

Original Article

Egg Allergy in US Children

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What is already known about this topic? Past studies found that egg allergy affects 0.8% of US children; further characterization of egg allergy among US children is necessary to help create appropriate management guidelines.

What does this article add to our knowledge? Egg allergy prevalence is 0.9% among all children and 1.3% among children <5 years. Among egg-allergic children, 64.2% reported baked egg tolerance and 60.2% had allergy to other foods. In addition, baked egg tolerance was associated with a significantly higher quality of life.

How does this study impact current management guidelines? Increased efforts are needed to ensure that children with egg allergy are appropriately evaluated to assess for comorbid food allergy, other atopic disease, and baked egg tolerance.

BACKGROUND: Egg allergy is common in young children (<5 years) and has significant negative impacts on quality of life. **OBJECTIVE:** The objective of this study was to characterize egg allergy prevalence, severity, baked egg tolerance, and other associated factors in a large US cohort.

METHODS: A national cross-sectional survey was administered from October 2015 to September 2016, resulting in complete parent-proxy responses for 38,408 children. Weighted proportions were estimated to compare egg allergy prevalence and characteristics between key subpopulations.

RESULTS: The overall prevalence of current, convincingly egg allergy was 0.9% among all children and 1.3% among children <5 years. Black children were over-represented among children with egg allergy, accounting for 23.4% (95% confidence interval: 13.1-38.4) of egg-allergic children despite comprising 13.2% (12.3-14.2) of the US pediatric population. Among children with egg allergy, 64.2% reported baked egg tolerance and 60.2% had allergy to other foods, with 29.3% having peanut allergy. Asthma was more prevalent in children with an egg allergy than children with other top 8 food allergies (46.5% [35.8-57.4] vs 33.2% [29.6-37.0], $P < .05$). Among children with current egg allergy,

those with baked egg tolerance reported that their food allergy resulted in significantly reduced psychosocial burden, relative to their baked egg-allergic counterparts ($M = 3.1$ [2.9-3.3] vs $M = 3.7$ [3.5-3.9]).

CONCLUSIONS: Egg allergy is common amongst young children. Nearly two-thirds of children with egg allergy reported baked egg tolerance. Increased efforts are needed to ensure that children with egg allergy are appropriately evaluated as many have comorbid allergic disease and determination of baked egg tolerance may improve quality of life. © 2020 Published by Elsevier Inc. on behalf of the American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2020; ■:■-■)

Key words: Food allergy; Atopy; Egg allergy; Prevalence; Pediatrics

Food allergies affect 7.6% of children in the United States¹ and are associated with substantial economic burden² as well as significant decreases in quality of life (QoL) for children and their caregivers.³ Past studies report that allergy to hen's egg

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Abbreviations used

EAI- Epinephrine autoinjector
 ED- Emergency department
 FAIM- Food Allergy Independent Measure
 QoL- Quality of life
 SPT- Skin prick testing

specifically affects 0.8% of all children¹ and 1.3% of children under <5 years, making it the second most common allergy in this cohort after cow's milk allergy.^{1,4,5} Furthermore, in a recent evaluation of anaphylaxis in infants <12 months of age, egg was found to be the most common food trigger.⁶ Although the severity of reactions to egg can vary, past studies have found that in children with asthma, anaphylaxis triggered by egg can be life threatening.⁷⁻⁹

There are 5 known egg proteins that have been implicated in IgE-mediated reactions.⁴ As some of these proteins are known to become denatured when heated,¹⁰ a subset of patients with egg allergy can tolerate egg that has been extensively heated ("baked egg" heated $\geq 350^\circ$ for >30 minutes).¹⁰⁻¹² In previous studies, tolerance to baked egg has been reported in 60% to 80% of children who have allergy to raw or lightly cooked egg.¹³ There is also some evidence that suggests that consumption of baked egg may increase tolerance to all forms of egg by inducing immunologic changes.¹⁰ For example, baked egg-allergic infants were much more likely to have persistent egg allergy (odds ratio >5) at 24 months, whereas infants who consumed baked egg between 12 and 24 months had a positive association with egg allergy resolution by 24 months.¹⁴

Among the top 9 food allergens (peanut, tree nut, milk, shellfish, egg, wheat, soy, fish, and sesame), egg is one of the most commonly outgrown. One past study showed 50% of US children outgrowing the allergy by age 6,¹⁵ whereas another study reported that only 12% outgrew their egg allergy by age 6 but 68% did so by age 16.¹⁶ Furthermore, the HealthNuts cohort reported remarkably high rates of allergy to raw egg at 1 year (9.5% of their population-based cohort), which dropped to 1.2% among the same children when reassessed at 4 years.¹⁷ For those who do not outgrow their allergy, avoidance of egg is the main form of management that is challenging as egg is a common ingredient in many foods.⁴ Further characterization of egg allergy severity, baked-egg tolerance, and allergy-related QoL among US children is needed. The goal of this study is to evaluate the prevalence, symptoms, and severity of egg allergy with a specific focus on those with baked egg tolerance and other associations via a large, population-based study of US households.

METHODS

A US population-based, cross-sectional survey was administered to a sample of 53,575 US households from October 2015 to September 2016. The study protocol was approved by the institutional review boards of Northwestern University and NORC at the University of Chicago.

Study participants and recruitment

Eligible study participants included adults (≥ 18 years old) who resided in a US household and able to complete the survey in English or Spanish via web or telephone. Similar to our 2009 to 2010 national survey,¹⁸ this study relied on a nationally representative

household panel to support population-level inference. Study participants were first recruited from NORC at the University of Chicago's nationally representative, probability-based AmeriSpeak Panel, with a survey completion rate of 51.2% (7218 responses of 14,095 invitees). Each child was assigned a base, study-specific sampling weight equal to his or her responding parent's nonresponse adjusted AmeriSpeak sampling weight. Child-specific weights were further adjusted to account for random selection of up to 3 children/household and raked to external pediatric population totals. Parental weights were reconciled with external population totals associated with age, sex, education, race/ethnicity, housing tenure, telephone status, and Census Division via iterative proportional fitting to improve external validity. To increase precision of population parameter estimates, the population-weighted AmeriSpeak responses were then augmented via iterative proportional fitting with calibration-weighted, non-probability-based responses obtained through Survey Sampling International. The complex survey development, sampling, weighting, and analysis procedures used here are detailed in the paper by Gupta et al.¹

Outcome measures

The primary outcome measure for the present study was the prevalence of pediatric egg allergy. Parent-reported egg allergies were only considered convincing if the most severe reaction reported to that food included at least 1 symptom on the stringent symptom list developed by our expert panel, even if such allergies were reported to be physician-diagnosed (Figure 1). Convincing egg allergies for which parents reported a doctor's diagnosis were considered physician-confirmed. A severe reaction history to egg was indicated by parent report of multiple specific stringent symptoms occurring within 2 or more of the following 4 organ systems (skin/oral mucosa, gastrointestinal, cardiovascular, and respiratory) in response to the question "Think back to the most severe allergic reaction to egg that your child has ever had. What were [his/her] symptoms?" Both current and outgrown egg allergies were assessed, as was the ability to tolerate baked egg. Complete description of survey development, testing, and categorization of allergy type has been published previously.¹ The text of survey items used in the present analyses are provided in Appendix A (available in this article's Online Repository at www.jaci-inpractice.org).

To assess the psychosocial burden of living with a food allergy, the food allergy independent measure (FAIM; provided in Appendix B, available in this article's Online Repository at www.jaci-inpractice.org) was administered to all respondents reporting a current food allergy. This validated parent-report measure comprises 6 questions, which are scored on a 7-point scale (1-7) with higher scores indicative of greater psychosocial burden and lower QoL.¹⁹ FAIM scores for the parent-proxy child form (<13 years) and parent-proxy teen form (13-17 years) were calculated as described by the scale authors.¹⁹

Statistical analysis

Complex survey-weighted means and proportions were calculated to estimate the US population prevalence of pediatric egg allergy and other characteristics using STATA 14 svy: prefix. Cluster robust standard errors accounted for clustering of multiple children within the same household. The FAIM exhibited excellent internal consistency (Cronbach's $\alpha > 0.8$), and a confirmatory factor analysis of the FAIM concluded that a 2-factor solution exhibited excellent fit to the data (confirmatory fit index ≥ 0.950 ; root mean square error of approximation < 0.08).²⁰ Two-sided hypothesis tests were used, with 2-sided $P < .05$ considered to be statistically significant.

- Skin and/or Oral Mucosa Symptoms
 - Hives*
 - Itching
 - Rash
 - Swelling* (except lip and/or tongue swelling)
 - Lip and/or tongue swelling*
 - Difficulty swallowing*
 - Hoarse voice
 - Itchy mouth
 - Throat tightening*
 - Mouth or throat tingling
 - Other: _____
- Respiratory Symptoms
 - Chest tightening*
 - Nasal congestion
 - Repetitive cough
 - Trouble breathing*
 - Wheezing*
 - Other: _____
- Gastrointestinal Symptoms
 - Belly pain
 - Cramps
 - Diarrhea
 - Nausea
 - Vomiting*
 - Other: _____
- Cardiovascular and/or Heart Symptoms
 - Chest pain*
 - Rapid heart rate*
 - Fainting, dizziness, or feeling light headed*
 - Low blood pressure*
 - Other: _____
- Other Symptoms
 - Anxiety
 - Feeling of impending doom
 - Headache
 - Other: _____

FIGURE 1. Specific reaction symptoms used to characterize “convincing” egg allergy. List of allergic reaction symptoms highlighting stringent symptoms indicative of convincing food allergy. All symptoms listed are offered as answer choices in the survey. Symptoms in bold italics comprised our expert panel’s stringent symptom list. A convincing food allergy required the patient report of at least 1 stringent symptom during the child’s most severe reaction to a given food. A severe reaction consisted of a parent report of at least 2 stringent symptoms from 2 different body systems during a child’s most severe reaction to a given food.

RESULTS

Egg allergy prevalence and demographic characteristics

Across the United States, 53,575 households were surveyed and complete parent-proxy responses were collected for 38,408 children. The overall prevalence of convincing egg allergy was 0.9% in all children and 1.3% of young children (<5 years). Demographic characteristics of parent-reported egg allergy were evaluated (Table I) and showed that black children made up a larger portion of children with an egg allergy compared with the proportion of black children in the general population (23.4% [13.1-38.4] vs 13.2% [12.3-14.2], $P < .05$). Conversely, white, non-Hispanic children made up a smaller proportion (40.8% [31.8-50.5] vs 52.8% [51.2-54.4], $P < .05$). Compared with children with other top 8 food allergies, a greater proportion of egg-allergy patients were young children 1 to 2 years of age (19.6% [12.7-29.1] vs 12.5% [9.4-16.4]) and 3 to 5 years of age (22.3 [16.4-29.6] vs 15.7 [13.0-18.8]). The age-specific prevalence of egg allergy peaks between 1 and 2 years of age, with 2% meeting convincing symptom-report criteria, and gradually declines across childhood, dropping to 0.5% of 14- to 17-year olds with convincing egg allergy (Figure 2).

Comorbid atopic conditions

When compared with the general population, egg-allergic children were more likely to have atopic comorbid conditions such as eczema (19.0% [12.2-28.2] vs 5.9% [5.3-6.5], $P < .05$), asthma (46.5% [35.8-57.4] vs 12.2% [11.4-13.0], $P < .05$), environmental allergies (38.2% [30.7-46.4] vs 12.8% [12.0-13.6], $P < .05$), and eosinophilic esophagitis (1.2% [0.5-2.7] vs 0.2% [0.1-0.2], $P < .05$). Asthma was more prevalent in egg-allergic children than children with other top 8 food allergies (46.5% [35.8-57.4] vs 33.2% [29.6-37.0], $P < .05$).

Baked egg tolerance

Baked egg tolerance was reported among 64.2% of the children with egg allergy. Children whose parents reported that they could not tolerate baked egg were more likely to be allergic to milk than children with baked egg tolerance (51.3% [29.5-72.6] vs 26.3% [19.6-34.4], $P = .03$). Children whose parents reported that they could not tolerate baked egg were also somewhat more likely to be allergic to multiple food allergens relative to children with baked egg tolerance (81.8% [69.0-90.1] vs 72.4% [64.3-79.2], $P = .18$). Differences in reaction symptomatology and outcomes between egg-allergic children who can versus cannot tolerate baked egg products are summarized in Figure 3.

Egg allergy and other major food allergens

Amongst egg-allergic children, 60.2% had a comorbid allergy with one of the other top 8 food allergens, with milk (35.2% [24.6-47.5]) and peanut (29.3% [22.0-37.7]) being the most common (Table II). Sesame (6.1% [3.5-10.3] vs 3.0% [2.2-4.2], $P = .030$) and soy (13.2% [7.3-22.9] vs 6.9% [5.0-9.5], $P = .05$) allergies were roughly twice as prevalent among egg-allergic children compared with children with the other top 8 food allergens. Among children with a parent-reported egg-allergic reaction occurring within the first year, prevalence rates of convincing peanut allergy were 21.5% (12.1-35.1), whereas only 9.8% (6.3-14.9) of children with reactions to cow’s milk in the first year of life had convincing peanut allergy. However, children with reported soy or wheat-allergic reactions—the other most common food allergies reported during the first year of life—had a comparable prevalence of peanut allergy with those reporting early egg allergy (soy = 18.9% [9.7-33.0]; wheat = 26.1% [12.1-47.5]).

TABLE I. Demographics and comorbid allergic disease

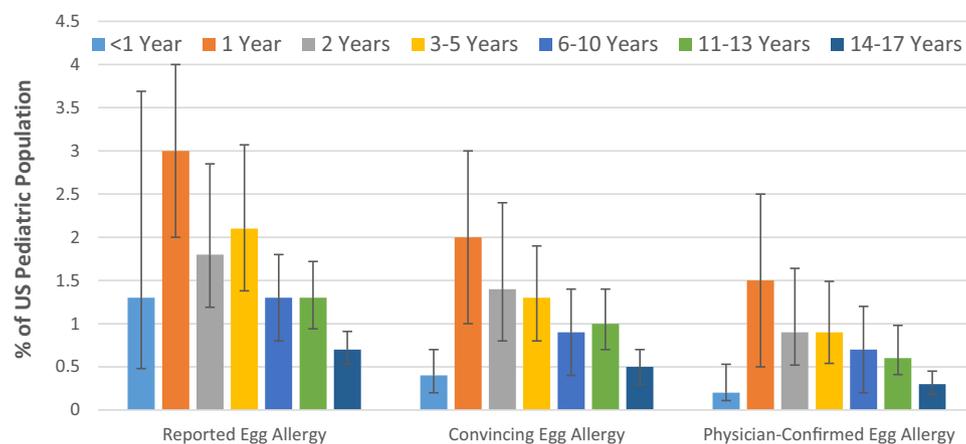
| Variable | All children (95% CI) | Children with egg allergy (95% CI) | Children with other allergies* (95% CI) |
|----------------------------------|-----------------------|------------------------------------|---|
| Race/ethnicity | | | |
| Asian, non-Hispanic | 3.2 (2.8-3.7) | 3.6 (1.8-6.9) | 2.8 (2.1-3.6) |
| Black, non-Hispanic | 13.2 (12.3-14.2) | 23.4 (13.1-38.4) | 15.0 (12.7-17.7) |
| White, non-Hispanic | 52.8 (51.2-54.4) | 40.8 (31.8-50.5) | 48.3 (44.3-52.2) |
| Hispanic | 24.1 (22.5-25.7) | 22.6 (15.9-31.0) | 27.6 (23.6-31.9) |
| Multiple/other | 6.6 (6.1-7.3) | 9.6 (5.6-16.1) | 6.9 (5.4-8.7) |
| Born in the United States | | | |
| Yes | 97.7 (97.3-98.0) | 95.1 (88.9-97.9) | 98.7 (98.0-99.2) |
| No | 2.3 (2.0-2.7) | 4.9 (2.1-11.2) | 1.3 (.8-2.0) |
| Sex | | | |
| Female | 48.9 (47.8-50.0) | 47.9 (37.5-58.6) | 54.9 (42.2-49.7) |
| Male | 51.1 (50.0-52.2) | 52.1 (41.4-62.6) | 54.1 (50.3-57.8) |
| Age (y) | | | |
| <1 | 5.3 (4.8-5.9) | 2.2 (1.2-4.0) | 2.1 (1.5-3.0) |
| 1-2 | 10.6 (10.0-11.3) | 19.6 (12.7-29.1) | 12.5 (9.4-16.4) |
| 3-5 | 16.2 (15.5-17.0) | 22.3 (16.4-29.6) | 15.7 (13.0-18.8) |
| 6-10 | 27.9 (26.9-28.8) | 26.3 (19.9-33.9) | 30.7 (27.4-34.2) |
| 11-13 | 16.6 (15.9-17.4) | 17.6 (12.2-24.8) | 16.9 (14.1-20.0) |
| 14-17 | 23.4 (22.4-24.4) | 12.0 (8.4-16.8) | 22.2 (19.3-25.3) |
| Household income (\$) | | | |
| <25,000 | 16.1 (14.9-17.3) | 12.7 (7.1-21.8) | 14.9 (12.2-18.1) |
| 25,000-49,000 | 22.2 (20.9-23.5) | 20.3 (14.1-28.3) | 22.5 (19.5-25.9) |
| 50,000-99,999 | 31.1 (29.8-32.5) | 38.7 (28.0-50.6) | 32.0 (28.8-35.4) |
| 100,000-149,000 | 19.2 (18-20.5) | 21.3 (15.7-28.2) | 20.8 (17.2-25.0) |
| ≥150,000 | 11.4 (10.3-12.6) | 7.0 (4.3-11.3) | 9.7 (7.5-12.5) |
| Other conditions | | | |
| Asthma | 12.2 (11.4-13.0) | 46.5 (35.8-57.4) | 33.2 (29.6-37.0) |
| Eczema | 5.9 (5.3-6.5) | 19.0 (12.2-28.2) | 15.7 (12.7-19.1) |
| Environmental allergies | 12.8 (12.0-13.6) | 38.2 (30.7-46.4) | 30.3 (27.0-34.0) |
| Eosinophilic esophagitis | 0.2 (0.1-0.2) | 1.2 (0.5-2.7) | 0.7 (.4-1.2) |

CI, Confidence interval.

These are weighted proportions.

Bold indicates statistical significance ($P < .05$).

*The other top 8 food allergies: peanut, tree nut, milk, wheat, soy, fish, shellfish, sesame.

**FIGURE 2.** Age-specific prevalence of current egg allergy by food allergy category.

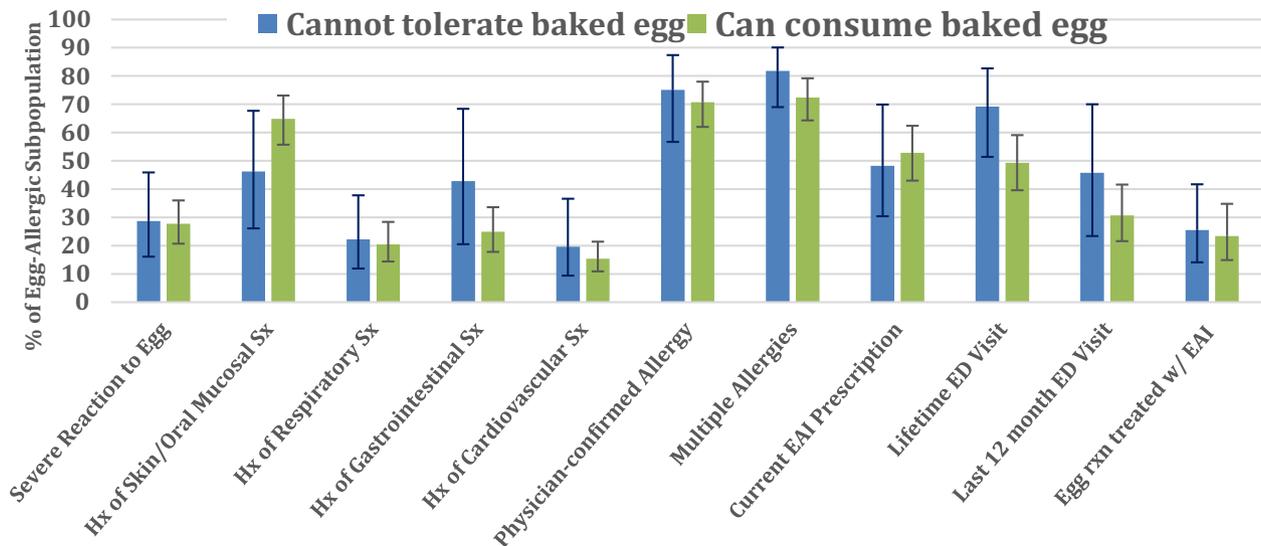


FIGURE 3. Comparison of outcomes between baked egg–tolerant versus baked egg–allergic children. *ED*, Emergency department; *Hx*, history; *Rxn*, reaction; *Sx*, symptom; *W/EAI*, with epinephrine autoinjector.

TABLE II. Comorbid food allergies in children with egg allergy

| Variable | Among children with egg allergy | Among children with top 8 food allergies besides egg* | <i>P</i> value |
|----------------------------------|---------------------------------|---|----------------|
| Baked egg tolerance | 64.2 (51.9-74.9) | — | |
| Top 8 food allergy (besides egg) | 60.2 (53.0-67.0) | — | |
| Comorbid food allergies | | | |
| Peanut | 29.3 (22.0-37.7) | 37.9 (34.2-41.7) | .07 |
| Milk | 35.2 (24.6-47.5) | 31.4 (27.6-35.5) | .53 |
| Shellfish | 15.9 (10.8-23.0) | 22.2 (19.4-25.3) | .1 |
| Tree nuts | 17.5 (12.3-24.2) | 20.3 (17.8-23.1) | .41 |
| Wheat | 11.5 (7.5-17.1) | 7.7 (5.6-10.6) | .14 |
| Soy | 13.2 (7.3-22.9) | 6.9 (5.0-9.5) | .05 |
| Fin fish | 11.7 (7.0-18.9) | 8.5 (6.6-10.8) | .25 |
| Sesame | 6.1 (3.5-10.3) | 3.0 (2.2-4.2) | .03 |

Bold indicates statistical significance ($P < .05$).

*The other top 8 food allergies: peanut, tree nut, milk, wheat, soy, fish, shellfish, sesame.

Reaction severity

Overall, 28.1% (21.5-36.0) children with egg allergy reported having experienced a severe allergic reaction (allergic symptoms in egg-allergic children compared with children with other allergies are summarized in Table E1, available in this article's Online Repository at www.jaci-inpractice.org). Egg-allergic children were more likely to have gone to the emergency department (ED) in their lifetime for any food-allergy reaction (not necessarily a reaction to egg), than children with the other top 8 food allergies (56.4% [46.6-65.8] vs 43.7% [39.9-47.6], $P = .02$). This also held true for ED visits within the last 12 months for egg-allergic children versus children with allergy to the other top 8 food allergens (36.1% [25.0-48.9] vs 18.0% [14.7-21.8], $P = .001$). Children with baked egg tolerance were less likely to report food allergy–related ED visits than their

baked egg–allergic counterparts—both over their lifetime (49.3% [39.6-59.1] vs 48.2% [27.1-69.9], $P = .05$) and within the last year (30.7% [21.6-41.6] vs 45.8% [23.4-70.0], $P = .26$). Allergic symptoms in each cohort are summarized in Table E2 (available in this article's Online Repository at www.jaci-inpractice.org).

Physician diagnosis

A physician diagnosis did not occur in 27.8% of children with convincing egg allergy. Egg-allergic children with baked egg tolerance lacked a physician diagnosis 25% of the time versus 29% in egg-allergic children without baked egg tolerance ($P = .63$). Furthermore, 34% of egg-allergic children with a history of severe reactions and 25% of egg-allergic children without a history of severe reactions lacked a physician

TABLE III. Outgrown egg allergy

| Variable | Characteristics of children who outgrew an egg allergy* |
|-------------------------------------|---|
| Age (y) | |
| 1-2 | 4.1 (1.8-8.9) |
| 3-5 | 20.9 (12.1-33.6) |
| 6-10 | 45.8 (31.3-60.9) |
| 11-13 | 10.2 (6.0-16.8) |
| 14-17 | 18.8 (11.6-29.0) |
| Has multiple current food allergies | 46.3 (27.6-66.0) |
| Baked egg tolerance | 70.5 (58.2-80.4) |
| Race/ethnicity | |
| Asian, non-Hispanic | 4.8 (2.2-10.1) |
| Black, non-Hispanic | 4.8 (2.1-10.5) |
| White, non-Hispanic | 53.3 (38.6-67.5) |
| Hispanic | 30.0 (16.6-48.0) |
| Multiple/other | 7.1 (3.7-13.2) |
| Sex | |
| Female | 42.4 (28.4-57.6) |
| Male | 57.6 (42.4-71.6) |
| Other conditions | |
| Asthma | 32.2 (21.4-45.3) |
| Eczema | 22.4 (13.6-34.7) |
| Environmental allergies | 30.7 (20.5-43.4) |
| Eosinophilic esophagitis | 4.0 (1.2-12.6) |
| Organ system involved | |
| Skin/mucosal tissue | 76.2 (57.0-88.5) |
| GI | 26.9 (14.2-45.1) |
| Respiratory | 16.5 (9.1-28.0) |
| Cardio | 7.6 (4.0-13.7) |

GI, Gastrointestinal.

*Comparison of children with egg allergy and the children with top 9 allergies besides egg.

diagnosis ($P = .24$). There were no differences found in those with a physician diagnosis versus those without with respect to mean age, sex, race, or ethnicity. Of the children with convincing egg allergy whose allergy was physician-diagnosed, 61.7% reported skin prick testing (SPT), 46.7% serum IgE blood testing, and 20.9% reported receiving an oral egg challenge.

Both reporting a current epinephrine autoinjector (EAI) prescription (32.2% [21.0-45.9] vs 58.4% [43.4-72.0], $P < .01$) and a history of EAI use to treat an egg-allergic reaction (13.6% [8.0-22.2] vs 28.1% [18.6-40.1], $P = .02$) were less common among children without physician- versus physician-confirmed egg allergy.

Outgrowth

In this survey, 418 children reported having a current convincing egg allergy and 152 reported having outgrown a convincing egg allergy (Table III). Amongst children who had outgrown an egg allergy, 70.5% could tolerate baked egg before outgrowing their allergy (vs 64% with current egg allergy) and 46.3% had multiple concurrent food allergies compared with 75.8% (68.7-81.7) with current egg allergy. In comparison with children with a current egg allergy, children who outgrew their egg allergy were somewhat less likely to have physician-diagnosed asthma (46.5% [35.8-57.4] vs 32.2% [21.4-45.3], $P = .09$).

TABLE IV. FAIM scores among egg-allergic children

| | Egg allergic children with baked egg tolerance, mean (95% CI) | Egg allergic children with baked egg allergy, mean (95% CI) |
|-----------|---|---|
| Mean FAIM | 3.1 (2.9-3.3) | 3.7 (3.5-3.9) |
| Q1 | 2.4 (2.1-2.7) | 2.8 (2.1-3.5) |
| Q2 | 2.8 (2.5-3.1) | 3.2 (2.8-3.5) |
| Q3 | 1.8 (1.5-2.1) | 2.0 (1.5-2.4) |
| Q4 | 1.9 (1.6-2.1) | 2.2 (1.8-2.6) |
| Q5 | 2.3 (2.0-2.6) | 3.1 (2.7-3.6) |
| Q6 | 1.6 (1.3-1.8) | 2.9 (2.3-3.3) |

CI, Confidence interval; FAIM, food allergy independent measure.

Food allergy–related quality of life

Children with convincing egg allergy who reported that they could consume baked egg products reported better food allergy–related QoL (assessed by FAIM) relative to baked egg–allergic children ($M_{\text{FAIM}} = 3.13$ vs 3.69; $P < .01$) (Table IV). This difference was also significant when these unadjusted analyses were restricted to children with only egg allergy and no other comorbid food allergies ($M_{\text{FAIM}} = 3.23$ vs 2.64; $P < .01$). Furthermore, these observed differences in FAIM scores remained statistically significant after adjustment for a variety of potential confounders including age, sex, race/ethnicity, income, history of severe reactions to egg, ED visits, physician diagnosis of egg allergy, epinephrine use, having an epinephrine prescription, and country of birth. Survey item–level scores are summarized in Table IV, each of which indicated greater burden among baked egg–allergic children.

DISCUSSION

To our knowledge, this is the first study to comprehensively describe current egg allergy prevalence among children from a large, representative sample of US households. Our study found that egg allergy is a common allergy primarily among young children, affecting 1.3% of children <5 years of age, with disease burden amongst black children and children with comorbid atopic conditions. Overall, egg-allergic children had high rates of comorbid food allergies, with 60.2% reporting an allergy to one of the other top 8 food allergens—primarily peanut and milk. Over one-third of the children with egg allergy reported that they could not tolerate baked egg and reported higher rates of comorbid food allergy and food allergy–related ED visits. Furthermore, those with baked egg tolerance reported better food allergy–related QoL. Thus, although the majority of children with egg allergy reported having a physician diagnosis, greater promotion of physician evaluation, including assessing baked egg tolerance, may be helpful for families managing this food allergy.

Although there are well-acknowledged limitations to cross-sectional parent-report prevalence survey data, it is notable that the present egg allergy prevalence estimates are largely consistent with data from high-quality international cohort studies. For example, our point prevalence estimate of 1.4% among 2-year-old US children is similar to the rate of 1.2% reported among 2-year-old children in the 9-country EuroPrevall consortium.²¹ Our point prevalence estimate of 1.3% among 3- to 5-year olds is also remarkably similar to challenge-confirmed point prevalence estimates among 4-year olds reported from the

Australian population-based HealthNuts study (1.2%),¹⁷ as well as estimates from 4-year-old participants in the Isle of Wight birth cohort (1.1%-1.4%).²² Furthermore, the distribution of prevalence rates across the pediatric age spectrum is consistent with longitudinal data published by Savage,¹⁶ who found that 50% of egg-allergic infants outgrew their egg allergy by age 12 and two-thirds by age 16. This was the case irrespective of the definition used for egg allergy—parent reported, convincing, or physician confirmed. Although US population-based birth cohort studies would provide much-needed validation of the current survey-based prevalence measures, the similarity between prevalence estimates gleaned from the present cross-sectional questionnaire and the aforementioned European and Australian birth cohort studies supports the utility of parent-proxy survey-based approaches to food allergy prevalence estimation in young children.

Egg allergy has been used as an important predictor of atopy among infants and young children. For example, the HealthNuts study also found that egg allergy is associated with 2-fold higher risk for asthma regardless of whether egg allergy was transient or persistent.²³ Similarly, our data support the idea that egg-allergic children may be particularly atopic, given that rates of asthma (46.5% vs 33.2%), eczema (19.0% vs 15.7%), and allergic rhinitis (38.2% vs 30.3%) were all higher among egg-allergic children, relative to children with other top 8 food allergies (Table 1). Furthermore, just over 60% of convincingly egg-allergic children in our study had a comorbid food allergy, with milk and peanut being the most common.

Given that the Learning Early About Peanut criteria use the presence of egg allergy during the first year as an indicator of increased peanut allergy risk, the present study examined the prevalence of peanut allergy in those reporting an egg-allergic reaction by 11 months. Among these individuals, 1 in 5 developed a peanut allergy, a 10-fold increase in risk over those who did not report such reactions. This suggests that egg-allergic reactions during infancy are considerably more predictive of peanut allergy than cow's milk reactions, where only 1 in 10 went on to develop a peanut allergy. However, when all children are considered (not just infants), data show that a lower proportion of egg-allergic children had comorbid peanut allergy than did those with other top 8 allergies. In addition, our data also suggest that early life soy- or wheat-allergic reactions may be similarly predictive of subsequent peanut allergy development, given that convincing peanut allergy was also prevalent among 1 in 5 individuals reporting reactions to either food.

In this study, over 25% of children with egg allergy were reported to have experienced a severe allergic reaction with egg exposure. A recent review of egg allergy studies reported that egg was the trigger for 7% to 12% of pediatric anaphylaxis presentations.²⁴ Specifically, amongst infants, however, a recent study found that egg was the most common food trigger for anaphylaxis, accounting for 38% of the cases.⁶ Notably, children with egg allergy in our study reported more frequent ED visits for food allergy concerns compared with children without egg allergy. Although the survey did not elicit detailed information to determine whether ED visits were specifically to address allergic reactions triggered by egg, these data nevertheless suggest that this population of children may benefit from increased attention and education.

Two-thirds of children with egg allergy in this study reported tolerating baked egg. This is consistent with a prospective study

reporting 63% of children with egg allergies passed an observed baked egg oral challenge.²⁵ In another study, children with known baked egg tolerance were more likely to pass native egg oral food challenge compared with children who could not tolerate baked egg or had not previously been exposed to egg.²⁶ Furthermore, even in those who reacted to raw egg, these reactions occurred at higher doses of raw egg and required epinephrine less often. This is consistent with our findings that children who reported baked egg tolerance had less severe anaphylactic reactions and reduced likelihood of reporting food allergy-related ED visits. Our study also demonstrated that the ability to eat baked egg products is associated with higher food allergy-related QoL and greater likelihood of reporting a previously outgrown egg allergy.

Nearly three-quarters of children who had a convincing history of egg allergy had their diagnosis confirmed by a physician, and our study found many reasons to continue encouraging potentially egg-allergic children to seek formal physician diagnosis. The general risks of not having confirmatory evaluation are many, including lack of education and preparedness with emergency medications to treat allergic reactions. Errors in allergen avoidance places the child at risk for potentially severe reactions, as well as unnecessary over-restriction of foods that can negatively affect growth and nutrition.^{27,28} Furthermore, specific to egg allergy, evaluation may lead to a determination of baked egg tolerance as well as evaluation of other possible food allergies and atopic diseases. One previous study reported that an ovomucoid skin prick test greater than 11 mm had a positive-predictive value of 100% for baked-egg intolerance²⁵; thus children with SPT <11 mm will need to discuss the risk and benefits of an oral baked egg challenge with their allergist. Understanding which egg protein a child is allergic to also aids in this discussion, as not all egg allergens are affected by heat.¹⁰

Compared with other allergens such as peanut, tree nuts, shellfish, and finfish, egg is a highly ubiquitous allergen that can be particularly difficult to avoid because it is not only a known ingredient in many baked goods, but is also frequently present as a "hidden" ingredient. For example, eggs are frequently used as clarifying agents, as components of soup stocks, cocktails, and as a wash on bread products to improve their appearance.^{29,30} Recent analysis of a prospective case series of 500 food-allergic infants followed over a 3-year period estimated that nearly 1 in 5 allergic infants experienced an egg-allergic reaction. Nearly all (87%) resulted from accidental exposure.³¹ Therefore, it is perhaps unsurprising that individuals with the ability to tolerate baked egg reported significantly greater food allergy-related QoL in our study, which was primarily influenced by reductions in reported allergen avoidance and concomitant adverse social impacts.

There were several limitations to this study. This was a survey-based study that is subject to responder recall bias. Furthermore, data on the frequency and reproducibility of reaction symptoms were not collected. Because roughly 1 in 4 children with egg allergy did not report physician confirmation of their egg allergy and few had undergone food challenges, underestimation of baked egg tolerance is possible. Lastly, although our prevalence findings are consistent with cohort studies, another limitation is that our estimates for physician diagnosis, allergy testing, and ED visits were based on parental reports and not medical records. Despite these limitations, this study reports on egg allergy in a large, nationally representative sample and used stringent criteria

developed in collaboration with an expert panel to exclude adverse responses not likely to be IgE-mediated food allergy. These rigorous criteria yielded a prevalence estimate similar to other population-based prevalence studies using clinical confirmation of disease over a similar time period.^{17,22} Our study also reinforces the importance of formal evaluation by a physician as egg allergy may be a marker of greater atopic burden. Understanding the higher prevalence in young children, the strong association with comorbid food allergy, and the improved QoL for those with baked egg tolerance provides important data for clinicians caring for these children.

CONCLUSIONS

Egg allergy is common amongst young children, with a peak prevalence of 2% in children aged 1 to 2 years. Children with egg allergy have higher rates of asthma, eczema, and allergic rhinitis relative to children with the other top 8 allergies. Although peanut and milk were the most common comorbid food allergies, children with egg allergy were also twice as likely to report comorbid sesame and soy allergies as were children with the other top 8 allergies. Nearly two-thirds of children with egg allergy were reported to be tolerant to baked egg products, which was associated with improved QoL and fewer food allergy-related ED visits. Increased efforts are needed to ensure that children with egg allergy are appropriately evaluated to assess for comorbid food allergy, other atopic disease, and baked egg tolerance.

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ONLINE REPOSITORY

APPENDIX A: FOOD ALLERGY PREVALENCE
QUESTIONNAIRE ITEMS USED IN "EGG ALLERGY
IN US CHILDREN"

Below is the text and corresponding conditional branching/skip logic used to administer questionnaire items via web and computer-assisted telephone interview. Parent-proxy responses to the following questions were coded, weighted, and used for the analyses described in "Egg Allergy in US Children."

QC0.

How many children do you have under the age of 18 in your household? If QC0=0, go to Demographics (QA9)

[IF QC0>0, display] Multikids.

We would like to ask some questions about [the child/the 2 children/up to 3 children] under the age of 18 in your household.

We would like the parent or legal guardian of these children to answer the questions about food allergies these children may or may not have. Are you the parent or legal guardian of these children?

1. Yes
2. No

[IF MULTIKIDS=2] NEWADULT.

Please have the parent/legal guardian take over the survey for the next set of questions. Click "Continue" to resume the survey.

Loop through child section question up to three (3) times, once per child. Loop1Intro.

In the next section, we're going to ask about your children based on who had the most recent birthday. For this first set of questions, please think of your child with the most recent birthday.

Loop2Intro.

Those are all the questions we have about the first child in your household with the most recent birthday.

Next, please think of your child with the next most recent birthday.

Loop3Intro.

Thank you for the information. Now we would like to ask you about one more child in your household.

After the first 2 children for whom you've already answered questions, please think of your child with the next most recent birthday.

QC1a_n.

How old is your child? If your child is less than 1 year of age, please enter 0.

____ Years

[if QC1a_n=0] QC1b_n.

How old (in months) is your child?

____ Months

QC2_n.

What is your child's gender?

1. Male
2. Female

QC3_n.

What is your child's race/ethnicity?

- a. American Indian/Alaska Native
- b. Asian
- c. Black
- d. Hispanic/Latino
- e. Native Hawaiian or other Pacific Islander
- f. White
- g. Other _____

QC4_n.

Has your child ever had a food allergy at any point during [his/her] lifetime?

1. Yes
2. No

QC8_n.

Has your child ever been diagnosed by a doctor with any of the following chronic conditions? Please select all that apply.

- a. Asthma
- b. Atopic dermatitis/eczema
- c. Diabetes
- d. Eosinophilic esophagitis (EoE)
- e. Food protein-induced enterocolitis syndrome (FPIES) (Note: this is a very specific and rare allergic condition)
- f. Hay fever/allergic rhinitis/seasonal allergies
- g. Insect sting allergy (please specify _____)
- h. Latex allergy
- i. Medication allergy (eg, to penicillin) (please specify _____)
- j. Urticaria/chronic hives
- k. Other chronic condition (please specify _____)
- l. None

QC5_n.

Was your child born in the United States?

1. Yes
2. No

CURRENT FOOD ALLERGY

QCC1_n.

Is your child currently allergic to any foods?

Do not include foods that your child can currently eat without having an allergic reaction.

Please indicate for each food whether your child currently has the allergy or not.

1. Peanut
2. Tree nuts such as almond, cashew, hazelnut, pecan, pistachio and walnut
3. Cow's milk
4. Egg
5. Shellfish such as shrimp, crab, lobster, clam, oyster, mussels, or scallop
6. Fin fish or fish product such as anchovies, catfish, cod, halibut, salmon, tuna, or fish sauce
7. Soy
8. Wheat
9. Sesame
10. Coconut

11. Avocado
12. Fruit or berry
13. Green peas
14. Lentils
15. Meat (Please specify if known_____)
16. Spices (Please specify if known_____)
17. Vegetables (Please specify if known_____)
18. Other allergy or additional details about reported allergy (Please describe)
19. Other allergy or additional details about reported allergy (Please describe)
20. Other allergy or additional details about reported allergy (Please describe)
21. Other allergy or additional details about reported allergy (Please describe)
22. Other allergy or additional details about reported allergy (Please describe)

Response options

1. Yes
2. No

[if QCC1_2_n=1] QCC1a_n.

Which of the following tree nuts is your child currently allergic to?

1. Almond
2. Cashew
3. Hazelnut
4. Pecan
5. Pistachio
6. Walnut
7. Other tree nut (Please specify if known_____)

Response options

1. Yes
2. No

[if QCC1_4_n=1] QCC1c_n.

Can your child eat baked foods containing egg? (eg, home-made or store-bought muffins, cakes, or other egg products baked for at least 25 minutes at 350° or greater).

1. Yes
2. No

[if QCC1_5_n=1] QCC1d_n.

Which of the following shellfish is your child currently allergic to?

1. Shrimp
2. Crab
3. Lobster
4. Mollusk such as clam, oyster, mussels or scallop
5. Other shellfish (Please specify if known_____)

Response options

1. Yes
2. No

[If QCC1_6_n=1]
QCC1e_n.

Which of the following fin fish is your child allergic to?

1. Anchovies
2. Catfish
3. Cod
4. Halibut
5. Salmon

6. Tuna
7. Fish sauce
8. Other (Please specify if known_____)

Response options

1. Yes
2. No

[If QCC1_12_n=1]
QCC1f_n.

Which of the following fruit or berries is your child allergic to?

1. Mango
2. Peach
3. Strawberry
4. Other fruit (Please specify if known_____)

Response options

1. Yes
2. No

START OF SECTION WHICH REPEATS FOR ALL CURRENT ALLERGIES

QCC2_n_x.

How old was your child when [he/she] had [his/her] first reaction to [Current Allergy X]?

If you are unsure, please provide your best guess. If your child was less than 1 year of age, please enter 0.

_____Years

[IF QCC2_n_x=0]

QCC3_n_x.

How old (in months) was your child when [he/she] had [his/her] first reaction to [Current Allergy X]?

If you are unsure, please provide your best guess.

_____Months

QCC4_n_x.

Did a doctor diagnose your child's [Current Allergy X] allergy?

1. Yes
2. No
3. I don't remember

[If QCC4_n_x=1; numbox 0- QC1a_n] QCC5_n_x.

How old was your child when a doctor first diagnosed [his/her] [Current Allergy X] allergy?

If you are unsure, please provide your best guess. If child was less than 1 year of age, please enter 0.

_____Years

[if QCC5_n_x=0] QCC6_n_x.

How old (in months) was your child when a doctor first diagnosed [his/her] [Current Allergy X] allergy?

If you are unsure, please provide your best guess.

_____Months

[IF QCC4_n_x.=1]

QCC7_n_x.

Was any testing done to confirm your child's [Current Allergy X] allergy diagnosis? If so, please specify.

Please select all that apply.

- a. No testing was conducted
- b. Skin prick or scratch test for [Current Allergy X] allergy

- c. Blood test for [Current Allergy X] allergy (eg, RAST, ImmunoCAP)
- d. Oral food challenge to [Current Allergy X] (ie, ate [Current Allergy X] under medical supervision)
- e. Alternative test for [Current Allergy X] allergy (eg, NAET) (Please specify if possible)
- f. I don't remember

QCC9_n_x.

Think back to the most severe allergic reaction to [Current Allergy X] that your child has ever had. What were [his/her] symptoms?

Please select all that apply. Skin symptoms:

1. Hives
2. Itching
3. Rash
4. Swelling (except lip/tongue swelling—please mark lip/tongue swelling under “Mouth/Throat Symptoms”)
5. Other: _____ Mouth/throat symptoms
6. Lip/tongue swelling
7. Difficulty swallowing
8. Hoarse voice
9. Itchy mouth
10. Throat tightening
11. Mouth or throat tingling
12. Other: _____ Breathing symptoms
13. Chest tightening
14. Nasal congestion
15. Repetitive cough
16. Trouble breathing
17. Wheezing
18. Other: _____ Gastrointestinal (GI) symptoms
19. Belly pain
20. Cramps
21. Diarrhea
22. Nausea
23. Vomiting
24. Other: _____ Cardiovascular/heart symptoms
25. Chest pain
26. Rapid heart rate
27. Fainting, dizziness, or feeling light headed
28. Low blood pressure
29. Other: _____ Other symptoms
30. Anxiety
31. Feeling of impending doom
32. Headache
33. Other: _____
34. Other reaction: _____

QCC10_n_x.

Have you used any of the following medications to treat your child's [Current Allergy X] allergy? Please select all that apply.

1. Epinephrine autoinjector (eg, *EpiPen*®, *Auvi-Q*®, *Adrenaclick*®/Generic)
2. Antihistamines (eg, *Benadryl*®, *Zyrtec*®)
3. Asthma inhaler (eg, albuterol)
4. Steroids (eg, prednisone, prednisolone)
5. Other medications (Please specify)
6. None of the above

END OF SECTION WHICH REPEATS FOR ALL CURRENT ALLERGIES

QC11_n.

Does your child have a current prescription for an epinephrine autoinjector (eg, *EpiPen*®, *Auvi-Q*®, *Adrenaclick*®/Generic) for [his/her] food [allergy/allergies]?

1. Yes
2. No

OUTGROWN FOOD ALLERGIES

QCO1_n.

Has your child ever “outgrown” any food allergies? (ie, Has your child ever been allergic to a food that [he/she] can now eat without having an allergic reaction?)

1. Yes
2. No

[IF QCO1_n=1] QCO2_n.

Which food allergies has your child outgrown?

Do not include foods that your child still cannot eat due to a current allergy.

Please indicate for each food whether your child has outgrown the allergy or not.

1. [QCC1_1>1]Peanut
2. Tree nuts such as almond, cashew, hazelnut, pecan, pistachio and walnut
3. [QCC1_3>1]Cow's milk
4. [QCC1_4>1]Egg
5. Shellfish such as shrimp, crab, lobster, clam, oyster, mussels, or scallop
6. Fin fish or fish product such as anchovies, catfish, cod, halibut, salmon, tuna, or fish sauce
7. [QCC1_7>1]Soy
8. [QCC1_8>1]Wheat
9. [QCC1_9>1]Sesame
10. [QCC1_10>1]Coconut
11. [QCC1_11>1]Avocado
12. Fruit or berry
13. [QCC1_13>1]Green peas
14. [QCC1_14>1]Lentils
15. [QCC1_15>1]Meat (Please specify if known)
16. [QCC1_16>1]Spices (Please specify if known)
17. [QCC1_17>1]Vegetables (Please specify if known)
18. [QCC1_18>1]Other allergy or additional details about reported allergy (Please describe)
19. [QCC1_19>1]Other allergy or additional details about reported allergy (Please describe)
20. [QCC1_20>1]Other allergy or additional details about reported allergy (Please describe)
21. [QCC1_21>1]Other allergy or additional details about reported allergy (Please describe)
22. [QCC1_22>1]Other allergy or additional details about reported allergy (Please describe)

Response options

1. Yes
2. No

[If QCO2_4_n=1]

QCO2c_n.

When your children were allergic to egg, were they able to eat baked foods containing egg? (eg, home-made or store-bought muffins, cakes, or other egg products baked for at least 25 minutes at 350° or greater).

1. Yes
2. No

START OF SECTION WHICH REPEATS FOR OUTGROWN ALLERGIES

QCO3_n_x.

How old was your child when [he/she] had [his/her] first reaction to [Outgrown Allergy X]? If child was less than 1 year of age, please enter 0.

_____Years

[if QCP3_n_x=0]. QCO4_n_x.

How old (in months) was your child when [he/she] had [his/her] first reaction to [Outgrown Allergy X]?

If you are unsure, please provide your best guess.

_____Months

QCO5_n_x.

Did a doctor diagnose your child's [Outgrown Allergy X] allergy?

1. Yes
2. No
3. I don't remember

[IF QCO5_n_x=1]

QCO6_n_x.

How old was your child you when a doctor first diagnosed [his/her] [Outgrown Allergy X] allergy? If you are unsure, please provide your best guess. If child was less than 1 year of age, please enter 0.

_____Years

[IF QCO6_n_x=0]

QCO7_n_x.

How old (in months) was your child when a doctor first diagnosed [his/her] [Outgrown Allergy X] allergy?

If you are unsure, please provide your best guess.

_____Months

[IF QCO5_n_x=1]

QCO8_n_x.

Was any testing done to confirm your child's [Outgrown Allergy X] allergy diagnosis? If so, please specify.

Please select all that apply.

- a. No testing was conducted
- b. Skin prick or scratch test for [Outgrown Allergy X] allergy
- c. Blood test for [Outgrown Allergy X] allergy (eg, RAST, ImmunoCAP)
- d. Oral food challenge to [Outgrown Allergy X] (ie, ate [Outgrown Allergy X] under medical supervision)
- e. Alternative test for [Outgrown Allergy X] allergy (eg, NAET) (Please specify if possible)
- f. I don't remember

QCO9_n_x.

How old was your child when [he/she] first outgrew [his/her] [Outgrown Allergy X] allergy? (ie, realized [he/she] could eat [Outgrown Allergy X] without having a reaction after becoming allergic)

If you are unsure, please provide your best guess. If your child was less than 1 year of age, please enter 0.

_____Years

[IF QCO9_n_x=0]

QCO10_n_x.

How old (in months) was your child [he/she] first outgrew [his/her] allergy? (ie, realized [he/she] could eat [Outgrown Allergy X] without having a reaction after becoming allergic)

If you are unsure, please provide your best guess.

_____Months

QCO14_n_x.

Think back to the most severe allergic reaction to [Outgrown Allergy X] that your child has ever had. What were [his/her] symptoms?

Please select all that apply. Skin symptoms:

1. Hives
2. Itching
3. Rash
4. Swelling (except lip/tongue swelling—please mark lip/tongue swelling under "Mouth/Throat Symptoms")
5. Other: _____

Mouth/throat symptoms

6. Lip/tongue swelling
7. Difficulty swallowing
8. Hoarse voice
9. Itchy mouth
10. Throat tightening
11. Mouth or throat tingling
12. Other: _____

Breathing symptoms

13. Chest tightening
14. Nasal congestion
15. Repetitive cough
16. Trouble breathing
17. Wheezing
18. Other: _____

Gastrointestinal (GI) symptoms

19. Belly pain
20. Cramps
21. Diarrhea
22. Nausea
23. Vomiting
24. Other: _____

Cardiovascular/heart symptoms

25. Chest pain
26. Rapid heart rate
27. Fainting, dizziness, or feeling light headed
28. Low blood pressure
29. Other: _____

Other symptoms

30. Anxiety
31. Feeling of impending doom
32. Headache

- 33. Other: _____
- 34. Other reaction: _____

END OF SECTION WHICH REPEATS FOR OUTGROWN ALLERGIES

QC13_n.

In the past 12 months, how many times has your child visited a hospital emergency department for [his/her] food [allergy/allergies]?
_____ Times

QC14_n.

In your child's lifetime how many times has [he/she] visited a hospital emergency department for [his/her] food [allergy/allergies]?
_____ Times

FOOD ALLERGY INDEPENDENT MEASURE— PARENT FORM

The following 4 questions are about the chance of something happening to your child because of [his/her] food allergy. Choose one of the answers provided. This is followed by 3 more questions about your child's food allergy.

How great do you think the chance is that your child...

CEO1_n. Will accidentally eat something to which [he/she] is allergic?

CEO2_n. Will have a severe reaction if [he/she] accidentally eats something to which [he/she] is allergic?

CEO3_n. Will die if [he/she] accidentally eats something to which [he/she] is allergic?

CEO4_n. **Cannot** do the right things for [his/her] allergic reaction (or have the right things done by others) should [he/she] accidentally eat something to which [he/she] is allergic?

| | | | | | | |
|-------------------|-------------------|--------------|-------------|------------|-----------------|----------------------|
| 0 | 1 | 2 | 3 | 4 | 5 | 7 |
| never (0% chance) | very small chance | small chance | fair chance | big chance | very big chance | always (100% chance) |

CIM1_n.

How many products must your child avoid because of [his/her] food allergy?

- 1. Almost none
- 2. Very few
- 3. A few
- 4. Some
- 5. Many
- 6. Very many
- 7. Almost all

CIM2_n.

Everyone does things with other people, such as: playing with friends, going to a birthday party, visiting, staying over with someone for a meal or eating out.

How much does your child's food allergy affect the things [he/she] does with others?

- 1. So little we don't actually notice it
- 2. Very little
- 3. Little
- 4. Moderately
- 5. A good deal
- 6. A great deal
- 7. A very great deal

APPENDIX B: FOOD ALLERGY INDEPENDENT MEASURE (FAIM) QUESTIONS

How big do you think the chance is that your child...

- 1. Will accidentally eat something to which he/she is allergic?
 - 2. Will have a **severe** reaction if he/she accidentally eats something to which he/she is allergic?
 - 3. Will die if he/she accidentally eats something to which he/she is allergic?
 - 4. **Cannot** do the right things for [his/her] allergic reaction (or have the right things done by others) should [he/she] accidentally eat something to which [he/she] is allergic
 - Never (0% chance)
 - Very small chance
 - Small chance
 - Fair chance
 - Big chance
 - Very big chance
 - Always (100% chance)
 - 5. How many products must your child avoid because of his/her food allergy?
 - Almost none
 - Very few
 - A few
 - Some
 - Many
 - Very many
 - Almost all
 - 6. Everyone does things with other people, such as playing with friends, going to a birthday party, visiting, staying over with someone for a meal, or eating out.
- How much does your child's food allergy affect the things you do with others?
- So little he/she doesn't actually notice it
 - Very little
 - Moderately
 - A good deal
 - A great deal
 - A very great deal

TABLE E1. Symptoms associated with allergic reaction to egg

| | Reaction symptoms: children with egg allergy | Reaction symptoms: children with egg allergy and baked egg tolerance | Reaction symptoms: children with egg allergy without baked egg tolerance | P value |
|--|---|--|--|---------|
| Any stringent skin/oral /mucosal tissue symptom(s) | 58.2 (46.8-68.8) | 64.9 (55.7-73.1) | 46.3 (26.1-67.7) | .12 |
| Hives | 49.7 (39.4-60.0) | 57.3 (47.8-66.2) | 36.2 (20.5-55.4) | .05 |
| Itching | 49.9 (39.6-60.3) | 52.4 (42.7-61.9) | 45.8 (25.8-67.3) | .60 |
| Rash | 38.3 (29.7-47.6) | 36.9 (28.3-46.4) | 40.6 (22.9-61.1) | .74 |
| Swelling | 21.8 (14.6-31.2) | 23.0 (13.9-35.6) | 19.6 (10.3-34.2) | .68 |
| Lip/tongue swelling | 19.1 (12.5-28.0) | 21.5 (13.0-33.4) | 15.0 (7.6-27.5) | .38 |
| Difficulty swallowing | 13.7 (9.8-18.8) | 14.7 (10.1-20.8) | 12.1 (6.3-22.1) | .6 |
| Hoarse voice | 9.1 (5.8-13.9) | 8.9 (5.3-14.4) | 9.5 (4.0-20.9) | .89 |
| Itchy mouth | 14.1 (8.3-23.0) | 15.3 (7.6-28.4) | 11.9 (6.2-21.6) | .59 |
| Throat tightening | 10.2 (6.9-15.0) | 9.1 (5.7-14.2) | 12.4 (5.8-24.2) | .49 |
| Mouth or throat tingling | 12.6 (6.7-12.4) | 11.3 (4.4-25.8) | 14.5 (6.1-30.8) | .68 |
| Any stringent respiratory symptom(s) | 21.1 (15.4-28.2) | 20.5 (14.4-28.4) | 22.2 (11.9-37.8) | .82 |
| Chest tightening | 5.0 (3.1-7.7) | 5.6 (3.4-9.2) | 3.8 (1.5-9.5) | .47 |
| Nasal congestion | 16.0 (9.8-24.9) | 15.4 (7.8-28.3) | 16.6 (8.4-30.4) | .87 |
| Repetitive cough | 11.0 (5.7-20.1) | 11.0 (4.2-25.6) | 11.2 (5.5-21.4) | .98 |
| Trouble breathing | 10.2 (6.8-15.1) | 9.6 (6.1-15.0) | 11.4 (5.2-23.1) | .71 |
| Wheezing | 12.3 (8.1-18.4) | 11.1 (6.3-18.8) | 14.7 (7.3-27.4) | .52 |
| Any stringent gastrointestinal symptom(s) | 31.3 (20.7-44.4) | 24.9 (17.8-33.6) | 42.8 (20.5-68.4) | .16 |
| Belly pain | 22.6 (12.4-37.6) | 15.9 (10.6-23.2) | 34.3 (12.6-65.4) | .14 |
| Cramps | 21.7 (11.7-36.9) | 13.8 (9.7-19.3) | 36.2 (14.2-66.0) | .049 |
| Diarrhea | 28.2 (17.6-41.8) | 22.7 (16.1-31.1) | 37.8 (15.7-66.5) | .25 |
| Nausea | 24.8 (14.5-39.2) | 16.4 (11.3-23.0) | 40.3 (18.0-67.5) | .04 |
| Vomiting | 31.3 (20.7-44.4) | 24.9 (17.8-33.6) | 42.8 (20.5-68.4) | .16 |
| Any stringent cardiovascular symptom(s) | 17.0 (12.0-23.6) | 15.4 (10.9-21.4) | 19.6 (9.4-36.6) | .82 |
| Chest pain | 3.7 (2.3-6.0) | 3.9 (2.1-7.1) | 3.5 (1.6-7.5) | .84 |
| Rapid heart rate | 6.1 (3.6-10.3) | 4.7 (2.7-7.9) | 8.3 (3.1-20.6) | .31 |
| Fainting/dizziness | 8.2 (4.8-13.6) | 7.8 (4.8-12.5) | 8.9 (2.8-25.0) | .83 |
| Low blood pressure | 3.6 (1.1-10.6) | 1.0 (0.2-4.6) | 8.3 (2.1-27.4) | .02 |

Bold indicates statistical significance ($P < .05$).

TABLE E2. Egg allergy severity amongst those with and without baked egg tolerance

| Egg allergy characteristics | Egg-allergic children without baked egg tolerance (95% CI) | Egg-allergic children with baked egg tolerance (95% CI) | P value |
|---|---|--|---------|
| Severe reaction to egg* | 28.7 (16.1-45.9) | 27.7 (20.7-36.0) | .90 |
| Physician-confirmed egg allergy | 75.1 (56.7-87.4) | 70.7 (62.0-78.0) | .63 |
| Multiple allergies | 81.8 (69.0-90.1) | 72.4 (64.3-79.2) | .18 |
| Current EAI prescription | 48.2 (27.1-69.9) | 52.8 (43.0-62.4) | .72 |
| Lifetime ED visit | 69.2 (51.4-82.7) | 49.3 (39.6-59.1) | .05 |
| Last 12-mo ED visit | 45.8 (23.4-70.0) | 30.7 (21.6-41.6) | .26 |
| Has treated egg-allergic reaction with EAI | 25.5 (14.1-41.7) | 23.4 (14.9-34.8) | .81 |

CI, Confidence interval; EAI, epinephrine autoinjector; ED, emergency department.

*A severe reaction consisted of a parent report of at least 2 stringent symptoms from 2 different body systems during a child's most severe reaction to a given food.