ARTICLE

# Prevalence of Allergic Disease in Foreign-Born American Children

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**Importance:** Improved understanding of allergic disease epidemiology lead to novel therapeutic and prevention strategies.

**Objectives:** To study the association between US birthplace and prevalence of childhood allergic disease and to determine the effects of prolonged US residence on allergic disease.

**Design, Setting, Participants:** Cross-sectional questionnaire distributed to 91 642 children aged 0 to 17 years enrolled in the 2007-2008 National Survey of Children's Health.

**Exposure:** Place of birth.

**Main Outcome and Measure:** Prevalence of allergic disease, including asthma, eczema, hay fever, and food allergies.

**Results:** Children born outside the United States had significantly lower odds of any atopic disorders than those born in the United States (logistic regression OR, 0.48; 95% CI, 0.38-0.61), including ever-asthma (0.53; 0.39-0.72), current-asthma (0.34; 0.23-0.51), eczema (0.43; 0.30-0.61), hay fever (0.39; 0.27-0.55), and food allergies (0.60; 0.37-0.99). The associations between child's birthplace and atopic disorders remained significant in multivariate models including age, sex, race/ethnicity, annual household income, residence in metropolitan areas, and history of child moving to a new address. Children born outside the United States whose parents were also born outside the United States had significantly lower odds of any atopic disorders than those whose parents were born in the United States ($P=.005$). Children born outside the United States who lived in the United States for longer than 10 years when compared with those who resided for only 0 to 2 years had significantly higher odds of developing any allergic disorders (adjusted OR, 3.04; 95% CI, 1.08-8.60), including eczema (4.93; 1.18-20.62; $P=.03$) and hay fever (6.25; 1.70-22.96) but not asthma or food allergies ($P \geq .06$).

**Conclusions and Relevance:** Children born outside the United States have a lower prevalence allergic disease that increases after residing in the United States for 1 decade.

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Allergic diseases are a significant cause of morbidity and health care expenditures worldwide.[1,2] The US prevalence of childhood asthma is 8.9% to 10.6%[3] and childhood atopic dermatitis (AD) is as high as 20%.[4,5] However, the prevalence of childhood allergic disease is much lower in other countries, such as Mexico and China.[2] Some reasons for the varying prevalence rates include differences in socioeconomic status, race/ethnicity, urban living, nutritional factors and adiposity, and pollutants, all of which are predictors of allergic disease.[3,6-8]

Different environmental and infectious exposures in developing countries may also have a role as part of the broader "hygiene hypothesis."[9] That is, certain infections and exposures can help guide the immature immune system away from a pro-allergic or inflammatory state, thereby decreasing the risk of developing asthma and AD. Lack of infectious stimuli may lead to upregulation of allergic responses. We previously reported that exposure to varicella zoster virus in early childhood was associated with lower odds of developing AD,[10] asthma, and hay fever, as well as decreased serum IgE, allergic sensitization, and persistent alterations of leukocyte subsets.[11] It would be expected that immigrants to the United States from developing countries, where infectious stimuli are more prevalent, would have a lower risk of allergic disease.

Few studies have examined the role of Allergic diseases in foreign-born Ameri-



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cans.[12-15] United States population-based estimates of the prevalence of several allergic disorders in foreign-born Americans are lacking, including eczema, hay fever, and food allergies. Further, little is known about whether foreign-born Americans develop more allergic disease after residing in the United States. We hypothesized that the prevalence of allergic disease is lower in foreign-born Americans due to different environmental exposures than in American-born children. It, therefore, stands to reason that increased exposure to certain provocative environmental factors with prolonged US residence increases the risk of allergic diseases. The objective of this study was to determine whether the prevalence of allergic disease is lower in foreign-born Americans but increases with prolonged residence in the United States.

## METHODS

### DATA SOURCES

We used data from the 2007-2008 National Survey of Children's Health (NSCH) of 91 642 households, which was designed to estimate the prevalence of various child health issues including physical, emotional, and behavioral factors. The NSCH was sponsored by the Maternal and Child Health Bureau and the US Department of Health and Human Services. The National Center for Health Statistics conducted the survey, using the State and Local Area Integrated Telephone Survey (SLAITS) program. The National Center for Health Statistics of Centers for Diseases Control and Prevention oversaw sampling and telephone interviews. Approval by the institutional review board was waived. The telephone numbers were chosen at random, followed by identification of the households with 1 or more children younger than 18 years. Parental interviews were conducted. Subsequently, 1 child was randomly selected for interview. Interviews were conducted in English, Spanish, and 4 Asian languages (Korean, Mandarin, Cantonese, and Vietnamese). The survey results were weighted to represent the population of noninstitutionalized children nationally and in each state. Using data from the US Bureau of the Census, weights were adjusted for age, sex, race/ethnicity, household size, and educational attainment of the most educated household member to provide a data set that was more representative of each state's population of noninstitutionalized children younger than 18 years.

### PREVALENCE OF ALLERGIC DISORDERS

History of asthma at any time in life was determined using the NSCH question, "Has a doctor or other health care provider *ever* told you that (child) had asthma?" History of asthma in the last year was determined by "During the past 12 months, have you been told by a doctor or other health professional that (child) had asthma?" These are referred to throughout the manuscript as ever- and current-asthma, respectively. Atopic dermatitis/eczema was determined by "During the past 12 months, have you been told by a doctor or other health professional that (child) had eczema or any kind of skin allergy?" Hay fever was determined by "During the past 12 months, have you been told by a doctor or other health professional that (child) had hay fever or any kind of respiratory allergy?" Food allergy was determined by "During the past 12 months, have you been told by a doctor or other health professional that (child) had any kind of food or digestive allergy?" A composite binary variable was created for any atopic disorders using responses to the above 4 questions.

To limit the effect health care access may have on the results, we excluded all participants who responded "no" to the question, "During the past 12 months, did (child) see a doctor, nurse, or other health care professional for any kind of medical care, including sick-child care, well-child check-ups, physical examinations, and hospitalizations?"

### BIRTHPLACE

Birthplace was determined using the NSCH sequence of questions, "Was (child's) mother born in the United States?" "Was (child's) father born in the United States?" "Was (child) born in the United States?" (binary). Among children born outside the United States, the duration of US residence was determined by "How long has (child) been in the United States?" Age at the time of immigration was derived by subtracting the duration of US residence from the current age.

### DATA PROCESSING AND STATISTICAL METHODS

All data processing and statistical analyses were performed in SAS (version 9.2.; SAS Institute, Inc). Analyses of survey responses were performed using SURVEY procedures. Univariate associations were tested by Rao-Scott $\chi^2$ tests and logistic regression models. Covariates for multivariable models were selected by constructing multiple models that included combinations of age, sex, race/ethnicity, annual household income, residence in a metropolitan area, and/or history of child moving to a new address as well as linear interaction terms between them. The best model was selected using the Bayesian Information Criteria, which penalizes for extra parameters and considers the large sample size.[16] Pseudo-$R^2$ was determined. Leverage was assessed with hat matrices, and influence assessed with changes in Pearson residuals when covariates were fitted to the model. Multicolinearity among the independent variables was assessed by calculating variance inflation factors. Complete data analysis was performed, that is, participants with missing data were excluded. Correction for multiple dependent tests ($k = 109$) with the approaches of Benjamini and Hochberg[17] yielded a critical $P$ value of .03.

## RESULTS

### POPULATION CHARACTERISTICS

Data were collected for a total of 91 642 children; 11 975 were excluded because of lack of health care interaction in the last 12 months with 79 667 participants analyzed. Prevalence of allergic diseases was significantly associated with older age, African American race, female sex, and history of child moving to a new address but not with annual household income or residence in a metropolitan area (**Table 1**). In particular, history of child moving to a new address was associated with increased prevalence of ever- and current-asthma and hay fever ($P < .001$) but not with eczema or food allergies ($P \geq .12$). These were considered as potential confounding variables and included in multivariate models.

### ASSOCIATION BETWEEN CHILD'S BIRTHPLACE IN THE UNITED STATES AND ALLERGIC DISEASES

Children born outside the United States had significantly lower prevalence of any allergic diseases than those born



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**Table 1. Participant Characteristics[a]**

| Variable | ≥1 Atopic Disorder | | | Birthplace | | |
|---|---|---|---|---|---|---|
| | No (n = 51 408) | Yes (n = 27 844) | *P* Value | Inside US (n = 76 864) | Outside US (n = 1989) | *P* Value |
| Age, mean (95% CI), y | 8.0 (7.9-8.1) | 8.8 (8.7-8.9) | <.001[b] | 8.2 (8.1-8.3) | 11.5 (11.0-11.9) | <.001[b] |
| Race/ethnicity | | | | | | |
| African American | 4559 (12.8) | 3513 (18.2) | <.001[a] | 7949 (14.7) | 156 (12.5) | <.001[c] |
| Hispanic | 6723 (21.9) | 3032 (15.4) | | 8894 (18.5) | 889 (53.4) | |
| White | 34 724 (56.2) | 18 175 (57.1) | | 52 574 (58.0) | 544 (17.2) | |
| Asian | 635 (2.4) | 330 (1.8) | | 863 (2.0) | 108 (6.6) | |
| Native Hawaiian/Pacific-Islander | 138 (0.05) | 92 (0.07) | | 220 (0.06) | 10 (0.05) | |
| American Indian | 471 (0.4) | 203 (0.3) | | 675 (0.4) | 3 (0.02) | |
| Other/mixed | 3271 (6.1) | 2082 (7.1) | | 5146 (6.3) | 247 (10.3) | |
| Female sex | 25 339 (49.8) | 12 685 (45.9) | <.001[c] | 36 847 (48.4) | 966 (50.6) | .45[c] |
| Household income, poverty level, % | | | | | | |
| 0-99 | 5939 (18.5) | 3281 (17.4) | .33[a] | 8633 (17.4) | 512 (36.9) | <.001[a] |
| 100-199 | 8422 (20.3) | 4626 (20.4) | | 12 562 (20.3) | 419 (21.9) | |
| 200-399 | 17 164 (30.6) | 9173 (31.8) | | 25 732 (31.4) | 502 (22.4) | |
| ≥400 | 19 883 (30.6) | 10 764 (30.4) | | 29 937 (30.9) | 556 (18.9) | |
| History of child moving to new address | 30 912 (64.1) | 17 986 (69.3) | <.001[c] | 47 392 (65.0) | 1714 (85.8) | <.001[c] |
| Residence in metropolitan area | 27 707 (85.2) | 15 486 (84.8) | .53[c] | 4695 (84.7) | 1274 (94.7) | <.001[c] |

Abbreviation: US, United States.
[a] Data are given as number (percent) unless otherwise indicated.
[b] Survey analysis of variance.
[c] Rao-Scott $\chi^2$ test. Frequencies may not total the 79 667 participants included for analysis because of missing values.

in the United States (20.3% vs 34.5%; logistic regression OR, 0.48; 95% CI, 0.38-0.61; $P < .001$) (**Table 2**). In particular, children born outside the United States had lower odds of ever-asthma (OR, 0.53; 95% CI, 0.39-0.72; $P < .001$), current-asthma (0.34; 0.23-0.51; $P < .001$), eczema (0.43; 0.30-0.61; $P < .001$), and hay fever (0.39; 0.27-0.55; $P < .001$). All associations remained significant in multivariate logistic regression models. Age, race/ethnicity, sex, and history of child moving to a new address were significant predictors in a subset analysis of American-born children but not with foreign-born children (eTable 1; http://www.jamapeds.com). Annual household income and residence in metropolitan area neither remained significant in multivariate models for either subset nor was there a significant effect modification on birthplace.

No significant interaction was noted between birthplace and race/ethnicity. In analyses stratified by individual race/ethnicity, the associations between child's birthplace and a number of allergic diseases remained significant in all racial/ethnic groups (eTable 2); although the subset analyses have limited power due to smaller numbers of subjects for each subgroup. To minimize the effects of transient viral-associated wheezing on the asthma outcome, a subset analysis was performed for moderate to severe current-asthma in children aged 7 years and older, and the results remained significant (OR, 0.27; 95% CI, 0.15-0.49; $P < .001$).

## ASSOCIATION BETWEEN PARENTS' BIRTHPLACE IN THE UNITED STATES AND ALLERGIC DISEASES

Children of parents born outside the United States had significantly lower prevalence of any allergic diseases than those whose parents were born in the United States ($P < .001$), including ever- and current-asthma ($P < .001$), eczema ($P \leq .001$), hay fever ($P < .001$), and food allergies ($P \leq .01$). These results remained significant in models that excluded foreign-born children (eTable 3). Further, there was an additive effect in which children of 2 foreign-born parents had lower prevalence of allergic disorders than those with a single parent born outside the United States.

## ADDITIVE PROTECTIVE EFFECT OF BOTH CHILD AND PARENTS BORN OUTSIDE THE UNITED STATES AGAINST ALLERGIC DISEASES

Children born outside the United States whose parents were also born outside the United States had significantly lower prevalence of any allergic diseases than those whose parents were born in the United States (18.2% vs 33.4%; logistic regression OR, 0.45; 95% CI, 0.25-0.78; $P = .005$) (**Table 3**). In particular, children born outside the United States with parents born outside the United States had lower odds of ever-asthma (OR, 0.38; 95% CI, 0.19-0.78; $P = .009$), current-asthma (0.37; 0.16-0.85; $P = .02$), hay fever (0.35; 0.16-0.77; $P = .01$) but not eczema (0.84; 0.45-1.55; $P = .57$) or food allergies (1.76; 0.67-4.66; $P = .25$). The associations remained significant in multivariate logistic regression models.

## PROLONGED RESIDENCE IN THE UNITED STATES BUT NOT AGE AT THE TIME OF IMMIGRATION INCREASES ALLERGIC DISORDERS IN CHILDREN BORN OUTSIDE THE UNITED STATES

Children born outside the United States who lived in the United States for longer than 10 years when compared with those who lived only 0 to 2 years in the United States had significantly higher odds of developing any allergic disorders (adjusted OR, 3.04; 95% CI, 1.08-8.60; $P = .03$), including eczema (4.93; 1.18-20.62; $P = .029$), and hay



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**Table 2. Association Between Immigrant Status and Atopic Disorders in Children**

| | Birthplace | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Inside US (n = 76 864) | | Outside US[a] (n = 1989) | | | | | |
| Atopic Disorder | Frequency | % (95% CI) | Frequency | % (95% CI) | OR (95% CI) | *P* Value | aOR (95% CI)[b] | *P* Value |
| **Child** | | | | | | | | |
| Asthma | | | | | | | | |
| Ever | 10 502 | 14.3 (13.6-14.9) | 204 | 8.1 (5.8-10.4) | 0.53 (0.39-0.72) | <.001 | 0.35 (0.24-0.52) | <.001 |
| Current | 7084 | 9.7 (9.2-10.2) | 91 | 3.5 (2.2-4.9) | 0.34 (0.23-0.51) | <.001 | 0.27 (0.17-0.43) | <.001 |
| Eczema | 10 133 | 13.3 (12.7-13.8) | 174 | 6.1 (4.1-8.1) | 0.43 (0.30-0.61) | <.001 | 0.45 (0.30-0.69) | <.001 |
| Hay fever | 14 442 | 17.3 (16.7-18.0) | 196 | 7.5 (5.1-9.9) | 0.39 (0.27-0.55) | <.001 | 0.34 (0.22-0.52) | <.001 |
| Food allergies | 4206 | 5.2 (4.8-5.6) | 74 | 3.2 (1.7-4.7) | 0.60 (0.37-0.99) | .045 | 0.81 (0.47-1.41) | .46 |
| ≥1 of the above disorders | 27 111 | 34.5 (33.7-35.4) | 480 | 20.3 (16.5-24.0) | 0.48 (0.38-0.61) | <.001 | 0.44 (0.33-0.58) | <.001 |
| **Mother** | | | | | | | | |
| Asthma | | | | | | | | |
| Ever | 8968 | 14.7 (14.1-15.4) | 971 | 10.1 (8.5-11.7) | 0.65 (0.54-0.78) | <.001 | 0.53 (0.42-0.67) | <.001 |
| Current | 6144 | 10.4 (9.8-10.9) | 505 | 5.4 (4.2-6.6) | 0.50 (0.39-0.64) | <.001 | 0.42 (0.31-0.58) | <.001 |
| Eczema | 8731 | 13.2 (13.5-14.8) | 1076 | 9.2 (8.0-10.5) | 0.62 (0.53-0.72) | <.001 | 0.58 (0.48-0.71) | <.001 |
| Hay fever | 12 795 | 18.7 (18.0-19.4) | 1004 | 10.0 (8.4-11.7) | 0.49 (0.40-0.59) | <.001 | 0.56 (0.45-0.70) | <.001 |
| Food allergies | 3634 | 5.6 (5.2-6.0) | 435 | 3.3 (2.6-3.9) | 0.57 (0.45-0.72) | <.001 | 0.61 (0.45-0.82) | .001 |
| ≥1 of the above disorders | 23 443 | 36.4 (35.5-37.3) | 2506 | 23.7 (21.6-25.8) | 0.54 (0.48-0.62) | <.001 | 0.54 (0.46-0.63) | <.001 |
| **Father** | | | | | | | | |
| Asthma | | | | | | | | |
| Ever | 6965 | 12.8 (12.1-13.5) | 748 | 8.6 (7.2-10.0) | 0.64 (0.53-0.77) | <.001 | 0.53 (0.41-0.68) | <.001 |
| Current | 4630 | 8.4 (7.9-9.0) | 404 | 4.5 (3.6-5.5) | 0.52 (0.41-0.65) | <.001 | 0.46 (0.34-0.62) | <.001 |
| Eczema | 7004 | 13.0 (12.3-13.7) | 894 | 9.5 (8.2-10.8) | 0.70 (0.59-0.82) | <.001 | 0.68 (0.54-0.85) | <.001 |
| Hay fever | 10 451 | 18.1 (17.3-18.9) | 842 | 9.6 (8.0-11.2) | 0.48 (0.40-0.58) | <.001 | 0.58 (0.46-0.75) | <.001 |
| Food allergies | 2940 | 5.3 (4.8-5.7) | 367 | 3.2 (2.5-3.9) | 0.60 (0.47-0.76) | <.001 | 0.64 (0.44-0.92) | .01 |
| ≥1 of the above disorders | 19 095 | 34.4 (33.4-35.4) | 2081 | 23.5 (21.2-25.7) | 0.59 (0.51-0.67) | <.001 | 0.61 (0.51-0.73) | <.001 |

Abbreviations: aOR, adjusted odds ratio; US, United States.

[a] Binomial logistic regression models were constructed with atopic disorders as the dependent (outcome) variables. The independent (explanatory) variable was birthplace of child, mother, or father in the United States (binary). Odds ratio (OR) and 95% CI for atopic outcomes were determined. Adjusted ORs were determined from multivariate models by including sex, current age, race/ethnicity, annual household income, residence in metropolitan area, and history of child moving to a new address as categorical variables.

[b] Parental refusal to answer a particular question or response of "don't know" occurred for the questions pertaining to eczema in 79, ever-asthma in 104, current-asthma in 107, hay fever in 155, food allergies in 120, and in the derived allergic disease variable 415 children, respectively.

No significant interactions were noted between birthplace and other covariates in multivariate models. Covariates in multivariable models were selected based on testing in univariate models and minimizing the Bayesian Information Criteria. No significant multicolinearity was found in multivariate models. Pseudo-$R^2$ was 1.0 for all models.

**Table 3. Protective Effects of Child and Parents' Birthplace Outside the United States Against Atopic Disorders Compared With Child Alone Born Outside the United States**

| | Birthplace Outside United States | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Child Alone (n = 372) | | Child and Either/Both Parents (n = 1627) | | | | | |
| Atopic Disorder | Frequency | % (95% CI) | Frequency | % (95% CI) | OR (95% CI) | *P* Value | aOR (95% CI)[a,b] | *P* Value |
| Asthma | | | | | | | | |
| Ever | 48 | 16.1 (7.5-24.7) | 156 | 6.8 (4.6-9.0) | 0.38 (0.19-0.78) | .009 | 0.30 (0.10-0.89) | .03 |
| Current | 21 | 7.5 (2.8-12.1) | 70 | 2.9 (1.5-4.3) | 0.37 (0.16-0.85) | .02 | 0.28 (0.09-0.83) | .02 |
| Eczema | 43 | 7.2 (4.0-10.3) | 134 | 6.0 (3.8-8.3) | 0.84 (0.45-1.55) | .57 | 1.21 (0.61-2.41) | .59 |
| Hay fever | 60 | 15.9 (6.5-25.3) | 137 | 6.1 (3.9-8.4) | 0.35 (0.16-0.77) | .01 | 0.27 (0.08-0.88) | .03 |
| Food allergies | 16 | 2.0 (0.4-3.5) | 59 | 3.4 (1.7-5.1) | 1.76 (0.67-4.66) | .25 | 3.68 (0.97-13.91) | .06 |
| ≥1 of the above disorders | 118 | 33.4 (22.3-44.5) | 365 | 18.2 (14.4-22.1) | 0.45 (0.25-0.78) | .005 | 0.42 (0.19-0.94) | .03 |

Abbreviations: aOR, adjusted odds ratio; OR, odds ratio.

[a] Binomial logistic regression models were constructed with atopic disorders as the dependent (outcome) variables. The independent (explanatory) variable was child and parent(s) vs child alone born outside the United States (binary). Odds ratio and 95% CI for atopic outcomes were determined.

[b] Adjusted OR (aOR) were determined from multivariate models by including sex, current age, race/ethnicity, annual household income, residence in metropolitan area, and history of child moving to a new address as categorical variables. No significant interactions were noted between birthplace and other covariates in multivariate models.

fever (6.25; 1.70-22.96; $P = .006$) but not asthma or food allergies (**Table 4**).

Age at the time of immigration was not associated with lower odds of any allergic disorders (eTable 4). Dura-



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**Table 4. Association Between Duration of Residence by Immigrants in the United States and Prevalence of Atopic Disease**

| | Duration of Residence in the United States, y[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0-2 (n = 462) | | 3-10 (n = 1129) | | | | >10 (n = 372) | | | |
| Atopic Disorder | Frequency[b] | % (95% CI) | Frequency[b] | % (95% CI) | aOR (95% CI)[c] | *P* Value | Frequency[b] | % (95% CI) | aOR (95% CI)[c] | *P* Value |
| Asthma | | | | | | | | | | |
| Ever | 41 | 8.0 (2.7-13.4) | 110 | 7.7 (4.8-10.5) | 1.05 (0.36-3.09) | .92 | 50 | 9.3 (4.5-14.1) | 1.70 (0.44-6.59) | .44 |
| Current | 15 | 1.9 (0.0-3.9) | 52 | 3.6 (1.7-5.5) | 2.69 (0.94-13.61) | .23 | 24 | 6.0 (1.8-10.2) | 7.44 (0.94-58.72) | .06 |
| Eczema | 44 | 5.1 (2.7-7.5) | 94 | 6.5 (3.4-9.7) | 1.96 (0.79-4.85) | .15 | 35 | 6.8 (1.9-11.7) | 4.93 (1.18-20.62) | .03 |
| Hay fever | 34 | 5.1 (2.1-8.1) | 111 | 7.8 (4.4-11.2) | 2.70 (0.91-8.00) | .07 | 50 | 10.9 (3.3-18.4) | 6.25 (1.70-22.96) | .006 |
| Food allergies | 14 | 3.9 (0.0-8.1) | 39 | 1.9 (0.8-3.0) | 0.27 (0.08-0.93) | .04 | 20 | 5.9 (1.5-10.2) | 0.63 (0.13-3.07) | .57 |
| ≥1 of the above disorders | 95 | 17.5 (10.7-24.2) | 264 | 19.7 (14.6-24.7) | 1.37 (0.64-2.94) | .42 | 116 | 26.9 (16.5-37.3) | 3.04 (1.08-8.60) | .03 |

Abbreviations: aOR, adjusted odds ratio; OR, odds ratio.

[a] Binomial logistic regression models were constructed with atopic disorders as the dependent (outcome) variables. The independent (explanatory) variable was duration of US residence for children born outside the United States (0-2, 3-10, and >10 years). Odds ratio and 95% CI for atopic outcomes were determined.

[b] Frequencies of subjects included for analysis may not equal the total number of subjects who were born outside the US (n = 1989) because of missing values.

[c] Adjusted OR were determined from multivariate models by including sex, current age, race/ethnicity, annual household income, residence in metropolitan area, and history of child moving to a new address as categorical variables. Covariates in multivariable models were selected based on testing in univariate models and minimizing the Bayesian Information Criteria. No significant multicolinearity was found in multivariate models. Psuedo-R2 was 1.0 for all models.

tion of US residence remained significant in models that included age of immigration (data not shown). Further, no significant interactions were noted between duration of US residence and age at the time of immigration, except for models of ever-asthma that had a significant linear interaction term but effect sizes were not significantly different for each contrast group.

## DISCUSSION

Using a population-based sample, we found that children born outside the United States have significantly lower prevalence of allergic disorders, including asthma, eczema, hay fever, and food allergies. The associations remained significant even after controlling for race/ethnicity, socioeconomic status, and residence in metropolitan areas. However, the odds of developing allergic disease significantly increased after residing in the United States for 1 decade or longer. These data indicate that duration of residence in the United States is a previously unrecognized factor in the epidemiology of atopic disease. Further, this suggests that foreign-born US residents might be at increased risk for later onset of allergic disease.

The results of this study are consistent with previous studies that found higher prevalence of asthma in US-born children compared with foreign-born children.[12-15] Analyses of the Third National Health and Nutrition Examination Survey (NHANES III) and National Health Interview Survey (NHIS) found that US-born Mexican Americans had significantly higher odds of having asthma than in Mexican-born Mexican Americans.[12] Similarly, a study of 4121 Mexican American children from NHANES III found that Mexican American children born in the United States were more likely to report wheezing in the last 12 months and have a positive skin prick test result to cat, house mite, *Alternaria alternata*, peanut, Bermuda grass, and short ragweed antigens.[13] A questionnaire-based study of 606 schoolchildren found lower prevalence of diagnosed asthma in respondents with Asian surnames living in the Chinatown neighborhood.[14] A questionnaire-based study of 204 schoolchildren found that birthplace in the United States was associated with higher odds of diagnosed asthma.[15] The present study suggests that foreign-born children of all races/ethnicities also have significantly less eczema, hay fever, and food allergies.

Previous studies also found that immigrants had lower prevalence of allergic disease compared with native-born persons in Italy, Israel, and Australia.[18-21] Thus, lower prevalence of childhood allergic disease in immigrants seems to occur in other developed nations. Future international studies are warranted to determine if the prevalence of allergic disease similarly increases with prolonged duration of residence.

The findings of the present study are consistent with the broader hygiene hypothesis, which suggests that either infections or certain microbial exposures in early childhood may confer protection against atopic disorders.[9] The odds of developing allergic disease dramatically increase after living in the United States for longer than 10 years. This suggests that the protective effects of the hygiene hypothesis may not be life-long and that subsequent exposure to allergens and other environmental factors may trigger atopic disease even later in life. In the present study, age at the time of immigration was not a significant predictor of allergic disease and did not significantly modify the effects of duration of US residence.

The additive protection against some atopic diseases by being born outside the United States and having parents born outside the United States suggests a relationship with parental behavioral. That is, parents born and raised outside the United States may, for example, follow a healthier diet or have foods with a different antigenic profile than typically encountered in the Western diet. Some cultures more commonly use spices, such as



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curcumin, and green tea that have anti-allergy and inflammatory properties.[22-24] We recently reported that the degree of obesity is associated with AD,[25,26] asthma severity, and total serum IgE levels.[27] Whether weight gain and development of its associated immune responses is associated with the development of allergic disease in immigrants has yet to be determined. Acculturation from prolonged US residence might ultimately modify these behavioral practices and increase the long-term risk of allergic diseases. This raises important questions about which lifestyle factors contribute toward the pathogenesis of atopic disease in foreign-born Americans.

In the present study, asthma and hay fever were associated with history of moving to a new address, particularly in American-born children. This may be caused by changes of both indoor and outdoor environmental exposures and/or psychosocial stress related to moving. Therefore, all multivariate models controlled for the effects of moving to a new address. Thus, the increasing prevalence of allergic disorders after prolonged residence in the United States seems to be independent of moving to a new address.

In the present study, age, race/ethnicity, sex, and history of child moving to a new address were significant predictors of allergic disease, which is consistent with the finding of previous studies.[6,7] A recent study found that socioeconomic status had less of an effect on asthma in foreign-born children compared with American-born US children.[28] In the present study, however, no such effect modification of household income was observed.

This study has several strengths, including being prospective, US population-based, with a large diverse sample, and a questionnaire that was administered in 6 different languages with the additional support of a telephone translation service. The adjusted ORs in the study did not move toward the null, which suggests that residual confounding is less likely to be a concern. However, this study has potential limitations. History of allergic disease is self-reported and not assessed clinically or verified with any diagnostic testing. Parents may not recall their child's diagnoses, which may contribute to false-negative outcomes. Moreover, clinical distinction of allergic disorders from mimicking disorders, such as asthma from transient viral wheeze, can be challenging, which may contribute to false-positive outcomes. Nevertheless, self-report and/or parental report of diagnoses is ubiquitous in epidemiology and large-scale population-based studies. Despite the large sample size, there were smaller sample sizes and broader CIs for individual subset analyses. Country of origin was not assessed in the survey in part to protect the identity of correspondents. To address this, we stratified the analyses by race/ethnicity because self-reported race is likely to have a high concordance with country/region of birth. There are many other variables that were not addressed in the study, including whether children/families moved back and forth between the United States and their country of origin as many immigrant children do, acculturation, diet, breastfeeding duration, day care attendance, and common allergenic exposures in the first year of life, such as pets in the home. Finally, mothers and fathers identified in the survey were biological, step, foster, or adoptive, which does not allow for accurate determination of the effects of biological family history of allergic disease. However, this approach more accurately depicts the child's living situation and is more ideal for demonstrating an association with parental lifestyle factors, such as dietary or cultural.

In conclusion, foreign-born Americans have significantly lower risk of allergic disease than US-born Americans. However, foreign-born Americans develop increased risk for allergic disease with prolonged residence in the United States. Further studies are needed to confirm these findings and to better understand allergic disease triggers in this group.

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**Online-Only Material:** Four eTables are available at http://www.jamapeds.com.

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## *Correction*

**Omission in eTable.** In the Original Article titled "Indicated Prevention of Adult Obesity: How Much Weight Change Is Necessary for Normalization of Weight Status in Children?" by Goldschmidt et al, published online November 5, 2012, and also in the January 2013 issue of *JAMA Pediatrics* (2013;167[1]:21-26), a footnote was inadvertently omitted from the eTable, and an eReference also should have appeared in the Supplement. In the Supplement, a citation for footnote *a* should have been attached to the eTable title, and the corresponding footnote below the eTable should have read as follows: "[a]Weight thresholds were calculated from Centers for Disease Control and Prevention height growth data.[1]" The corresponding eReference should have been given as follows: 1. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, et al. CDC growth charts: United States. *Adv Data*. June 8, 2000;(314):1-27.



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