

Self-reported adverse food reactions and anaphylaxis in the SchoolNuts study: A population-based study of adolescents

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Background: Adolescents are at the highest risk of death from anaphylaxis, yet few population-based studies have described the frequencies and risk factors for allergic reactions caused by accidental allergen ingestion in this group.

Methods: We describe the prevalence, frequency, and associated risk factors for recent adverse food reactions in 10- to 14-year-olds in Melbourne, Australia, recruited from a stratified, random, population-based sample of schools (SchoolNuts, n = 9663; 48% response rate). Self-reported food allergy and adverse reaction details, including anaphylaxis, were identified by using a student questionnaire over the past year.

Results: Of 547 students with possible IgE-mediated food allergy, 243 (44.4%; 95% CI, 40.3% to 48.7%) reported a reaction to a food. Fifty-three (9.7%; 95% CI, 7.2% to 12.2%) students reported 93 anaphylaxis episodes. Peanut and tree nuts were the most common food triggers. Among students with current IgE-mediated food allergy, those with resolved or current asthma (adjusted odds ratio [aOR], 1.9 [95% CI, 1.1-1.3] and 1.7 [95% CI, 1.1-2.6]) and those with more than 2 food allergies (aOR, 1.9 [95% CI, 1.1-3.1]) were at greatest risk of any adverse food reaction, and those with nut allergy were most at risk of severe reactions (aOR, 2.9 [95% CI, 1.1-4.4]). Resolved or current asthma was not associated with increased risk of severe reactions (aOR, 0.8 [95% CI, 0.3-2.2] and 1.6 [95% CI, 0.7-3.7]).

Conclusions: Adolescents with food allergy are frequently exposed to food allergens. Those with asthma and more than 2 food allergies were at the greatest risk for adverse food reactions. Those with nut allergies were most at risk of severe reactions. (J Allergy Clin Immunol 2017;■■■:■■■-■■■.)

Key words: Food allergy, anaphylaxis, adolescents, schools, peanut allergy, asthma

Food allergy affects up to 10% of children and 2% to 3% of adults and appears to be increasing in prevalence.¹⁻⁴ This increase in food allergy prevalence has coincided with increased reports of food-induced anaphylaxis. The greatest increase in anaphylaxis has been reported in the 0- to 5-year age group⁵; however, more recent data suggest that the increase in food-induced anaphylaxis is now occurring more rapidly in the periadolescent age period (5-14 years).^{6,7} Adolescents also constitute the highest proportion of deaths from anaphylaxis.⁸⁻¹¹

Studies to date reporting the frequency of adverse food reactions and anaphylaxis have been limited to selected food allergens only,¹²⁻¹⁹ occurred in younger children,²⁰ or been based on allergy clinic or health care facility presentation.²¹ Few population studies have described the frequency of adverse food reactions, including anaphylaxis, among adolescents.

Additionally, predicting those adolescents with food allergy who might be at greatest risk of food reactions is also difficult.²² Reported risk factors for anaphylaxis-related fatalities have included delayed administration or failure to administer adrenalin,²³ having peanut or tree nut allergy (70% to 90% of anaphylaxis-related deaths are due to these foods),^{8-11,24} and having coexisting or poorly controlled asthma.²³ However, these factors have not been explored formally in a population setting or in the high-risk adolescent age group. Understanding the predictors for adverse food reactions, including anaphylaxis, for

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Abbreviations used

aOR: Adjusted odds ratio
OR: Odds ratio

the population of adolescents with food allergy underpins the development of age-appropriate prevention and management strategies.

The aim of this study was to determine the frequency and associated risk factors for adverse food reactions reported in the preceding 12 months among those with IgE-mediated food allergy in a large population-based cohort of 10- to 14-year-old students.

METHODS

The SchoolNuts study is a cross-sectional population-based study that aimed to determine the population prevalence of challenge-proved food allergy and to assess risk factors for adverse reactions to foods in early adolescence. The early adolescent period (10-14 years) was selected to allow assessment of children across the transition from primary (10-11 years) to secondary school (12-14 years), where greater autonomy and independence occurs, which is also consistent with the onset of puberty. The study had 2 stages: stage 1, parent and student questionnaires; stage 2, clinic-based assessments. Questionnaires were used to determine the likelihood of IgE-mediated food allergy, after which the students and their parents were invited to attend a hospital clinic visit for allergy testing and food challenge. This study reports the data from stage 1 student questionnaires.

Participant selection and recruitment

Stratified cluster sampling of primary and secondary school students in the greater metropolitan Melbourne area (population of 3.9 million in 2011)²⁵ was used to recruit a sample of 10- to 14-year-old adolescents between July 2011 and December 2014. Seventy percent of the population of the state of Victoria reside in Melbourne.²⁵ Schools were randomly selected to reflect the variation in socioeconomic status throughout the various school districts and included each of the government, Catholic, and independent school sectors in the Australian education system. Schools were eligible for inclusion if they were less than 80 km from the central business district and had more than 20 students per year level. A list of schools was obtained from the 2010 Melbourne Street Directory stratified by primary (grades 5 and 6) versus secondary (years 7 and 8) schools and subdivided into government, Catholic, and independent schools. Each school within those groups was then assigned a number, and a random number generator was used to select schools. These 229 schools (representing 20,965 students) were approached to participate by letter of invitation, 117 (51.1%) of which participated in the study. At each participating school, all students in years 5, 6, 7, and 8 were then invited to take part.

Parental consent was required for students to complete the student questionnaire. Consented students completed questionnaires as part of a school visit by the research team ($n = 9,663$). Families were invited to complete a parent questionnaire sent through the school. Fifty-seven percent of student questionnaires had a corresponding parent questionnaire completed ($n = 5,507$).

Questionnaire details and definitions

The student questionnaire included questions regarding the child's history of food allergy and asthma and knowledge and attitudes toward food allergy. Student-reported resolved asthma was defined as an affirmative response to the following question: "Have you ever had asthma?" Current asthma was defined as an affirmative response to the following question: "Do you still have asthma?"

Students reporting current food allergy, current asthma, or both were asked to complete additional more detailed sections of the questionnaire regarding their asthma, food allergy, or both. Those with current food allergy were asked to specify foods to which they were allergic: peanut, other nuts (nut type specified), hen's egg, cow's milk, sesame, fish, shellfish, soy, and other food (specified). Those students who did not complete further food allergy questions and those who reported a food allergy that was unlikely to be IgE-mediated (celiac disease, lactose intolerance, or reactions to additives) were excluded from the current analyses. The remaining students were classified as "possibly IgE-mediated food allergic."

Students were asked whether they had experienced an adverse food reaction in the past 12 months (see Fig E1 in this article's Online Repository at www.jacionline.org for details of the questionnaire). Details of each food reaction were sought, including the food trigger, self-report of anaphylaxis, use of adrenaline autoinjector, locale of the reaction (home, school, restaurant, and friend's home), symptoms (skin rash, facial swelling, vomiting, diarrhea, and breathing difficulties), and time frame of each reaction (<1 hour from food ingestion and reaction, 1-4 hours, >4 hours, and unknown). The definition of anaphylaxis was based on the Australasian Society of Clinical Immunology and Allergy definition of anaphylaxis, which categorizes any reaction involving acute onset of respiratory compromise as anaphylaxis (Australasian Society of Clinical Immunology and Allergy definition was any acute onset illness with typical skin features [urticarial rash or erythema/flushing, and/or angioedema] PLUS involvement of respiratory and/or cardiovascular and/or persistent severe gastrointestinal symptoms OR any acute onset of hypotension or bronchospasm or upper airway obstruction where anaphylaxis is considered possible, even if typical skin features are not present).²⁶ Each reaction was categorized into one of 5 groups according to time of onset of reaction and symptoms (see Fig 1 for details): (1) confirmed anaphylaxis; (2) unrecognized anaphylaxis; (3) likely IgE mediated; (4) unlikely IgE mediated; and (5) unable to be classified. V.L.M. initially reviewed and classified all cases. Dr Allen reviewed all categorizations, and any discrepancies were resolved by Dr Tang.

Students reporting multiple reactions were assigned based on the most severe reaction reported. Fig 1 shows categorization of students based on participation and classification of each reaction.

The parent questionnaire replicated questions regarding asthma and food allergy status included in the student questionnaire; however, details of food allergy reactions in the past 12 months were not included in the parent questionnaires.

Statistical methods

Self-reported possible food allergy prevalence was expressed as the observed proportion with 95% CIs. Kappa analysis was performed to measure the agreement between dyads of student and parent responses for self-reported food allergy. The prevalence of adverse reactions was calculated as the number of students reporting a reaction in the past 12 months divided by those with probable IgE-mediated food allergy.

We used logistic regression models to first identify risk factors for having adverse food reactions among those with possible IgE-mediated food allergy. Second, among those with adverse food reactions, we assessed risk factors for severe compared with mild reactions.

Multivariable logistic regression was used to examine the association between demographic factors (sex, school type, school sector, and student's country of birth) and clinical factors of interest (resolved and current asthma, number of food allergies, and type of food allergies) and the risk of adverse food reactions expressed as odds ratios (ORs) and 95% CIs. A separate regression model was conducted for each clinical factor, with the demographic factors included as *a priori* confounders and other clinical factors retained only as confounding variables if they altered the OR by greater than 10%. STATA software was used for all statistical analyses (release 14.0; StataCorp, College Station, Tex).

Ethical approval was obtained from the Royal Children's Hospital Human Research and Ethics Committee, the Department of Education and Early Childhood Development, and the Catholic Education Office.



*mutually exclusive groups

1. Confirmed anaphylaxis – student stated the reaction was anaphylaxis and symptoms included breathing difficulties in less than 1 hour.,
2. Unrecognised anaphylaxis – Student reported reaction was not anaphylaxis or they did not know or didn't answer but symptoms included breathing difficulties and occurred in less than one hour.
3. Likely IgE mediated – student stated the reaction was not anaphylaxis, symptoms (skin rash, facial swelling, vomiting, diarrhoea, breathing difficulties occurred within 1-4 hours and breathing difficulties were not reported as a symptom.
4. Unlikely IgE mediated – symptoms were >4 hours and/or included diarrhoea as the only symptom.
5. Unable to be classified – insufficient reaction details were completed to be able to classify the reaction type.

FIG 1. Overview of student participation in the SchoolNuts study.

RESULTS

Study population

Table I outlines the demographic characteristics of the study population. The mean age was 12 ± 1.2 years, with balanced participation in terms of sex (50.5% males) and school level (51.7% attended primary school). Nearly half the students (47.3%) attended government schools, which matches the school sector breakdown in Victoria.²⁷ A total of 831 students reported current food allergy (8.9%; 95% CI, 8.3% to 9.5%), with 620 (6.6%; 95% CI, 5.6% to 6.9%) classified as having a possible IgE-mediated food allergy (Fig 1). Kappa analysis showed a

strong correlation between student and parent responses for self-reported food allergy (0.75 [95.8%]). Current asthma was reported by 177 (32.4%; 95% CI, 28.5% to 36.3%) of those with possible IgE-mediated food allergy ($n = 547$), 33.7% (95% CI, 27.8% to 39.6%) of those reporting any reaction ($n = 243$; Table II), and 45.2% (95% CI, 40.4% to 48.7%) of those reporting reactions that met the criteria for anaphylaxis in the past 12 months ($n = 53$; Table III). Peanut ($n = 294$) and tree nut ($n = 249$) were the most commonly reported food allergies at 3.0% (95% CI, 2.8% to 3.5%) and 2.6% (95% CI, 2.3% to 3.0%), respectively.

TABLE I. Demographic description of the SchoolNuts study population (n = 9663)

Demographic description	No.	Percentage
Sex		
Male	4878	50.5
Female	4785	49.5
Age		
Mean (SD [y])	11.9 (1.2)	—
Median (range [y])	12.0 (9-15)	—
Student's country of birth*		
Australia	8233	85.7
Other	1380	14.3
School level		
Primary	4994	51.7
Secondary	4669	48.3
School type (ICSEA), mean (SD)†		
Catholic (1082 [77.2])	2871	29.7
Government (1001 [49.1])	4619	47.8
Independent (1148.6 [42.5])	2173	22.5

*Numbers do not add up to total because of missing data.

†The Index of Community Socio-educational Advantage (ICSEA) scale for each school is generated from student-level parent occupation and education, location, and percentage indigenous student enrollment, as developed by the Australian Curriculum, Assessment and Reporting Authority.

Details of food allergy reactions in the past 12 months among those with possible IgE-mediated food allergy

Table IV details all episodes of food-induced allergic reactions reported in the 12 months before the study. Among those students with possible IgE-mediated food allergy (n = 547), a total of 372 allergic reactions were reported by 243 (44.4%; 95% CI, 40.3% to 48.7%) students. More than 1 reaction was reported by 34% of students (n = 73). A total of 53 students reported 93 reactions that met the criteria for anaphylaxis (confirmed anaphylaxis [n = 44] and unrecognized anaphylaxis [n = 49]) over the 12-month period, resulting in a prevalence of 9.7% (95% CI, 7.2% to 12.2%).

Peanut and tree nut were the reported trigger foods for 43.8% (106/242) of all IgE-mediated reactions and 57% (53/93) of all severe reactions (confirmed and unrecognized anaphylaxis). Cashew and walnut were the most common tree nuts reported. Home was the location for 37 (39.8%) of the 93 episodes of all types of anaphylaxis (confirmed and unrecognized anaphylaxis), whereas restaurants were the location for 17% (n = 16) and schools for 8.6% (n = 8). Of the 44 episodes of confirmed anaphylaxis, adrenaline autoinjectors were used for 19 (43.2%) episodes.

Risk factors for reporting an adverse food reaction in the past 12 months among those with a possible IgE-mediated food allergy

Table II presents the risk factor analysis for having an adverse reaction to a food in the last 12 months among those with possible IgE-mediated food allergy (n = 547). Adjusted multivariable analysis showed that female subjects (adjusted odds ratio [aOR] 1.9; 95% CI, 1.3-2.5), those with either a history of asthma (aOR, 1.9; 95% CI, 1.1-3.2) or current asthma (aOR, 1.7; 95% CI, 1.1-2.6), and those with more than 2 food allergies (vs single food allergy: aOR, 1.9; 95% CI, 1.1-3.8) were more likely to report an adverse food reaction in the past 12 months. Those

with nut allergy were less likely to report a food reaction in the past 12 months than those without nut allergy (aOR, 0.7; 95% CI, 0.5-0.8).

Risk factors for a food allergy reaction in the past 12 months that met the criteria for anaphylaxis among those with IgE-mediated food allergy reporting a reaction

We compared those who reported a nonsevere IgE-mediated reaction in the past 12 months (n = 95) with those who reported a reaction consistent with anaphylaxis (confirmed or unrecognized anaphylaxis, n = 53). There was no association between risk of anaphylaxis and demographic factors, current or resolved asthma, and number of food allergies. However, those with nut allergy were almost 3 times more likely to report anaphylaxis in the past 12 months than those without nut allergy (aOR, 2.9; 95% CI, 1.1-4.4; Table III).

No evidence of associations were found for modifiable risk factors, including previous prescription of an adrenalin autoinjector, carriage patterns for autoinjectors, or higher risk of accidental allergen exposure through knowingly eating the food to which the student was allergic or eating foods labeled with precautionary allergen labeling, such as “may contain traces of” (data not shown).

DISCUSSION

This is one of the first studies to investigate the population prevalence and characterization of adverse food reactions, including anaphylaxis, and associated risk factors in adolescents. These results show that in a population-based sample of 10- to 14-year-old students with possible IgE-mediated food allergy, almost half (44.4%) reported food-induced allergic reactions in the preceding 12 months, and almost 1 in 10 (9.7%) reported at least 1 reaction with symptoms consistent with anaphylaxis. Reactions occurred most frequently in the home and were triggered most commonly by peanut and tree nuts. Reporting any food allergy reaction in the past 12 months was associated with female sex, having more than 2 food allergies, and having asthma (resolved or current). Nut allergy was the only risk factor found to be associated with reporting anaphylaxis. We observed a trend of increased asthma among those with food allergies reporting anaphylaxis compared with milder reactions. However, our results did not show that those with asthma were at significantly increased risk for severe reactions.

A major strength of this study is that it is both population based and highly detailed in its investigation of food-induced allergic reactions in the adolescent age group. This allowed study of all adolescents with food allergies and those experiencing adverse food reactions and is not limited to clinical samples, such as those presenting to health care facilities for treatment after a reaction or managed by allergy clinics. Although clinical samples have the strength of more robust diagnosis and definition of adverse reactions and anaphylaxis, they risk overrepresenting those with more severe food allergy phenotypes, higher socioeconomic status, and greater access to specialized medical management and education.

This study also has some limitations. The definition of anaphylaxis relied on self-reported symptoms involving breathing difficulties, which might have overestimated the true

TABLE II. Factors predicting adverse food reactions among students with IgE-mediated food allergy in the past 12 months in the SchoolNuts study

	IgE-mediated allergy (no reaction), no. (%)	IgE-mediated allergy (reaction), no. (%)	Crude OR (95% CI)	aOR (95% CI)*	P value
Total (n = 547)	304 (55.6)	243 (44.4)			
Sex					
Male (n = 262)	165 (63.0)	97 (37.0)	1.00	1.00	
Female (n = 285)	139 (48.8)	146 (51.2)	1.8 (1.3-2.5)	1.9 (1.3-2.8)	.001
School					
Primary (n = 302)	167 (55.3)	135 (44.7)	1.00	1.00	
Secondary (n = 245)	137 (55.9)	108 (44.1)	0.9 (0.7-1.4)	1.1 (0.7-1.2)	.69
School type					
Government (n = 234)	140 (59.8)	94 (40.2)	1.00	1.00	
Catholic (n = 175)	100 (57.1)	75 (42.9)	1.1 (0.8-1.6)	1.3 (0.8-2.0)	.28
Independent (n = 138)	64 (46.4)	74 (53.6)	1.2 (1.1-2.6)	1.4 (0.8-2.3)	.24
Student's country of birth					
Australia (n = 488)	269 (55.1)	219 (44.9)	1.00	1.00	
Other (n = 58)	42 (58.6)	24 (41.4)	0.9 (0.5-1.5)	0.9 (0.5-1.6)	.69
Asthma details					
No asthma (n = 237)	153 (64.6)	84 (35.4)	1.00	1.00	
Resolved asthma (n = 76)	37 (48.7)	39 (51.3)	1.9 (1.1-3.2)	1.9 (1.1-3.2)	.02
Current asthma (n = 177)	95 (53.7)	82 (33.7)	1.1 (1.0-2.2)	1.7 (1.1-2.6)	.01
Food allergy details					
No. of food allergies					
Single (n = 306)	182 (59.5)	124 (40.5)	1.00	1.00	
Two (n = 138)	76 (58.1)	62 (44.9)	1.9 (0.8-1.8)	1.1 (0.7-1.7)	.73
Multiple (n = 101)	45 (44.6)	56 (55.4)	1.8 (1.1-2.9)	1.9 (1.1-3.1)	.02
Type of food allergy					
Without nut (n = 211)	105 (49.8)	106 (50.2)	1.00	1.00	
With nut (n = 336)	199 (59.2)	137 (40.8)	0.7 (0.5-1.0)	0.7 (0.5-1.0)	.09

Numbers might not add up to total because of missing values.

*All models were adjusted *a priori* for sex, school type, school sector, and student's county of birth. Separate models were fit for the clinical factors of asthma and food allergy details, and food allergy models (number and type of food allergies) were additionally adjusted for asthma because of evidence of confounding.

prevalence of anaphylaxis. This definition might also have captured asthmatic episodes that were by chance associated with meals, along with true episodes of food-induced anaphylaxis. However, this is unlikely to have greatly inflated our estimates of anaphylaxis because almost all reactions involving breathing difficulties also had 1 or more symptoms of skin rash, facial swelling, and/or vomiting. In addition, the study population was restricted to those living in urban/suburban areas of Victoria (within 80 km of the central business district), and therefore findings might not be generalizable to rural areas. The study was also underpowered to assess the important issue of fatalities in this age group.

Although parents have a robust appreciation of their child's clinical history, an adolescents' increasing engagement outside the home might reduce the likelihood that parents fully share the adolescent's experience of food allergy. Hence a further strength of SchoolNuts is the inclusion of both adolescent and parent reporting. This has also allowed validation of self-reported responses for food allergy, asthma, and allergic reaction details addressing the limitation of self-reported data. Kappa analysis showed strong correlation between student and parent dyad responses for self-reported food allergy. However, validation of student reports of food reaction details against parent responses was not possible because of differences in questionnaires. Medication or health care contact questions relevant to asthma were not included in the student questionnaire.

A recent systematic review and meta-analysis of food-induced anaphylaxis in patients with food allergy reported a pooled

incidence rate of self-reported anaphylaxis in 0- to 19-year-olds of 4.93/100 person years (95% CI, 2.78-8.74) with a range of 0.6 to 8.9/100 person years based on 10 studies.²⁸ Comparison with our results is difficult because the included articles either involved younger children,^{19,20} were based on selected food allergies only,¹³⁻¹⁹ or involved high-risk allergy clinic populations.²¹ Population-representative studies in adolescence are limited, and comparison is difficult because of differences in population food allergy prevalence and study methodologies.

A large study of 11- to 15-year-old Turkish students (n = 10,096) also recruited adolescents and parents through schools. Using self-reported questionnaires, they reported a slightly higher prevalence of parent-reported food allergy (11.3%) than in our study of adolescent-reported food allergy (9.7%) and a much lower rate of reactions in the past year (3.6% vs 44.5%) in our study. These authors did not report separately on the frequency of anaphylaxis.²⁹

Reported only by abstract at this stage, a large birth cohort study in Sweden with a follow-up at 16 years of age reported much lower rates of adverse reactions, with 8.5% of 16-year-olds reporting reactions to food in the past 12 months and 0.8% experiencing anaphylaxis. Overall food allergy prevalence was not reported.³⁰

Finally, in a population-based study of 0- to 17-year-olds in Germany, 38% self-reported food-induced allergic reactions. However, the majority of the reactions were due to oral allergy syndrome.³¹

TABLE III. Factors predicting severe adverse food reactions (anaphylaxis) among students with IgE-mediated food allergy in the past 12 months in the SchoolNuts study

	IgE-mediated reaction (not severe), no. (%)	IgE-mediated reaction (severe), no. (%)	Crude OR (95% CI)	aOR (95% CI)*	P value
Total (n = 148)	95 (64.2)	53 (35.8)			
Sex					
Male (n = 63)	37 (58.7)	26 (41.3)	1.00	1.00	
Female (n = 85)	58 (68.2)	27 (31.8)	0.7 (0.3- 1.3)	0.9 (0.4-1.9)	.92
School					
Primary (n = 86)	51 (59.3)	35 (40.7)	1.00	1.00	
Secondary (n = 62)	44 (71.0)	18 (29.0)	0.6 (0.3-1.2)	0.6 (0.3-1.3)	.24
School type					
Government (n = 57)	38 (66.7)	20 (33.3)	1.00	1.00	
Catholic (n = 56)	34 (60.7)	22 (39.3)	1.3 (0.6-2.8)	1.1 (0.5-2.3)	.76
Independent (n = 35)	23 (65.7)	12 (34.3)	1.0 (0.4-2.5)	0.9 (0.4-2.3)	.77
Student's country of birth					
Australia (n = 135)	85 (63.0)	50 (37.0)	1.00	1.00	
Other (n = 13)	10 (76.9)	3 (23.1)	0.5 (0.1-1.9)	0.6 (0.1-2.4)	.45
Asthma details					
No asthma (n = 70)	47 (67.1)	23 (32.9)	1.00	1.00	
Resolved asthma (n = 22)	16 (72.7)	6 (27.3)	0.9 (0.3-2.4)	0.8 (0.3-2.2)	.80
Current asthma (n = 56)	33 (57.1)	24 (45.2)	1.4 (0.7-3.0)	1.6 (0.7-2.6)	.24
Food allergy details					
No. of food allergies					
Single (n = 73)	51 (69.3)	22 (30.7)	1.00	1.00	
Two (n = 33)	21 (63.6)	12 (36.4)	1.3 (0.6-3.1)	1.5 (0.6-2.9)	.39
Multiple (n = 42)	23 (54.8)	19 (45.2)	1.9 (0.9-4.2)	2.1 (0.9-3.8)	.09
Type of food allergy					
Without nut (n = 45)	34 (75.6)	11 (24.4)	1.00	1.00	
With nut (n = 103)	61 (59.2)	42 (40.8)	2.9 (0.9-4.7)	2.9 (1.1-4.4)	.03

Numbers might not add up to total because of missing values.

*All models were adjusted *a priori* for sex, school type, school sector, and student's county of birth. Separate models were fitted for the clinical factors of asthma and food allergy details, and the food allergy models (number of food allergies and type of food allergies) were additionally adjusted for asthma because of evidence of confounding.

Previously, our HealthNuts study has reported the highest rate of challenge-proved food allergy in the world for 1-year-old infants.¹ At almost 10%, a very high burden of food allergy is experienced by parents of allergic infants, with implications for the Australian health care system. Self-reported food allergy prevalence of 6.6% in young adolescents within the SchoolNuts study supports the natural history of resolution of food allergy for many children with food allergy. However, the finding that almost half of 10- to 14-year-old adolescents with food allergies experienced reactions in the past 12 months highlights the ongoing burden that food allergy has on subjects, with subsequent effects on their families and health care facilities.

We found that female subjects were more likely to report experiencing any adverse food reaction in the past 12 months but found no significant sex difference associated with anaphylaxis. This is in contrast to observations of increased risk of fatality from anaphylaxis in adolescent male subjects and might reflect the younger age group in our study.⁹

Our data suggest a benefit from the current compulsory training around food allergy that has been in place in the educational sector in Australia (first introduced from 2008 in some states) because fewer reactions occurred in schools compared with restaurants and homes. However, this might simply reflect that more meals are eaten at home versus school or eating out. Moreover, the finding that just over half of reactions occurred in the home highlights the importance of allergen avoidance and education/management strategies targeted at preventing accidental exposure in all environments and not just schools.

We note that less than half (43.2%) of the cases of confirmed anaphylaxis reported adrenalin autoinjector administration, and this worrying result requires further exploration. It is unclear whether this is simply a result of underreporting as a result of retrospective recall or whether this represents true underadministration. However, it is important to note that the well-known risk of anaphylaxis, including reported fatalities in the school environment, has resulted in legislated guidelines for anaphylaxis management for schools in Australia. All Victorian schools with an enrolled student at risk of anaphylaxis are mandated to have an annually updated action plan for each student at risk of anaphylaxis, staff must undertake regular training on anaphylaxis management and autoinjector administration, and generic autoinjectors must be available within the school.

In SchoolNuts one third (32.4%) of adolescents with food allergy reported current asthma. This is much higher than in the Turkish school-based population-representative study, which reported a prevalence of asthma of 12.3% in those with food allergy.²⁹ We also found those with asthma (both resolved and current asthma) were almost twice as likely to report a food reaction in the past 12 months compared with those with no history of asthma. Surprisingly, those reporting anaphylaxis had more asthma than those reporting milder reactions; however, asthma was not found to be significantly associated with increased risk of anaphylaxis. This trend toward increased association of asthma with increased severity of reactions is supported by case series that report up to 50% of children

TABLE IV. Details of self-reported food allergy episodes (n = 372) reported by students with possible IgE-mediated food allergy (n = 243) in the past 12 months in the SchoolNuts study

Episodes	All reactions, no. (%)	Confirmed anaphylaxis, no. (%)*	Unrecognized anaphylaxis, no. (%)†	Likely IgE mediated, no. (%)‡	Unlikely IgE mediated, no. (%)§	Reactions that could not be classified, no. (%)
	372	44 (11.8)	49 (13.1)	149 (40.1)	42 (11.2)	88 (23.7)
Trigger food						
Peanut	66 (17.7)	17 (38.6)	15 (30.6)	30 (20.1)	0	4 (4.5)
Tree nut	49 (13.2)	11 (25.0)	10 (20.4)	1 ²³ (15.4)	0	5 (5.7)
Nut, unspecified	17 (4.6)	5 (11.4)	3 (6.1)	9 (6.0)	0	0
Egg	23 (6.2)	2 (4.5)	2 (4.1)	17 (11.4)	1 (2.4)	1 (1.1)
Milk	56 (15.1)	5 (11.4)	2 (4.1)	19 (12.8)	22 (52.4)	8 (9.1)
Shellfish and fish	16 (4.3)	2 (4.5)	5 (10.2)	8 (5.4)	0	1 (1.1)
Sesame	1 (0.3)	0	1 (2.0)	0	0	0
Kiwifruit	12 (3.2)	0	1 (2.0)	11 (7.4)	0	0
Pine nut	2 (0.5)	0	2 (4.1)	0	0	0
Soy	5 (1.3)	1 (2.3)	1 (2.0)	2 (1.3)	0	1 (1.1)
Wheat	11 (2.9)	0	1 (2.0)	0	9 (21.4)	1 (1.1)
Other foods	48 (12.9)	0	4 (8.2)	24 (16.1)	8 (19.0)	12 (13.6)
Food not reported	66 (17.7)	1 (2.3)	2 (4.1)	6 (4.0)	2 (4.8)	55 (62.5)
Symptoms¶						
Skin rash	150 (40.3)	26 (59.1)	26 (53.1)	87 (58.4)	3 (7.1)	8 (9.1)
Facial swelling	96 (25.8)	33 (75.0)	19 (38.8)	41 (27.5)	0	3 (3.4)
Vomiting	61 (16.4)	12 (27.3)	9 (18.4)	31 (20.8)	5 (11.9)	4 (4.5)
Diarrhea	32 (8.6)	2 (4.5)	3 (6.1)	14 (9.4)	12 (28.6)	1 (1.1)
Breathing difficulty	131 (35.2)	44 (100.0)#	49 (100.0)**	34 (22.8)	0	1 (1.1)
Other	78 (21.0)	9 (20.4)	12 (24.5)	28 (18.8)	26 (61.9)	3 (3.4)
NA	73 (19.6)	0	0	3 (2.0)	2 (4.8)	68 (77.3)
Location						
Home	170 (45.7)	17 (38.6)	20 (40.1)	87 (58.4)	25 (59.5)	21 (23.9)
Restaurant	33 (8.9)	7 (15.9)	9 (18.4)	13 (8.7)	3 (7.1)	1 (1.1)
School	27 (7.3)	4 (9.1)	4 (8.2)	15 (10.1)	3 (7.1)	1 (1.1)
Friend's house	21 (5.6)	4 (9.1)	3 (6.1)	10 (6.7)	1 (2.4)	3 (3.4)
Other	50 (13.4)	12 (27.3)	9 (18.4)	20 (13.4)	8 (19.0)	1 (1.1)
NA	71 (19.1)	0	4 (8.2)	4 (2.1)	2 (4.8)	61 (69.3)
EpiPen used						
Yes	26 (6.9)	19 (43.2)	6 (12.2)	1 (0.7)	0	0
No	319 (85.8)	21 (47.7)	40 (81.6)	145 (97.3)	38 (90.5)	75 (85.2)
Do not know	15 (4.0)	4 (9.1)	1 (2.0)	3 (2.0)	4 (9.5)	3 (3.4)
NA	12 (3.2)	0	2 (4.1)	0	0	10 (11.4)

Tree nut details: *almond × 1, pistachio × 2, hazelnut × 1, cashew × 2, walnut × 3, Brazil nut × 1, and macadamia × 1; †walnut × 3, cashew × 6, and almond × 1;

‡cashew × 11, walnut × 5, hazelnut × 6, almond × 1, and macadamia × 1; and ||hazelnut × 1, and walnut × 4. *Other food details:* †pineapple × 1, eggplant × 2, kiwifruit × 5, and confectionary × 1; ‡watermelon × 1, chocolate × 2, strawberry × 3, celery × 2, citrus fruit × 3, avocado × 1, pineapple × 4, tomato × 3, mango × 1, mushroom × 1, banana × 1, eggplant × 1, and apple × 1; §cauliflower × 1, pork × 1, food coloring × 2, citrus × 1, spring roll × 1, banana × 1, fructose × 1, and lactose × 1; and ||chocolate × 4, strawberry × 1, kiwifruit × 2, cake × 1, beef × 1, rice × 1, blueberry × 1, and garlic × 1.

NA, Not available.

¶Numbers do not add up to total because each episode could have multiple symptoms recorded.

#Forty-one of 44 episodes of confirmed anaphylaxis reported breathing difficulties with 1 or more symptoms of skin rash, facial swelling, and/or vomiting.

**Forty-two of 49 episodes of "unrecognized anaphylaxis" reported breathing difficulties with 1 or more symptoms of skin rash, facial swelling, and/or vomiting.

(0-18 years) with reactions severe enough to present to an emergency department having coexistent asthma³² and almost all fatalities from food-induced anaphylaxis reported to have coexisting asthma.^{10,11} Our study might have been underpowered to observe an association for asthma and anaphylaxis, and we did not capture or report on fatality data. Asthma as a risk factor for food-induced anaphylaxis requires further investigation.

Peanut and tree nuts were the most common food allergies reported in our study, including among students with a history of anaphylaxis, which is consistent with other studies.^{24,32-34} Among those reporting reactions, nut allergy increased the risk 3-fold of having a reaction consistent with anaphylaxis when compared with those without nut allergy. Yet among those with

IgE-mediated food allergy, nut allergy was associated with decreased risk of having a reaction in the past 12 months. This apparently paradoxical result might be the result of widespread awareness of the potential severity of nut allergy and adoption of strategies to assist in nut avoidance, such as food policies banning nuts. It might also be easier to avoid nut ingestion than other more ubiquitous food allergens, such as egg or milk. However, the association of nut allergy with more severe reactions might be that once accidental exposure to an allergen occurs, nuts elicit more severe reactions than exposure to other allergens, such as milk and egg, which are often tolerated in a baked or processed form.^{35,36}

Having more than 2 food allergies doubled the risk of a food allergy reaction compared with those with a single food allergy,

and there was a trend toward higher risk of reactions consistent with anaphylaxis among those with more than 2 food allergies compared with those with a single food allergy. This might reflect that the chance of accidental exposure is higher if multiple food allergens need to be avoided. Additionally, this might be indicative of a higher-risk subset of adolescents with multiple food allergies because of coexisting allergies to the more common later-onset allergies (fish/shellfish, nuts, or both) together with persistent milk allergy, egg allergy, or both. Milk and egg allergy have previously been thought to resolve by early school age, but recent data suggest increasing persistence into adolescence, with persistent allergy associated with more severe reactions to milk and egg.^{35,36} Turner's report of anaphylaxis in adolescents from a tertiary clinical center in London³⁷ showed that the majority of those with recent severe anaphylactic reactions had been triggered by exposure to cow's milk protein in the context of persistent cow's milk allergy from earlier childhood. Although the study by Turner³⁷ did not report the presence of other coexisting food allergies, adolescents with multiple food allergies, including unresolved milk allergy, egg allergy, or both, might represent a higher-risk phenotype for anaphylaxis that has not been sufficiently considered to date.

In conclusion, within a population-based sample of 10- to 14-year-old adolescents with food allergy in Melbourne, Australia, there was an alarmingly high rate of food-induced allergic reactions, including anaphylaxis. Reactions occurred most frequently in the home and were most commonly triggered by peanut and tree nuts. Those with asthma and more than 2 food allergies were at greatest risk for reactions, but those with nut allergies were most at risk of reactions consistent with anaphylaxis.

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Clinical implications: Adolescents are at highest risk of death from food-induced anaphylaxis. This study offers population-representative data on the frequency, characteristics, and associated risk factors for adverse food reactions among adolescents. It highlights also the alarming frequency of adverse food reactions among adolescents and the need for specific management and education strategies aimed at allergen avoidance in this high-risk age group.

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