Different Slopes for Different Folks: Socioeconomic and Racial/Ethnic Disparities in Asthma and Hay Fever among 173,859 U.S. Men and Women

Jarvis T. Chen,[1] Nancy Krieger,[1] Stephen K. Van Den Eeden,[2] and Charles P. Quesenberry[2]

[1]Department of Health and Social Behavior, Harvard School of Public Health, Boston, Massachusetts, USA; [2]Division of Research, Kaiser Foundation Research Institute, Oakland, California, USA

Although allergic diseases such as asthma and hay fever are a major cause of morbidity in industrialized countries, most studies have focused on patterns of prevalence among children and adolescents, with relatively few studies on variations in prevalence by race/ethnicity and socioeconomic position among adults. Our study examined racial/ethnic and socioeconomic patterns in the prevalence of asthma overall, asthma with hay fever, asthma without hay fever, and hay fever overall, in a population of 173,859 women and men in a large prepaid health plan in northern California. Using education as a measure of socioeconomic position, we found evidence of a positive gradient for asthma with hay fever with increasing level of education but an inverse gradient for asthma without hay fever. Hay fever was also strongly associated with education. Compared with their White counterparts, Black women and men were more likely to report asthma without hay fever, and Black women were less likely to have asthma with hay fever. Asian men were also more likely to report asthma with hay fever, and Asian women and men were much more likely to have hay fever. Racial/ethnic disparities in prevalence of allergic diseases were largely independent of education. We discuss implications for understanding these social inequalities in allergic disease risk in relation to possible differences in exposure to allergens and determinants of immunologic susceptibility and suggest directions for future research. *Key words*: allergic disease, Asian, asthma, atopy, Black, education, gender, hay fever, race/ethnicity, social inequality, socioeconomic factors, women. *Environ Health Perspect* 110(suppl 2):211–216 (2002).
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Patterns of association between allergic diseases and socioeconomic position are complex, with specific allergic diseases having different relationships to deprivation and affluence. For example, although several large population studies support an inverse association between socioeconomic position and asthma prevalence, particularly using measures of poverty and housing deprivation (*1–5*), some studies have also suggested a positive association (*6*) or associations that vary with specific types of asthma (*7,8*). Meanwhile, hay fever is commonly considered a disease of affluence, with prevalences positively associated with socioeconomic position in studies of populations in the United Kingdom and other European countries (*9–14*). Contributing to the confusing interpretation of these trends in the United States is that while much research has focused on asthma and hay fever in childhood and adolescence, relatively fewer studies have explored racial/ethnic and socioeconomic patterns in asthma and hay fever among adults (*15,16*).

A clearer understanding of variations in allergic diseases by race/ethnicity and socioeconomic position is important because these diseases are among the most common causes of chronic ill health in the United States and other industrialized countries. In addition, many studies have demonstrated increases in the prevalence of asthma and hay fever over the past several decades (*16–19*), indicating the relative importance of environmental influences in driving population patterns of disease.

To address the paucity of data on racial/ethnic and socioeconomic disparities of allergic diseases in U.S. adults, we analyzed the allergic disease experience in a multiracial/ethnic population for whom socioeconomic data were available. Framing our investigation is an ecosocial, life-course perspective (*20,21*) on the epidemiology of allergic disease, which emphasizes exploring how socioeconomic experience and socially mediated experiences of race/ethnicity and racial discrimination influence timing and intensity of exposure to environmental allergens, as well as modifiers of immunologic susceptibility to allergic disease. We also explored the possibility that different kinds of asthma may exhibit different relationships to race/ethnicity and socioeconomic position. For example, asthma researchers often distinguish between atopic asthma and nonatopic asthma on the basis of immunologic characteristics (*22*). Although atopy has been shown to be a risk factor for asthma in several studies (*23–25*), little research has been conducted on possible differences in socioeconomic and racial/ethnic patterns for both atopic and nonatopic asthmas. In our analyses, we differentiated between atopic and nonatopic asthma by using concomitant data on experience of hay fever. Categorization of asthma cases on the basis of presence or absence of hay fever, which is considered an atopic disease, may enable us to distinguish different forms of asthma in the absence of direct immunologic measures (*16*).

Methods

Study Population

The study population comprised members of the Kaiser Permanente Medical Care Program who received a multiphasic health checkup between 1964 and 1972. The program is a prepaid healthcare program that, at the time of recruitment of the cohort, served close to one third of the San Francisco Bay Area (California) population. Members who underwent the multiphasic health checkup took a health-screening examination, which included medical and social history questionnaires, a series of clinical laboratory tests, a chest X ray, electrocardiogram, and an examination by physician.

For these analyses, we included data from the first multiphasic health checkup between 1964 and 1972 for those members who were between 15 and 74 years of age and had complete data on race/ethnicity. The resulting study population comprised 94,325 women and 79,534 men.

Variables Definitions

Allergic symptoms. We dichotomized subjects as to the presence or absence of an allergic disease on the basis of their answers to a series of questions about their experience of asthma and hay fever within the preceding year. The questionnaire did not attempt to define for the respondent what a symptom or a disease was (examples below):
• Asthma: "Have you had asthma in the last year?"

• Hay fever: "Have you had hay fever in the last year?"

Using hay fever as a marker of atopy, we further cross-classified asthma and hay fever cases to yield the categories: asthma with hay fever (atopic asthma), asthma without hay fever (nonatopic asthma), and hay fever without asthma (atopy without asthma) (16).

Table 1. Sociodemographic characteristics, smoking status, and birthplace of men and women in the Kaiser Permanente multiphasic health checkup population (1964–1972), San Francisco Bay area.

	Women (n = 94,325) n (%)	Men (n = 79,534) n (%)
Age (years)		
15–24	15,619 (16.6)	8,852 (11.1)
25–34	22,826 (24.2)	20,531 (25.8)
35–44	20,352 (21.6)	19,118 (24.0)
45–54	18,957 (20.1)	16,413 (20.6)
55–64	12,036 (12.7)	10,469 (13.2)
65–74	4,535 (4.8)	4,151 (5.2)
Race		
White	72,604 (77.0)	62,053 (78.0)
Black	14,298 (15.2)	10,611 (13.3)
Asian	3,841 (4.1)	3,389 (4.3)
Other	3,582 (3.8)	3,481 (4.4)
Education		
Elementary	14,891 (15.8)	12,998 (16.3)
High school/trade	36,172 (38.4)	24,309 (30.6)
College, 1–2 years	14,076 (14.9)	11,040 (13.9)
College, 3–4 years	12,705 (13.5)	11,939 (15.0)
Postgraduate	10,935 (11.6)	14,764 (18.6)
Unknown	5,546 (5.9)	4,484 (5.6)
Year of multiphasic exam		
1964	7,983 (8.5)	5,764 (7.3)
1965	20,762 (22.1)	16,734 (21.0)
1966	14,242 (15.1)	10,895 (13.7)
1967	11,199 (11.9)	9,833 (12.4)
1968	9,583 (10.2)	8,462 (10.6)
1969	8,205 (8.7)	7,557 (9.5)
1970	8,808 (9.3)	7,738 (9.7)
1971	10,105 (10.7)	9,802 (12.3)
1972	3,438 (3.6)	2,749 (3.5)
Smoking		
Never	40,411 (46.8)	24,357 (33.1)
Current	35,686 (41.3)	33,479 (45.5)
Past	10,266 (11.9)	15,692 (21.3)
Place of birth		
Born in U.S.	63,430 (67.3)	53,717 (67.5)
Born outside U.S.	17,054 (18.1)	14,801 (18.6)
Birthplace unknown	13,841 (14.7)	11,016 (13.9)

Socioeconomic position. The only socioeconomic data available pertained to subjects' education at the time of the multiphasic checkup. No data on income or wealth were available, and occupational data were missing or not coded. Education, defined as highest level of schooling completed, was categorized as follows: elementary school, high school/trade, 1–2 years of college, 3–4 years of college, and postgraduate. Because of the small number of subjects with trade school education (n = 9,922, 6% of the sample), we grouped these subjects with those with high school education. Level of schooling was missing for 6% of the sample.

Race/ethnicity. At the time of the multiphasic health checkup, we recorded "skin color" of the subject as "white," "black," "yellow," or "other" on the basis of the judgment of examination staff. We directed the examination staff to mark white for Caucasian, black for Negro, yellow for Oriental, other for Polynesian, Indian, etc. The yellow category consisted primarily of individuals of east Asian descent (primarily Chinese and Japanese) (26). In these analyses, we have interpreted yellow to represent individuals of Asian descent. Because the "other" group represents a heterogeneous mix of racial/ethnic origins, results for this group have been omitted from the discussion and tables below, although we retained them as a separate group in all regression models.

Two additional variables included in our analyses as likely confounders or effect modifiers were smoking status and birthplace. Smoking is a well-established correlate of respiratory disease (21). We categorized subjects as current smoker, past smoker, or never smoked at time of multiphasic checkup. We included birthplace as a covariate in our analyses because of previously reported variations in asthma and hay fever prevalence by birthplace and immigration status among Asians in the United Kingdom and Australia (27,28). We categorized subject birthplace as "U.S.," "non-U.S.," or "unknown" (14% of sample).

Statistical Methods

For individual allergic symptoms, we modeled the odds of having experienced the symptom within the last year, given covariates, using a logistic regression model. To model associations between covariates and cross-classified asthma/hay fever status, we created a four-level nominal variable (asthma with hay fever, asthma without hay fever, hay fever without asthma, and no asthma/no hay fever), and we extended the standard logistic regression models to handle multinomial data (29). For a four-level nominal variable, this yields three nonredundant logits, by which the odds of reporting asthma with hay fever, asthma without hay fever, and hay fever without asthma can each be compared with the odds of reporting no asthma and no hay fever.

We adjusted all multivariate models for age in 10-year categories and year of multiphasic exam. We further adjusted models for race/ethnicity and education for smoking and birthplace to check for possible confounding. We also fitted stratified models by race/ethnicity, age, birthplace, and smoking to explore possible effect modification.

Results

Table 1 presents sociodemographic characteristics of the study population. The mean age was 40 years old, and 51% overall had at most a high school education, ranging from 41% among Asians to 63% among Blacks. Overall, 3.2% of the population had asthma (1.8% asthma with hay fever and 1.4% asthma without hay fever), and 16% had hay fever, with prevalences varying by race/ethnicity and education (Table 2).

Table 3 presents multivariate models to estimate the relative odds of asthma in relation to race/ethnicity and education, both overall and for asthma with and without hay fever. Comparable multivariate models for hay fever overall are also included. Models for hay fever without asthma yielded similar results to those obtained for hay fever overall and so we omitted them from the table (results available upon request).

Table 2. Age-adjusted (in 10-year categories) prevalences of allergic disease by sex, race/ethnicity, and education, Kaiser Permanente Multiphasic Health Checkup population (1964–1972).

	Asthma		Asthma with hay fever		Asthma without hay fever	
	Women, % (n)	Men, % (n)	Women, % (n)	Men, % (n)	Women, % (n)	Men, % (n)
All	3.2 (2,997)	3.4 (2,659)	1.8 (1,723)	1.9 (1,437)	1.4 (1,274)	1.6 (1,222)
Race/ethnicity						
White	3.2 (2,301)	3.4 (2,056)	1.9 (1,375)	1.9 (1,154)	1.3 (926)	1.5 (902)
Black	3.4 (477)	3.7 (371)	1.6 (231)	1.6 (163)	1.7 (246)	2.1 (208)
Asian	2.9 (109)	3.5 (114)	1.9 (73)	2.1 (69)	1.0 (36)	1.4 (45)
Other	3.2 (110)	3.5 (118)	1.3 (44)	1.5 (51)	1.9 (66)	2.0 (67)
Education						
Elementary	3.3 (493)	3.5 (441)	1.4 (209)	1.5 (179)	1.9 (284)	2.1 (262)
High school/trade	3.1 (1,126)	3.1 (740)	1.7 (627)	1.5 (356)	1.4 (499)	1.6 (384)
College, 1–2 years	3.3 (467)	3.7 (394)	2.1 (298)	2.1 (219)	1.2 (169)	1.7 (175)
College, 3–4 years	3.1 (392)	3.7 (432)	2.0 (257)	2.3 (270)	1.1 (135)	1.4 (162)
Postgraduate	3.3 (360)	3.6 (528)	2.4 (256)	2.4 (354)	1.0 (104)	1.2 (174)
Education unknown	2.9 (159)	2.9 (124)	1.4 (76)	1.4 (59)	1.5 (83)	1.5 (65)
						(continued)

Race/Ethnicity and Allergic Disease

For asthma overall, we observed no significant increase or decrease in the odds of asthma for either Black or Asian women or men relative to Whites. However, when we further cross-classified asthma with hay fever, Black women and men had a 20% lower odds of asthma with hay fever than White women and men and a 40% higher odds of asthma without hay fever. After adjustment for covariates, the decreased risk of asthma with hay fever persisted for Black women but not for men, whereas the increased risk of asthma without hay fever persisted for both Black women and men. In contrast, Asian men had an increased odds of asthma with hay fever, which, after adjustment for covariates, was 30% higher than that of White men.

The odds of hay fever overall was strongly elevated for both Asian women and men, with 1.5-fold excess odds among Asian women and 2-fold excess odds among Asian men relative to their White counterparts. Prevalence of hay fever among Black women and men, in contrast, did not differ significantly from that among Whites.

Birthplace outside of the United States was consistently associated with a significantly decreased risk of all forms of asthma and hay fever.

Education and Allergic Disease

For asthma overall, we observed no clear pattern of association of asthma with education for women. For men, the odds of asthma was significantly elevated for men with elementary education and postgraduate education relative to high school education, suggesting a possible U-shaped relationship. When we cross-classified asthma with hay fever, however, the odds of reporting asthma with hay fever were positively associated with education for both women and men, with the effect more pronounced for men. In contrast, the odds of reporting asthma without hay fever were inversely associated with education for women and men, with a steeper gradient observed among women.

Education level, moreover, was positively associated with the odds of reporting hay fever, with a steeper gradient seen for men. Among the men, those with a postgraduate education had a 60% higher odds of reporting hay fever relative than those with a high school education, compared with a 30% excess odds among women, after adjustment for covariates.

Race/Ethnicity and Education in Combination

Adjusting for education mildly attenuated racial/ethnic disparities in the odds of asthma with hay fever and asthma without hay fever, particularly for Black women and men in relation to asthma with hay fever, although the general pattern of racial/ethnic disparities remained unchanged. Additional adjustment for smoking and birthplace did not result in further changes to the estimates. Meanwhile, adjustment for education did little to alter estimates of the increased risk of hay fever for Asian women and men. Adjustment for education did suggest a slight increase in the odds of hay fever for Black women and men, which, after adjustment for smoking and birthplace, persisted for Black men.

Adjustment for race/ethnicity resulted in a slight attenuation of the education gradient for both asthma with hay fever and asthma without hay fever. In contrast, adjustment for race/ethnicity had no effect on the observed positive gradient of associations between hay fever and education.

We found little evidence of effect modification of educational gradients by race/ethnicity in racial/ethnically stratified models, nor did we find strong evidence of effect modification by age, birthplace, or smoking (results available upon request).

Discussion

Our analyses revealed markedly different patterns of socioeconomic and racial/ethnic inequalities with respect to asthma (with and without concomitant hay fever) and hay fever

in a large population of U.S. adults enrolled in a large prepaid health plan. With respect to asthma, we found that the overall lack of relationship of education to asthma prevalence among women and that the possible U-shaped relationship observed among men resulted from opposing education gradients for asthma with hay fever (atopic asthma) and asthma without hay fever (nonatopic asthma). Similarly, we found a strong positive association of hay fever with education.

We also found differing patterns of racial/ethnic disparities in allergic disease experience. Black women and men experienced significantly increased odds of asthma without hay fever relative to Whites but decreased odds of asthma with hay fever. Meanwhile, Asians experienced odds of asthma both with and without hay fever comparable to those of Whites, although the data did make some suggestion of an increased odds of asthma with hay fever among Asian men relative to White men. However, Asians also experienced a marked increase in the odds of hay fever relative to Whites, with Asian men experiencing almost 2-fold greater odds.

Limitations and Strengths

Before interpreting our results, it is important to consider limitations and strengths of our study. Studies of atopy and asthma typically deal with the absence of fully accurate and reliable measures of allergic disease (22). Consequently, misclassification is a chronic concern in studies such as ours, particularly given our reliance on self-reported information about experiences of allergic disease and the absence of, for example, allergen skin-prick tests as a biologic measure of atopy. Nondifferential misclassification of allergic disease status may account for some of the modestly sized odds ratios reported in our study. Following a practice common in recent surveys of respiratory health among children (13,16), we explored the use of a broader, symptomatic definition of asthma that included self-reported wheeze, but

Table 2. Continued.

	Hay fever without asthma		Hay fever		Chronic rhinitis	
	Women, % (*n*)	Men, % (*n*)	Women, % (*n*)	Men, % (*n*)	Women, % (*n*)	Men, % (*n*)
All	14.9 (14,023)	13.4 (10,562)	16.8 (15,746)	15.3 (11,999)	6.7 (6,253)	8.2 (6,452)
Race/ethnicity						
White	14.4 (10,407)	12.9 (7,917)	16.3 (11,782)	14.8 (9,071)	7.2 (5,201)	8.7 (5,372)
Black	15.6 (2,220)	13.4 (1,394)	17.3 (2,451)	15.0 (1,557)	4.9 (693)	6.6 (681)
Asian	22.8 (859)	23.2 (777)	24.7 (932)	25.3 (846)	3.3 (124)	4.7 (154)
Other	15.3 (537)	13.9 (474)	16.6 (581)	15.4 (525)	6.7 (235)	7.3 (245)
Education						
Elementary	11.6 (1,714)	10.6 (1,337)	13.0 (1,923)	12.0 (1,516)	6.3 (921)	7.6 (977)
High school/trade	14.2 (5,112)	11.7 (2,809)	15.9 (5,739)	13.2 (3,165)	6.6 (2,386)	8.8 (2,116)
College, 1–2 years	15.8 (2,223)	13.9 (1,508)	17.9 (2,521)	15.9 (1,727)	7.1 (993)	9.1 (995)
College, 3–4 years	17.7 (2,252)	15.7 (1,851)	19.8 (2,509)	18.0 (2,121)	6.8 (866)	8.3 (983)
Postgraduate	18.5 (2,013)	17.5 (2,580)	20.8 (2,269)	19.9 (2,934)	6.9 (753)	7.2 (1,052)
Education unknown	13.0 (709)	10.9 (477)	14.4 (785)	12.3 (536)	6.3 (334)	7.8 (329)

Table 3. Odds ratios and 95% confidence intervals for asthma and hay fever in relation to race/ethnicity, education, smoking, and birthplace, Kaiser Permanente multiphasic health checkup population (1964–1972), San Francisco Bay area.

	All asthma		Asthma with hay fever		Asthma without hay fever		All hay fever	
	Women OR (95% CI)	Men OR (95% CI)	Women OR (95% CI)	Men OR (95% CI)	Women OR (95% CI)	Men OR (95% CI)	Women OR (95% CI)	Men OR (95% CI)
Race								
White[a]	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Asian[a]	0.87 (0.72, 1.06)	1.03 (0.85, 1.25)	1.02 (0.80, 1.29)	1.23 (0.96, 1.57)	0.85 (0.61, 1.19)	1.09 (0.81, 1.48)	1.53 (1.42, 1.66)	1.88 (1.73, 2.04)
Black[a]	1.03 (0.93, 1.14)	1.05 (0.93, 1.17)	0.80 (0.70, 0.93)	0.79 (0.67, 0.93)	1.42 (1.23, 1.64)	1.38 (1.18, 1.61)	0.99 (0.95, 1.04)	0.95 (0.90, 1.01)
White[b]	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Asian[b]	0.88 (0.72, 1.07)	1.03 (0.85, 1.25)	1.03 (0.81, 1.30)	1.22 (0.96, 1.57)	0.84 (0.60, 1.18)	1.09 (0.81, 1.48)	1.55 (1.43, 1.67)	1.90 (1.75, 2.06)
Black[b]	1.03 (0.93, 1.14)	1.10 (0.98, 1.23)	0.84 (0.73, 0.97)	0.91 (0.77, 1.08)	1.35 (1.17, 1.56)	1.33 (1.14, 1.56)	1.05 (1.00, 1.10)	1.07 (1.01, 1.14)
White[c]	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Asian[c]	0.96 (0.78, 1.16)	1.08 (0.89, 1.31)	1.12 (0.88, 1.43)	1.30 (1.01, 1.67)	0.94 (0.67, 1.32)	1.15 (0.84, 1.56)	1.61 (1.48, 1.74)	1.99 (1.83, 2.17)
Black[c]	1.00 (0.90, 1.10)	1.08 (0.96, 1.21)	0.80 (0.69, 0.93)	0.90 (0.76, 1.06)	1.32 (1.14, 1.53)	1.31 (1.12, 1.53)	1.02 (0.97, 1.07)	1.06 (1.00, 1.13)
Education								
Elementary[a]	1.11 (0.99, 1.23)	1.14 (1.01, 1.29)	0.86 (0.73, 1.01)	1.01 (0.84, 1.21)	1.35 (1.16, 1.57)	1.26 (1.07, 1.49)	0.88 (0.83, 0.93)	0.99 (0.93, 1.06)
High school[a]	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
College, 1–2 years[a]	1.06 (0.95, 1.19)	1.09 (0.96, 1.24)	1.19 (1.03, 1.37)	1.26 (1.06, 1.49)	0.93 (0.78, 1.11)	0.97 (0.81, 1.17)	1.09 (1.04, 1.15)	1.14 (1.07, 1.21)
College, 3–4 years[a]	0.99 (0.88, 1.11)	1.20 (1.06, 1.36)	1.14 (0.98, 1.33)	1.60 (1.36, 1.88)	0.86 (0.70, 1.04)	0.92 (0.77, 1.11)	1.21 (1.15, 1.28)	1.37 (1.29, 1.45)
Postgraduate[a]	1.06 (0.94, 1.20)	1.26 (1.12, 1.42)	1.37 (1.18, 1.59)	1.85 (1.59, 2.15)	0.75 (0.61, 0.93)	0.87 (0.72, 1.05)	1.31 (1.24, 1.38)	1.59 (1.50, 1.68)
Education unknown[a]	0.93 (0.77, 1.11)	0.91 (0.74, 1.12)	0.81 (0.63, 1.05)	0.94 (0.70, 1.26)	1.06 (0.83, 1.37)	0.88 (0.66, 1.17)	0.97 (0.89, 1.05)	0.98 (0.89, 1.09)
Elementary[d]	1.11 (0.99, 1.23)	1.14 (1.01, 1.29)	0.88 (0.75, 1.03)	1.02 (0.84, 1.22)	1.32 (1.13, 1.53)	1.24 (1.06, 1.46)	0.87 (0.83, 0.92)	0.99 (0.92, 1.06)
High school[d]	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
College, 1–2 years[d]	1.06 (0.95, 1.19)	1.10 (0.97, 1.24)	1.18 (1.02, 1.36)	1.25 (1.05, 1.48)	0.94 (0.78, 1.12)	0.98 (0.82, 1.18)	1.09 (1.03, 1.15)	1.13 (1.06, 1.20)
College, 3–4 years[d]	0.99 (0.88, 1.12)	1.22 (1.07, 1.38)	1.12 (0.96, 1.30)	1.57 (1.33, 1.85)	0.89 (0.73, 1.08)	0.96 (0.80, 1.16)	1.21 (1.15, 1.28)	1.35 (1.26, 1.43)
Postgraduate[d]	1.06 (0.94, 1.20)	1.28 (1.14, 1.44)	1.33 (1.14, 1.55)	1.81 (1.55, 2.12)	0.79 (0.64, 0.98)	0.92 (0.76, 1.11)	1.31 (1.24, 1.39)	1.60 (1.51, 1.70)
Education unknown[d]	0.93 (0.78, 1.11)	0.91 (0.74, 1.11)	0.82 (0.63, 1.05)	0.94 (0.70, 1.26)	1.05 (0.82, 1.35)	0.87 (0.65, 1.15)	0.96 (0.88, 1.04)	0.97 (0.87, 1.08)
Elementary[c]	1.13 (1.01, 1.26)	1.14 (1.01, 1.29)	0.90 (0.76, 1.05)	1.01 (0.84, 1.22)	1.34 (1.16, 1.56)	1.25 (1.06, 1.47)	0.89 (0.84, 0.94)	0.99 (0.93, 1.06)
High school[c]	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
College, 1–2 years[c]	1.06 (0.95, 1.19)	1.09 (0.96, 1.23)	1.17 (1.01, 1.34)	1.22 (1.02, 1.44)	0.95 (0.79, 1.13)	0.98 (0.82, 1.13)	1.08 (1.03, 1.14)	1.11 (1.04, 1.18)
College, 3–4 years[c]	0.98 (0.87, 1.10)	1.19 (1.05, 1.34)	1.07 (0.92, 1.25)	1.48 (1.26, 1.74)	0.90 (0.74, 1.10)	0.96 (0.80, 1.16)	1.18 (1.12, 1.25)	1.29 (1.21, 1.37)
Postgraduate[c]	1.04 (0.92, 1.17)	1.22 (1.09, 1.38)	1.25 (1.07, 1.45)	1.63 (1.39, 1.91)	0.80 (0.65, 0.99)	0.93 (0.77, 1.12)	1.26 (1.19, 1.33)	1.48 (1.40, 1.57)
Education unknown[c]	0.95 (0.79, 1.15)	0.96 (0.78, 1.20)	0.84 (0.64, 1.10)	1.00 (0.74, 1.37)	1.08 (0.83, 1.41)	0.92 (0.68, 1.24)	0.97 (0.89, 1.06)	0.97 (0.87, 1.08)
Smoking status								
Never smoked[c]	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Current smoker[c]	1.04 (0.96, 1.13)	0.80 (0.73, 0.88)	0.79 (0.71, 0.88)	0.59 (0.52, 0.66)	1.41 (1.24, 1.60)	1.05 (0.91, 1.20)	0.80 (0.77, 0.83)	0.66 (0.63, 0.69)
Past smoker[c]	1.17 (1.04, 1.32)	0.90 (0.80, 1.00)	1.20 (1.03, 1.39)	0.81 (0.70, 0.94)	1.13 (0.93, 1.38)	1.00 (0.84, 1.19)	1.06 (1.00, 1.12)	0.91 (0.86, 0.96)
Smoking unknown[c]	1.01 (0.76, 1.35)	0.59 (0.43, 0.81)	0.87 (0.59, 1.28)	0.43 (0.28, 0.67)	1.19 (0.79, 1.79)	0.80 (0.51, 1.23)	0.88 (0.77, 1.02)	0.72 (0.61, 0.84)
Birthplace								
Born in U.S.[c]	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Born outside U.S.[c]	0.69 (0.61, 0.77)	0.75 (0.67, 0.85)	0.55 (0.47, 0.64)	0.63 (0.53, 0.74)	0.83 (0.70, 0.98)	0.84 (0.71, 1.00)	0.70 (0.66, 0.74)	0.73 (0.69, 0.77)
Birthplace unknown[c]	0.67 (0.55, 0.81)	0.85 (0.71, 1.03)	0.60 (0.46, 0.77)	0.75 (0.57, 0.98)	0.72 (0.55, 0.95)	0.93 (0.71, 1.22)	0.79 (0.72, 0.86)	0.84 (0.76, 0.92)

Abbreviations: CI, confidence interval; OR, odds ratio.
[a]All models are adjusted for age in 10-year categories and year of multiphasic health checkup. [b]Adjusted for age in 10-year categories, year of multiphasic health checkup, and race/ethnicity. [c]From a multivariate model with age (in 10-year categories), year of multiphasic health checkup, race/ethnicity, education, smoking status, and birthplace. [d]Adjusted for age in 10-year categories, year of multiphasic health checkup, and education.

found evidence that in this adult population, a symptomatic definition that included wheeze tended to misclassify smoking-related respiratory symptoms as asthma (results available upon request).

With respect to measurement, our study was also limited by the availability of only a single indicator of socioeconomic position, as measured by subject's own education level. Although other socioeconomic measures, such as occupational class or income, may be more indicative of current socioeconomic circumstances, we do note that subject's educational attainment may be more reflective of socioeconomic circumstances over the subject's early life, including time periods such as childhood and adolescence, which may be of particular importance in the etiology of allergic disease (21). Lack of more detailed data on childhood and adult socioeconomic position ruled out the possibility of more rigorously testing the hypothesis that socioeconomic position over the life course underlies observed racial/ethnic disparities in allergic disease.

A potential limitation with respect to the relevance of our results to current patterns of allergic disease concerns the age of these data, which were collected from 1964 to 1972. We note that whereas the prevalences we report from this time period are generally lower than are current estimates of asthma and hay fever prevalence, racial/ethnic and socioeconomic variations in asthma and hay fever persist into the present and remain largely unexplained. By showing differing socioeconomic and racial/ethnic patterns of risk depending on the type of asthma being studied, evident over 30 years ago, we present an analysis of allergic disease that is highly relevant to current efforts to understand the etiology of asthma and hay fever in different communities.

A second potential limitation with respect to generalizability arises because all members of the study population by definition had access to healthcare. Studying a population with access to healthcare is unlikely to lead to spurious associations; rather, the likely bias would be an underestimation of socioeconomic gradients in asthma occurrence, whether positive or negative. A positive gradient (higher rates among more affluent persons) would result

from the comparison group not representing the poorest sectors of society (without access to medical care); by the same logic, the absence of the truly impoverished would lead to an underestimate of a negative gradient.

Despite these limitations, a major strength of our study is the availability of uniformly collected allergic disease data in such a large population, which enabled us to explore a variety of associations of differing magnitudes. In particular, the large number of Asian men and women in our study has yielded the first reported estimates of asthma and hay fever prevalence for Asian Americans.

Interpretation

The different socioeconomic patterns observed for asthma with hay fever, asthma without hay fever, and hay fever overall may represent socioeconomic variation in exposure to allergens, differences in determinants of immunologic susceptibility, and/or variations in timing of exposures. For example, with respect to exposures, one study of home allergens and asthma in children has recently reported that low socioeconomic conditions are associated with high levels of cockroach allergen, but lower levels of dust mite allergen (30). Higher socioeconomic conditions were associated with high levels of dust mite allergen. Meanwhile, suburban environments may be more associated with exposure to pollen-related aeroallergens. The differing size of allergen particles involved may dictate whether allergic manifestations occur in the lungs (asthma) or in the nasal passages (hay fever).

Alternatively, these results may reflect variations in immunologic susceptibility. Factors such as vaccination practices, diet, use of antibiotics, and adoption of certain hygiene practices may vary with socioeconomic position and support a predominantly T_H2-type cytokine response (10–12,31–34). The "hygiene hypothesis" (10) suggests that the immune system of the newborn infant is skewed toward T_H2 responses and requires appropriately timed environmental stimulation (e.g., viral or bacterial infection) to create a more balanced immune response. More affluent socioeconomic circumstances are thought to be associated with later age at infection, at which point immune dysregulation toward a predominantly T_H2 response and resulting atopy may have already occurred.

A more complex mechanism to explain our results may involve complex patterns in the timing of both exposure to different types of allergens and determinants of immunologic susceptibility. Little is known about how the timing of events that

determine the T_H1–T_H2 balance and the timing of exposures to aeroallergens may interact. One could speculate that the relative risk of atopic versus nonatopic forms of asthma may be determined by whether exposure to aeroallergens occurs before or after significant immune modulating events. For example, exposure to cockroach and other indoor aeroallergens among socioeconomically deprived children may occur after early childhood infections and correspond to earlier-onset nonatopic asthma, whereas exposure to outdoor aeroallergens among more affluent children may occur prior to or in the absence of later childhood infections, and correspond to later onset atopic asthma.

The racial/ethnic disparities in allergic disease experience similarly suggest different socially mediated patterns of exposure to allergens and immune modulators, both in relation to and independent of educational level. Broadly speaking, Asians in our study appeared to be at higher risk of atopic conditions compared with Whites (asthma with hay fever, hay fever, allergic rhinitis), and Blacks were at great risk of nonatopic asthma (i.e., without hay fever). Although these observed patterns may be due partly to variations in HLA gene frequencies (35), observed differences in racial/ethnic patterns by birthplace suggest that nongenetic, social and/or environmental factors may also drive these patterns. Specifically, in our study, Asians born in the United States were at greater risk of all allergic conditions than were those born outside the United States. These results are in accord with studies of hay fever and asthma in Asian populations in the United Kingdom and Australia showing increased risk associated with birthplace and with time since immigration (27,28). The different patterns of risk found among Asians born in the United States compared with that of those born outside the United States suggest that environmental factors and possibly acculturation may play important roles in determining risk of asthma and atopy.

In conclusion, our findings suggest that future research should explore how socioeconomic position affects risk of asthma and hay fever, as well as potential mechanisms, beyond genetic factors, that may explain the associations, independent of educational level, of nonatopic asthma with Black race/ethnicity and hay fever and atopic asthma with Asian race/ethnicity. Additionally, studies of allergic disease should routinely examine variations in prevalence simultaneously by race/ethnicity, socioeconomic position, and gender, as a means of furthering research on the complex interaction of social environmental factors with immunologic diseases.

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