National prevalence and risk factors for food allergy and relationship to asthma: Results from the National Health and Nutrition Examination Survey 2005-2006

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Background: The national prevalence and patterns of food allergy (FA) in the United States are not well understood.
Objective: We developed nationally representative estimates of the prevalence of and demographic risk factors for FA and investigated associations of FA with asthma, hay fever, and eczema.
Methods: A total of 8203 participants in the National Health and Nutrition Examination Survey 2005-2006 had food-specific serum IgE measured to peanut, cow's milk, egg white, and shrimp. Food-specific IgE and age-based criteria were used to define likely FA (LFA), possible FA, and unlikely FA and to develop estimates of clinical FA. Self-reported data were used to evaluate demographic risk factors and associations with asthma and related conditions.
Results: In the United States, the estimated prevalence of clinical FA was 2.5% (peanut, 1.3%; milk, 0.4%; egg, 0.2%; shrimp, 1.0%; not mutually exclusive). Risk of possible FA/LFA was increased in non-Hispanic blacks (odds ratio, 3.06; 95% CI, 2.14-4.36), males (1.87; 1.32-2.66), and children (2.04; 1.42-2.93). Study participants with doctor-diagnosed asthma (vs no asthma) exhibited increased risk of all measures of food sensitization. Moreover, in those with LFA, the adjusted odds ratio for current asthma (3.8; 1.5-10.7) and an emergency department visit for asthma in the past year (6.9; 2.4-19.7) were both notably increased.
Conclusion: Population-based serologic data on 4 foods indicate an estimated 2.5% of the US population has FA, and increased risk was found for black subjects, male subjects, and children. In addition, FA could be an under-recognized risk factor for problematic asthma. (J Allergy Clin Immunol 2010;126:798-806.)

Key words: *Asthma, eczema, egg, food allergy, food sensitization, food-specific serum IgE, peanut, hay fever, milk, prevalence, risk, shrimp*

Food allergy (FA) is a large and growing public health problem in the United States. Previous studies have estimated that US FA prevalence may be nearly 4%.[1] Targeted studies have also found evidence of higher risk of FA among non-Hispanic black subjects and associations between FA and asthma.[2-4] As awareness of the problem continues to grow, child day cares, schools, and public institutions are developing protective policies and health programs. Public institutions are also prioritizing funding for FA research.

A comprehensive population-level study on the prevalence of and risks associated with FA in the United States would inform these public health efforts. The overall magnitude of the problem has been difficult to estimate, however, because of the lack of a representative nationwide sample of the total population together with an objective, clinical approach to measuring and defining FA. Many reports have focused on specific subpopulations or foods or depended on self-reported or clinical manifestations of FA, possibly excluding those with atypical or unrecognized symptoms.[5-7]

Knowledge of the clinically measured, national prevalence of FA and the identification of populations at risk is needed to enable public health policy makers and care providers to prioritize, allocate resources, and develop plans to recognize and treat FA better. Furthermore, evidence suggests that FA is associated with and may exacerbate other immune-mediated conditions. This association has not been confirmed in a nationally representative population.

The National Health and Nutrition Examination Survey (NHANES) recently completed the first objective serologic measurement of food sensitivity in a representative sample of the US population. Branum and Lukacs[2] previously reported the prevalence of detectable IgE antibodies in children from these

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Abbreviations used
ED: Emergency department
FA: Food allergy
LFA: Likely food allergy
NHANES: National Health and Nutrition Examination Survey
OR: Odds ratio
PFA: Possible food allergy
PIR: Poverty Income Ratio
UFA: Unlikely food allergy

data while estimating FA prevalence among children on the basis of self-report data from the National Health Interview Survey. In this article, we use serologic data from both children and adults in the NHANES to derive and report the US population-based estimates of clinical FA, identify high-risk populations, and explore associations with other immune-mediated conditions.

METHODS

The NHANES 2005-2006 study cohort

The NHANES is a Centers for Disease Control and Prevention, National Center for Health Statistics program, designed to assess the health and nutritional status of adults and children in the United States, that began in the early 1960s. NHANES 2005-2006 was the seventh nationally representative NHANES survey and included 10,348 participants from 30 sites across the continental United States.[8] The NHANES 2005-2006 protocol was approved by the National Center for Health Statistics, Centers for Disease Control and Prevention, Ethics Review Board.[9] Blood was collected from 80.6% of the study participants. Serum was separated and frozen for laboratory testing including food-specific serum IgE panels to 4 common food allergens. Blood samples were insufficient to perform complete panels in 134 participants (1.3%). The remaining study population consisted of all participants with complete food-specific serum IgE panels (n = 8203; 79.3%). Participants excluded because of incomplete or missing panels were younger but otherwise not different with respect to a variety of demographic characteristics.

Participants were asked to self-identify their race and ethnicity, which NHANES combines into 1 race/ethnicity designation. Instead of actual family income, the Poverty Income Ratio (PIR) was used. It represents the ratio of family income to the poverty threshold as defined by the US Census Bureau. PIR values below 1.0 are below the poverty threshold. PIR thresholds of 1.3 and 3.5 were used for classification in adjusted logistic models; these thresholds are used to establish eligibility for US food assistance programs.[10]

Household education was defined as the highest education level obtained by the household reference person (typically the household head).

Food sensitization and FA risk groups

Food panels consisted of assays to determine serum IgE concentrations specific to peanut, cow's milk, egg white, and shrimp allergens. Clinical studies have demonstrated that higher food-specific IgE levels indicate a greater likelihood of clinical FA.[1,11,12] Food-specific serum IgE levels to peanut, milk, egg, and shrimp were measured in study participants ages 6+ years old, and only to peanut, milk and egg in participants 1 to 5 years old; the volume of blood draws and number of assays were limited in general among the youngest NHANES participants. IgE levels were also measured for 15 inhalant allergens.[13] Serum IgE assays were performed at a central laboratory (Elmhurst Memorial Hospital, Elmhurst, Ill) by using standardized methodology (ImmunoCAP 1000; Phadia US, Portage, Mich). The lower limit of allergen-specific IgE detection was 0.35 kU/L. Food sensitization was defined as having at least 1 food-specific serum IgE ≥0.35 kU/L, and multiple food sensitization was defined as 2 or more food sensitizations out of the panel of 4 foods.

Among participants above this threshold for food sensitivity, we defined 3 mutually exclusive FA risk categories: unlikely FA (UFA), possible FA (PFA), and likely FA (LFA). These FA risk groups were based on previous studies relating food-specific IgE concentrations with diagnosis of FA by using criteria that include diagnostic oral food challenges. Generally, lower food-specific IgE levels, between 0.35 and 2 kU/L, have been associated with a relatively low probability (UFA) of reacting (10% to 20%); moderate IgE levels, between 0.7 and 5 kU/L, have been associated with ~50% probability of reacting (PFA); and high IgE levels, between 5 and 15 kU/L, have been associated with a 95% probability of reacting (LFA).[1,11,12] However, the exact 95% probability thresholds vary by age and the specific food type. Therefore, the following 95% predictive levels have been proposed, based on positive predictive values for clinical reactivity: egg, 7 kU/L; milk, 15 kU/L; and peanut, 14 kU/L.[1] Clinical studies have also determined that 95% predictive levels differ for young children (ie, ≤2 years old): egg, 2 kU/L[14]; milk, 5 kU/L.[15] There is a lack of data correlating outcomes of allergy for shrimp with IgE levels, and thus no well established IgE cutpoint for likely shrimp allergy. Therefore, shrimp was treated in accordance with the typical patterns described, using a threshold of 5 kU/L. This appears reasonable on the basis of the limited data that do exist for shrimp.

When considering all 4 foods together, risk category assignment was based on the highest risk for FA across all food groups. Thus, UFA was defined as having at least 1 food-specific serum IgE between 0.35 and 2 kU/L, PFA as having at least 1 food-specific IgE between 2 kU/L and the applicable 95% predictive level, and LFA as having at least 1 food-specific IgE greater than or equal to the 95% predictive level.

Because participants with IgE sensitization at low levels (ie, 0.35-2 kU/L) are less likely to have clinical FA, we were particularly interested in those with higher IgE levels associated with PFA or LFA. Clinical FA rates were estimated by summing 50% of participants with PFA plus 95% of participants with LFA, based on the probabilities of reacting in each of those risk categories, as described. Thus, "clinical FA" may be interpreted to mean that ingestion of that food would reproducibly lead to clinical symptoms consistent with an acute allergic reaction.

Asthma, hay fever, and eczema questions

We explored associations between FA and 3 other immune-mediated conditions: asthma, hay fever, and eczema. These conditions we identified from participant self-report of doctor diagnosis. Specifically, the following NHANES 2005-2006 survey questions were used to define these conditions:

- Diagnosed asthma: Has a doctor or other health professional ever told you that you have asthma? (MCQ.010)
- Current asthma: Do you still have asthma? (MCQ.035)
- Emergency department (ED) visit for asthma in the previous year: During the past 12 months, have you had to visit an emergency room or urgent care center because of asthma? (MCQ.050)
- Diagnosed hay fever: Has a doctor or other health professional ever told you that you have hay fever? (AGQ.010)
- Diagnosed eczema: Has a doctor or other health professional ever told you that you have eczema? (AGQ.180)

The 3 asthma questions were asked in the order indicated. If an answer to an asthma question was not yes, then the remaining asthma questions were skipped.

Statistical analyses

Participants in NHANES are selected by using a complex, multistage, probability sampling design, and all percentages, means, percentiles, and odds ratios (ORs) were weighted to represent the civilian, noninstitutionalized US population. SEs, CIs, and *P* values were developed in accordance with the complex survey design by using Taylor series linearization methods. Statistical analyses were conducted by using SAS statistical software (Version 9.2; SAS Institute Inc, Cary, NC) survey procedures. Logistic regression was performed to model participants with PFA or LFA compared with those with no FA with only demographic predictors included in the model (age, gender, race/ethnicity, income), and *P* values for main effects were reported. Prevalence rates for food sensitization and FA risk groups were calculated for 3 doctor-diagnosed health outcomes (asthma, hay fever, and eczema), and adjusted

ORs were reported based on logistic regression modeling. Prevalence rates were calculated for food sensitization and FA risk groups for 4 mutually exclusive levels of asthma status (no asthma, doctor-diagnosed asthma but not current, current asthma, and ED visit for asthma in the past 12 months). The Cochran-Armitage trend test was used to test for an increase in the prevalence of FA as asthma status becomes more current and more severe. Logistic regression was performed for the asthma status outcomes, and ORs were reported. This logistic regression was performed as an unadjusted model by using only FA status as a predictor and also as an adjusted model, which included inhalant sensitization along with the demographic predictors. 95% CIs were developed by using *t* statistics.

RESULTS

Study population characteristics

The study population was demographically diverse and representative of the US population (Table I). Allergic sensitization (ie, serum allergen-specific IgE level ≥ 0.35 kU/L) was common: 16.8% were sensitized to at least 1 food, 41.3% to at least 1 inhalant allergen, and 13.9% to at least 1 food and 1 inhalant allergen. Self-reported doctor-diagnosed asthma (14.6%), hay fever (10.8%), and eczema (9.1%) were also common. Of those with diagnosed asthma, 9.6% reported an ED or urgent care visit for asthma within 12 months.

TABLE I. Demographic and clinical features of the 2005-2006 NHANES FA cohort

Characteristic	N§	Percentage‖
Overall	8203	
Age (y)		
1-5	909	5.3 ± 0.4
6-19	2869	19.0 ± 0.6
20-39	1672	28.0 ± 0.9
40-59	1361	30.2 ± 1.1
60+	1392	17.6 ± 1.6
Sex		
Male	3998	48.8 ± 0.5
Female	4205	51.2 ± 0.5
Race/ethnicity		
Non-Hispanic white	3239	69.5 ± 2.9
Non-Hispanic black	2124	11.8 ± 1.9
Hispanic*	2461	13.1 ± 1.4
Other	379	5.6 ± 0.8
PIR		
≤1.3	2669	20.0 ± 1.3
1.3-3.5	3003	38.5 ± 1.5
>3.5	2171	41.5 ± 2.3
Household education		
High school or less	4267	43.4 ± 2.0
Above high school	3676	56.6 ± 2.0
Disease		
Diagnosed eczema	715	9.1 ± 0.7
Diagnosed hay fever	586	10.8 ± 0.7
Diagnosed asthma	1157	14.6 ± 0.6
Current asthma	730	8.8 ± 0.5
ED visit†	123	9.6 ± 1.1
Sensitization‡		
Food	1729	16.8 ± 0.6
Inhalant	3495	41.3 ± 1.1
Both food and inhalant	1350	13.9 ± 0.6

*Defined as "Mexican American" or "other Hispanic" in NHANES.
†Among those with diagnosed asthma.
‡Sensitization: at least 1 allergen-specific serum IgE ≥0.35 kU/L. Food and inhalant categories are not mutually exclusive.
§Unweighted counts.
‖Weighted % ± SE.

Prevalence of food sensitization and clinical FA in the United States

The overall prevalence of food sensitization in the US was 16.8% (see this article's Fig E1 in the Online Repository at www.jacionline.org; Table II). By age, the highest prevalence was 28.1%, in participants 1 to 5 years and declined steadily with age to 13.0% in adults 60+ years old (Fig E1; see this article's Table E1 in the Online Repository at www.jacionline.org). The prevalence of milk (22.0%) and egg (13.9%) sensitization was highest in children 1 to 5 years. Peanut sensitization was most common in older children and young adults (6-19 years, 10.7%; 20-39 years, 8.7%). Shrimp sensitization, which was not measured in children under age 5 years, did not vary appreciably by age.

The US population prevalences for PFA and LFA were 3.1% and 1.0%, respectively (Table II). The estimated US population prevalence of clinical FA was 2.5% (Fig 1; Table II). These estimates are based on 4 common foods and do not account for allergies that are known to occur to other foods; see Discussion section. Overall clinical FA prevalence differed significantly and declined with age, highest in children 1 to 5 years (4.2%) and lowest in adults 60+ years (1.3%) (Fig 1; Table E1). The clinical FA estimates for individual foods also varied by age. The prevalences of clinical FA to milk, egg, and peanut were each approximately 1.8% in children 1 to 5 years; clinical peanut allergy was most prevalent (2.7%) in children 6 to 19 years; clinical peanut and shrimp allergies were most prevalent (0.9% to 1.2%) in adults age 20 to 59 years; and shrimp allergy was most prevalent (0.7%) in adults 60+ years old (Fig 1).

Multiple food sensitizations occurred in 4.7% of the US population (Table II). By age, the highest prevalence was in the youngest children (1-5 years, 11.6%) and declined steadily with age to 3.1% in adults 60+ years (see this article's Fig E2 in the Online Repository at www.jacionline.org; Table E1). Multiple clinical FA was present in 1.3% of the population overall (Table II). It was more frequent in younger children (1-5 years, 3.4%) than in older children (1.8%) and adults (1.1% to 1.3%) and was uncommon in adults 60+ years old (0.6%) (Table E1). The most common combinations of PFA/LFA occurred in children 1 to 5 years; the prevalence of PFA/LFA to milk, egg, and peanut; to both milk and egg; and to milk and peanut were each 0.4% in this age group. The next most common PFA/LFA combination was to peanut and shrimp; the prevalence of this combination was 0.3% in children 6 to 19 years; 0.1% to 0.2% in participants 20 to 59 years; and 0.07% in participants 60+ years. Other PFA/LFA combinations were uncommon (< 0.1%).

Demographic risk factors for PFA/LFA

Significant prevalence differences in food sensitization, PFA, and LFA were observed in commonly investigated demographic subgroups (age [Fig E3], sex, race/ethnicity, and household income). Food sensitization and PFA/LFA were more prevalent in male than female subjects to peanut, shrimp, and milk, but not egg (see this article's Fig E4 and Table E2 in the Online Repository at www.jacionline.org). For example, the prevalences of detectable food sensitization, PFA, and LFA to peanut in male

TABLE II. Food sensitization prevalence* and clinical FA estimates in the United States (2005-2006)†

Food sensitization	Sensitization ≥0.35 kU/L	Unlikely FA 0.35-2.0 kU/L	Possible FA 2.0 kU/L-PL¶	Likely FA ≥PL¶	Estimated clinical FA rate#
Food sensitization‡	16.8 ± 0.6 (1729)	12.7 ± 0.3 (1267)	3.1 ± 0.4 (320)	1.0 ± 0.2 (142)	2.5 ± 0.3
Milk	5.7 ± 0.5 (650)	5.0 ± 0.4 (581)	0.69 ± 0.18 (62)	0.05 ± 0.04 (7)	0.40 ± 0.09
Egg	3.9 ± 0.4 (371)	3.6 ± 0.4 (327)	0.24 ± 0.06 (26)	0.12 ± 0.04 (18)	0.23 ± 0.05
Peanut	7.6 ± 0.4 (772)	5.3 ± 0.3 (509)	1.9 ± 0.3 (208)	0.34 ± 0.07 (55)	1.3 ± 0.1
Shrimp§	5.9 ± 0.4 (568)	4.5 ± 0.3 (408)	0.79 ± 0.13 (84)	0.62 ± 0.12 (76)	1.0 ± 0.1
Multiple food sensitization‖	4.7 ± 0.4 (498)	2.6 ± 0.3 (250)	1.7 ± 0.2 (169)	0.53 ± 0.12 (79)	1.3 ± 0.2

*Weighted % ± SE (N).
†Overall N = 8203.
‡Food sensitization: at least 1 food ≥0.35 kU/L.
§Information only available for participants ≥6 years.
‖Multiple food sensitization: 2 or more foods ≥0.35 kU/L.
¶PL, 95% predictive level: for ages 1 to 5 years, 5 kU/L; for age 6+ years, cow's milk 15 kU/L, egg white 7 kU/L, peanut 14 kU/L, shrimp 5 kU/L.
#Estimated clinical FA rate: 50% of participants with PFA + 95% of participants with LFA.

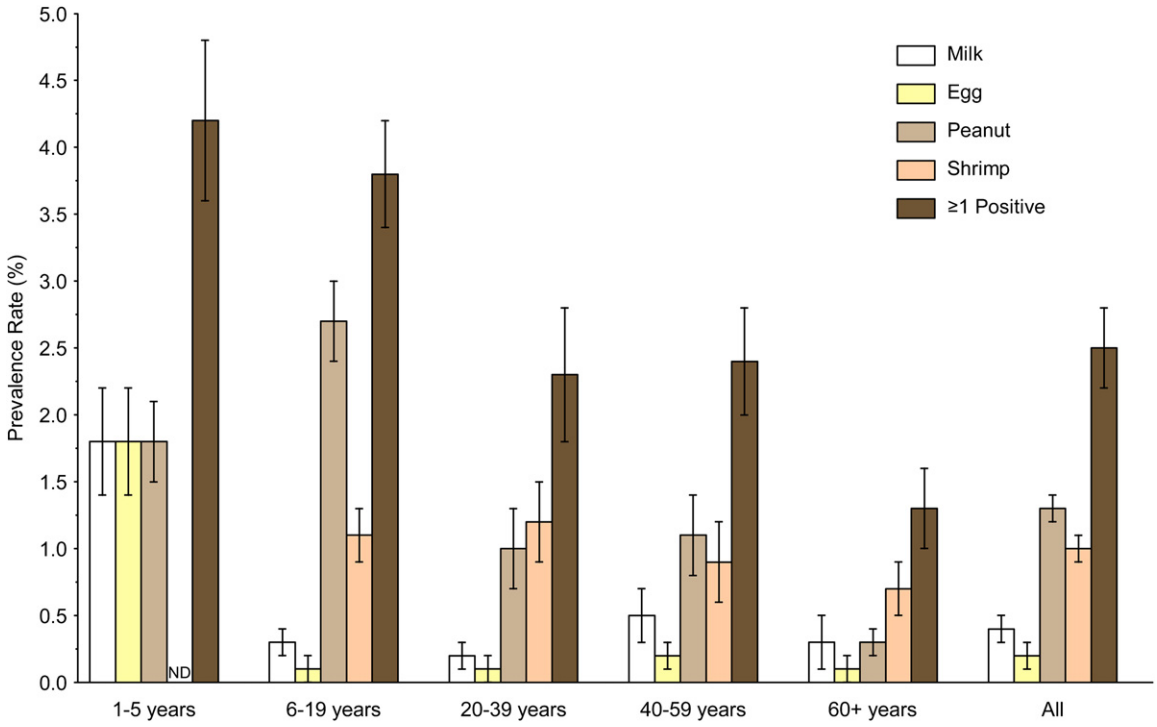

FIG 1. Clinical FA prevalence estimates in the United States (2005-2006) by age. *ND,* Not done.

subjects were 10.0%, 2.4%, and 0.6%, respectively, compared with 5.2%, 1.4%, and 0.1% in female subjects. Food sensitization and PFA/LFA were more prevalent in non-Hispanic black subjects and least prevalent in non-Hispanic white subjects (see this article's Fig E5 and Table E3 in the Online Repository at www.jacionline.org); these distinctions were greatest for shrimp and peanut. For example, the prevalences of detectable food sensitization, PFA, and LFA to shrimp in non-Hispanic black subjects were 12.8%, 2.2%, and 2.3%, respectively, compared with 3.8%, 0.6%, and 0.3% in non-Hispanic white subjects. Food sensitization and PFA/LFA were generally more prevalent in individuals living in poverty and least prevalent in higher-income households (see this article's Fig E6 and Table E4 in the Online Repository at www.jacionline.org). For example, the prevalences of detectable food sensitization, PFA, and LFA to at least 1 food for PIR ≤1.3 were 19.0%, 3.4%, and 1.3%, respectively, compared with 15.3%, 3.0%, and 0.6% for PIR >3.5. The prevalence of food sensitization tended to be higher in households with less educated participants, but these differences were not statistically significant (see this article's Fig E7 and Table E5 in the Online Repository at www.jacionline.org).

We also performed logistic regression modeling to determine the relative significance of these demographic factors in PFA/LFA risk. There were significantly increased odds of PFA/LFA in children, non-Hispanic black subjects, and male subjects (Table III). Further subpopulation analyses revealed that the unadjusted OR (95% CI) of PFA/LFA in black boys compared with the remainder of the population was 4.4 (2.8-6.7). Household income and education level were not associated with PFA/LFA in this model.

TABLE III. Demographic predictors of PFA or LFA*

Predictor	OR (95% CI)†	Effect *P* value‡
Age (y)		
1-5	2.04 (1.42-2.93)	<.001
6-19	1.80 (1.46-2.23)	
20+	1.00	
Race/ethnicity		
Non-Hispanic black	3.06 (2.14-4.36)	<.001
Hispanic	1.14 (0.71-1.81)	
Other	1.09 (0.56-2.14)	
Non-Hispanic white	1.00	
Sex		
Male	1.87 (1.32-2.66)	<.001
Female	1.00	
PIR		
≤1.3	0.94 (0.65-1.34)	.46
1.3-3.5	1.06 (0.79-1.43)	
>3.5	1.00	
Household education		
High school or less	1.03 (0.79-1.34)	.83
Above high school	1.00	

*Overall N = 6557.
†Adjusted model: PFA/LFA vs no FA = age + race/ethnicity + sex + PIR + household education.
‡Wald χ^2 test for significance of each factor.

Relationship among food sensitization, FA, and asthma

In weighted, bivariate analyses, the prevalences of all food sensitizations and FA risk groups were higher in participants with doctor-diagnosed asthma compared with those with no asthma. The odds of food sensitization (2.3); sensitization to milk (2.0), egg (2.9), peanut (2.3), shrimp (1.9), and multiple foods (2.4); and UFA (1.9), PFA (2.8), and LFA (2.0) were all significantly increased (Table IV). As asthma increased in persistence and severity, the prevalences of food sensitization and FA significantly increased. For example, the prevalences of food sensitization in those with no asthma, diagnosed but not current asthma, current asthma without recent ED visits, and current asthma with recent ED visits were 14.9%, 20.6%, 31.5%, and 35.0%, respectively ($P < .001$, Cochran-Armitage test for trend; Table V). Notably, the prevalence of LFA in those with an ED visit for asthma in the previous year (8.5%) was remarkably higher than in those with current asthma but without a recent ED visit (1.3%), diagnosed but not current asthma (1.1%), and no asthma (0.9%; $P <$ .001 for trend).

To understand better the relationship between asthma, especially asthma persistence and recent severe asthma exacerbations, and FA risk groups, we developed logistic regression models, after adjusting for inhalant sensitization and demographic variables (age, sex, race/ethnicity, household income; Fig 2; see this article's Table E6 in the Online Repository at www.jacionline.org). The adjusted odds of diagnosed asthma (vs no asthma) were significantly increased in those with UFA and PFA and tended to be increased in LFA. Similarly, the adjusted odds of current asthma (vs diagnosed asthma, not current) were significantly increased in those with UFA, PFA, and LFA. Importantly, the adjusted odds of an ED visit for asthma in the previous year (vs diagnosed asthma, no ED visit) were highest in those with LFA (OR, 6.9; 95% CI, 2.4-19.7) but not increased in UFA or PFA.

TABLE IV. Prevalence and risk of food sensitization and FA in diagnosed asthma

Food sensitization/FA	% Asthma‖	% No asthma	OR¶ (95% CI)
Counts*	n = 1157	n = 7037	
Food sensitization†	27.5	14.9	2.3 (1.9-2.7)
Milk	9.1	5.2	2.0 (1.5-2.5)
Egg	8.2	3.2	2.9 (2.4-3.5)
Peanut	13.3	6.6	2.3 (1.9-2.8)
Shrimp‡	9.1	5.3	1.9 (1.2-2.9)
Multiple food sensitization§	8.8	4.0	2.4 (1.9-3.1)
UFA	19.0	11.5	1.9 (1.7-2.1)
PFA	6.6	2.5	2.8 (1.7-4.5)
LFA	1.9	0.9	2.0 (1.1-3.7)

*Unweighted counts.
†Food sensitization: at least 1 food ≥0.35 kU/L.
‡Information only available for participants ≥6 years.
§Multiple food sensitization: 2 or more foods ≥0.35 kU/L.
‖Self-reported diagnosis by doctor or other health professional.
¶Adjusted model: food sensitization/allergy = diagnosed asthma + age + sex + race + PIR.

Relationship among food sensitization, FA, and hay fever and eczema

In participants with hay fever, the prevalence and odds of food sensitization and FA risk groups were significantly increased, although not for LFA (Table VI). In participants with eczema, only the odds of LFA were significantly increased. In a fully adjusted model (including inhalant sensitization and demographic variables), the odds of diagnosed hay fever were significantly increased only in those with PFA (OR, 2.0; 95% CI, 1.4-2.8; see this article's Table E7 in the Online Repository at www.jacionline.org). The odds of diagnosed eczema were not significantly increased for any FA risk group (Table E7) except that in an unadjusted model, the odds of eczema were increased only in those with LFA (OR, 2.1; 95% CI, 1.2-.3.7).

DISCUSSION

This study found that the prevalence estimate of clinical allergy to peanut, milk, egg, and/or shrimp was 2.5% and was associated with childhood, male sex, and non-Hispanic black race/ethnicity. We also found an association of LFA with current asthma and ED visits for asthma in the previous year.

For the first time in a US nationally representative sample, specific serum IgE levels were used to quantify allergic sensitization to common foods. This is important because clinical studies have demonstrated that higher food-specific IgE levels indicate a greater likelihood of clinical FA. Although age-specific distinctions in food sensitization and FA have long been suspected, this was also the first time in a US national study that food sensitization was assessed in younger children (1-5 years old) together with older adults (at least 60 years old). These cohort strengths allowed for a comprehensive, contemporary US public health perspective on the prevalence of and risks associated with higher food-specific serum IgE levels, indicative of PFA or LFA.

This investigation estimated clinical FA rates of 2.5% in the US population. They are highest in children (4.2% in participants 1-5 years, 3.8% in participants 6-19 years), and lowest in older adults (1.3% in participants 60+ years). These overall estimates are lower than some other studies. Sampson[1] estimated the prevalence

TABLE V. Prevalence* of food sensitization and FA by asthma status

Food sensitization/FA	% No asthma¶	% Diagnosed asthma (not current)	% Current asthma but no ED visit for asthma	% Current asthma with ED visit for asthma in past year	*P* value#**
Counts†	n = 7037	n = 427	n = 607	n = 123	
Food sensitization‡	14.9 ± 0.7	20.6 ± 2.8	31.5 ± 2.4	35.0 ± 5.7	<.001
Milk	5.2 ± 0.5	8.2 ± 1.5	9.6 ± 1.6	10.9 ± 3.8	<.001
Egg	3.2 ± 0.3	8.2 ± 1.2	8.0 ± 1.6	9.6 ± 3.0	<.001
Peanut	6.6 ± 0.5	6.8 ± 1.4	17.5 ± 2.3	17.5 ± 2.6	<.001
Shrimp§	5.3 ± 0.5	6.9 ± 1.6	9.6 ± 1.9	16.0 ± 5.2	.002
Multiple food sensitization‖	4.0 ± 0.3	7.3 ± 0.9	9.1 ± 2.0	13.8 ± 4.3	<.001
UFA	11.5 ± 0.4	16.2 ± 2.5	21.2 ± 2.4	19.2 ± 4.7	<.001
PFA	2.5 ± 0.4	3.4 ± 0.8	9.0 ± 1.9	7.3 ± 1.8	<.001
LFA	0.9 ± 0.2	1.1 ± 0.4	1.3 ± 0.3	8.5 ± 3.3	<.001

*Weighted % ± SE (N).
†Unweighted counts.
‡Food sensitization: at least 1 food ≥0.35 kU/L.
§Information only available for participants ≥ 6 years.
‖Multiple food sensitization: 2 or more foods ≥0.35 kU/L.
¶Self-reported diagnosis by doctor or other health professional.
#*P* value result of Cochran-Armitage test for linear trend.
**Adjusted model: food sensitization/allergy = asthma severity + age + sex + race + PIR.

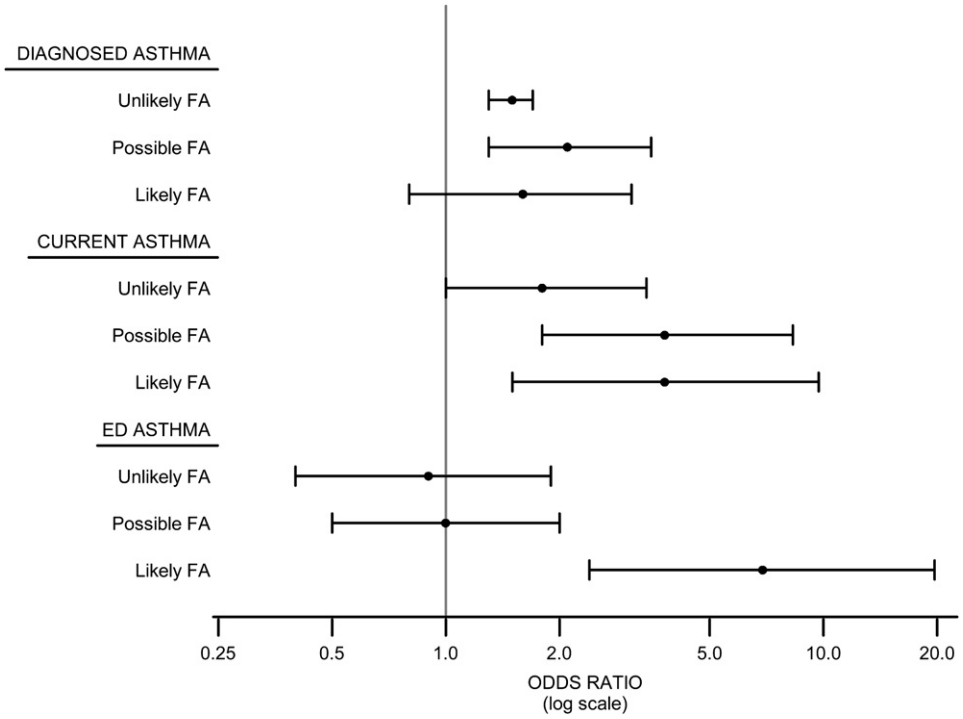

FIG 2. FA and asthma risk in United States (2005-2006). Adjusted ORs for diagnosed asthma, current asthma, and ED visit for asthma in the previous year in those with UFA, PFA and LFA. Adjusted model: asthma outcome = food sensitization + inhalant sensitization + age + sex + race + PIR. Diagnosed asthma modeled against all participants without asthma. Current asthma modeled against all participants diagnosed with asthma but not currently having asthma. ED asthma modeled against all participants diagnosed with asthma or currently having asthma but not having an ED visit related to asthma.

of FA in the United States to be 3.5% to 4.0%. Bock[7] reported a 6% prevalence of food challenge-confirmed FA in infants less than 3 years of age. Our estimates were remarkably similar to those reported by Branum and Lukacs[2] from the 2007 National Health Interview Survey, in which the prevalence of self-reported food or digestive allergy in children was 3.9%. Our US prevalence of peanut sensitization of 7.6% is consistent with that observed by Arbes et al in NHANES III (1988-1994).[5] These investigators reported an 8.6% prevalence of peanut sensitization in participants 6 to 59 years by allergy skin prick testing. Importantly, NHANES III did not include younger children or older adults, whereas our data indicate that peanut sensitization is less prevalent in these age groups,[5] and excluding them to achieve a comparable age population to NHANES III increases the estimated peanut

TABLE VI. Prevalence and risk of food sensitization and FA in diagnosed hay fever and eczema

	Hay fever‖			Eczema‖		
Food sensitization/FA	**Yes**	**No**	**OR¶ (95% CI)**	**Yes**	**No**	**OR¶ (95% CI)**
Counts*	n = 586	n = 7599		n = 715	n = 7470	
Food sensitization†	24.9	15.7	2.4 (1.8-3.2)	17.8	16.7	1.1 (0.8-1.5)
Milk	6.8	5.5	1.9 (1.2-2.9)	7.0	5.6	1.0 (0.6-1.7)
Egg	6.9	3.6	2.6 (1.5-4.3)	6.4	3.7	1.5 (0.9-2.6)
Peanut	15.0	6.6	3.4 (2.7-4.5)	7.6	7.6	1.0 (0.8-1.4)
Shrimp‡	7.3	5.8	1.7 (1.1-2.5)	5.8	6.0	1.1 (0.8-1.6)
Multiple food sensitization§	8.0	4.3	2.6 (1.8-3.9)	6.1	4.6	1.3 (0.8-2.0)
UFA	17.7	12.0	2.0 (1.5-2.8)	12.7	12.6	1.0 (0.7-1.5)
PFA	6.4	2.7	3.3 (2.4-4.7)	3.2	3.1	1.0 (0.6-1.5)
LFA	0.9	1.0	1.2 (0.4-4.1)	1.9	1.0	2.0 (1.1-3.8)

*Unweighted counts.
†Food sensitization: at least 1 food ≥0.35 kU/L.
‡Information only available for participants ≥6 years.
§Multiple food sensitization: 2 or more foods ≥0.35 kU/L.
‖Self-reported diagnosis by doctor or other health professional.
¶Adjusted model: food sensitization/allergy = hay fever/eczema + age + sex + race + PIR.

sensitization prevalence to 8.3%. Our clinical peanut allergy estimate of 1.3% is higher than that of a US telephone survey in 2002 by Sicherer et al,[6] which determined self-reported peanut allergy to be present in 0.6% of the population. Although there were limited shrimp-specific data on which to base our threshold partitioning PFA and LFA, our clinical shrimp allergy estimate of 1.0% appears consistent with another US telephone survey conducted by Sicherer et al,[3] which found a 2.0% prevalence of physician-diagnosed or convincing reactions to any type of shellfish. Furthermore, a sensitivity analysis showed that the estimated prevalence of clinical FA reported in this article is very robust to the particular choice of threshold used to differentiate PFA and LFA to shrimp.

Prevalence differences between studies are attributable to differences in cohort enrollment, how food sensitization or FA was determined, and the panel of foods tested. Our study was strengthened by the nationally representative nature of the cohort, the consistent methodologies used by the NHANES, and the use of standardized food-specific serum IgE, increasing levels of which predict an increasing probability of clinical food reactivity.[1,11,12] Those with low-level sensitization (0.35-2 kU/L) were excluded from clinical FA estimates to minimize the impact of low-level sensitization, which is thought to be associated with a relatively low probability of clinical allergic reactivity, on the results. This study was limited by the fact that the NHANES relied solely on IgE levels for determination of clinical FA estimates, without detailed clinical or questionnaire-based information to corroborate the relevance of these findings. Moreover, there are no predictive values available from studies of adults. Therefore, this study might overestimate FA prevalence because it is possible that higher IgE levels in adults do not correlate as highly with allergy, or it might underestimate FA prevalence by measuring specific IgE to only 4 common foods. Including other common allergenic foods (eg, tree nuts, sesame, fish, wheat, soy) would likely have increased overall prevalence estimates. Nevertheless, this study provides a consistent, contemporary picture of FA prevalence in the United States.

Childhood (1-19 years), male sex, and non-Hispanic black race/ethnicity were identified as significant risk factors for FA. In fact, the odds of black boys having FA were 4.4 times higher than others in the general population. Childhood is well recognized as a time when food allergies, especially to milk and egg, are more prevalent. Our study's observation of the high peanut allergy prevalence through childhood (1.8% in children 1-5 years, 2.7% in children 6-19 years), and the low peanut allergy prevalence in older adults (0.3% in participants 60+ years) has not been previously observed.[6] The overall decreasing trend in FA with increasing age may reflect a combination of 2 factors: (1) the general loss of sensitization with age, noting that allergy to foods such as milk and egg typically resolve over time, whereas peanut and shellfish more typically persist, together with (2) a possible cohort effect associated with the increasing prevalence of allergy in children in recent years.[16]

Male sex and black race/ethnicity were significant risk factors for inhalant allergen sensitization in NHANES II[17] and NHANES III.[5] With specific regard to FA, Sicherer et al[3] found that self-reported shellfish allergy was more prevalent among black than white subjects, whereas Branum and Lukacs[2] found higher rates of sensitization to shrimp, milk, and peanuts among non-Hispanic black children than other children. Our results are consistent with these but are supported by, to our knowledge, the first population-based study among all ages using objective clinical data to identify male sex and black race/ethnicity as risk factors for FA. FA may be under-recognized in black subjects, male subjects, and children, because it was self-reported in the other US-wide studies instead of being determined by food-specific serum IgE levels.

The higher prevalence of food sensitization and FA risk categories in participants with asthma, hay fever, and eczema is consistent with other national studies.[18,19] In our study, the link between FA and asthma appeared especially strong. There was increased prevalence of all food sensitization and FA risk categories in those with diagnosed asthma, as well as increased prevalence and likelihood of FA in those with current asthma (indicative of asthma persistence) and ED visits for asthma in the previous year (indicative of severe asthma exacerbations). Indeed, the odds of patients with asthma and FA experiencing a recent severe asthma exacerbation were 6.9 times higher than those without FA.

This relationship between FA and asthma severity may or may not be causal in nature. For example, severe asthma may be associated with greater atopy in general.[20,21] In this context, FA

might be a marker for a generalized atopic phenotype of severe asthma, but ingesting the allergenic food might not be directly responsible for the asthma severity and severe asthma attacks.

Alternatively, the relationship between FA and asthma severity could be causal, noting that asthma symptoms are induced by foods in people with food allergy up to 30% of the time, although usually with other allergic symptoms.[4,22] However, bronchial hyperreactivity and asthma worsening can be induced, in the absence of immediate bronchospasm, by the ingestion of small amounts of food allergens in sensitized individuals.[23,24] FA has been recently found to be a major risk factor for severe asthma and life-threatening asthma episodes. Several smaller studies have identified food sensitization as a significant risk factor for severe asthma.[25,26] Roberts et al[27] reported that 54% of children with asthma requiring intubation for a severe asthma exacerbation had food sensitization, compared with 10% of hospitalized children with asthma at the same hospital. Asthma is coincident in nearly all people who have fatal anaphylactic reactions, and severe asthma is a common manifestation.[28,29]

Thus, although the relationship may or may not be causal, this study provides further credence and a national perspective to the concern that FA may be an under-recognized trigger of severe asthma exacerbations. Offending foods are notoriously occult and are often hidden in other foods, leading to accidental ingestion. Food-allergic reactions might be triggered only when combined with exercise. In these circumstances, the onset of food-induced symptoms can often be delayed by 2 to 4 hours after ingestion and manifest only after vigorous physical exertion.[30,31] With these challenges to clinical detection of food-triggered asthma, heightened suspicion is necessary to identify food-triggered asthma episodes. Recognition of FA-triggered asthma exacerbations might improve preventive and therapeutic management and result in better clinical outcomes.

In summary, this NHANES investigation provides a comprehensive, contemporary US public health perspective on the prevalence and risks associated with higher food-specific serum IgE levels indicative of PFA or LFA. Black race/ethnicity and male sex were identified as important risk factors for FA. Along with childhood, these risk factors might identify at-risk populations in which FA is under recognized. A US population-level association between FA and severe asthma exacerbations was also identified. Because the cross-sectional design of this study does not substantiate inferences of causation, prospective clinical investigation of this association is needed. Nevertheless, these findings raise awareness that FA may be contributing to severe asthma episodes.

Clinical implications: Black subjects, male subjects, and children represent at-risk populations for whom clinical FA may be under-recognized. Furthermore, population-level associations suggest that FA may contribute to severe asthma episodes.

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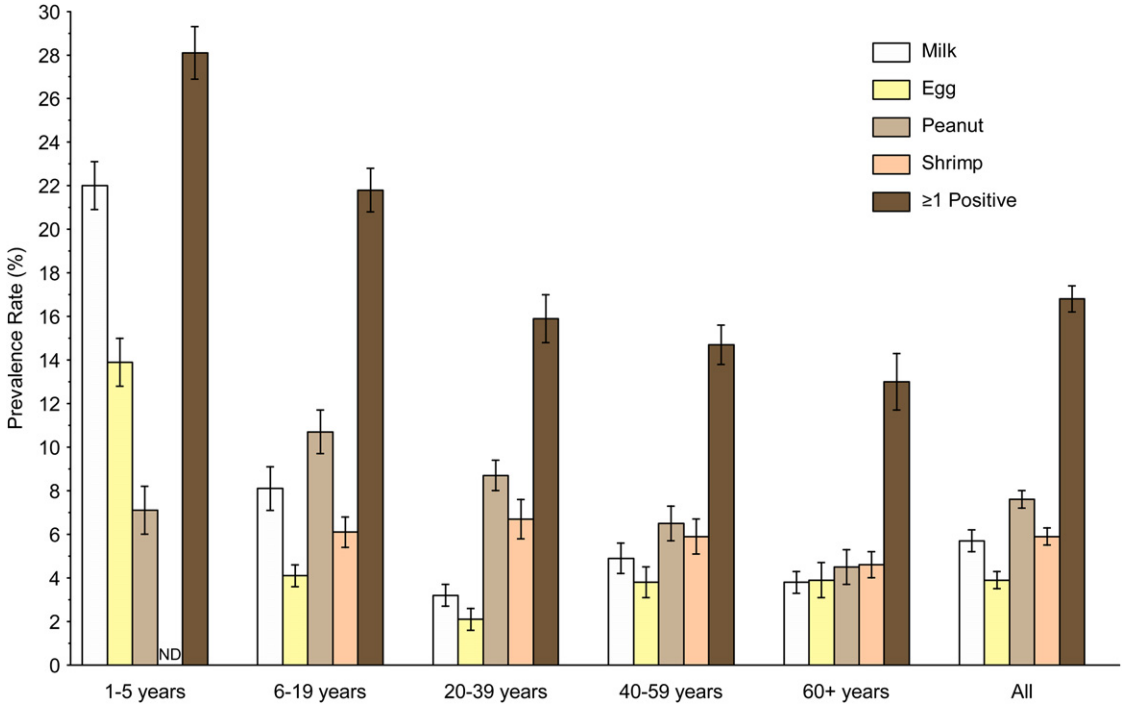

FIG E1. Food sensitization prevalence in the United States (2005-2006) by age. *ND*, Not done.

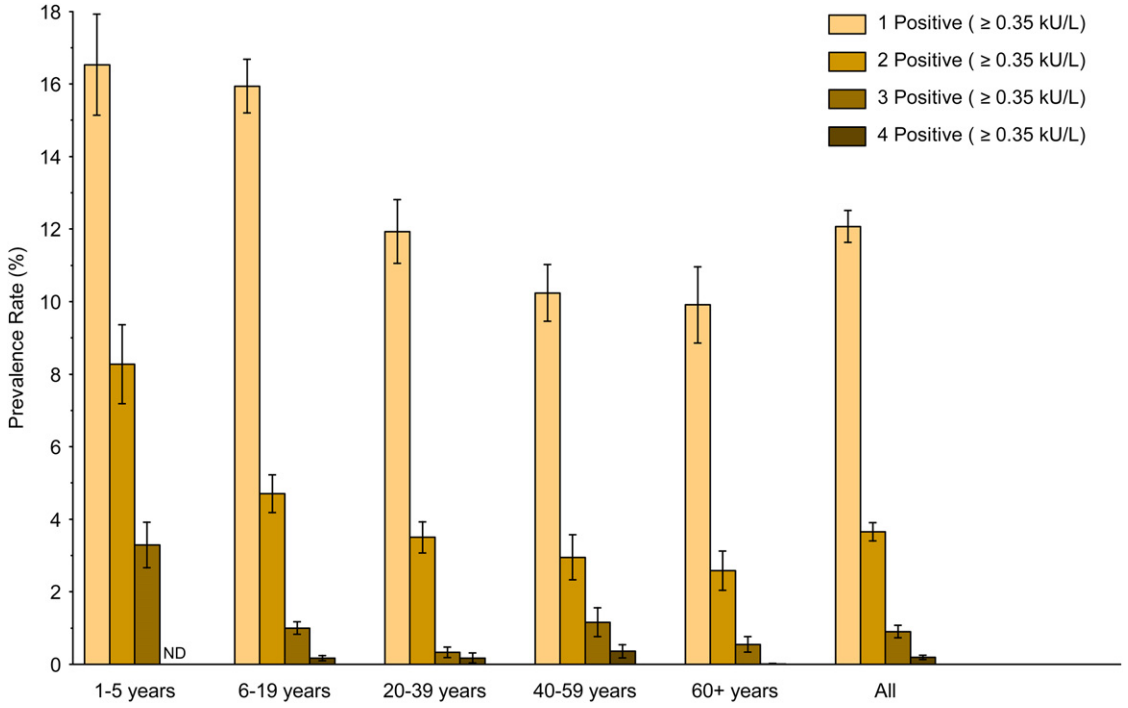

FIG E2. Single and multiple food sensitization prevalence in the United States (2005-2006) by age. *ND*, Not done.

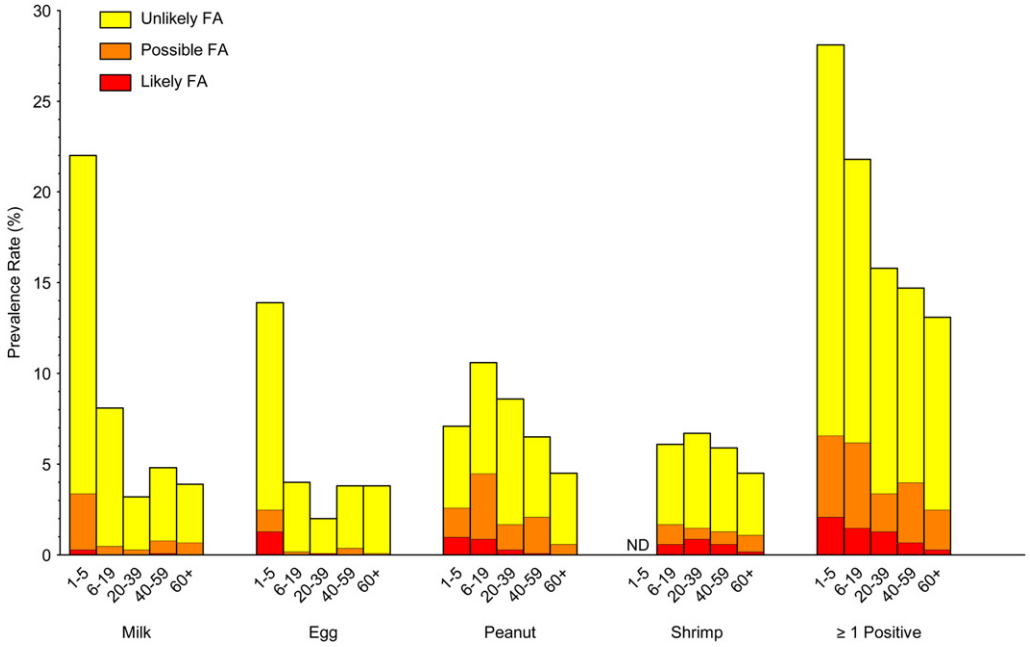

FIG E3. Food allergy risk prevalence in the United States (2005-2006) by age. *ND,* Not done.

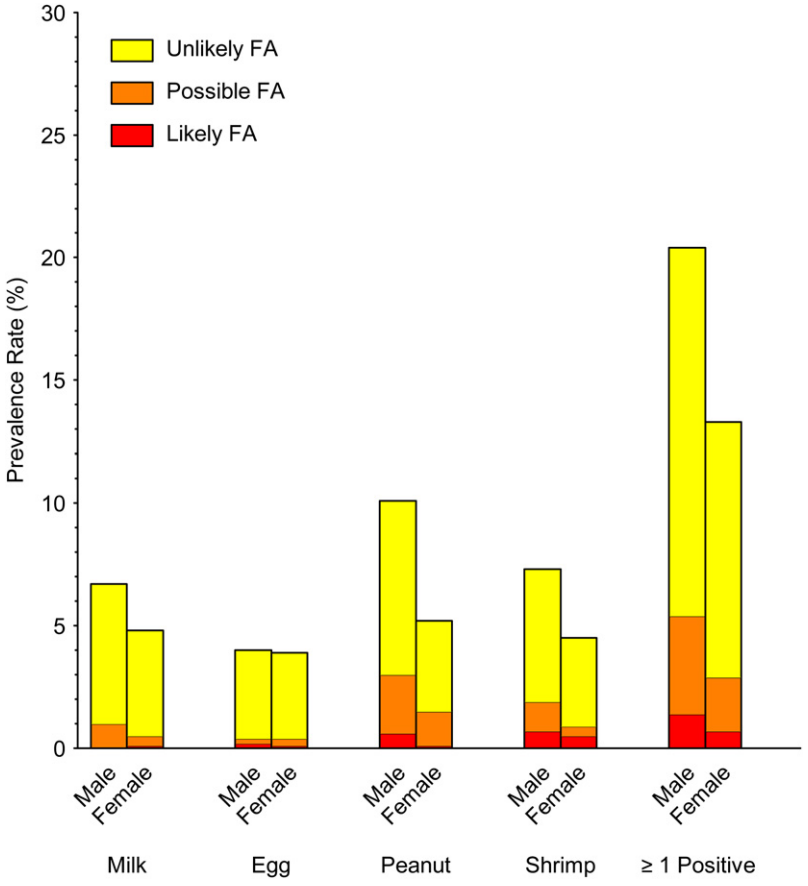

FIG E4. Food allergy risk prevalence in the United States (2005-2006) by gender.

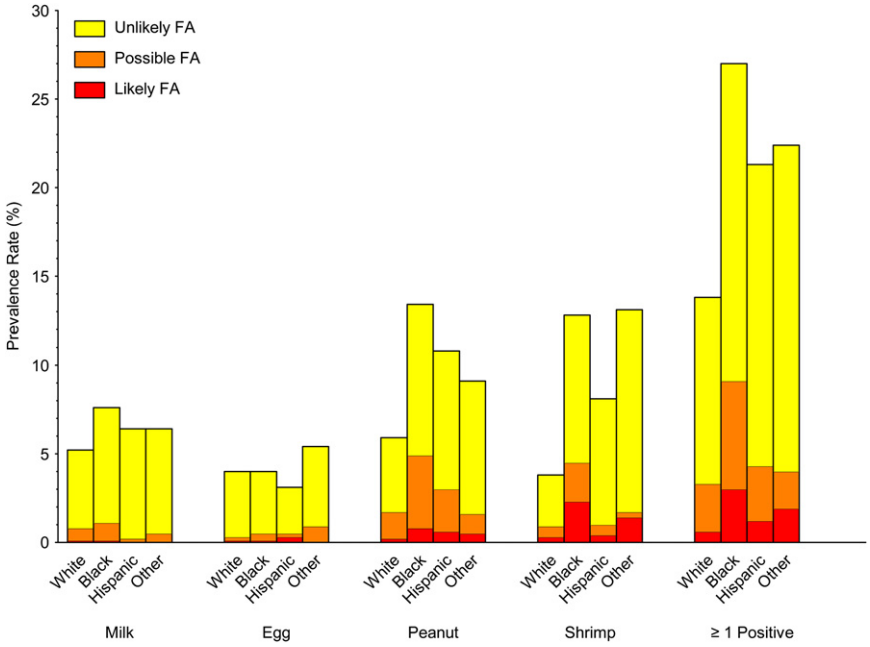

FIG E5. Food allergy risk prevalence in the United States (2005-2006) by race/ethnicity.

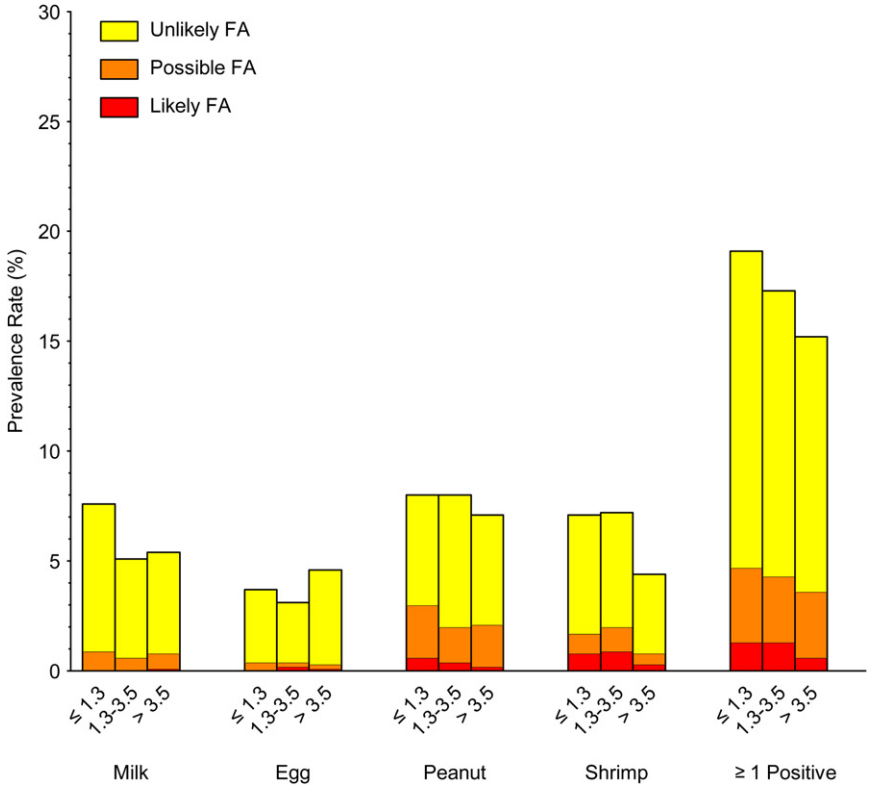

FIG E6. Food allergy risk prevalence in the United States (2005-2006) by poverty income ratio.

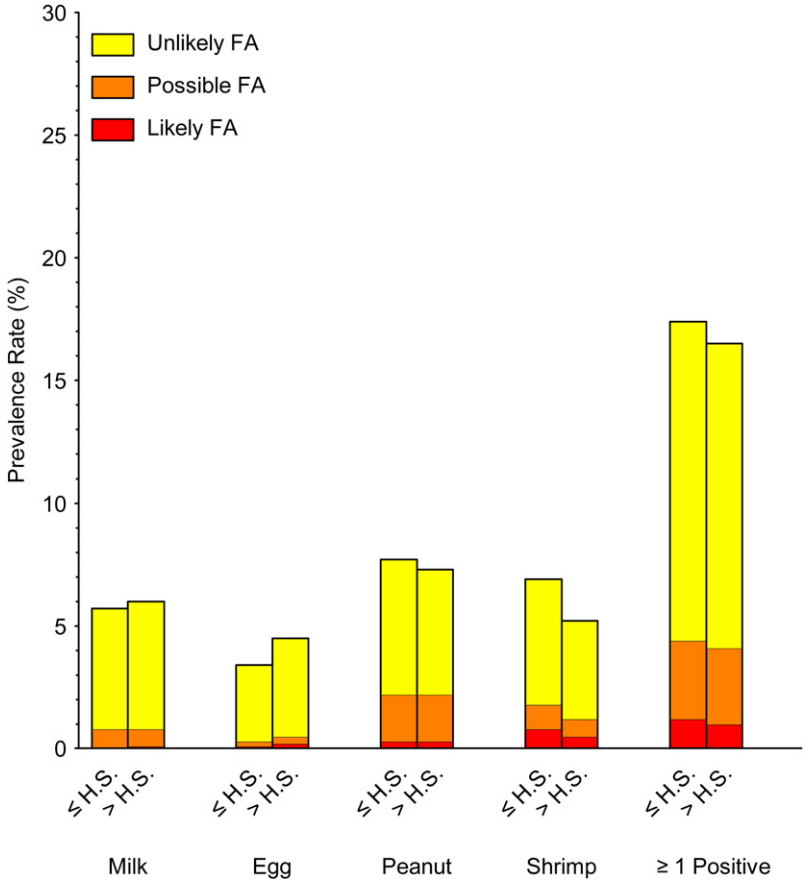

FIG E7. Food allergy risk prevalence in the United States (2005-2006) by household education. *HS,* High school education.

TABLE E1. Food sensitization prevalence* and clinical FA estimates in the United States (2005-2006) by age

	Sensitization ≥0.35 kU/L	Unlikely FA 0.35-2.0 kU/L	Possible FA 2.0 kU/L-PL‖	Likely FA ≥PL‖	Estimated clinical FA Rate¶
Food sensitization†					
1-5	28.1 ± 1.2 (291)	21.5 ± 1.0 (230)	4.5 ± 0.8 (40)	2.1 ± 0.4 (21)	4.3 ± 0.6
6-19	21.8 ± 1.0 (702)	15.6 ± 0.9 (473)	4.7 ± 0.6 (150)	1.5 ± 0.3 (79)	3.8 ± 0.4
20-39	15.9 ± 1.1 (313)	12.4 ± 0.7 (236)	2.1 ± 0.5 (51)	1.3 ± 0.4 (26)	2.4 ± 0.5
40-59	14.7 ± 0.9 (217)	10.7 ± 0.6 (161)	3.3 ± 0.6 (45)	0.75 ± 0.30 (11)	2.3 ± 0.4
60+	13.0 ± 1.3 (206)	10.6 ± 1.2 (167)	2.2 ± 0.4 (34)	0.25 ± 0.15 (5)	1.3 ± 0.3
Milk					
1-5	22.0 ± 1.1 (230)	18.6 ± 0.9 (198)	3.1 ± 0.7 (27)	0.28 ± 0.13 (5)	1.8 ± 0.4
6-19	8.1 ± 1.0 (254)	7.6 ± 0.9 (240)	0.50 ± 0.19 (13)	0.01 ± 0.01 (1)	0.26 ± 0.10
20-39	3.2 ± 0.5 (50)	2.9 ± 0.5 (45)	0.32 ± 0.15 (5)	(0)	0.16 ± 0.07
40-59	4.9 ± 0.7 (59)	4.0 ± 0.7 (48)	0.75 ± 0.34 (10)	0.12 ± 0.13 (1)	0.49 ± 0.22
60+	3.8 ± 0.5 (57)	3.2 ± 0.5 (50)	0.67 ± 0.31 (7)	(0)	0.33 ± 0.15
Egg					
1-5	13.9 ± 1.1 (144)	11.4 ± 1.1 (117)	1.2 ± 0.3 (15)	1.3 ± 0.4 (12)	1.8 ± 0.4
6-19	4.1 ± 0.5 (99)	3.8 ± 0.5 (92)	0.20 ± 0.13 (4)	0.05 ± 0.03 (3)	0.14 ± 0.06
20-39	2.1 ± 0.5 (28)	1.9 ± 0.5 (27)	(0)	0.13 ± 0.13 (1)	0.12 ± 0.12
40-59	3.8 ± 0.7 (46)	3.4 ± 0.6 (40)	0.41 ± 0.18 (6)	(0)	0.20 ± 0.09
60+	3.9 ± 0.8 (54)	3.7 ± 0.8 (51)	0.11 ± 0.11 (1)	0.03 ± 0.02 (2)	0.08 ± 0.06
Peanut					
1-5	7.1 ± 1.1 (68)	4.5 ± 0.9 (44)	1.6 ± 0.7 (14)	1.0 ± 0.3 (10)	1.8 ± 0.3
6-19	10.7 ± 1.0 (345)	6.1 ± 0.8 (192)	3.6 ± 0.5 (118)	0.92 ± 0.23 (35)	2.7 ± 0.3
20-39	8.7 ± 0.7 (178)	6.9 ± 0.5 (133)	1.4 ± 0.3 (38)	0.31 ± 0.16 (7)	1.0 ± 0.3
40-59	6.5 ± 0.8 (104)	4.4 ± 0.5 (74)	2.0 ± 0.5 (27)	0.09 ± 0.07 (3)	1.1 ± 0.3
60+	4.5 ± 0.8 (77)	3.9 ± 0.7 (66)	0.59 ± 0.11 (11)	(0)	0.29 ± 0.05
Shrimp‡					
1-5	Not Done	Not Done	Not Done	Not Done	Not Done
6-19	6.1 ± 0.7 (254)	4.4 ± 0.6 (167)	1.1 ± 0.2 (41)	0.63 ± 0.13 (46)	1.1 ± 0.2
20-39	6.7 ± 0.9 (141)	5.2 ± 0.6 (110)	0.61 ± 0.24 (12)	0.94 ± 0.26 (19)	1.2 ± 0.3
40-59	5.9 ± 0.8 (92)	4.6 ± 0.6 (71)	0.71 ± 0.26 (13)	0.56 ± 0.26 (8)	0.89 ± 0.27
60+	4.6 ± 0.6 (81)	3.4 ± 0.6 (60)	0.91 ± 0.32 (18)	0.22 ± 0.15 (3)	0.67 ± 0.24
Multiple food sensitization§					
1-5	11.6 ± 1.4 (117)	6.1 ± 1.1 (70)	3.9 ± 0.7 (32)	1.5 ± 0.5 (15)	3.4 ± 0.5
6-19	5.9 ± 0.6 (194)	3.0 ± 0.5 (83)	2.0 ± 0.4 (67)	0.89 ± 0.23 (44)	1.8 ± 0.3
20-39	4.0 ± 0.5 (73)	2.3 ± 0.4 (37)	1.0 ± 0.4 (25)	0.67 ± 0.32 (11)	1.2 ± 0.3
40-59	4.5 ± 0.8 (61)	2.3 ± 0.6 (30)	1.9 ± 0.4 (25)	0.27 ± 0.15 (6)	1.2 ± 0.3
60+	3.1 ± 0.6 (53)	1.9 ± 0.4 (30)	1.2 ± 0.3 (20)	0.05 ± 0.03 (3)	0.65 ± 0.19

*Weighted % ± Standard Error (N).

†Food sensitization: at least one food ≥ 0.35 kU/L.

‡Information only available for ≥6 years.

§Multiple food sensitization: 2 or more foods ≥ 0.35 kU/L.

‖PL, predictive level: for ages 1-5 years, 5 kU/L; for age 6+, cow's milk 15 kU/L, egg white 7 kU/L, peanut 14 kU/L, shrimp 5 kU/L

¶Estimated Clinical FA Rate = 50% of participants with PFA + 95% of participants with LFA.

TABLE E2. Food sensitization prevalence* and clinical FA estimates in the United States (2005-2006) by sex

Characteristic	Sensitization ≥0.35 kU/L	UFA 0.35-2.0 kU/L	PFA 2.0 kU/L-PL‖	LFA ≥PL‖	Estimated clinical FA rate¶
Food sensitization†					
Male	20.4 ± 0.9 (967)	15.0 ± 0.7 (686)	4.0 ± 0.5 (187)	1.4 ± 0.2 (94)	3.3 ± 0.3
Female	13.4 ± 0.9 (762)	10.4 ± 0.6 (581)	2.2 ± 0.4 (133)	0.75 ± 0.24 (48)	1.8 ± 0.3
Milk					
Male	6.7 ± 0.8 (347)	5.7 ± 0.6 (312)	1.0 ± 0.3 (32)	0.02 ± 0.01 (3)	0.50 ± 0.15
Female	4.8 ± 0.5 (303)	4.3 ± 0.4 (269)	0.44 ± 0.13 (30)	0.08 ± 0.08 (4)	0.30 ± 0.09
Egg					
Male	4.0 ± 0.5 (190)	3.6 ± 0.4 (166)	0.20 ± 0.09 (12)	0.17 ± 0.08 (12)	0.27 ± 0.10
Female	3.8 ± 0.5 (181)	3.5 ± 0.5 (161)	0.28 ± 0.09 (14)	0.06 ± 0.03 (6)	0.20 ± 0.06
Peanut					
Male	10.0 ± 0.8 (481)	7.1 ± 0.5 (312)	2.4 ± 0.4 (130)	0.56 ± 0.12 (39)	1.7 ± 0.2
Female	5.2 ± 0.5 (291)	3.7 ± 0.4 (197)	1.4 ± 0.3 (78)	0.14 ± 0.04 (16)	0.83 ± 0.17
Shrimp‡					
Male	7.4 ± 0.5 (329)	5.4 ± 0.4 (233)	1.2 ± 0.2 (49)	0.74 ± 0.17 (47)	1.3 ± 0.2
Female	4.6 ± 0.5 (239)	3.6 ± 0.4 (175)	0.42 ± 0.12 (35)	0.52 ± 0.18 (29)	0.70 ± 0.19
Multiple food sensitization§					
Male	5.7 ± 0.5 (290)	3.0 ± 0.3 (134)	1.9 ± 0.3 (100)	0.83 ± 0.21 (56)	1.7 ± 0.3
Female	3.9 ± 0.5 (208)	2.2 ± 0.4 (116)	1.5 ± 0.3 (69)	0.24 ± 0.09 (23)	1.0 ± 0.2

*Weighted % ± SE (N).
†Food sensitization: at least 1 food ≥0.35 kU/L.
‡Information only available for participants ≥6 years.
§Multiple food sensitization: 2 or more foods ≥0.35 kU/L.
‖PL, Predictive level: for ages 1-5 years, 5 kU/L; for age 6+ years, cow's milk 15 kU/L, egg white 7 kU/L, peanut 14 kU/L, shrimp 5 kU/L.
¶Estimated clinical FA rate = 50% of participants with PFA + 95% of participants with LFA.

TABLE E3. Food sensitization prevalence* and clinical FA estimates in the United States (2005-2006) by race/ethnicity

Characteristic	Sensitization ≥0.35 kU/L	UFA 0.35-2.0 kU/L	PFA 2.0 kU/L-PL‖	LFA ≥PL‖	Estimated clinical FA rate¶
Food sensitization†					
Non-Hispanic white	13.8 ± 0.7 (478)	10.5 ± 0.6 (373)	2.7 ± 0.4 (87)	0.63 ± 0.16 (18)	1.9 ± 0.3
Non-Hispanic black	27.0 ± 1.2 (617)	17.9 ± 1.0 (403)	6.1 ± 0.7 (135)	3.0 ± 0.5 (79)	5.9 ± 0.6
Hispanic	21.2 ± 1.4 (545)	17.0 ± 1.2 (419)	3.1 ± 0.4 (87)	1.2 ± 0.3 (39)	2.7 ± 0.3
Other	22.3 ± 4.0 (89)	18.4 ± 3.6 (72)	2.1 ± 0.6 (11)	1.9 ± 0.9 (6)	2.8 ± 1.0
Milk					
Non-Hispanic white	5.2 ± 0.6 (193)	4.4 ± 0.5 (167)	0.75 ± 0.24 (25)	0.05 ± 0.06 (1)	0.43 ± 0.13
Non-Hispanic black	7.6 ± 0.9 (209)	6.5 ± 0.8 (185)	1.0 ± 0.3 (20)	0.10 ± 0.05 (4)	0.58 ± 0.14
Hispanic	6.5 ± 0.4 (213)	6.2 ± 0.4 (198)	0.24 ± 0.05 (13)	0.04 ± 0.03 (2)	0.16 ± 0.04
Other	6.4 ± 2.1 (35)	5.9 ± 1.9 (31)	0.47 ± 0.26 (4)	(0)	0.23 ± 0.13
Egg					
Non-Hispanic white	3.9 ± 0.4 (136)	3.7 ± 0.4 (127)	0.16 ± 0.08 (5)	0.09 ± 0.06 (4)	0.17 ± 0.07
Non-Hispanic black	4.0 ± 0.5 (105)	3.5 ± 0.5 (90)	0.44 ± 0.17 (11)	0.09 ± 0.07 (4)	0.31 ± 0.09
Hispanic	3.1 ± 0.3 (107)	2.6 ± 0.3 (91)	0.19 ± 0.11 (6)	0.32 ± 0.14 (10)	0.39 ± 0.15
Other	5.4 ± 1.4 (23)	4.5 ± 1.4 (19)	0.94 ± 0.57 (4)	(0)	0.47 ± 0.28
Peanut					
Non-Hispanic white	5.9 ± 0.5 (191)	4.2 ± 0.4 (134)	1.5 ± 0.3 (49)	0.19 ± 0.08 (8)	0.93 ± 0.15
Non-Hispanic black	13.4 ± 0.9 (300)	8.5 ± 0.6 (177)	4.1 ± 0.6 (96)	0.85 ± 0.24 (27)	2.8 ± 0.4
Hispanic	10.8 ± 1.0 (250)	7.8 ± 0.9 (174)	2.4 ± 0.4 (59)	0.60 ± 0.21 (17)	1.7 ± 0.3
Other	9.1 ± 1.7 (31)	7.5 ± 1.6 (24)	1.1 ± 0.3 (4)	0.53 ± 0.35 (3)	1.0 ± 0.4
Shrimp‡					
Non-Hispanic white	3.8 ± 0.3 (117)	2.9 ± 0.3 (92)	0.63 ± 0.15 (19)	0.33 ± 0.13 (6)	0.63 ± 0.14
Non-Hispanic black	12.8 ± 1.2 (247)	8.3 ± 0.8 (152)	2.2 ± 0.4 (42)	2.3 ± 0.4 (53)	3.3 ± 0.4
Hispanic	8.0 ± 0.8 (171)	7.1 ± 0.8 (137)	0.57 ± 0.11 (20)	0.35 ± 0.13 (14)	0.62 ± 0.12
Other	13.2 ± 4.0 (33)	11.4 ± 3.9 (27)	0.34 ± 0.23 (3)	1.4 ± 1.0 (3)	1.5 ± 0.9
Multiple food sensitization§					
Non-Hispanic white	3.9 ± 0.4 (128)	2.1 ± 0.3 (69)	1.5 ± 0.3 (50)	0.26 ± 0.11 (9)	1.0 ± 0.2
Non-Hispanic black	7.9 ± 0.8 (186)	3.3 ± 0.5 (77)	3.1 ± 0.4 (67)	1.5 ± 0.4 (42)	3.0 ± 0.5
Hispanic	5.5 ± 0.5 (160)	3.0 ± 0.4 (87)	1.6 ± 0.4 (48)	0.82 ± 0.23 (25)	1.6 ± 0.2
Other	7.3 ± 2.5 (24)	5.8 ± 1.9 (17)	0.36 ± 0.20 (4)	1.1 ± 0.7 (3)	1.2 ± 0.7

*Weighted % ± SE (N).

†Food sensitization: at least 1 food ≥0.35 kU/L.

‡Information only available for participants ≥6 years.

§Multiple food sensitization: 2 or more foods ≥0.35 kU/L.

‖PL, Predictive level: for ages 1-5 years, 5 kU/L; for age 6+ years, cow's milk 15 kU/L, egg white 7 kU/L, peanut 14 kU/L, shrimp 5 kU/L.

¶Estimated clinical FA rate = 50% of participants with PFA + 95% of participants with LFA.

TABLE E4. Food sensitization prevalence* and clinical FA estimates in the United States (2005-2006) by poverty income ratio

Characteristic	Sensitization ≥0.35 kU/L	UFA 0.35-2.0 kU/L	PFA 2.0 kU/L-PL‖	LFA ≥PL‖	Estimated clinical FA rate¶
Food sensitization†					
≤1.3	19.0 ± 1.1 (593)	14.4 ± 0.9 (443)	3.4 ± 0.3 (96)	1.3 ± 0.2 (54)	2.9 ± 0.3
1.3-3.5	17.3 ± 1.0 (653)	13.0 ± 0.7 (480)	3.0 ± 0.4 (114)	1.3 ± 0.4 (59)	2.8 ± 0.4
>3.5	15.3 ± 1.0 (401)	11.6 ± 0.8 (288)	3.0 ± 0.5 (90)	0.64 ± 0.19 (23)	2.1 ± 0.3
Milk					
≤1.3	7.6 ± 0.8 (258)	6.7 ± 0.7 (233)	0.89 ± 0.26 (23)	0.04 ± 0.03 (2)	0.48 ± 0.12
1.3-3.5	5.1 ± 0.7 (225)	4.5 ± 0.6 (202)	0.60 ± 0.19 (20)	0.02 ± 0.01 (3)	0.32 ± 0.10
>3.5	5.4 ± 0.7 (135)	4.6 ± 0.7 (117)	0.69 ± 0.24 (16)	0.10 ± 0.09 (2)	0.44 ± 0.15
Egg					
≤1.3	3.7 ± 0.5 (119)	3.3 ± 0.4 (108)	0.35 ± 0.18 (9)	0.03 ± 0.02 (2)	0.20 ± 0.11
1.3-3.5	3.1 ± 0.4 (122)	2.7 ± 0.4 (105)	0.16 ± 0.06 (7)	0.20 ± 0.11 (10)	0.27 ± 0.11
>3.5	4.5 ± 0.6 (100)	4.3 ± 0.7 (89)	0.21 ± 0.11 (6)	0.05 ± 0.03 (5)	0.16 ± 0.06
Peanut					
≤1.3	7.9 ± 0.6 (224)	5.0 ± 0.5 (142)	2.4 ± 0.4 (60)	0.58 ± 0.16 (22)	1.7 ± 0.2
1.3-3.5	7.9 ± 0.5 (299)	6.0 ± 0.3 (211)	1.6 ± 0.3 (68)	0.38 ± 0.16 (20)	1.1 ± 0.2
>3.5	7.1 ± 0.8 (208)	5.0 ± 0.6 (129)	1.9 ± 0.5 (68)	0.21 ± 0.08 (11)	1.2 ± 0.2
Shrimp‡					
≤1.3	7.1 ± 0.6 (202)	5.4 ± 0.5 (143)	0.92 ± 0.29 (28)	0.80 ± 0.24 (31)	1.2 ± 0.3
1.3-3.5	7.1 ± 0.8 (226)	5.2 ± 0.5 (156)	1.1 ± 0.3 (37)	0.86 ± 0.24 (33)	1.4 ± 0.3
>3.5	4.4 ± 0.5 (115)	3.6 ± 0.4 (91)	0.47 ± 0.16 (15)	0.34 ± 0.18 (9)	0.56 ± 0.17
Multiple food sensitization§					
≤1.3	5.3 ± 0.3 (171)	2.5 ± 0.2 (81)	2.2 ± 0.2 (64)	0.60 ± 0.13 (26)	1.7 ± 0.2
1.3-3.5	4.4 ± 0.5 (169)	2.3 ± 0.3 (87)	1.3 ± 0.3 (48)	0.72 ± 0.29 (34)	1.3 ± 0.3
>3.5	4.6 ± 0.7 (121)	2.7 ± 0.5 (62)	1.7 ± 0.4 (45)	0.26 ± 0.08 (14)	1.1 ± 0.2

*Weighted % ± SE (N).

†Food sensitization: at least 1 food ≥0.35 kU/L.

‡Information only available for participants ≥6 years.

§Multiple food sensitization: 2 or more foods ≥0.35 kU/L.

‖PL, Predictive level: for ages 1-5 years, 5 kU/L; for age 6+ years, cow's milk 15 kU/L, egg white 7 kU/L, peanut 14 kU/L, shrimp 5 kU/L.

¶Estimated clinical FA rate = 50% of participants with PFA + 95% of participants with LFA.

TABLE E5. Food sensitization prevalence* and clinical FA estimates in the United States (2005-2006) by household education

Characteristic	Sensitization ≥0.35 kU/L	UFA 0.35-2.0 kU/L	PFA 2.0 kU/L-PL‖	LFA ≥PL‖	Estimated clinical FA rate¶
Food sensitization†					
High school or less	17.3 ± 0.6 (928)	13.0 ± 0.4 (687)	3.2 ± 0.2 (163)	1.2 ± 0.2 (78)	2.7 ± 0.3
Above high school	16.5 ± 0.9 (744)	12.4 ± 0.7 (530)	3.1 ± 0.6 (153)	1.0 ± 0.2 (61)	2.5 ± 0.4
Milk					
High school or less	5.7 ± 0.5 (367)	4.9 ± 0.3 (332)	0.77 ± 0.28 (32)	0.02 ± 0.01 (3)	0.41 ± 0.13
Above high school	5.9 ± 0.7 (272)	5.2 ± 0.6 (238)	0.66 ± 0.19 (30)	0.08 ± 0.07 (4)	0.41 ± 0.13
Egg					
High school or less	3.4 ± 0.5 (186)	3.1 ± 0.5 (169)	0.22 ± 0.10 (11)	0.06 ± 0.03 (6)	0.17 ± 0.06
Above high school	4.4 ± 0.5 (183)	4.0 ± 0.5 (156)	0.26 ± 0.09 (15)	0.17 ± 0.08 (12)	0.29 ± 0.08
Peanut					
High school or less	7.7 ± 0.5 (381)	5.5 ± 0.4 (257)	1.9 ± 0.2 (99)	0.33 ± 0.09 (25)	1.3 ± 0.1
Above high school	7.4 ± 0.7 (359)	5.1 ± 0.5 (226)	1.9 ± 0.4 (105)	0.32 ± 0.08 (28)	1.3 ± 0.2
Shrimp‡					
High school or less	6.9 ± 0.5 (334)	5.1 ± 0.4 (236)	1.0 ± 0.2 (50)	0.84 ± 0.20 (48)	1.3 ± 0.2
Above high school	5.2 ± 0.5 (213)	4.0 ± 0.4 (152)	0.70 ± 0.15 (34)	0.48 ± 0.17 (27)	0.81 ± 0.16
Multiple food sensitization§					
High school or less	4.8 ± 0.4 (272)	2.5 ± 0.3 (138)	1.8 ± 0.2 (93)	0.49 ± 0.11 (41)	1.4 ± 0.2
Above high school	4.8 ± 0.6 (217)	2.6 ± 0.4 (106)	1.6 ± 0.4 (75)	0.54 ± 0.18 (36)	1.3 ± 0.3

*Weighted % ± SE (N).
†Food sensitization: at least 1 food ≥0.35 kU/L.
‡Information only available for participants ≥6 years.
§Multiple food sensitization: 2 or more foods ≥0.35 kU/L.
‖PL, Predictive level: for ages 1-5 years, 5 kU/L; for age 6+ years, cow's milk 15 kU/L, egg white 7 kU/L, peanut 14 kU/L, shrimp 5 kU/L.
¶Estimated clinical FA rate = 50% of participants with PFA + 95% of participants with LFA.

TABLE E6. Adjusted ORs* for asthma risk

	Diagnosed asthma†	Current asthma‡	ED visit for asthma§
UFA	1.5 (1.3-1.7)	1.8 (1.0-3.4)	0.9 (0.4-1.9)
PFA	2.1 (1.3-3.5)	3.8 (1.8-8.3)	1.0 (0.5-2.0)
LFA	1.6 (0.8-3.1)	3.8 (1.5-9.7)	6.9 (2.4-19.7)
No food sensitization	1.0	1.0	1.0

*Adjusted model: asthma outcome = food sensitization + inhalant sensitization + age + sex + race + PIR.
†Diagnosed asthma modeled against all participants without asthma.
‡Current asthma modeled against all participants diagnosed with asthma but not currently having asthma.
§ED asthma modeled against all participants diagnosed with asthma or currently having asthma but not having an ED visit related to asthma.

TABLE E7. Adjusted OR* for eczema and hay fever

Food sensitization/FA	Diagnosed eczema†	Diagnosed hay fever‡
UFA	0.9 (0.6-1.3)	1.3 (0.9-1.7)
PFA	0.8 (0.5-1.3)	2.0 (1.4-2.8)
LFA	1.7 (0.9-3.3)	0.7 (0.2-2.6)
No food sensitization	1.0	1.0

*Adjusted model: outcome = food sensitization + inhalant sensitization + age + sex + race + PIR.
†Diagnosed eczema modeled against all participants without eczema.
‡Diagnosed hay fever modeled against all participants without hay fever.