidence of cockroaches	4 (4.2%)
Evidence of rodents	1 (1.1%)
Mildew in ceiling/walls/windows	12 (12.6%)
Evidence of leak	10 (10.5%)
Kitchen	
Moisture leaks	30 (31.6%)
Dirty pots on stove	27 (28.4%)
Exposed food	42 (44.2%)
Overflowing trash	8 (8.4%)
Plumbing leaks	19 (20.0%)
Greasy stove	20 (21.1%)
Evidence of cockroaches	9 (9.5%)
Evidence of rodents	19 (20.0%)

^aData missing for 1 home.

Distribution of Mouse and Cockroach Allergens

Mouse and cockroach allergens were found in most homes (Table 3). Overall, 98% of homes had detectable Mus m 1 in any room. The median bedroom Mus m 1 concentration was 0.29 µg/g and the median kitchen Mus m 1 concentration was 0.13 µg/g. Mus m 1 concentrations of ≥1.6 µg/g were found in 34% of homes, with 22% of bedrooms and 29% of kitchens having concentrations of ≥1.6 µg/g. Bla g 1 was detected in any room in 65% of homes, and Bla g 2 was detected in 40% of homes. The median bedroom Bla g 1 concentration was below the level of detection, and the median kitchen Bla g 1 concentration was 0.6 U/g. Median bedroom and kitchen Bla g 2 concentrations were below the level of detection. Bla g 1 concentrations of ≥2 U/g were found in 16% of bedrooms and 40% of kitchens. Bla g 2 concentrations of ≥2 U/g were found in 20% of bedrooms and 37% of kitchens.

Mouse and Cockroach Allergen Concentrations and Home Characteristics

The relationship between home characteristics and allergen concentrations of Mus m 1, Bla g 1, and Bla g 2 in the overall home, bedroom, and kitchen were analyzed. Mus m 1 was detected in virtually all homes (94 of 95); therefore, the authors could not examine home characteristics associated with detectable vs undetectable Mus m 1 concentrations. Home characteristics were examined to determine whether any characteristics were associated with increased Mus m 1, but none were predictive of concentrations of ≥1.6 µg/g or ≥8 µg/g. Evidence of cockroaches (live or dead) anywhere in the home was strongly associated with Bla g 1 and Bla g 2 concentrations. For Bla g 1, evidence of cockroaches in any room was associated with concentrations of ≥0.4 U/g (OR 8.39, 95% CI 1.60–81.36) and ≥2 U/g (OR 21.71, 95% CI 4.26–118.39). For Bla g 2, evidence of cockroaches in any room was associated with concentrations of ≥1 U/g (OR 19.41, 95% CI 3.52–190.48), ≥2 U/g (OR 21.90, 95% CI 4.30–138.91), and ≥8 U/g (OR 81.0, 95% CI 10.20–893.14). Multifamily dwellings compared with single-family homes were more likely to have Bla g 2 concentrations of ≥2 U/g (OR 3.52, 95% CI 1.0–11.82). Having a smoker in the home was associated with Bla g 1 concentrations of ≥2 U/g (OR 4.57, 95% CI 1.22–17.00). Evidence of smoking also was associated with Bla g 2 concentrations of ≥2 U/g (OR 4.92, 95% CI 1.46–16.38) and ≥8 U/g (OR 5.58, 95% CI 1.15–29.27).

In participant bedrooms, evidence of mildew, wall-to-wall carpeting, and stuffed toys were not associated with increased Bla g 1 or Bla g 2 concentrations. In fact, bedrooms with wall-to-wall carpeting were less likely to have Bla g 1 concentrations of ≥2 U/g (OR 0.19, 95% CI 0.04–0.71). Similar findings were observed for Bla g 2 concentrations.

The relationship between kitchen characteristics and cockroach allergen concentrations were analyzed in each home, including exposed food, dirty cooking pots, and overflowing trash in the kitchen. Dirty pots on the stove were associated with Bla g 1 concentrations of ≥8 U/g (OR 4.15, 95% CI 1.35–12.70), but none of the other kitchen characteristics were associated with increased concentrations of Bla g 1 or Bla g 2. Similar home characteristics were found to be associated with allergen levels when analyzed using ordinal logistic regression (results not shown). There was no association between increased mouse or cockroach allergen concentrations and exposure to pets.

The study sought to explore the association between bedroom and kitchen allergen concentrations. Bedroom and kitchen concentrations of Bla g 1 (Spearman rank correlation $\rho = 0.60$), Bla g 2 ($\rho = 0.72$), and Mus m 1 ($\rho = 0.70$) were highly correlated. Detection of each respective allergen in the bedroom significantly increased the likelihood of finding the corresponding allergen in the kitchen.

Table 3

Distribution of cockroach and mouse allergen concentrations in homes of participants (N = 95)

Allergen	Room	Median	Range	At or above limit of detection	At or above sensitization risk cutoff	At or above morbidity risk cutoff
Mus m 1	any room			≥0.01 µg/g 93 (97.9%)	≥1.6 µg/g 32 (33.7%)	≥8 µg/g 17 (17.9%)
	bedroom	0.29	BD–94.84	92 (96.7%)	21 (22.1%)	10 (10.5%)
	kitchen	0.13	BD–220.83	74 (81.3%)	26 (28.6%)	13 (14.3%)
Bla g 1	any room			≥0.4 U/g 62 (65.3%)	≥2 U/g 38 (40%)	≥8 µg/g 24 (25.3%)
	bedroom	BD	BD–41.40	41 (43.2%)	15 (15.8%)	2 (2.1%)
	kitchen	0.60	BD–908.80	53 (58.2%)	36 (39.6%)	24 (26.4%)
Bla g 2	any room			≥1.0 U/g 38 (40.0%)	≥2 U/g 35 (36.9%)	≥8 µg/g 29 (30.5%)
	bedroom	BD	BD–138.0	27 (28.4%)	19 (20%)	10 (10.5%)
	kitchen	BD	BD–404.30	34 (37.4%)	34 (37.4%)	29 (30.9%)

Abbreviation: BD, below limit of detection.

Mus m 1 concentrations in the bedroom were not highly associated with Bla g 1 (Spearman rank correlation $\rho = 0.24$) or Bla g 2 ($\rho = 0.20$) concentrations in the bedroom. Mus m 1 concentrations in the kitchen also were not highly associated with Bla g 1 ($\rho = 0.24$) or Bla g 2 ($\rho = 0.16$) concentrations in the kitchen. One association found was that homes with Bla g 2 concentrations of ≥ 2 U/g in the bedroom were more likely to have Mus m 1 concentrations of ≥ 1.6 µg/g in the bedroom ($P = .03$).

Relationship between Home Characteristics and Other Common Indoor Allergens

Although the present study focused primarily on 2 major allergens that have been extensively studied in high-risk inner-city populations, other relevant indoor allergens were measured, including Der p 1, Der f 1, Can f 1, and Fel d 1. Evidence of smokers in the home was associated with detectable concentrations of Der p 1 in the bedroom (OR 4.56, 95% CI 1.18–25.72). Wall-to-wall carpeting in the bedroom was associated with Can f 1 concentrations of ≥ 2 µg/g in the bedroom (OR 10.93, 95% CI 1.48–476.87). Compared with homes without pets, cat and dog ownership was positively associated with high (≥ 8 µg/g) concentrations of the respective allergen (Fel d 1, OR 258.00, 95% CI 15.55–11,961.14; Can f 1, OR 40.50, 95% CI 5.27–448.66). Dog ownership was associated with having Bla g 2 concentrations below the level of detection ($P = .02$); however, there were no other significant associations between dog or cat ownership and evidence of cockroaches or mice in the homes or concentrations of Bla g 1, Bla g 2, or Mus m 1 in the homes.

Discussion

Several studies have examined the relationship between increased cockroach and mouse allergen exposure and home characteristics.^{7,12,22,23} Those previous investigations have been performed primarily in inner-city and suburban pediatric populations and have informed intervention strategies aimed at these targeted populations.^{24–27} Studies reporting home characteristics and the prevalence of mouse and cockroach allergen in rural populations have been limited, and it is unknown whether intervention strategies tailored for inner-city or suburban populations are relevant or beneficial for rural pediatric populations. Similar to other high-risk populations, the authors' previously published data showed significant associations between sensitization and detectable bedroom concentrations of mouse and cockroach allergen in the homes of children in the present study population.¹⁶ Thus, the authors sought to examine the association between home characteristics and mouse and cockroach allergen concentrations in the homes of children with asthma living in the rural Arkansas Delta.

Results from the National Cooperative Inner-City Asthma Study showed a significant prevalence of Mus m 1 allergen in 95% of homes, with the highest concentrations being found in kitchens.²³ In this inner-city population, median kitchen concentrations of Mus m 1 were reported at 1.60 µg/g and median bedroom concentrations were reported at 0.52 µg/g. Matsui et al²⁸ reported detectable mouse allergen in 75% of suburban bedrooms, with a median bedroom concentration of 22 ng/g (0.02 µg/g). Results of the present study showed that detectable Mus m 1 concentrations were prevalent in the rural population under investigation, with 98% of homes having detectable Mus m 1 in any room. The median kitchen (0.16 µg/g) and bedroom (0.29 µg/g) concentrations of Mus m 1 were found to be much lower than reported concentrations in urban populations but similar to or higher than concentrations reported in suburban homes. The authors previously reported that mouse allergen sensitization was related to these low allergen concentrations,¹⁶ and this is a finding that was similarly reported in the suburban population.²⁸ Although others have reported specific home characteristics, such as place of residence (city vs suburban), food remains, or cockroach exposure as factors associated with high mouse concentrations,^{22,23} the authors did not find any home characteristics associated with Mus m 1 concentrations of ≥ 1.6 µg/g.

Rosenreich et al¹¹ reported that detectable cockroach allergen (Bla g 1) was found in 85% of bedrooms of inner-city children with asthma, and more recently the Inner City Asthma Study investigators reported that approximately 40% of inner-city homes had Bla g 1 allergen concentrations > 2 U/g.¹ The present findings were similar in that 65% of homes had detectable Bla g 1 in any room, and 40% of homes had Bla g 1 concentrations of ≥ 2 U/g in any room. Median cockroach allergen concentrations for the rural Delta population were lower than previously reported in inner-city populations^{7,29} but higher than concentrations reported in a predominantly suburban population.¹² In previous investigations, high Bla g 1 concentrations were significantly higher in multifamily homes compared with detached single-family homes among inner-city homes.^{1,27} The present findings were similar for Bla g 2, with multifamily dwellings being more likely to have detectable and increased concentrations of Bla g 2 compared with single-family homes. The authors found no association with Bla g 1 concentrations and multifamily vs single-family homes. Other home characteristics that have been associated with cockroach exposure include food or food remains in the bedroom and lack of mattress or pillow encasements in a suburban population.¹² The authors found no relationship between food or food remains in the bedroom and cockroach exposure, and none of the present study participants had mattress or pillow encasements.

Perry et al¹² reported that Bla g 1 was detectable in 43% of suburban kitchens, with the presence of live or dead cockroaches and dirty pots on the stove being factors associated with Bla g 1

concentrations. In the present study, the authors found detectable concentrations of Bla g 1 in 58% and Bla g 2 in 37% of rural kitchens, and findings were similar to those previously reported in a suburban population, with dirty pots on the stove being associated with cockroach concentrations in the kitchen; however, no other kitchen-specific characteristics predicted cockroach allergen exposure.

Compared with other populations, data from the present study suggest relevant similarities and differences in the prevalence and distribution of mouse and cockroach aeroallergens in the homes of children with asthma living in the rural Delta region of Arkansas. Allergen concentrations tended to be lower than those reported in inner-city homes but similar to concentrations detected in suburban homes. The authors previously reported on the significant association between exposure to these low-level concentrations of mouse and cockroach allergen and allergic sensitization.¹⁶ However, in the present study, they did not find many of the previously reported associations between home characteristics and high allergen mouse and cockroach allergen concentrations. In addition to mouse and cockroach allergens, the associations between other indoor allergens and home characteristics were explored. The most striking findings were the strong associations between pet ownership and high pet allergen concentrations and the fact that dog ownership was associated with undetectable concentrations of Bla g 2. The lack of association between allergen concentrations and home characteristics may have been due to the relatively small study population, which is a limitation of the present study. The ability to carry out multiple home visits in rural regions is significantly limited by cost, travel, and time constraints. Compared with major metropolitan areas with population densities >5,000 persons per square mile, most counties in the Arkansas Delta region have population densities no greater than 30 persons per square mile (Census Bureau, 2012); thus, it is not only difficult from a time and travel standpoint but also cost prohibitive to carry out home visits in rural regions. To minimize missing data and maximize the number of participants with completed home visits, the authors carefully planned and coordinated each home visit with the families and made multiple attempts to visit each home to collect data. All home inspection data collections were conducted by trained research staff, and interviews were collected at face-to-face meetings between the child's caregiver and research staff to ensure high-quality data.

As the authors previously reported, sensitization was associated with exposure to mouse and cockroach allergens in this rural study population¹⁶; therefore, an investigation of home environmental factors that may be related to increased allergen exposure in children with asthma in the Delta is relevant. Together with the present findings, the data suggest that home environment and aeroallergen exposure requires further investigation in rural populations, particularly in larger populations at high risk for poor health outcomes. This study adds to the current body of literature because it demonstrates the home environmental distribution of cockroach and mouse allergens and the relation to home characteristics in a high-risk population living in a rural environment. Additional studies are needed in rural asthmatic populations to determine the significance of home allergen exposure and possibly exposure in other settings, such as schools, that may contribute to the increased morbidity, as previously reported.^{5,7,12,16,18}

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