

Socioeconomic status and race as risk factors for cockroach allergen exposure and sensitization in children with asthma

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Background: The domestic cockroach has been identified as an important source of indoor aeroallergens worldwide in both temperate and tropical climates. Because cockroach populations are highest in crowded urban areas, some have suggested that the increased asthma morbidity and mortality rates in inner cities could be related in part to cockroach allergen exposure. We have examined cockroach allergen exposure in the homes of children with asthma in both urban and suburban locations and have related the rates of exposure and sensitization to socioeconomic, racial, and demographic factors.

Objective: The study was designed to determine the independent contribution of race, socioeconomic status, and place of residence to the risk of cockroach allergen exposure and sensitization in children with asthma.

Methods: Eighty-seven children with moderate to severe allergic asthma, aged 5 to 17 years, participating in a prospective trial of immunotherapy, were evaluated. Extracted dust samples from three home locations were analyzed by using two-site monoclonal immunoassays for major cockroach allergens (Bla g 1 and Bla g 2). A puncture skin test with a mixed cockroach allergen extract was performed in 81 of the 87 subjects.

Results: In the 87 homes evaluated, 26% of the bedroom dust samples had detectable levels of cockroach allergen. In homes with detectable bedroom cockroach allergen levels, mean Bla g 1 and Bla g 2 concentrations in urban and suburban homes were similar. Over 80% of children with bedroom Bla g 1 or Bla g 2 of 1 U/gm or greater demonstrated skin sensitivity to cockroach allergen. The rate of cockroach sensitization was directly related to the level of bedroom exposure. African-American race was the only factor that was independently associated with cockroach allergen exposure ($p = 0.05$). Lower socioeconomic status, age greater than 11 years, cockroach exposure, and African-American race were all independently associated with cockroach allergen sensitization on the basis of stepwise multiple linear regression analysis.

Conclusions: African-American race and low socioeconomic status were both independent, significant risk factors for cockroach allergen sensitization in children with atopic asthma. Cockroach allergen is detectable throughout the house, including the critical bedroom environment. (*J Allergy Clin Immunol* 1996;97:1393-1401.)

Key words: Cockroach allergen, sensitization, socioeconomic status, race, urban, children, asthma

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The cockroach has been identified, together with several dust mite species and domesticated pets, as an important source of indoor allergens in homes throughout the world.¹⁻⁵ Although over 60 species of cockroach have been identified, in North America⁶ the most common indoor species are the German, Oriental, and American. Substandard housing and multiple urban dwellings promote cockroach infestation in American inner cities.⁷ From a clinical perspective, cockroach allergens are known to represent an important risk factor for

Abbreviation used

SES: Socioeconomic status

acute asthma in predisposed atopic individuals first seen in emergency departments.^{8,9} Some authors have suggested a link between cockroach allergen exposure and the observed increases in asthma-associated morbidity and mortality rates among African Americans and Hispanics who live in inner cities across the United States.⁹ However, independent contributions of race and socioeconomic status (SES) to the risk of severe asthma have remained obscure because racial segregation and poverty have continued to coexist in many major American cities. In this investigation, we have directly examined this issue within the framework of a prospective immunotherapy study in childhood asthma by ascertaining the degree to which cockroach allergen exposure and sensitization are influenced by SES, age, race, gender, and place of residence.

METHODS

Subjects

A group of 106 children with asthma (5 to 17 years of age; mean age, 11 ± 2.7 years) were participants in a controlled clinical trial of immunotherapy for allergic childhood asthma (Johns Hopkins Childhood Asthma Study). All of the children had positive skin test responses to multiple indoor and outdoor aeroallergens and moderate to severe asthma that required daily medication for at least 6 months of the year. They were recruited by advertisement and were seen at five outpatient practices in the Baltimore metropolitan area from March 1986 to February 1991. Participants included urban and suburban residents with a broad range of SES. Suburban versus urban residence was determined by zip code; if the home was in one of 19 zip codes that lay within or largely within the Baltimore city boundaries, residents were considered to be urban dwellers. Quantitative house dust analyses for cockroach allergens (Bla g 1 and Bla g 2) were performed in 87 homes; the remainder were sampled early in the study before Bla g 1 and Bla g 2 assays were available. The study group that was included in the statistical analyses consisted of 66 boys and 21 girls, 48 white and 39 African-American children, 37 urban and 50 suburban residents (Table I). The study was approved by the Johns Hopkins Joint Committee on Clinical Investigation.

SES

The socioeconomic stratification for each family was computed on the basis of the subject's type of residence and the occupation and years of education of the head of the family by using the method of Hollingshead and

TABLE I. Demographic characteristics of study subjects

Characteristic	Number (%)
Gender	
Male	66 (76)
Female	21 (24)
Race	
White	48 (55)
African-American	39 (45)
Age (yr)	
Range	5-17
Mean $\pm$ SD	11.1 ± 2.7
Residence	
Urban	37 (42)
Suburban	50 (58)
SES	
I (high)	5 (6)
II (high)	16 (18)
III (middle)	38 (44)
IV (low)	20 (23)
V (low)	8 (9)

Redlich.¹⁰ The residential status was ranked on a scale from 1 to 6, which ranged from the finest homes (grade 1) to the poorest tenements (grade 6). The occupational status was ranked in the following seven groups: (1) executives and major professionals, (2) managers and lesser professionals, (3) administrative personnel of large companies and semiprofessionals, (4) technicians and clerical workers, (5) skilled workers, (6) semiskilled workers, and (7) unskilled workers. The educational status was ranked in the following seven steps: (1) graduate professional training, (2) standard college or university graduation, (3) partial college training, (4) high school graduation, (5) partial high school, (6) junior high school, and (7) less than 7 years of schooling. According to these criteria, each subject received a summed score that was grouped into SES levels I to V. For statistical purposes, we considered SES I and II to be high, SES III to be middle, and SES IV and V to be low status.

Skin tests

Eighty-one children successfully completed cockroach skin testing. Skin testing was performed by the puncture method with a bifurcated needle and glycerinated full-strength mixed (German and American) cockroach extract with allergenic potency of 580 U/ml Bla g 1 and 80 U/ml Bla g 2 (Hollister-Stier Laboratories, Spokane, Wash.). The wheal diameters observed at 15 minutes were compared with skin reactions produced by a histamine (10 mg/ml) positive control and phenol-saline-human serum albumin negative control. Wheal diameters equal to or greater than the diameter of the histamine control (4.9 ± 1.1 mm) were considered positive.¹¹

House dust sampling

The settled dust specimens used for allergen analysis were collected from 87 subjects' homes by using a hand-held electric vacuum cleaner equipped with individual collection bags (Douglas Redivac model no. 6735; Scott Fetzer Co., Walnut Ridge, Ark.). Multiple sites were sampled in each residence during a single home visit by a trained technician. The bedroom samples included dust collection from the bed and floor surrounding the bed of the child with asthma. The dust from the family room or living room was collected from a couch, stuffed chair, and the adjacent floor. The kitchen and bathroom floor samples were mixed. All floor samples were obtained by vacuuming a 1 m² area for 2 minutes. The filters from the vacuum cleaners were removed, sealed in separate plastic bags for each of the three sites within each home, and stored at -20° C until they were processed.

Extraction and ELISA

Dust extracts were prepared by extracting 100 mg of sieved dust (mesh pore size, 0.3 mm) in 2 ml of borate-buffered saline solution containing 5% bovine serum albumin, pH 8.0, at 4° C overnight with continuous rotation. The samples were centrifuged at 800 rpm for 8 minutes, and the clear-tinted supernatant was removed, sterile-filtered to remove all fine particles, and stored in plastic tubes at -20° C until it was assayed. The final extract was assayed for Bla g 1 and Bla g 2 by using quantitative two-site monoclonal antibody-based ELISAs, as previously described.¹² The lower limit of detection for both assays was 0.8 U/gm of sieved fine dust.

Statistics

A stepwise multiple linear regression analysis was used to examine the independent contribution of each dependent variable to the overall risk of cockroach allergen exposure or sensitization. On examination of both domestic cockroach allergen levels or sensitization, the dependent variables were SES, age, race, gender, and urban versus suburban residence. Significance ($p < 0.05$) was tested for each variable, sequentially controlling for all other factors by means of the likelihood ratio test. Relative risks for individual dependent variables were also computed with their 95% confidence intervals. Cockroach allergen exposure was considered as any detectable level (≥ 0.8 U/gm) and sensitization as positive skin test ($\geq$ half diameter of histamine wheal). All statistical analyses were performed with SPSS for Windows (SPSS, Inc., Chicago, Ill.¹³).

RESULTS

Distribution of cockroach allergen within households

Fig. 1 shows the cockroach allergen concentrations measured in separate settled dust specimens from the bedroom, kitchen, and living room. The relative distribution of the two allergens among

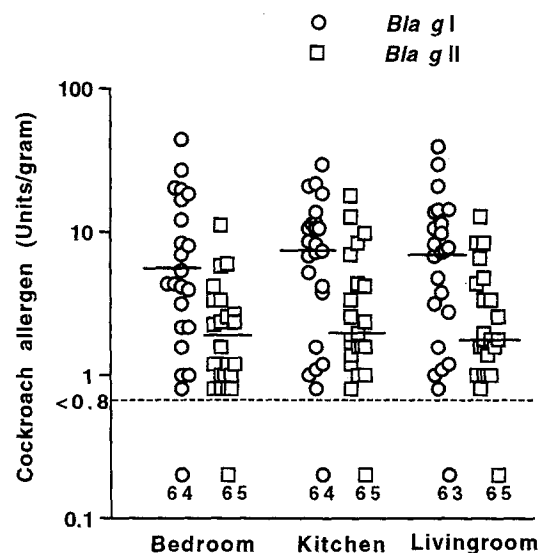


FIG. 1. Distribution of cockroach allergen Bla g 1 and Bla g 2 in three locations of homes of 87 children with moderate to severe asthma. The limit of detection of the assay is 0.8 U/gm. Median levels of homes with detectable cockroach allergens are indicated by horizontal bars. Numbers below the dotted line indicate numbers of samples that contained less than 0.8 U/gm of fine settled dust.

these three rooms was almost identical. Of the 87 homes evaluated, 26% of the bedroom samples had detectable levels of one or both cockroach allergens. Bla g 1 levels were higher than Bla g 2 levels on an arbitrary unit basis at each of the three sites.

The level of cockroach allergen (Bla g 1 + Bla g 2) in the kitchen was significantly associated with the cockroach allergen levels measured in the bedroom ($r = 0.73$, $p < .001$) and living rooms ($r = 0.78$, $p < 0.001$). For all subsequent analyses, the bedroom dust cockroach allergen levels were used because the bedroom was considered the most important source of prolonged allergen exposure for the child.

In those homes with detectable bedroom cockroach allergen levels, the mean Bla g 1 concentrations in urban and suburban homes were similar: 10.7 U/gm (range, 1.0 to 44 U/gm; $n = 16$) and 8.2 U/gm (range, 2.2 to 20.4 U/gm; $n = 6$), respectively. For Bla g 2 the mean levels in urban and suburban homes were also similar: 2.8 U/gm (range, 0.8 to 11.2 U/gm; $n = 15$) and 2.4 U/gm (range, 1.0 to 6.0 U/gm; $n = 7$), respectively. There was no statistical difference (t test, $p \geq 0.2$) observed in the mean levels of Bla g 1 or

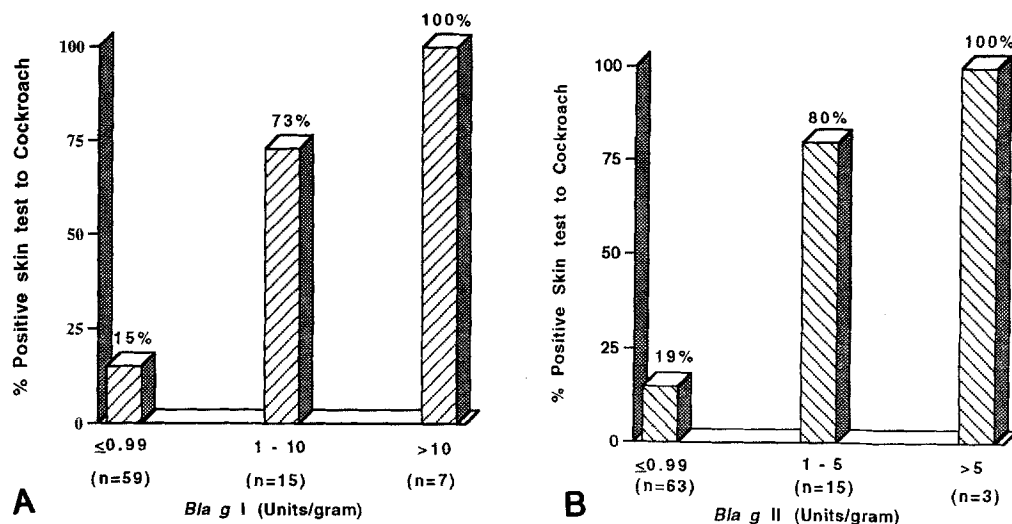


FIG. 2. Rate of cockroach skin sensitivity related to levels of cockroach allergens in bedroom dust samples for Bla g 1 (**A**) and Bla g 2 (**B**). Cockroach allergen levels were significantly related to the presence of a positive skin test response ($p < 0.001$).

Bla g 2 measured in urban homes in Baltimore compared with those measured in the suburban homes.

Relationship of cockroach exposure to allergic sensitization

Thirty-three percent of the 81 children skin tested had a positive skin test response to the cockroach allergen. As illustrated in Fig. 2, the frequency of positive skin test results increased progressively with cockroach allergen levels measured in dust for both Bla g 1 and Bla g 2. All seven children who lived in bedrooms with more than 10 U/gm Bla g 1 (Fig. 2, *A*) and all three children with bedroom Bla g 2 levels greater than 5 U/gm (Fig. 2, *B*) had a positive skin test response. When the data were combined, the amount of total cockroach allergen (Bla g 1 + Bla g 2) measured in settled bedroom dust was significantly associated with a positive skin test response in the occupant with asthma ($p < 0.001$, chi square test).

Risk factors for cockroach allergen exposure

As shown in Fig. 3, *A*, cockroach allergen was found more frequently in the bedrooms of children of lower SES. Either Bla g 1 or Bla g 2 was found in 46% of samples from lower SES homes, 26% of samples from middle class homes, and not at all in samples from higher SES homes ($p < 0.001$, chi square test). Fig. 3, *B*, shows the relative frequency of cockroach allergen exposure in the different socioeconomic strata as analyzed by race. The only significant racial difference was found in the mid-

dle SES in which cockroach allergen was found in samples from homes of African Americans 11 times more frequently than those from homes of white persons ($p < 0.001$). Fig. 3, *C*, presents the frequency of bedroom cockroach allergen divided by the family's SES, which is then further subdivided by urban or suburban location; the frequency of detectable levels in urban and suburban locations in any SES grouping was not significantly different.

Table II presents the calculated odds ratio for bedroom cockroach allergen exposure when analyzed according to the subject's SES, race, urban or suburban residence, gender, and age. In this study group an African-American child was 15.8 times more likely to be exposed to cockroach allergen in his or her bedroom than a white child ($p < 0.001$). Children living in urban areas were 4.4 times more likely to have cockroach allergen in their bedrooms than those living in suburban areas. A child of low SES was 4.2 times more likely to be exposed to cockroach allergen than a child of middle or high SES ($p < 0.001$). When the relative contributions of the subject's race, SES, urban or suburban residence, age, and gender to cockroach allergen exposure were analyzed by a stepwise multiple linear regression (Table III), only race was related to cockroach allergen exposure.

Risk factors for cockroach allergen sensitization by skin test

Fig. 4, *A*, shows the progressive increase in positive skin test reactivity with a decreasing SES ($p < 0.001$, chi square test). The SES data were

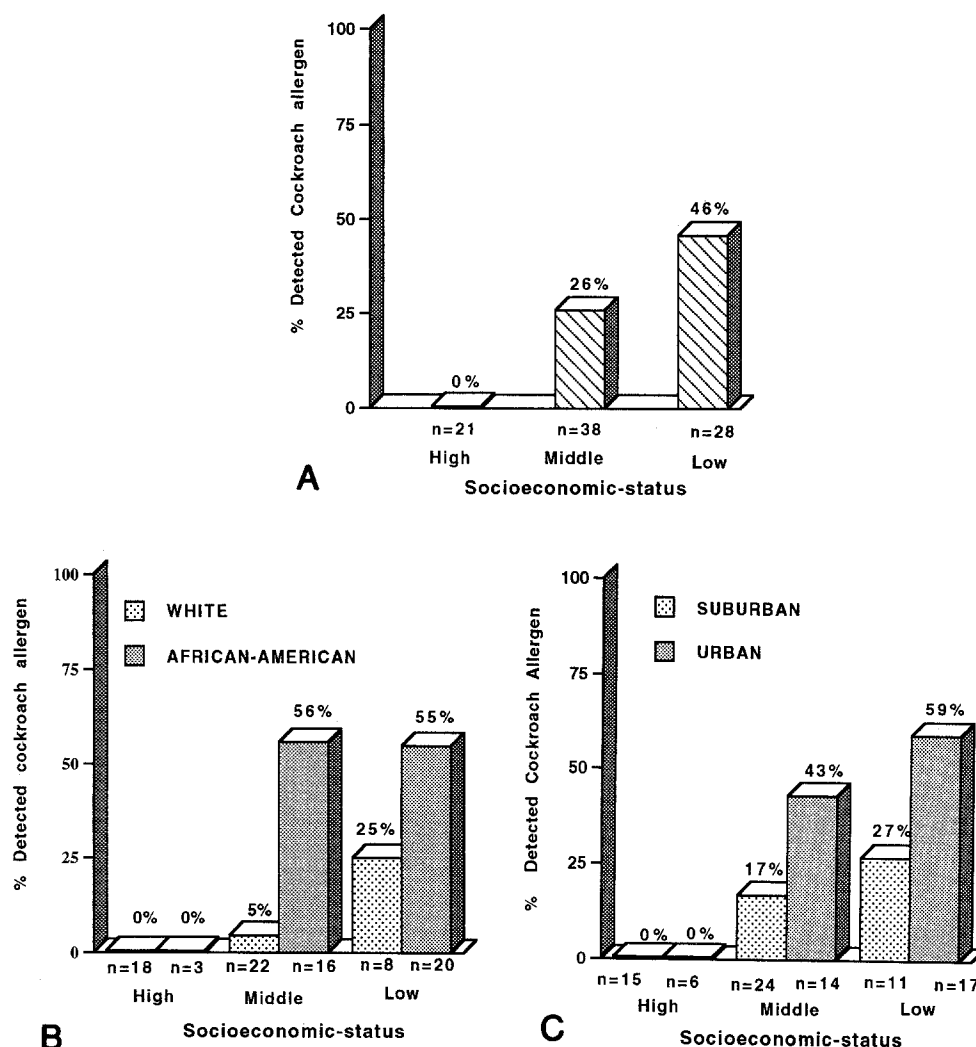


FIG. 3. Cockroach allergen exposure analyzed by the subject's SES (A), race nested within SES (B), and residence nested within SES (C). SES was significantly associated with exposure ($p < 0.001$). A significant difference in race was only seen in the middle SES ($p < 0.001$). Urban versus suburban residence was not significantly different in any of the three SES groups.

TABLE II. Odds ratios for cockroach sensitization and exposure

Risk factors	Odds ratio	
	Exposure	Sensitization
SES (low)	4.2 (1.6-11.6)	11.9 (4.3-40.8)
Race (African-American)	15.8 (4.2-59.5)	16.4 (4.8-55.9)
Residence (urban)	4.4 (1.6-12.2)	4 (4-10.7)
Gender (female)	0.6 (0.2-2)	0.9 (0.3-2.7)
Age (>11 yr)	1.8 (0.7-4.7)	1.7 (0.7-4.3)

Numbers in parentheses are 95% confidence intervals for odds ratios.

further analyzed by race as shown in Fig. 4, B. A significant difference in cockroach allergen sensitization rates was observed for race only in the middle SES group ($p < 0.001$). When the SES data

were then sorted on the basis of urban versus suburban location of the individual, there was no significant difference in any of the three SES groups (Fig. 4, C).

TABLE III. Stepwise multiple linear regression analysis of cockroach exposure and sensitization

Risk factor	Exposure (<i>n</i> = 87)*	Sensitization (<i>n</i> = 81)†
Race (African-American)	<i>t</i> = 2.0 (<i>p</i> = 0.05)	<i>t</i> = 2.7 (<i>p</i> = 0.009)
SES (low)	<i>t</i> = 0.4 (<i>p</i> = 0.66)	<i>t</i> = 4.8 (<i>p</i> < 0.001)
Residence (urban)	<i>t</i> = -1.6 (<i>p</i> = 0.11)	<i>t</i> = 0.11 (<i>p</i> = 0.91)
Age (>11 yr)	<i>t</i> = 1.0 (<i>p</i> = 0.32)	<i>t</i> = 2.6 (<i>p</i> = 0.012)
Gender	<i>t</i> = -0.5 (<i>p</i> = 0.62)	<i>t</i> = 0.4 (<i>p</i> = 0.66)
Cockroach skin test	<i>t</i> = 4.9 (<i>p</i> = 0.0001)	—
Cockroach allergen exposure	—	<i>t</i> = 2.2 (<i>p</i> = 0.032)

*Multiple *R* = 0.73; *F* = 20.4, 1 *df*, *p* < 0.00001 for equation with included variables.†Multiple *R* = 0.49; *F* = 24.5, 1 *df*, *p* < 0.00001 for equation with included variables.

Table II displays the odds ratio of demographic characteristics for the development of cockroach allergen sensitivity as assessed by a positive skin test response. Thirty-three percent of the study group was sensitized to cockroach allergen. An African-American child was 16.4 times more likely to become sensitized to cockroach allergen than a white child (*p* < 0.001). Moreover, children living in urban areas were four times more likely to have positive skin test reactivity to cockroach allergen than suburban residents. A child in the low SES group was 11.9 times more likely to become sensitized to cockroach allergen than a child living in a middle or high socioeconomic environment (*p* < 0.001).

The independent contributions of the various demographic factors to the risk of cockroach allergen sensitization, as assessed by stepwise multiple linear regression, are presented in Table III. African-American race, low SES, age greater than 11 years, and cockroach allergen exposure were independently associated with a positive skin test response to cockroach to a statistically significant degree.

DISCUSSION

This is the first detailed examination of the relationship of cockroach allergen exposure and sensitization among children with asthma to socioeconomic and demographic factors. Previous studies have suggested that cockroach sensitization is an affliction of the inner city poor, but the complex interrelationship of race, poverty, and residence has been difficult to unravel. We found that race and SES were both independent predictors of cockroach sensitization; and the rate of sensitization among low SES African-American subjects with asthma was quite high, 75%. On the other hand, only race was significantly associated with current exposure. No one of higher SES, either white or African American, was exposed to cock-

roach or sensitized to the allergen, no matter where he or she lived.

In the original description of cockroach sensitivity in 1967, Bernton and Brown¹⁴ found higher rates of sensitization among Puerto Ricans and African Americans than among Jews and Italians in New York City and believed that the difference was related to the "improved economic conditions" of the latter groups. Shulaner¹⁵ also found a relationship to poverty and overcrowding, and a recent report by Gelber et al.⁸ relates exposure and sensitization to urban housing, race, and poverty as indicated by lack of medical insurance. Several reports by Kang et al.^{1, 16} have all involved inner city residents in Chicago, who have largely been minorities and poor, with at least 60% unemployment. More recently, exposure and sensitization have been described in poor rural populations as well.^{12, 17} None of these studies conducted individual measures of SES, which integrates educational background, employment, and housing status. From our work, SES appears to be an important variable that independently influences both exposure and sensitization rates.

Our findings confirm the reports of others that cockroach allergen exposure and sensitization is significantly more common in patients with asthma living in urban homes compared with those living in suburban homes.^{16, 18, 19} However, despite higher rates of exposure and sensitization among urban subjects, place of residence was not independently associated with cockroach exposure after correction for SES; families of lower SES were likely to be exposed wherever they lived. This is in agreement with the observations of Gelber et al.⁸ who used lack of health insurance as a marker of poverty and showed that this was a more important correlate of sensitization than urban residence per se, as well as with others¹⁷ who have categorized patients on the basis of access to private medical

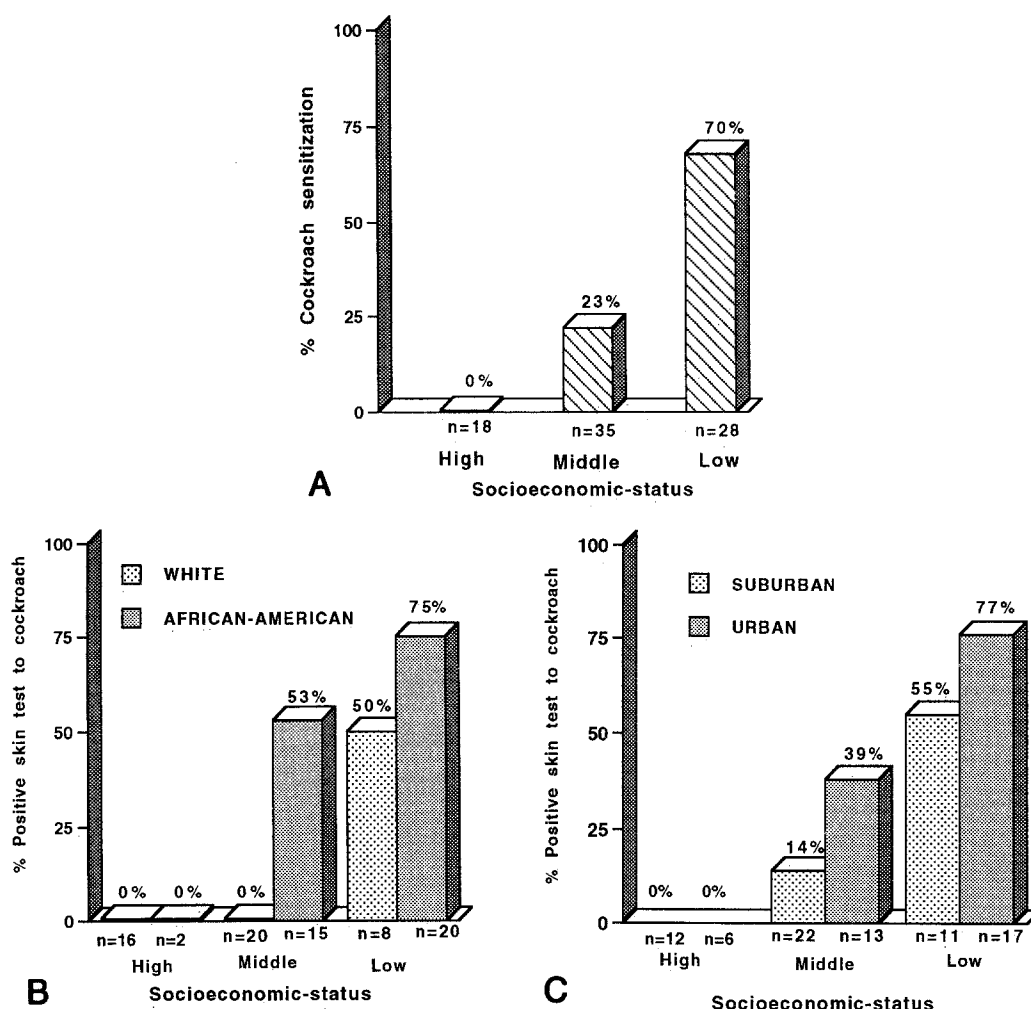


FIG. 4. Sensitization to cockroach allergen analyzed in terms of the subject's SES (A), race nested within SES (B), and residence nested within SES (C). SES was significantly associated with cockroach sensitization ($p < 0.001$). A significant difference in race was seen only in the middle SES ($p < 0.001$). Urban versus suburban residence did not show any difference in any of the three SES groups.

care. Our study, like these previous studies, is a description of a restricted population; in our case, the sample was restricted to patients with moderate to severe asthma who were willing to participate in a clinical trial and had a diagnosis of allergic asthma.

Our results are also consistent with studies showing that poverty and race are risk factors for increased asthma morbidity among patients with asthma attending urban emergency departments for treatment of acute asthma. Gelber et al.⁸ and Call et al.⁹ showed that cockroach sensitization was a risk factor for acute severe asthma in patients visiting emergency departments; and both groups implied that this factor was associated with poverty. In a study of hospitalization for treatment of

asthma in the state of Maryland, Wissow et al.²⁰ showed that low SES was the principal determinant for hospitalization; geographic and racial factors in hospitalization rates were similar when SES was taken into account. Our study, however, was limited by its population because it was not randomly sampled and because the sample size was small.

We used antigen concentrations in the bedroom as a surrogate for household infestation, in part because we and others have found that cockroach antigens are widely distributed in homes^{9, 12} and in part because sensitization was logically more likely to be related to bedroom exposure where subjects spend many hours each night. Perhaps as a result, we found a closer relationship between exposure

and frequency of cockroach sensitization than has been previously reported. For example, Kang and Sulit¹ showed only a loose relationship between the number of cockroaches reported in inner-city homes in Chicago and sensitization to cockroach extract, whereas we found that all children with settled bedroom dust levels of Bla g 1 above 10 U/gm were sensitized compared with 17% of children whose dust had undetectable antigen levels.

Race was independently associated with current cockroach allergen exposure and sensitization in this study (Table III). An African-American child was 16 times more likely to be exposed or sensitized to cockroach antigen than a white child. Both sensitization and exposure were consistently higher in African-American subjects in each category of SES. In stepwise linear regression, race was significantly associated with exposure even when controlling for SES and residence. This is at variance with other studies of sensitization,^{1, 18} but we used a more standardized assessment of SES and believe that the racial differences are real. We have no explanation for our finding that cockroach exposure was less closely related to African-American race than was sensitization, and we can only speculate that it might relate to longer cumulative exposure before our study. Alternatively, racially based genetic differences important in the regulation of cockroach IgE immune responses and total IgE production may play a role.

The importance of these findings is that they support the notion that cockroach hypersensitivity is a unique risk factor for asthma among the urban poor. Recent epidemiologic data show that prevalence of asthma and morbidity and death associated with asthma are significantly greater in poor African Americans living in the inner city; that is, hospitalization for treatment of asthma is almost three times as high,²¹ and the mortality rate is five times as high.²² The reason for these differences is clearly complex and involves both social and medical factors,²³ but one risk factor of clear importance is IgE-mediated sensitivity to indoor allergens, including cockroach. Case-control studies from inner-city emergency departments^{8, 9} show that individuals who are both sensitized and currently exposed to indoor allergens are at much greater risk for acute asthma attacks. These studies and others¹ have demonstrated that cockroach allergen is an important indoor allergen in many inner city homes. It is important to understand to what degree these findings are attributable to race, poverty, or residence in old dilapidated housing,

because each has a different implication for corrective public health policy. Hopefully, our findings that race and SES but not place of residence are independent risk factors for cockroach sensitization will stimulate further studies to increase our understanding of the root causes of increased urban asthma morbidity rates.

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