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Evaluating the Factors that Relate to Asthma Severity in Adolescents

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Abstract

Over the past 5 years, we have been engaged in a cross-sectional evaluation of risk factors for higher asthma severity in adolescents aged 13–18. All recruitment takes place through public and private schools. The sample from which our current findings are derived includes 151 adolescents covering a wide spectrum of asthma severity and socioeconomic status (SES) and representing both African American and Caucasians. An asthma severity instrument has been developed and validated for the purpose of this study. This yields an asthma severity score which is a continuous variable. Female gender and the number of positive skin tests are the best independent correlates to the asthma severity score. Among the 18 aeroallergens used in the study, the American cockroach *Periplaneta americana* is the only one that relates to the asthma severity score in a stepwise regression model. The two other cockroaches, German and oriental, as well as the dust mites *Dermatophagoides farinae* and *Dermatophagoides pteronyssinus*, correlate with the asthma severity only in simple regression analysis. The relationship between asthma severity and cockroach sensitivity is strongest within the lowest-income per family member quartile. This is consistent with the additional observations that (1) significantly higher rates of sensitization for cockroaches are observed in the lowest-income quartile subjects and (2) higher levels of the cockroach allergen Bla g 1 are found in their homes. Preliminary analysis suggests that ethnic background may interact with environmental exposure in that, within the lowest-income quartile, Caucasians have lower sensitization rates to cockroaches and other allergens compared to African Americans. Within the Caucasian population, income does not appear to influence sensitization rates. The treatment that adolescents with asthma receive for their respiratory disease is characterized by an overall low rate of prescribed inhaled corticosteroids (37% in the moderately severe and severe groups). This inadequacy in treatment is accentuated by SES: 28% of adolescents in the highest and 6% in the lowest-income quartile are prescribed these medications. Our findings are consistent with the hypothesis that the higher asthma morbidity and mortality observed in the African American population is related to higher exposure and sensitization to allergens such as those from cockroaches that are more prevalent in lower SES environments. It is possible that genetic factors contribute to the higher degree of sensitization. In addition, individuals of low SES are subjected to inadequate medical management of their asthma.

Key Words

Asthma
Adolescents
Cockroach allergy
Severity
Socioeconomic status

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Introduction

The marked increase in asthma mortality and morbidity in the United States during the last 15 years has mainly affected the African American population, in particular those individuals of low socioeconomic status (SES) [1-3]. The reason(s) behind the overall problem and of the disproportionate effect of asthma on African Americans is (are) unknown. However, it has been hypothesized that (1) because significant numbers of African Americans live in poverty-stricken areas, they have an increased chance of sensitization and exposure to unique allergens such as those from cockroaches and (2) at the same time, poor patients with asthma have an increased chance of receiving lower quality medical management. In conjunction with the above, the question is raised whether African Americans are predisposed to develop a higher degree of allergic sensitization independent of socioeconomic factors and environmental exposure.

During the past 4 years, we have been conducting a study to test the above hypotheses in adolescents with asthma. We have chosen this population because it shares characteristics with both children and adults: on the one hand, adolescents are still exposed to an environment that is determined by the SES of their parents/guardians and is quite simple and homogeneous in nature (home and school); on the other hand, adolescents are becoming (or have become) self-managers of their medical problem(s), thus allowing for potential educational and/or therapeutic interventions to be targeted directly at them, avoiding the confounding effects that parents' behavior may impose to such a process. Some preliminary findings of this study are presented in this article.

Methods

Subject Recruitment

The recruitment of adolescents with asthma constitutes a major aspect of this project. The aim is to recruit equal numbers of adolescents with asthma in 4 ethnic/SES groups: African Americans of low versus middle/high SES and Caucasians of low versus middle/high SES. It was pertinent by design that the source of the population would be the same across the targeted ethnic/SES groups. Therefore, we chose to recruit strictly from middle and high schools and to accept any respondent, regardless of the degree of certainty of the diagnosis of asthma. To achieve our goals, we have established the collaboration of (1) public school systems of Baltimore City and 3 surrounding counties (3 counties refused to participate) and (2) private schools in the same areas (93 out of 111 schools agreed to participate). The level of collaboration is different, depending on the policy of the particular school system or private school. In most cases, schools identify through their files the number of students who reported asthma as a medical condition. We then provide each school with that number of packages containing a coverletter to the parents/guardians and a brochure which are

then forwarded to the families. If interested, the family of an adolescent with asthma contacts us to learn more about the study and to schedule an appointment.

Subject Evaluation

The evaluation protocol is designed to include 3 contacts with the family. The first 2 contacts take place at the Johns Hopkins Asthma and Allergy Center. The elements of the evaluation are:

(1) a study questionnaire. This is a large (1.5 hour) instrument that includes 16 sections. It is administered separately to both the adolescent and his/her parent/guardian. The sections cover demographic information, environment, asthma presentation and severity, treatment, barriers to care, psychosocial elements of asthma, other atopic disorders and other medical history;

(2) routine spirometric pulmonary function measurements for the adolescent;

(3) testing of the metered-dose inhaler technique;

(4) evaluation of reversibility of airway obstruction by a nebulized β -agonist;

(5) determination of airway reactivity to methacholine;

(6) skin prick testing with a panel of 18 aeroallergens: ragweed, mugwort, Bermuda grass, rye grass, oak, birch, *Dermatophagoides pteronyssinus*, *Dermatophagoides farinae*, cat, dog, *Blattella germanica*, *Periplaneta americana*, *Blattella orientalis*, *alternaria*, *aspergillus*, *cladosporium*, mouse and rat, and

(7) nasal lavage for total and differential leukocyte counts.

In addition, a daily diary including a.m. and p.m. peak-flow measurements, symptom scores and medication usage is kept for 15 days between the 2 visits. The 3rd contact with the family takes place at their home, where dust sampling of the living room, the adolescent's bedroom and the kitchen is performed. The house dust is then assayed for the dust mite allergens Der p 1 and Der f 1, the cat allergen Fel d 1 and the German cockroach allergen Bla g 1.

Assessment of Asthma Morbidity

A significant portion of our efforts was devoted to the development of an instrument with which we can reliably assess the severity of the disease in adolescent asthmatic patients. We based the assessment on the following parameters:

(1) frequency of symptomatology during the past year (for higher accuracy and because of the commonly encountered seasonal characteristics of allergic asthma in childhood, the evaluation is separate for each season);

(2) effect of asthma symptoms on participation in sports and other physical activities during the past year;

(3) utilization of emergency medical facilities in the past year;

(4) lifetime hospitalizations for asthma (recent hospitalizations weigh more than those that occurred earlier than 5 years prior to the evaluation);

(5) asthma-related absenteeism from school and/or work in the past year;

(6) average use of inhaled bronchodilators in the 3-month period prior to the evaluation, and

(7) number of oral steroid courses prescribed for asthma in the past year.

The scoring system for the above information was developed based on arbitrary weighing preferences derived from our team. This was then validated through several protocols (see below).

Data Analysis

We report in this article data relating to the characteristics of the study population as it pertains to demographics, skin test sensitivities, allergen exposure, asthma management and asthma severity. We have used frequency distributions for this purpose. In addition, we are presenting elements of the validation processes that the asthma severity instrument has undergone. These data have been analyzed using simple regressions. Finally, we have addressed the issue of determinants of asthma severity and allergen sensitization using forward, stepwise multiple regressions.

Results

Population Characteristics

So far, we have enrolled 151 adolescent asthmatic persons in the study. We have estimated the ratio of mailed packages to positive responses to be approximately 20:1. The average age of our population is 14.8 years, with an SD of 1.5 years. Females comprise 58.3% of the sample and African Americans 39.6%. African American females account for 16.6% of the population. The average age of onset of asthma is 5.9 ± 4.4 years. The median household income is \$44,500 and the median income per family member \$10,000. As expected, income distribution is skewed toward lower levels, but appears to be representative of this area's population. With respect to the education of the parent/guardian, it should be noted that 53.7% had at least some college attendance. When we correlated the level of education with the household income, the r value was 0.57 ($p < 0.0001$), not surprisingly suggesting that these 2 parameters have a substantial degree of independence and should be used as such in evaluations that revolve around the concept of SES. When we analyzed the distribution of ethnic backgrounds within the population with respect to family income, we found that, whereas relatively equal numbers of African Americans and Caucasians (40:30) comprised the group below the median, only 15 African Americans versus 56 Caucasians had a household income above the median value (χ^2 : $p < 0.0001$). This relative deficiency in mid-high-income African Americans does not yet offer us adequate power to analyze our asthma severity risk factor data by comparing 4 distinct populations, that is low-income African Americans, low-income Caucasians, mid-high-income African Americans and mid-high-income Caucasians. This is the primary analysis our project is aiming at. In our interim analyses, we have used regressions with income and ethnic background as covariates.

Validation of the Asthma Severity Score

Following the development of the asthma severity score, we engaged in a validation protocol involving 15 randomly

selected individuals who had already participated in the study. These subjects were asked to pay an additional visit to the Johns Hopkins Asthma and Allergy Center with their parent/guardian. In this return visit, they were interviewed by a panel of 3 physicians, 2 allergists and 1 pulmonologist. The physicians had no access to any information we had obtained through our study questionnaire or through objective testing. Following a 15-min interview with the adolescent and the parent/guardian, each physician scored the severity of asthma on a 6-point Likert scale (no asthma, mild asthma, mild to moderate, moderate, moderate to severe and severe asthma). We then calculated the correlation coefficients between the average physician score and our asthma severity score. In addition, we obtained and averaged the inter-physician correlation coefficients. The average physician versus asthma severity score was 0.70 ($p = 0.004$), whereas the average inter-physician r was 0.75, indicating that there was similar agreement on the level of severity among the 3 physicians and between the physicians and our instrument's scoring system. In a second phase of the validation, the same physicians were given the relevant information from the same subjects' questionnaires and were asked to evaluate this information on the same scale. The physicians were masked as to the names of the subjects. The average physician versus asthma severity score r was 0.88 ($p = 0.0001$), whereas the average inter-physician r was 0.64. These data indicate that (1) our asthma severity instrument contains questions that appropriately reflect severity as judged by specialist clinicians and (2) the scoring of these questions and, therefore, the relative importance of the information this questionnaire captures, are in strong agreement with expert opinion.

To provide a qualitative aspect to the severity score that our instrument produces, we used best-fit regression analysis to relate the physicians' evaluations to this score. Through this analysis, we have determined that a severity score below 26 is considered mild asthma, a score between 27 and 37 mild to moderate asthma, a score between 38 and 48 moderate asthma, a score between 49 and 60 moderately severe and a score above 61 severe asthma. Figure 1 depicts the frequency distribution of the asthma severity score for all subjects. Based on the above analysis, 23.4% of the adolescents we have recruited so far fall into the moderate, moderate to severe and severe categories and, as expected, the majority of our population has mild disease.

We also evaluated the relationship between our validated asthma severity score and objective pulmonary function parameters obtained during the first phase of the study. Simple regression analysis yielded $r = 0.36$ ($p < 0.0001$) for the relationship between the asthma severity score and the percent

FEV₁ predicted values. For the percent FVC predicted, $r = 0.24$ ($p = 0.006$). Also strong was the relationship between the asthma severity score and FEV₁/FVC ($r = 0.37$; $p < 0.0001$). In a smaller sample ($n = 96$), we found no correlation between the asthma severity score and the logPD₂₀ to methacholine provocation. This finding probably reflects the fact that the severe adolescent asthmatic individuals did not fulfill the safety criteria ($>70\%$ predicted baseline FEV₁) to undergo methacholine challenge. Average (over 15 days) a.m./p.m. PEFR variability also correlated with the asthma severity score with $r = 0.28$ ($p = 0.02$). Overall, the consistently significant relationships between our severity score and objective parameters of lung function provide further support to the validity and sensitivity of this scoring system.

The final step in our validation process was to test the reproducibility of the scoring system. Fourteen adolescents with their parents/guardians were readministered the severity section of our study questionnaire during their second study visit, approximately 15 days after the first visit. Simple regression analysis between the visit 1 and visit 2 asthma severity scores show a strong relationship ($r = 0.85$; $p < 0.0001$). This confirmed the test-retest reliability of the severity score.

Allergen Sensitization

The prevalence of at least 1 positive skin test in the population we have recruited is 75%. Fifteen and a half percent have between 1 and 2 positive tests, 35.6% between 3 and 6 and 23.9% between 7 and 15 (out of 18 applied). Using stepwise regression analysis, we assessed the predictors of total positive skin tests by entering gender, ethnic background, parent/guardian's education level, yearly income per family member, housing density (number of people per room in the house) and exposure to smoking in the analysis. Ethnic background was the only independent predictor of the number of positive skin tests ($r = 0.355$; $p < 0.0001$), with African Americans having more positive tests compared to Caucasians. Indeed, when the size of the skin-test-induced wheal (average maximal perpendicular diameter) for each of the 18 extracts was compared between African Americans and Caucasians, the former had statistically significant higher responsiveness to every single extract, with the exception of the two dust mites (*D. pteronyssinus* and *D. farinae*), cat and aspergillus.

The percentages of adolescents who are positive for each of the applied skin tests are depicted in figure 2. Cat and the dust mite *D. farinae* had the highest sensitization rates in the population, whereas the weed mugwort and the molds aspergillus and cladosporium had the lowest. When the preva-

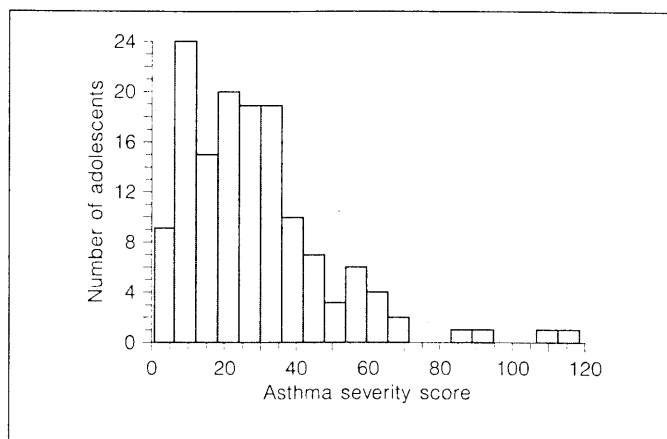
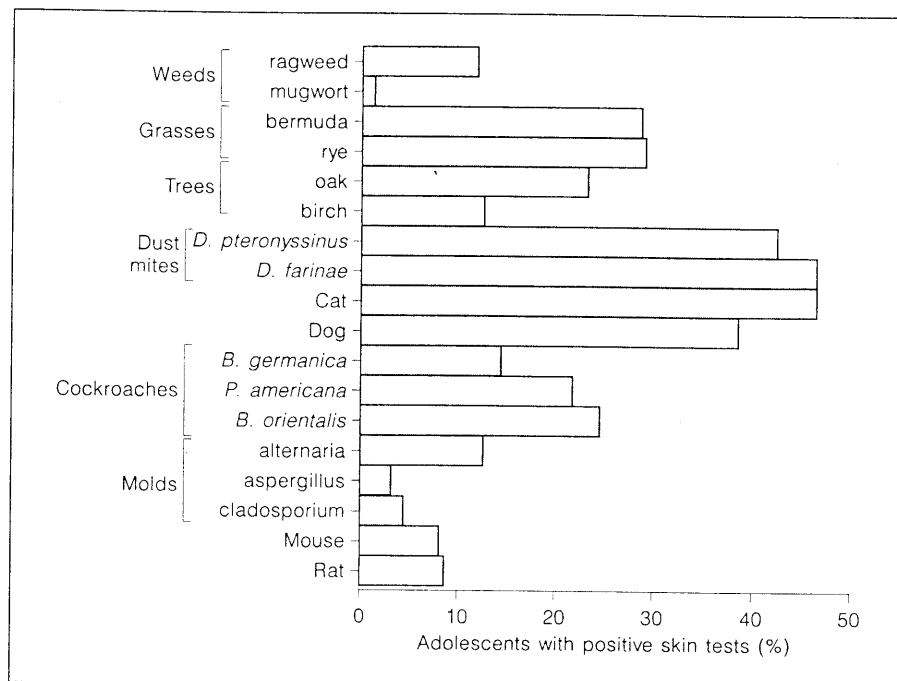


Fig. 1. Frequency distribution of the asthma severity score in a population of 151 adolescents. Based on the best-fit analysis of the relationship between this score and the evaluation by a group of specialists, a severity score 26 and below is considered mild asthma, a score between 27 and 37 mild to moderate asthma, a score between 38 and 48 moderate asthma, a score between 49 and 60 moderately severe asthma and a score above 61 severe asthma.

lence of specific skin test positivity was compared between the highest- and the lowest-income per family member quartiles, significantly higher sensitization rates were observed in the lowest-income quartile for the 3 cockroaches and for Bermuda grass (26.5 vs. 7.9, 38.2 vs. 10.5, 41.2 vs. 13.2 and 44.1 vs. 15.8 for *B. germanica*, *P. americana*, *B. orientalis* and Bermuda grass, expressed as percents, respectively). In addition, higher, albeit not statistically significant, sensitization rates were observed in the low-income quartile for mouse, rat, alternaria, dog, oak and rye grass. On the other hand, a strong trend was observed for the highest-income quartile to be more sensitized to *D. farinae* (62 vs. 38%; $p = 0.08$). Although the lowest-income quartile was relatively balanced with respect to ethnic background (21 African Americans and 15 Caucasians), only 6 out of the 36 subjects in the highest-income quartile were African Americans. For this reason, we attempted to determine the factors that contribute to the size of the skin test wheal to the above 5 allergenic extracts that yielded different sensitization rates between the highest- and lowest-income quartiles by using stepwise regression analysis in which several SES-related variables, ethnic background and the overall number of positive skin tests were entered. In all cases, the number of positive skin tests to indoor allergens (for the 3 cockroaches) or to outdoor allergens (for Bermuda grass) was the best correlate to the size of the skin test wheal; in the analysis for *P. americana*, ethnic background was also en-

Fig. 2. Histograms representing the percentage of adolescents with asthma who had a positive epicutaneous skin test to each of the depicted 18 allergen extracts. A positive skin test is defined by an average wheal diameter that is ≥ 3 mm above that of the diluent control. These results derive from 151 subjects. Twenty-five percent were skin test negative; these were the adolescents with the mildest disease.



tered in the model, with African Americans having stronger responses. In the analysis of *D. farinae*, ethnic background was also an independent predictor, with Caucasians having higher skin test wheal sizes compared to African Americans. One could argue that the number of positive skin tests reflects general atopic diathesis and that this is a major driving force in allergen sensitization. Overall, this diathesis may be stronger in African Americans. However, the group of extracts from indoor allergenic sources we are employing in this project is quite skewed toward allergens which, in the northeast United States, are associated with poor housing conditions. It is therefore possible, that SES is a confounding variable in the relationship between a particular sensitization and the total number of positive skin tests. Also, cross-reactivities between the 3 cockroach allergens may further interfere in these analyses.

Home Dust Analysis

It is quite obvious that no conclusions can be drawn with respect to the reasons why SES may be a factor determining sensitization to particular allergens unless allergen exposure as a function of SES is examined. So far, we have collected dust samples from the homes of 63 of our subjects. Four areas in each home (kitchen, living room, bedroom, family room) were sampled. For analysis, we used the sample with the highest average levels for each allergen (Der p 1, Der f 1, Fel d 1: living room; Bla g 1: kitchen). The levels of

Table 1. Levels of allergens in the homes of 63 adolescents with asthma, separated in 3 income groups

Allergen	Median allergen level			p values		
	HI	MI	LO	HI vs. MI	HI vs. LO	MI vs. LO
Bla g 1 (42)	1.5	2.1	6.3	0.50	0.10	0.005
Der p 1 (63)	32.0	105.0	36.0	0.60	0.36	0.10
Der f 1 (63)	850.0	331.5	120.0	0.29	0.07	0.47
Fel d 1 (63)	1,148.0	702.5	1,786.0	0.40	0.60	0.34

HI = Highest-income quartile; MI = mid 50% of the population; LO = lowest-income quartile.

Bla g 1 levels are U/g; all others are μ g/g. Figures in parentheses denote the number of households where an adequate quantity of dust was found for a measurement to be made.

these 4 allergens are presented in table 1. For the purpose of this analysis, the population was divided into 3 groups based on household income: highest quartile, mid 50% of the population and lowest quartile. Despite our low power to detect significant differences with this number of observations, we found that differences between the 3 income groups exist with respect to the cockroach allergen Bla g 1 and the dust mite allergen Der f 1. These differences are quite consistent with those observed in the skin test results:

Table 2. Results from simple regression analyses associating the asthma severity score (depending variable) with various independent variables. r and p values from statistically significant relationships are in bold.

Independent variable	r values	p values	Independent variable (individual skin tests)	r values	p values
Gender	0.21	0.01	Ragweed	0.08	0.37
Ethnic origin	0.08	0.36	Mugwort	0.01	0.89
Parent/guardian education	0.01	0.89	Bermuda grass	0.06	0.48
Total yearly household income	0.07	0.41	Rye grass	0.007	0.94
Income per family member	0.03	0.76	Oak	0.01	0.90
Housing density	0.06	0.50	Birch	0.01	0.89
Exposure to smoking	0.20	0.02	<i>D. pteronyssinus</i>	0.18	0.03
Number of (+) skin tests	0.24	0.005	<i>D. farinae</i>	0.18	0.04
Number of (+) skin tests (indoor allergens)	0.31	0.0002	Cat	0.09	0.27
Number of (+) skin tests (outdoor allergens)	0.11	0.20	Dog	0.15	0.08
			<i>B. germanica</i>	0.20	0.02
			<i>P. americana</i>	0.18	0.03
			<i>B. orientalis</i>	0.16	0.06
			Alternaria	0.02	0.78
			Aspergillus	0.07	0.44
			Cladosporium	0.02	0.84
			Mouse	0.12	0.16
			Rat	0.11	0.19

high income, compared to low income, is associated with higher levels of Der f1; the reverse is true for the levels of Bla g1. By combining the evaluation of house dust allergen levels with skin testing, one can speculate that allergen exposure is indeed another major determinant of skin test reactivity. It is thus reasonable to conclude that the adolescents with asthma of low-income families have excessive sensitization to cockroaches as a result of higher exposure. Their trends for higher skin test positivities to other indoor allergens such as mouse and rat may also be exposure related. However, their overall increased sensitivity to outdoor allergens is more difficult to explain. Higher exposure may be the most important factor determining the higher degree of sensitization to *D. farinae* of adolescents from high-income families; it is the adolescents with the highest atopic diathesis within those families that tend to develop such sensitivity. The association with the Caucasian background is most probably spurious, due to the overwhelming Caucasian predominance in the highest-income quartile.

Preliminary Findings on Asthma Morbidity Factors in Adolescents

To determine the best predictors of asthma severity as assessed by our scoring system, the asthma severity score was first logarithmically transformed. This resulted in an almost normal distribution. We then constructed a number

of multiple regression models utilizing forward stepwise analysis. The first analysis incorporated 7 independent variables (gender, ethnic background, total positive skin tests, parent/guardian's education level, yearly income per family member, number of people per room and exposure to smoking). This analysis yielded a multiple r of 0.34 with $p = 0.0004$, allowing two variables in the model: total positive skin tests and gender (females having higher severity scores). Driven by these results, our second analysis applied the same statistical technique to relate the asthma severity score to the size of the wheal induced by the 18 allergens used in our study. Only one variable was entered in this model, the skin test wheal size to the American cockroach, *P. americana* ($r = 0.191$, $p = 0.03$). Interestingly, the next two strongest partial correlation coefficients in this model belonged to the other two cockroaches, *B. germanica* and *B. orientalis*. When the asthma severity score was correlated through simple regressions against the variables used in the stepwise regression models, gender, (females > males), skin test wheal size to *D. pteronyssinus*, *D. farinae*, *B. germanica*, *P. americana*, the number of positive skin tests, the number of positive skin tests to indoor allergens and the exposure to smoking (assessed in a binomial fashion: > vs. < than 1 h of exposure per day) yielded statistically significant results (see table 2). Some of these relationships were SES specific: when we performed this type of simple regression

analysis within the lowest- and the highest-income per family member quartiles, the relationship between the asthma severity score and skin test wheal size for *P. americana* was much stronger in the lowest ($r = 0.34$) as opposed to the highest-income quartile ($r = 0.001$). Similar results were obtained for *D. farinae*, the number of positive skin tests and the number of positive skin tests to indoor allergens. The relationship of smoking exposure to asthma severity was stronger in the highest ($r = 0.23$) compared to the lowest-income quartile ($r = 0.05$), and that for *D. pteronyssinus* and for *B. germanica* was the same in the two SES groups. Because of the low number of African Americans in the highest-income quartile, it is quite difficult to discern the role of ethnic background in these relationships. Nevertheless, we used two-way ANOVA to analyze sensitization to cockroaches and rodents with highest-/lowest-income quartiles and ethnic background as the main interactive effects. This analysis indicated that in Caucasians, SES does not appear to have any effect on sensitization rates. In contrast, in African Americans, higher sensitization rates were observed in the lowest compared to the highest-income quartile.

Significant correlations were found between the size of the skin test wheal to the American cockroach *P. americana* and various aspects of pulmonary function: against percent FEV₁ predicted: $r = 0.26$, $p = 0.0014$; against percent FVC predicted: $r = 0.24$, $p = 0.004$; against FEV₁/FVC: $r = 0.16$, $p = 0.05$; against MMEF/FVC: $r = 0.18$, $p = 0.03$. Significant correlations between some of the above pulmonary function outcomes and the size of the skin test wheal were observed for several other indoor allergens. These included the other 2 cockroaches *B. germanica* and *B. orientalis*, rat, the two dust mites, cat and dog. Overall, the 3 cockroaches and rat yielded the most consistent and strongest relationships to pulmonary function outcomes. In strong contrast, no significant relationships to outdoor allergens (weeds, trees, grasses) were detected.

Medical Management and Socioeconomic Status

Appropriately prescribed medications constitute an integral part of asthma management. While prescribed asthma medications do not always accurately reflect proper usage, they are a foundation of medical management and a prerequisite for proper care. As part of their participation in the study, both the parent/guardian and the adolescent were interviewed separately to obtain a listing of prescribed asthma medications. As described above, nominal categorization of our subject into mild, mild to moderate, moderate, moderate to severe or severe asthma was done using our asthma severity instrument. Appropriately, asthma severity correlated with the number of asthma medications pre-

scribed (for the parent/guardians; $r = 0.51$, $p = <0.0001$; for the adolescents; $r = 0.49$, $p = <0.0001$). We also classified asthma medications into broad categories including short-acting β -agonists, methylxanthines, cromolyn/nedocromil and inhaled corticosteroids. All were prescribed at higher rates in the more severe groups. However, inhaled corticosteroids were prescribed in 13.8% of the collapsed, mild to moderate and moderate asthma severity group and in only 36.8% of the collapsed moderate to severe and severe group. The practice of not prescribing inhaled corticosteroids by US physicians is quite inconsistent with both the US National Panel and the international guidelines for asthma management [4]. We do not feel that these data reflect skepticism for the usage of these medications in such an age group because they are consistent with those we have recently reported in adults with moderate to severe disease [5]. To elucidate how this pattern manifests itself across socioeconomic strata, we analyzed the distribution of prescribed asthma medications by subdividing our population into family income quartiles and comparing the highest to the lowest. Only 6% of the lowest quartile were prescribed inhaled steroids compared to 28% of the high-income quartile ($p = 0.03$ by Fisher's exact test). Also, β -agonists were prescribed at a lower rate in the lowest-income quartile (42 vs. 89%; $p = <0.0001$). These findings indicate that adolescents from low-income families receive inappropriate care for their asthma.

Discussion

This study is contributing to the many efforts to delineate the cause(s) behind increased asthma morbidity and mortality and its preponderance among African Americans within the US population. The data we presented offer insights into the predictors of asthma morbidity in adolescents. The hypotheses which prompted the design of this project cannot yet be definitively confirmed. However, many elements of our findings point toward their correctness.

The first suggestive conclusion is that socioeconomic factors are related to allergen exposure. Our preliminary data indicate that exposure to cockroach allergen is higher in adolescents of low-income families. Interestingly, a different pattern tends to emerge in the high-income group, where the dust mite *D. farinae* appears to be more prevalent. Most experts in the field would argue that this may be related to the differences in housing structures and to the nature of furniture and floor covers that are thought to exist between socioeconomic groups. There is, however, no definitive study to confirm these speculations.

We have further found that cockroach sensitization is strongly associated with low income; this observation confirms previously published work and should be attributed to higher exposure [6]. Overall atopic diathesis may also be a predisposing factor for skin test positivity to cockroach, as it is for any skin test positivity. There is no scientific evidence to support the possibility that such diathesis is characteristic of low income. Nevertheless, it is rather intriguing that several outdoor allergen sensitivities also appear to be more prevalent in the low-income group, as it is quite difficult to explain such finding on the basis of allergen exposure. This observation may tempt us to invoke genetic elements, such as those associated with ethnic background. At first look, this would not appear to be the case since the two major ethnic groups, African Americans and Caucasians, are in balance within the lowest-income quartile. However, 80% of the adolescents whose family belongs to the highest-income quartile are Caucasians. We find a consistent tendency for African Americans to have higher skin test sensitivities compared to Caucasians. Indeed, African American ethnic background was found to be the single factor relating to the number of positive skin tests in stepwise regression analysis. Given that the average income per family member of African American adolescents is exactly 50% of that of their Caucasian counterparts ($p = 0.0001$), one can again argue that the differences in skin test reactivity are driven by SES. From our preliminary analysis, however, in which African American and Caucasian adolescents from low-income and high-income families were compared as 4 separate groups, it is suggested that low income is driving sensitization to cockroaches and rodents only in the African American subgroup. The interaction of SES, and ethnic background may therefore be crucial in determining the risk of sensitization.

Asthma severity in adolescents is obviously multifactorial. Even after testing several potential factors, our ability to account for the asthma severity score variance barely exceeds 10%. However, two factors seem to be well associated with more severe asthma: atopic sensitization and female gender. The former is more specifically related to cockroach sensitization. Our current analysis promotes the American cockroach as the major culprit; however, in previous interim analyses of this project, we found both the German and oriental cockroaches forming the strongest relationships with asthma severity. In the current analysis, these 2 species were 'runners up' for the best predictor spot among all other allergens following the American cockroach. This interchangeable role may be due to a significant degree of cross-reactivity [7, 8] or to the probable association of all 3 species with poor housing conditions. Al-

though several studies have associated cockroach sensitization with asthma, especially in inner-city populations, [6, 9] our work is unique in that it relates this type of allergy to the severity of the disease. That the relationship between asthma severity and cockroach sensitization is apparent in the analysis of the whole group is probably due to the fact that, reflective of the general population, our sample is skewed toward lower SES strata. Indeed, when this relationship is examined separately in the two extreme income quartiles, it is much stronger in the low-income quartile, and it disappears in the high-income quartile.

In children, most studies suggest that asthma is worse in males compared to females [10, 11]. In contrast, females appear to have worse disease in adulthood [5, 12]. This is, we believe, the first effort to examine the issue in adolescents. Our finding is quite interesting because it infers that the pathophysiologic mechanism behind the inequality of asthma severity between women and men may lie in the events that take place during adolescence; it is reasonable to suggest puberty as a target for evaluation.

We also find discrepancies in the quality of asthma management between high- and low-income quartiles with respect to the rate of prescribed anti-inflammatory as well as bronchodilator medications. We have not yet analyzed additional aspects of the quality of care including the existence of action plans, the use of spacer devices and the metered-dose inhaler technique. However, what we are reporting here is alarming enough to raise the hypothesis that poor asthma management may be a contributor to the increased asthma morbidity and mortality in inner-city African Americans.

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