Geographic variability in childhood asthma prevalence in Chicago

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Background: Childhood asthma prevalence has been shown to be higher in urban communities overall without an understanding of differences by neighborhood.

Objective: To characterize the geographic variability of childhood asthma prevalence among neighborhoods in Chicago.

Methods: Asthma screening was conducted among children attending 105 Chicago schools as part of the Chicago Initiative to Raise Asthma Health Equity. Additional child information included age, sex, race/ethnicity, and household members with asthma. Surveys were geocoded and linked with neighborhoods. Neighborhood information on race, education, and income was based on 2000 census data. Bivariate and multilevel analyses were performed.

Results: Of the 48,917 surveys, 41,255 (84.3%) were geocoded into 287 neighborhoods. Asthma prevalence among all children was 12.9%. Asthma rates varied among neighborhoods from 0% to 44% (interquartile range, 8% to 24%). Asthma prevalence (mean, SD, range) in predominantly black neighborhoods (19.9, ±7, 4% to 44%) was higher than in predominantly white neighborhoods (11.4, ±4.7, 2% to 30%) and predominantly Hispanic neighborhoods (12.1, ±6.8, 0% to 29%). Although sex, age, household members with asthma, and neighborhood income significantly affected asthma prevalence, they did not explain the differences seen between neighborhoods. Race explained a significant proportion (about 80%) but not all of this variation.

Conclusion: Childhood asthma prevalence varies widely by neighborhood within this urban environment. Adjacent areas in Chicago were identified with significantly different asthma prevalence. A better understanding of the effect of neighborhood characteristics may lend insight into potential interventions to reduce childhood asthma. (J Allergy Clin Immunol 2008;121:639-45.)

Key words: *Asthma, children, disparities, neighborhood variability, asthma prevalence*

Asthma is already the most prevalent chronic disease of childhood in the United States, with an estimated 8.9 million children in the United States affected.[1,2] Racial differences in prevalence have been identified as an important public health concern,[1] as has the problem of increased asthma prevalence in certain US urban populations.[3-5] Zip code areas in New York City with predominantly low income minority children have been shown to have high asthma prevalence.[6]

Chicago has been documented to have one of the highest asthma mortality rates in the United States.[7] The asthma experience in Chicago has been well documented, with some studies showing Chicago to have poor outcomes with respect to asthma morbidity and mortality and a marked socioeconomic/racial gradient with respect to asthma outcomes.[8-10] Chicago hospitalization rates have also been shown to be twice as high as suburban Chicago or overall US rates.[11]

Although there is one study in adults that has examined a small number of high-risk neighborhoods in Chicago,[12] there has not been a published study of the variability of childhood asthma prevalence among a broad range of urban neighborhoods. The purpose of this study is to determine variability of childhood asthma prevalence and the role of race and demographic characteristics on asthma prevalence among 287 Chicago neighborhoods.

METHODS

Study population

A cross-sectional survey screening for asthma was conducted as part of the Chicago Initiative to Raise Asthma Health Equity (CHIRAH) study among children attending Chicago Public and Catholic elementary and middle schools during the 2003 to 2004 and 2004 to 2005 school years. An overview of the study methods follows; however, for further details on study methods, refer to Shalowitz et al.[13] In 2004, Chicago Public Schools (CPS) had 320,557 students in 486 elementary schools. CPS students were 50% African American (AA), 38% Hispanic, and 9% white. Eighty-five percent of CPS students were considered low-income. Schools were eligible for asthma screening if (1) greater than 50% of the enrolled students came from within the school district, (2) the school did not have on-site asthma screening within the previous 2 years, and (3) the school principal agreed. Schools were stratified on the basis of the percentage of AA students enrolled (>50% vs ≤50%) and family income by using subsidized lunches as a proxy for income (>70% receive subsidized or free lunches vs <70% received subsidized or free lunches). This process resulted in 4 school groups (high/low AA and mid/low income). Ninety-two schools were identified by population proportionate sampling methods within each of the 4 race-income sampling groups (high AA/low income;

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The Chicago Initiative to Raise Asthma Health Equity is supported by the National Heart, Lung, and Blood Institute, 5U01 HL072478-05. R.S.G. is supported by the National Institute of Child Health and Human Development through a Child Health Research Career Development Award, "Faculty Development Program for Pediatric Clinician-Scientists," K12 HD052902.

Disclosure of potential conflict of interest: J. J. Shannon receives grants/research support from the National Heart, Lung, and Blood Institute Asthma Disparities Front and is employed by Parkland Health and Hospital System. The rest of the authors have declared that they have no conflict of interest.

Received for publication May 23, 2007; revised November 8, 2007; accepted for publication November 12, 2007.

Available online February 13, 2008.

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0091-6749

doi:10.1016/j.jaci.2007.11.036

Abbreviations used
AA: African American
CHIRAH: Chicago Initiative to Raise Asthma Health Equity
CPS: Chicago Public Schools
IQR: Interquartile range
MOR: Median odds ratio
OR: Odds ratio

high AA/mid-income; low AA/low income; low AA/mid-income). The population proportionate sampling adjusted for school size, thereby providing an equal chance of a child being surveyed regardless of school size. In addition, 5 of the 92 schools were selected in each race-income sampling group to represent larger neighborhood areas. For those 5 schools, the 2 geographically closest cluster schools to each of these schools were selected, adding 40 additional schools to the 92 schools selected by population proportionate sampling.

Of these 132 schools, 27 refused to participate, and 1 of the selected cluster schools was a duplicate selection. The duplicate was replaced by the next closest school, yielding a final sample of 105 schools that were widely dispersed throughout the city. Reasons for refusal generally related to competing academic priorities for the principal's attention and unwillingness to distract classes from their lessons. All children in grades kindergarten through 8 were eligible to be surveyed in the selected schools. One hundred five of 132 schools selected chose to participate (79.5%). A total of 48,917 (78.9%) completed surveys were returned from 105 schools and are included in this analysis. Demographic information for survey participants is included in Table I.

The institutional review boards of Northwestern University and the Cook County Bureau of Health Services approved the school screening protocol. The CPS board and the Archdiocese of Chicago approved the asthma screening protocol in their respective schools.

Survey instrument

The screening survey was distributed at the schools and taken home by the students for an adult caregiver to complete in English or Spanish. It consisted of questions including the child's birth date, height, weight, sex, report of physician-diagnosed or nurse-diagnosed asthma, age at diagnosis, the race/ethnicity of the child, current asthma status, relationship to the child of the person completing the survey, the names and ages of others living in the same household with asthma, and the child's home address. Asthma in children was defined as parental report that their child had physician-diagnosed or nurse-diagnosed asthma. The individual variables used included sex, age, race/ethnicity, and household member with asthma. The sampled subjects were geocoded by using ArcGIS US Streetmap (CMC International, Dallas, Tex) and linked with neighborhoods.

Neighborhood selection criteria

The Chicago neighborhoods used in this analysis represent neighborhood clusters adapted from the Project on Human Development in Chicago Neighborhoods.[14] The project's scientific directors defined *neighborhoods* spatially, as a collection of people and institutions occupying a subsection of a larger community. The project collapsed 847 census tracts in the city of Chicago to form 343 *neighborhood clusters*. The predominant guideline in formation of the neighborhood clusters was that they should be as ecologically meaningful as possible, composed of geographically contiguous census tracts, and internally homogenous on key census indicators. The project settled on an ecological unit of about 8000 people, which is smaller than the 77 established community areas in Chicago (of which the average size is almost 40,000 people), but large enough to approximate local neighborhoods. Geographic boundaries (eg, railroad tracks, parks, and freeways) and knowledge of Chicago's neighborhoods guided this process. Throughout this article, *neighborhood* refers to neighborhood cluster.

TABLE I. Demographic characteristics of sample population (N = 41,255)

Variable	Frequency (N)	Sample prevalence (%)	Cases with asthma in subpopulation	Asthma prevalence (%) in subpopulation
Report diagnosis of asthma	5318	12.9		
Race/ethnicity				
White	12,367	30.0	1164	9.4*
Black, non-Hispanic	11,849	28.7	2293	19.4*
Hispanic, nonblack	16,716	40.5	1792	10.7*
Black, Hispanic	323	0.8	69	21.4*
Sex				
Male	20,325	49.3	3046	15.0*
Female	20,930	50.7	2272	10.9*
Household member with asthma				
Yes	3594	8.7	1359	37.8*
No	37,661	91.3	3959	9.6*
Age groups (y)				
0 to 5	4648	11.3	545	11.7*
6 to 8	13,933	33.8	1709	12.3*
9 to 11	13,350	32.4	1823	13.7*
≥12	9324	22.6	1241	13.3*

*$P < .0001$ based on multiple comparisons for population groups with more than 2 categories and pairwise t test for population groups with only 2 categories.

Neighborhood variables

Neighborhood information on race, education and income were extracted from the 2000 aggregated census tract data. The tract-level data were linked with and reaggregated into the neighborhoods used in this analysis. The neighborhood variables were derived from the corresponding 2000 census tract-level measures. Child population measures (race and ethnicity) are the sum of those census tracts within 1 neighborhood. Neighborhood educational attainment is the percentage of the population, greater than or equal to 25 years old, with a high school diploma or higher degree. Neighborhood income is the median family household income in the neighborhood.

Analysis

Chicago neighborhoods with greater than 15 children from our sample were included in the analysis. Individual factors (age, sex, race, and household member with asthma) were analyzed by performing cross-tabulations, and significant relationships with asthma prevalence were established by using χ^2 statistics. Neighborhood factors (education, income, and neighborhood race) were analyzed by performing simple linear regression analyses, and significance was established using t test statistics. SAS statistical software version 9 (SAS Institute, Cary, NC) was used for the analyses.

Spatial autocorrelation cluster analysis was performed to characterize significant asthma prevalence variability between adjacent neighborhoods.[14] In spatial cluster analysis, local spatial autocorrelation statistic–Moran's I is used to evaluate the spatial patterns of neighborhood asthma prevalence. It is possible that a single neighborhood stands out as a significant cluster, whereas its adjoining neighborhoods have no significant spatial patterns. An adjoining neighborhood itself may not be surrounded in a significant way by all high or low prevalence neighborhoods. Significant spatial clusters (the neighborhood with high childhood asthma prevalence surrounded by the neighborhoods with high childhood asthma prevalence, and the neighborhood with low childhood asthma prevalence surrounded by the neighborhoods with low childhood asthma prevalence) and spatial outliers (the

TABLE II. Multivariate model of individual and community factors contributing to differences in neighborhood asthma prevalence

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Age groups						
6-8 y old vs 3-5 y old				1.05 (0.95-1.16)	1.05 (0.95-1.16)	1.05 (0.95-1.16)
9-11 y old vs 3-5 y old				1.12 (1.01-1.24)	1.11 (1.00-1.22)	1.11 (1.00-1.22)
12 y and older vs 3-5 y old				1.14 (1.03-1.27)	1.13 (1.02-1.26)	1.13 (1.02-1.26)
Boy vs girl				1.48 (1.40-1.56)	1.48 (1.40-1.57)	1.48 (1.40-1.57)
Household member with asthma (yes vs no)				4.52 (4.21-4.86)	4.35 (4.05-4.68)	4.36 (4.06-4.69)
Black (yes vs no)			2.1 (1.93-2.21)		2.01 (1.86-2.18)	2.05 (1.88-2.24)
Hispanic (yes vs no)					1.16 (1.07-1.25)	1.17 (1.08-1.26)
Neighborhood income (low vs high)		1.32 (1.18-1.47)				0.95 (0.87-1.03)
Neighborhood level variance (SE)	0.140 (0.019)	0.122 (0.017)	0.028 (0.008)	0.101 (0.016)	0.024 (0.007)	0.023 (0.007)
MOR	1.43 (1.36-1.49)	1.39 (1.33-1.46)	1.11 (1.17-1.22)	1.35 (1.29-1.41)	1.16 (1.10-1.20)	1.16 (1.10-1.20)

Values are OR (95% CI) unless otherwise stated.

neighborhood with high childhood asthma prevalence surrounded by the neighborhoods with low childhood asthma prevalence, and the neighborhood with low childhood asthma prevalence surrounded by the neighborhoods with high childhood asthma prevalence) were identified on the basis of the local Moran's I statistic.[15] Spatial autocorrelation analysis was performed in GeoDa0.9.5-i5 software (Spatial Analysis Laboratory, University of Illinois Urbana-Champaign, Urbana, Ill).

Multilevel logistic regression analysis was performed for 41,255 individuals nested within 287 neighborhoods to estimate both individual and neighborhood effects on childhood asthma. In the multilevel logistic regression analysis, a nonconditional model (also called *null model*) was used to estimate the neighborhood level variance. This variance reflects the total neighborhood level variance including all individual and neighborhood variables in our model. It should be 0 under null hypothesis. The neighborhood level random variance was then translated into a median odds ratio (MOR), which can be compared with the intuitive odds ratios (ORs) of individual variables.[16,17] The MOR is interpreted as how much a child's probability of asthma would (in median) increase if this child moved to a neighborhood with a higher asthma risk because of the factors in our model. A MOR of 1 indicates that there are no differences between neighborhoods in the probability of the child having asthma. We first estimated the null model (model 1 in Table II), then included neighborhood and individual variables. For example, neighborhood socioeconomic status measured by median family income was introduced into the models as a 2-category variable. A series of multilevel models were developed to assess the relative effects of neighborhood income on child asthma compared with individual factors' effect. All individual and neighborhood variables were looked at in this manner, and some of these models are presented in Table II. SAS GLIMMIX (SAS Institute) was used for multilevel analysis.

RESULTS

Study population

Of the total 48,917 CHIRAH subjects, 44,570 (91.1%) had addresses that could be mapped, and 42,549 subjects were mapped within the city of Chicago. Two hundred eighty-seven of Chicago's 343 neighborhoods had >15 children from the survey in residence, representing 41,255 (84%) of the 48,917 CHIRAH subjects. Among the 41,255 children surveyed, 30% were white, 28.7% black, and 40.5% Hispanic (Table I). Children were 11.3% age 0 to 5 years old, 33.8% age 6 to 8 years, 32.4% age 9 to 11 years, and 22.6% 12 years and older; 49.3% of children were boys. Almost 9% of children in the sample had a household member with asthma, and 12.9% of the children had asthma. White children had a mean asthma prevalence of 9.4%, black children had a mean asthma prevalence of 19.4%, and Hispanic children had a mean asthma prevalence of 10.7 ($P < .0001$; Table I).

Variability of asthma in Chicago

Childhood prevalence of asthma varied greatly depending on what neighborhood a child lives in within Chicago. Asthma prevalence ranged from 2% in some neighborhoods to 44% in others (Fig 1). To show that variability in prevalence could be high in geographically contiguous neighborhoods, we conducted a spatial cluster analysis to detect significant differences across neighborhoods. All 287 neighborhoods were included in the analysis. Four neighborhood outliers with high asthma prevalence were bordered by neighborhoods with significantly lower asthma prevalence. Twenty-nine high prevalence neighborhoods were bordered by other high prevalence neighborhoods. Twelve neighborhood outliers with low asthma prevalence were bordered by neighborhoods with significantly higher asthma prevalence, and 30 neighborhoods with a low prevalence of asthma were bordered by other low prevalence neighborhoods. Two hundred twelve neighborhoods were found to be nonsignificant (Fig 2). The mean asthma prevalence for a high neighborhood was 23.5% (± 6.9%), and the mean asthma prevalence for a low neighborhood was 9.6% (± 1.8%).

Race and neighborhood asthma prevalence

The race of a community was significantly correlated to asthma prevalence (see this article's Fig E1 in the Online Repository at www.jacionline.org). As the African American population increased in a community, so did the childhood asthma prevalence ($P < .0001$; Fig 3). In addition, 212 of the 287 neighborhoods in the study had greater than 2/3 (67%) of their population classified as white, black, or Hispanic by census data. Of the 72 neighborhoods with a predominantly white population, the mean childhood asthma prevalence was 11.4% (±4.7), with a range from 2% to 30% and an interquartile range (IQR; 25% to 75%) from 8.6% to 14.2%. Of the 108 neighborhoods with a predominantly black population, the mean childhood asthma prevalence was

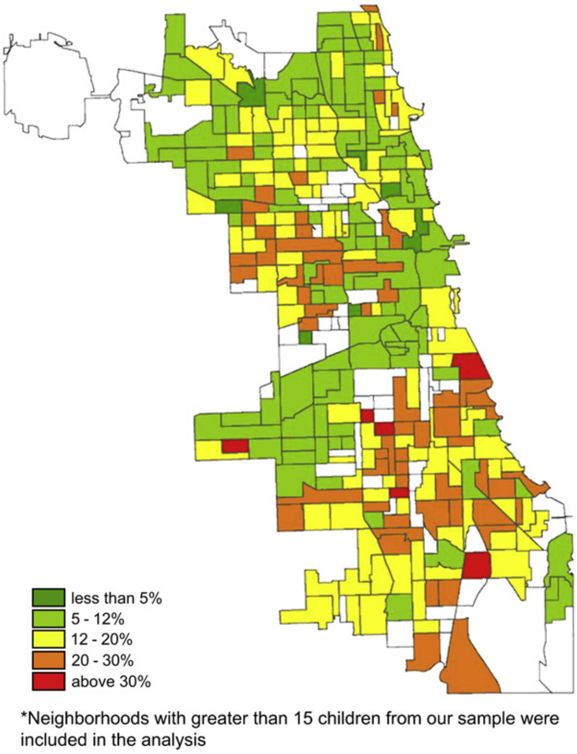

FIG 1. Childhood asthma prevalence in Chicago neighborhoods.

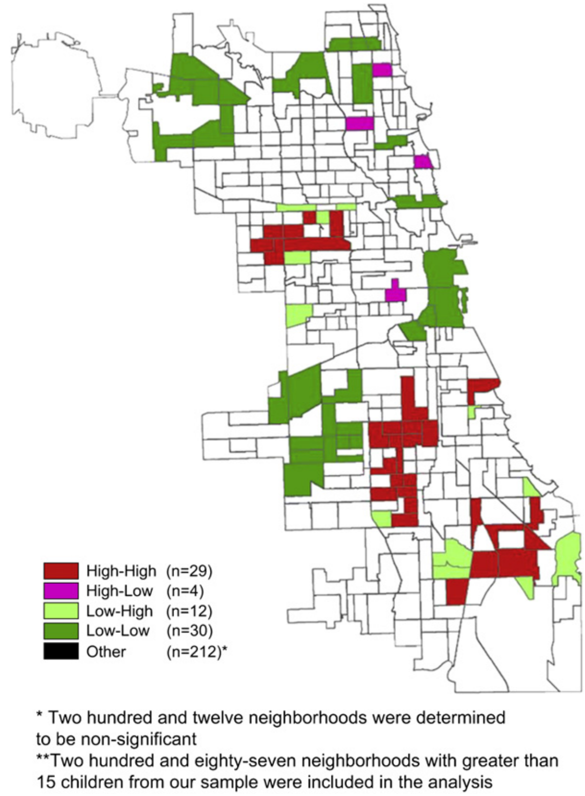

FIG 2. Childhood asthma spatial clusters in Chicago neighborhoods.

19.9% (±7.0), with a range from 4% to 44% and an IQR (25% to 75%) from 15.4% to 23.9%. Of the 32 neighborhoods with a predominantly Hispanic population, the mean childhood asthma prevalence was 12.1% (±6.8), with a range from 0% to 29% and an IQR (25% to 75%) from 7.7% to 13.2%.

Individual and community characteristics and asthma prevalence

The survey identified 3 individual characteristics of the child that were examined in relationship to neighborhood asthma prevalence. Sex was significantly related to asthma prevalence, with boys having higher asthma prevalence (15%) compared with girls (11%; $P < .0001$). Children with a household member with asthma were significantly more likely to have asthma themselves (38% vs 10%, respectively; $P < .0001$). Finally, age was significantly correlated to asthma prevalence, with the older age groups having higher asthma prevalence. For children 3 to 5 years old, the asthma prevalence was 11.7%; for children age 6 to 8 years, the asthma prevalence was 12.3%; for children age 9 to 12 years, the asthma prevalence was 13.7%; and for children older than 12 years, the asthma prevalence was 13.3% ($P < .0001$).

Fig 4 shows community variables in relation to asthma prevalence. Children from neighborhoods with lower incomes had higher asthma prevalence ($P < .0001$). However, educational attainment of the neighborhoods did not have a significant effect on a child's asthma status.

Finally, the base model (model 1 in Table II) with MOR (1.43; CI, 1.36-1.49) indicates a significant variation in childhood asthma between neighborhoods. Model 2 shows that neighborhood income individually has a strong relationship to asthma prevalence but does not significantly affect the neighborhood variation seen in asthma prevalence. Model 3 displays the strong effect of race individually and on the neighborhood variation. Black race alone seems to explain about 80% of the neighborhood level variance (0.14-0.028/0.14 = 0.80). Individual

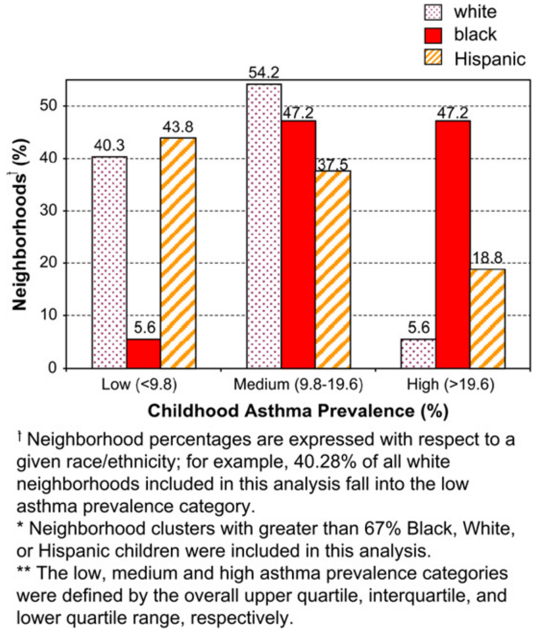

FIG 3. Childhood asthma prevalence in Chicago neighborhoods by race/ethnicity.

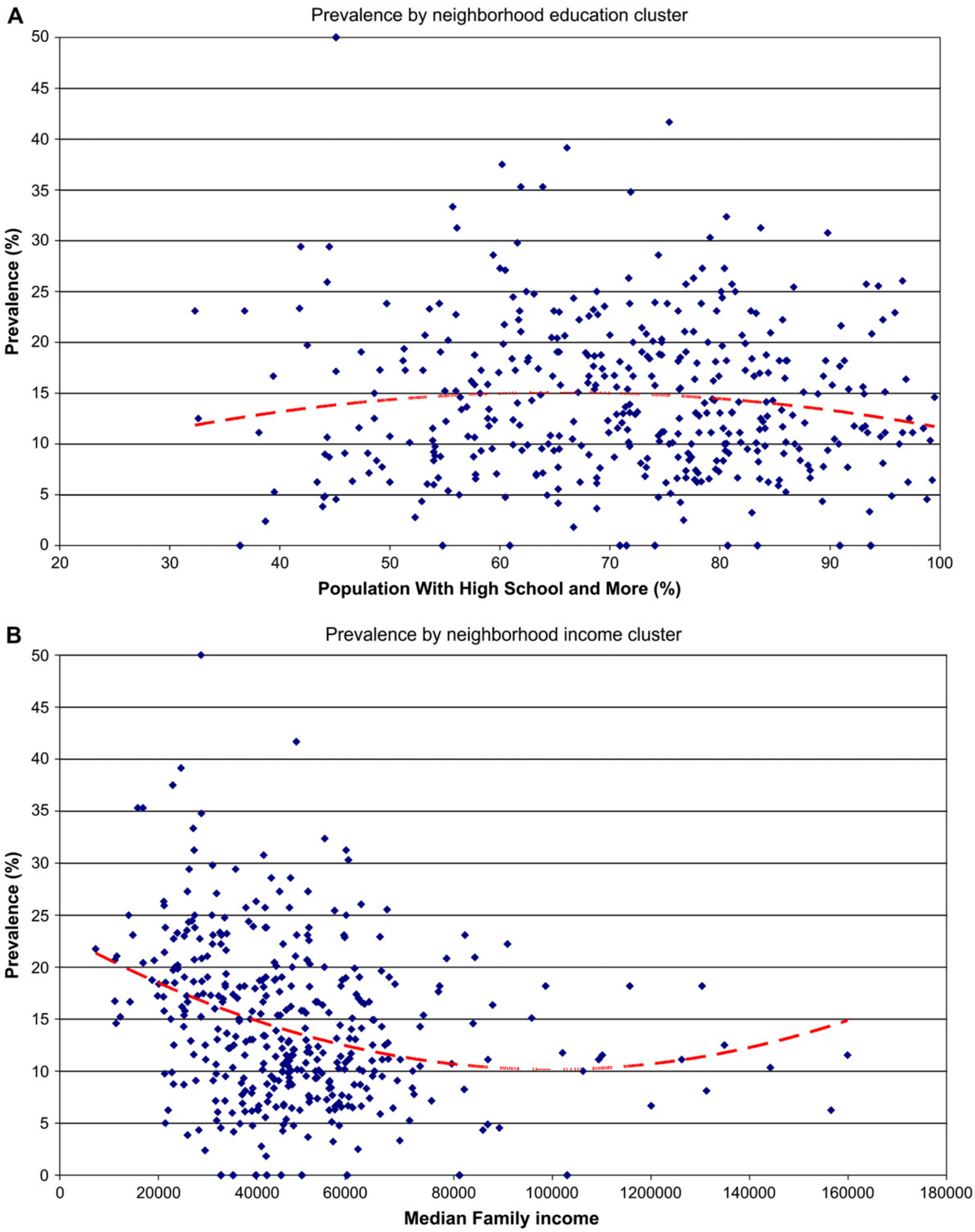

FIG 4. Childhood asthma prevalence by neighborhood education cluster (**A**) and neighborhood income cluster (**B**).

characteristics including age group, sex, and household member with asthma also individually have an effect but do not change the model MOR significantly (model 4). After adding race/ethnicity, specifically black race to the other variables in the model (models 5 and 6), a large amount of the variation is explained, and neighborhood income becomes nonsignificant. Model 6 suggests significant neighborhood variation remains that can not be explained by the variables in our analysis.

DISCUSSION

To our knowledge, our study is the first to show both a significant variability in asthma prevalence by neighborhoods in an urban environment and a degree of clustering of similar prevalence among contiguous neighborhoods. Although black children had significantly higher overall asthma prevalence compared with white children, the prevalence ranged dramatically depending on which predominantly black neighborhood the child lived in. Similarly, childhood asthma prevalence varied widely for white and Hispanic children depending on the neighborhood a child lived in. Although children who were from a lower income neighborhood, who had a household member with asthma, who were boys, or who were greater than 9 years old had a higher individual prevalence of asthma, these factors had little influence on the differences seen between neighborhoods. Most noteworthy was that race of the child, particularly black, at least among these Chicago neighborhoods, seems to be an important factor associated with asthma prevalence. Although the majority of predominantly black neighborhoods have high asthma prevalence, there is still a great degree of variation, with a minority of black neighborhoods having low asthma prevalence. Therefore, race does not explain all of the geographic variation and may be serving as a proxy for many sociocultural environmental risk factors for asthma prevalence.

Urban communities have been shown to have disproportionately higher asthma prevalence and morbidity.[3,18-20] Our study demonstrates that asthma rates are not universally high throughout an urban environment but vary significantly by neighborhood. A better understanding of these neighborhood factors will help elucidate the true reasons for the increased asthma prevalence. Previous studies have looked at race and poverty as 2 potential indicators for urban asthma. One study showed that all children living in an urban environment are at increased risk for asthma, regardless of race or poverty,[21] whereas another showed racial differences to exist only among the very poor.[22] A recent study showed neighborhood problems to be associated with greater asthma symptoms and family problems to be associated with asthma physiology.[23,24] A study looking at New York City children by zip codes found higher asthma prevalence in zip codes with increased low income minority populations.[6] Our data suggest that although overall asthma prevalence is higher in black than white children in an urban setting, a significant indicator of asthma prevalence is the neighborhood and community in which a child lives.

Community factors that have been associated with asthma prevalence include exposure to air pollution[4,25-29]; housing problems including sensitization to cockroach,[30-32] dust mite,[32,33] mouse,[34,35] and rat allergens[36]; decreased exposure to endotoxins (the hygiene hypothesis)[37-39]; community income and education[40,41]; and exposure to violence.[42,43] The interplay between these community factors and individual factors known to be associated with asthma including age, sex,[44,45] race,[46,47] family history,[48] smoking,[49,50] diet,[51,52] and stress[53,54] is valuable. Our data confirm the association between asthma prevalence and community income, individual age, household members with asthma, and sex. A better understanding of the main community factors associated with asthma and the true relationship between individual and community factors is needed.

Many of the community factors that have been suggested thus far have a negative effect on communities and asthma prevalence. Although these factors are important, it may be useful to look at community factors that could have a positive effect on asthma prevalence. Some factors may include a community's social capital such as its stability, diversity, interaction, and community engagement. A community's economic potential and access to amenities may also positively influence asthma outcomes.

The public heath implications of this study are significant. Although factors such as urban environment and race have been shown to be important contributors to asthma prevalence, we found wide variations on the basis of a child's neighborhood. A deeper look into the neighborhoods with high asthma prevalence bordering neighborhoods with low asthma prevalence is warranted and may give us new insight into community factors responsible for these large differences. Also, looking closer at the predominantly black neighborhoods with low asthma prevalence and the predominantly white neighborhoods with high asthma prevalence may prove to be valuable in determining community factors that are driving increases in asthma prevalence.

There are, as with all studies, limitations to the design that need to be highlighted. We obtained community data from the 2000 census, and individual data were collected from 2003 to 2005. Because the community data are 3 to 5 years older than the individual data, there may be some discrepancies. Our study was based on school samples of children and a certain census per school. For this reason, we did not have an exact census of children from each neighborhood, and any neighborhood with less than 15 children was not included in our study. Also, a small bias may exist for children not yet in school. Our sample of children, however, was large, and 84% of Chicago neighborhoods were represented.

In summary, childhood asthma prevalence in the United States continues to be at a historic high, with the disparity between black and white children increasing.[34,55] Although individual factors continue to be important contributors, our study confirms that neighborhood factors may play a significant role in the prevalence of childhood asthma. A better understanding of potentially unexplored neighborhood and community factors related to asthma prevalence and differences in prevalence seen across neighborhoods is an essential step to understanding the true cause of and preventing any future increase in childhood asthma.

We thank the CHIRAH team and the Chicago public and archdiocesan schools, without whom this project would not have been possible. We also thank those who provided financial support. Dr Gupta had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Clinical implications: Childhood asthma prevalence varies significantly by neighborhood. A discussion with families of avoidable neighborhood asthma triggers is warranted.

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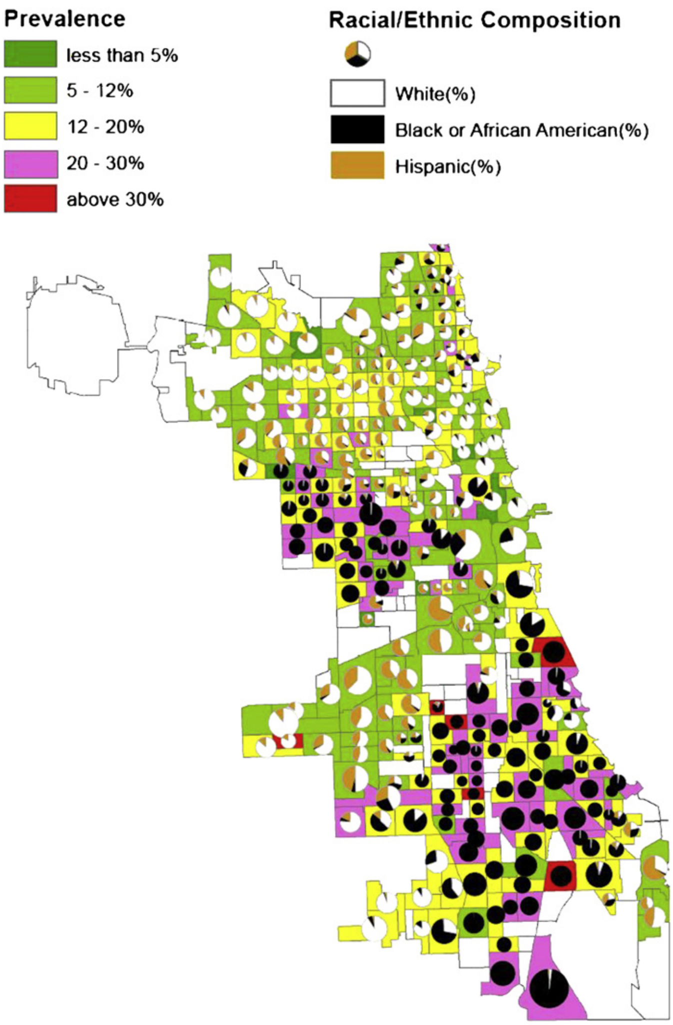

*The size of the race/ethnicitiy circles are based on the size of the neighborhood and are not representative of sample size
**Two hundred and eighty-seven neighborhoods with greater than 15 children from our sample were included in the analysis

FIG E1. Childhood asthma prevalence and racial distribution in Chicago neighborhoods.