

Prevalence of clinic-defined food allergy in early adolescence: The SchoolNuts study

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Background: Rising rates of food-induced anaphylaxis have recently been shown in the adolescent age group, following earlier descriptions of a rise in children younger than 5 years. However, few population-based studies have examined the prevalence of food allergy in adolescence using objective measures such as oral food challenge (OFC).

Objective: We sought to determine the prevalence of food allergy among a population-based sample of 10- to 14-year-old adolescents using clinical evaluation including OFC to confirm the diagnosis.

Methods: Schools were randomly selected from greater metropolitan Melbourne, Australia. Students aged 10 to 14 years, and their parents, were asked to complete a questionnaire regarding the adolescent's food allergy or food-related reactions. Clinic evaluation, which consisted of skin prick tests and OFC where eligible, was undertaken if students were suspected to have current food allergy from parent response. Among 9816 students assessed, 5016 had complete parent response and clinic evaluation when eligible. An additional 4800 students had student questionnaires only.

Results: The prevalence of clinic-defined current food allergy based on history, sensitization data, and OFC results was 4.5% (95% CI, 3.9-5.1), with the most common food triggers being peanut, 2.7% (95% CI, 2.3-3.2), and tree nut, 2.3% (95% CI, 1.9-2.8). Among the additional group of 4800 adolescents who had only self-reported food allergy status available, the prevalence of self-reported current food allergy was 5.5% (95% CI, 4.9-6.2), with peanut, 2.8% (95% CI, 2.3-3.3), and tree nut, 2.3% (95% CI, 1.9-2.8), the most common.

Conclusions: Approximately 1 in 20 10- to 14-year-old school students in Melbourne has current food allergy. This high prevalence suggests that the previously reported rise in food-induced anaphylaxis in this age group may reflect an increasing prevalence of food allergy rather than simply increased reporting of anaphylaxis. (*J Allergy Clin Immunol* 2017;■■■:■■■-■■■.)

Key words: Food allergy, adolescence, anaphylaxis, peanut allergy, tree nut allergy, prevalence, population

Although previous data on hospital anaphylaxis admission rates showed that anaphylaxis related to food allergy was most common among preschool-aged children,^{1,2} more recent Australian data suggest that the increase in food anaphylaxis admission rates for older children is accelerating at a greater rate than for preschool-aged children.³ However, despite the accelerating increase in rates of anaphylaxis, the prevalence of food allergy in this age group at the population level has not been studied to the same extent as in early childhood.⁴⁻⁶ In particular, few studies have used objective tests for sensitization (skin prick test [SPT] or specific IgE [sIgE] levels) and oral food challenge (OFCs) tests as the diagnostic criteria when measuring the prevalence of food allergy in older children.⁷⁻⁹

We aimed to assess the population prevalence of clinic-confirmed food allergy and to investigate disease characteristics in the early adolescent age group within the SchoolNuts study.

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Abbreviations used

ICSEA: Index of Community Socio-educational Advantage
 OFC: Oral food challenge
 sIgE: Specific IgE
 SPT: Skin prick test

METHODS**Study design**

A school-based, cross-sectional stratified cluster sampling of primary and secondary school students in greater metropolitan Melbourne (population 3.6 million) was used to recruit a sample of 10- to 14-year-old children (from 2011 to 2014). Schools were randomly selected to reflect the variation in socioeconomic status throughout school districts, and included each of the government, Catholic, and independent school sectors. 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 versus secondary 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 by an independent statistician to select schools to approach.

At each participating school, we invited all students in years 5 and 6 (primary schools) and 7 and 8 (secondary schools) to take part. Researchers visited the schools to distribute a self-administered questionnaire to parent-consented students (student questionnaire). Their parents were also asked to complete a questionnaire (parent questionnaire). To improve the parent participation rate, modified versions of the parent questionnaires with survey questions shortened were subsequently sent by mail, email, or SMS to those who had not completed the full parent questionnaire.

Questionnaire identification of possible food allergy cases (phase 1). The student questionnaire included questions regarding the student's history of food allergy and asthma, and knowledge and attitudes toward food allergy. The parent questionnaire collected additional information on the student's history of food allergy along with family's demographic characteristics, and the allergy history of the other family members.

We selected students eligible for clinic evaluation by a 2-step process. On the basis of the assumption that parents have a better understanding about the history of the student's food allergy, we identified the students with possible current food allergy through the response to the parent questionnaire. Broad criteria were used to capture all cases of possible current food allergy, which was a positive response to either of the following questions:

1. "Does your child currently have food allergy?"
2. "Has your child ever had food allergy, a food reaction, or food-related anaphylaxis?"

Or a negative response to the following question:

3. "Has your child ever eaten the following common allergens (egg, cow's milk, sesame, fish, shellfish, soy, peanut, tree nuts)?" to capture students who may have unrecognized food allergy.

Trained allergy research nurses then collected further information of the reaction/allergy by phone to evaluate whether current food allergy was likely, and if so, whether it was possibly IgE-mediated or not. Students were invited for clinic evaluation when the history suggested current IgE-mediated food allergy (ie, evidence of an acute allergic reaction following ingestion of a food).

Clinic evaluation (phase 2). Students with parent-reported possible food allergy from phase 1 underwent an SPT to a panel of 15 food allergens (egg white, cow's milk, soy, peanut, cashew, almond, hazelnut, walnut, pistachio, macadamia, pecan, brazil nut, pine nut, sesame, shellfish) along with a positive and a negative saline control (ALK-Abelló SA, Madrid, Spain) as well as any other reported allergens using a single tine lancet (Stallergenes, Antony, France) on the student's volar forearm. Blood samples were also collected for serum IgE level measurement.

OFC test. Students were eligible for OFC if they had a positive SPT result to a food they had a history of reaction to and currently avoiding, or they had never eaten. We considered participants with the following criteria to be highly likely to be clinically allergic to that food and did not perform the OFC.^{10,11}

1. SPT wheal size of 3 mm or more AND 1 or more of the following:
 - a. a history of severe reaction requiring multiple doses of adrenaline;
 - b. an episode of anaphylaxis when older than 10 years; and
 - c. a convincing history of recent reaction (in the past 12 months) consistent with IgE-mediated food allergy.

Or

2. A history of reaction and highly sensitized (SPT wheal size of ≥ 8 mm).

A small number of OFCs were conducted despite a negative SPT result due to equivocal history. OFC dosage protocols were consistent with those of the Australian Society of Clinical Immunology and Allergy using graded, incremental doses administered at 15- to 20-minute intervals. Criteria to define a positive OFC result were based on the standardized criteria used in the HealthNuts study with 1 modification, namely, the inclusion of strictly defined subjective persistent symptoms in the upper airways or the gastrointestinal tract^{12,13} (for details, see this article's Online Repository at www.jacionline.org).

OFCs were deemed positive if they showed 1 or more of the following reactions within 2 hours of ingestion: 3 or more concurrent noncontact urticaria persisting for at least 5 minutes, perioral or periorbital angioedema, vomiting/diarrhea, or evidence of circulatory or respiratory compromise. When the student did not show objective signs, but had the subjective symptoms of itchy mouth or throat, abdominal pain or nausea, tightness in throat, difficulty talking or difficulty breathing, continuing up to the timing of the next dose, the previous dose was repeated. If the above symptoms persisted for a total of more than 40 minutes or reoccurred on 3 doses, it was recorded as a positive reaction as per previous guidelines.¹⁴

OFCs were deemed negative when the student had a negative result on the day of the OFC and did not report any positive reactions during home-based food introduction in the week after the OFC.

Definitions

We classified students into 2 groups depending on the availability of the parent questionnaire and completion of research nurse history. Students who had a parent questionnaire, with successful phone contact and completion of clinic evaluation when eligible, had a clinic-defined food allergy status available and were classified as the clinic group. *Current clinic-defined food allergy* was defined as a positive OFC or convincing recent or severe history in the context of IgE sensitization (SPT wheal size of ≥ 3 mm or sIgE ≥ 0.35), or highly sensitized (SPT wheal size of ≥ 8 mm) (see [Table 1](#) for details). Students eligible for an OFC but declined were also treated as inconclusive current food allergy cases.

We classified the remaining students, who had a student questionnaire only or parent questionnaire but without nurse contact or completion of clinic evaluation when eligible, as the questionnaire group. An affirmative response to "Do you have current food allergy?" to core foods was defined as self-reported current food allergy among the questionnaire group ([Table II](#)).

We defined the core foods to which we evaluated the prevalence of allergy as cow's milk, egg, soy, wheat, peanut, tree nuts, pine nut, sesame, fish, shellfish, kiwi, banana, avocado, meats, and legumes, on the basis of the most commonly reported allergens in clinics.¹⁵

Ethics

Ethical approval was obtained from the Royal Children's Hospital Human Research Ethics Committee (Human Research Ethics Committee no. 31079), the Department of Education and Early Childhood, and the Catholic Education Office.

TABLE I. Clinic-defined food allergy status (clinic group)

Status	Summary	Recent or severe IgE reaction*	SPT wheal size	OFC result
Clinic-defined current food allergy	Positive OFC results with sensitization		≥3 or sIgE ≥0.35†	Positive
	Recent or severe reaction with sensitization	Yes	≥3 or sIgE ≥0.35‡	Not required
	Highly sensitized		≥8§	Not required
Clinic-defined inconclusive current food allergy	Sensitized, currently avoiding, without recent or severe reaction	No	≥3 and <8	Declined OFC
	Inconclusive OFC results			Inconclusive
	Subjective symptoms on OFC with no evidence of sensitization		<3 and sIgE <0.35	Positive
Clinic-defined no current food allergy	Negative OFC results			Negative
	Not sensitized, currently avoiding, without recent or severe reactions	No	<3 and sIgE <0.35	Not required
	No parent report of possible current food allergy, or nurse-confirmed history of no current IgE-mediated food allergy if parent-reported status unclear in questionnaire		Clinic evaluation not required	

*Recent reaction is defined as an IgE reaction in the past 1 y or anaphylaxis at age 10 y or later; severe reaction is anaphylaxis requiring 2 or more epinephrine administrations. †n = 5 cases in this category had SPT wheal size of <3 mm and sIgE of <0.35 but convincing objective signs at OFC.

‡n = 5 cases in this category had SPT wheal size of <3 mm and sIgE of <0.35 but convincing recent or severe reaction with objective signs.

§Students with an SPT wheal size of ≥8 mm who had never ingested that food were considered eligible for OFC.

TABLE II. Self-reported food allergy status (questionnaire group)

Status	Summary
Self-reported current food allergy	Student reporting current food allergy to 1 or more core foods*
Self-reported inconclusive current food allergy	Student reporting “Don’t know” or missing response to whether they have current food allergy
	Student reporting current food allergy but allergen not stated
Self-reported no current food allergy	Student reporting no current food allergy to any core food

*Core foods were defined as cow’s milk, egg, soy, wheat, peanut, tree nuts, pine nut, sesame, fish, shellfish, kiwi, banana, avocado, meats, and legumes.

Participants’ demographic characteristics

We calculated the socioeconomic status of participants by using the Index of Community Socio-educational Advantage (ICSEA) score for each school, which is generated from student-level parent occupation and education, location, and percent indigenous student enrolment developed by the Australian Curriculum, Assessment and Reporting Authority.¹⁶

Statistical analysis

The prevalence and 95% CIs of clinic-defined current food allergy and self-reported current food allergy were each calculated as the observed proportion among the clinic group and the questionnaire group, respectively. A sensitivity analysis was conducted to determine whether the prevalence estimates of clinic-defined current food allergy were likely to be influenced by differences in demographic factors between students with complete participation (clinic group) and students with incomplete participation (questionnaire group) or nonparticipants (students who were eligible but did not participate). Weights were used to adjust the estimated prevalence to reflect the distribution of risk factors among the combined sample of participants and nonparticipants. The weights were the inverse of the probability of participation, obtained after fitting a logistic regression model using the ICSEA score, which was available for the whole study population including nonparticipants.¹⁷ All statistical analysis was undertaken using Stata version 14.1 (StataCorp, College Station, Tex).

RESULTS

School and student participation

Of the 229 schools contacted, 117 (51.1%) participated in the study. The proportion of participating schools in each of the government, Catholic, and independent school sectors reflected

the overall distribution of school types in Victoria, with the exception of slightly fewer government primary schools.¹⁸ There were no consistent patterns for differences in participation according to either size of the school or socioeducational advantage (see Table E1 in this article’s Online Repository at www.jacionline.org). Participating government primary schools had a slightly lower median ICSEA score, which indicates less socioeducational advantage.

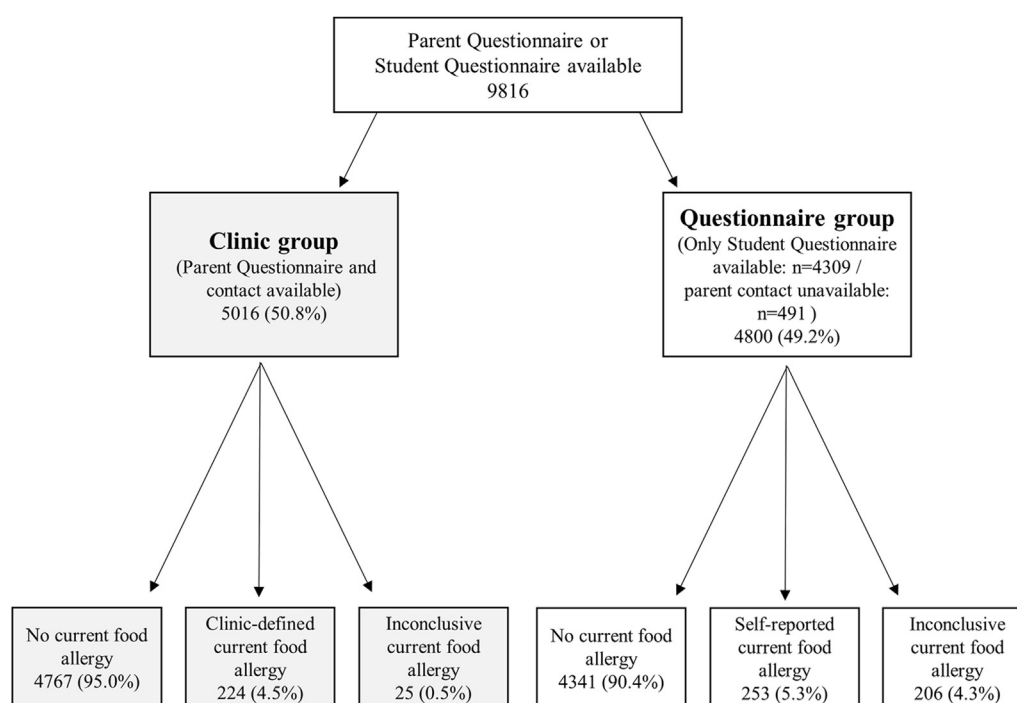
Among the 20,965 eligible students in the participating schools, the student questionnaire was completed by 9,663 (46.1%) students. The parent questionnaire in written, online, or SMS format was available for 5,354 students who completed the student questionnaire (55.4%) and 153 students without the student questionnaire, which resulted in parent participation for 5507 students (26.3% of the total number of eligible students). A total of 9,816 students had either a student questionnaire or a parent questionnaire available.

Fig E1 in this article’s Online Repository at www.jacionline.org describes the school, student, and parent participation in the study. Among the students with a parent questionnaire, 1875 (34.0%) were eligible for further contact having responses suggesting possible current food allergy, of which we successfully contacted 1546 (82.4%). Current food allergy was considered unlikely following clinical history for 1031 (66.7%) students due to the reasons described in Fig E1. Among the 515 students (33.3%) who were eligible for clinic evaluation, 353 (68.5%) completed the evaluation. Overall, 5016 students had a parent questionnaire and completed clinic evaluation when eligible

TABLE III. Demographic characteristics of the study population

Characteristic	Whole study population (N = 9816) % (n/N)	Clinic group (n = 5016) % (n/N)	Questionnaire group (n = 4800) % (n/N)
Student's sex (male)	50.7 (4973/9814)	51.7 (2594/5015)	49.6 (2379/4799)
Student's school grade			
Primary school (year 5-6)	51.7 (5078/9814)	55.1 (2765/5014)	48.2 (2313/4800)
Secondary school (year 7-8)	48.3 (4736/9814)	44.9 (2249/5014)	51.8 (2487/4800)
Student's country of birth			
Australia	85.7 (8365/9765)	88.3 (589/5013)	82.9 (3941/4752)
Other	14.3 (1400/9765)	11.8 (589/5013)	17.1 (811/4752)
ICSEA*			
Quartile 1 (least advantaged)	24.9 (2445/9816)	15.9 (796/5016)	34.3 (1649/4800)
Quartile 2	23.2 (2278/9816)	20.3 (1017/5016)	26.3 (1261/4800)
Quartile 3	26.8 (2633/9816)	31.6 (1588/5016)	21.8 (1045/4800)
Quartile 4	25.1 (2460/9816)	32.2 (1615/5016)	17.6 (845/4800)

*The ICSEA is a scale of socioeducational advantage generated from student-level parent occupation and education, remoteness, and percent indigenous student enrolment. Lower scores indicate more disadvantage.

**FIG 1.** Overview of the prevalence analysis.

from the history provided by the parent questionnaire and phone contact (classified as the clinic group).

Students who had a parent questionnaire response suggesting possible food allergy but were not contactable ($n = 329$), and those who were contacted and eligible for clinic evaluation but declined ($n = 162$), were combined with the remainder of the students who only had a student questionnaire ($n = 4309$) in the questionnaire group. The demographic characteristics of the whole study population and the 2 groups are presented in Table III.

The prevalence of current food allergy

Fig 1 describes the overview of participation and the analysis. The prevalence of clinic-defined current food allergy was 4.5% (95% CI, 3.9-5.1). The prevalence of current food allergy for

each core food is presented in Table IV, with the most common food triggers being peanut, 2.7% (95% CI, 2.3-3.2), and tree nut, 2.3% (95% CI, 1.9-2.8). Among the individual tree nuts, cashew had the highest prevalence (1.6%). Egg had the highest clinic-defined prevalence (0.5%) among the other (non-nut) foods. Further information on the numbers of students who were diagnosed with clinic-defined current allergy by each of the criteria used for diagnosing food allergy is provided in Table V.

Among the additional group of 4800 adolescents who had only self-reported food allergy status available, the prevalence of self-reported current food allergy was 5.5% (95% CI, 4.9-6.2), with peanut, 2.8% (95% CI, 2.3-3.3), and tree nut, 2.3% (95% CI, 1.9-2.8), the most common. Although cashew was the most commonly self-reported tree nut allergen (0.7%), 52 students (1.1%) in the questionnaire group did not specify which tree nut

TABLE IV. Prevalence of current food allergy to each core food

Food	Clinic group, %, 95% CI (n/5016)*	Questionnaire group, %, 95% CI (n/4800)*
Any core food	4.5, 3.9-5.1 (224)	5.5, 4.9-6.2 (253)
Peanut	2.7, 2.3-3.2 (135)	2.8, 2.3-3.3 (127)
Tree nut (any tree nut)	2.3, 1.9-2.8 (116)	2.3, 1.9-2.8 (106)
Individual tree nut		
Cashew	1.6 (82)	0.7 (32)
Pistachio	1.0 (48)	0.5 (24)
Walnut	0.7 (34)	0.4 (18)
Hazelnut	0.7 (34)	0.3 (13)
Macadamia	0.2 (11)	0.2 (7)
Pecan	0.2 (9)	0.2 (7)
Almond	0.1 (4)	0.2 (9)
Brazil nut	0.1 (4)	0.1 (5)
Unspecified tree nut†		1.1 (52)
Other food (nonpeanut/tree nut food)	1.4, 1.1-1.8 (70)	3.3, 2.8-3.9 (151)
Pine nut	0.1 (6)	0.1 (5)
Sesame	0.2 (9)	0.3 (15)
Egg	0.5 (26)	0.7 (32)
Cow's milk	0.2 (12)	0.9 (41)
Shellfish	0.3 (15)	0.8 (35)
Fish	0.2 (8)	0.6 (29)
Soy	<0.1 (1)	0.3 (13)
Wheat	0.1 (3)	0.3 (13)
Kiwi	0.1 (7)	0.5 (23)
Banana	0 (0)	0.2 (7)
Other core food‡	0.1 (3)	0.2 (7)

Prevalence was calculated for each food when there were more than 5 students allergic in either group, with 95% CI for the population prevalence for peanut, tree nut (any tree nut), or other food (any core non-nut food). The total number of students with allergy to each core food is larger than the number of students with allergy to any core food because, on average, each individual had allergy to 2.8 core foods in the clinic group and 2.0 core foods in the questionnaire group (calculated by treating unspecified tree nut as 1 allergen).

*Prevalence for each food or group was calculated as the proportion of the number of students with clinic-defined current allergy or self-reported allergy among the children in the clinic group and the questionnaire group, respectively, with exclusion of the students with inconclusive allergy status to each food or group from the denominator. †n = 52 students in the questionnaire group did not specify the tree nut that they were allergic to.

‡Other clinic-defined core food allergy was to avocado (n = 3), and other self-reported core food allergy was to avocado (n = 1), meats (n = 4), and legumes (n = 2).

they were allergic to. Milk was the most common self-reported allergen (0.9%) among the other foods.

Coexistence of peanut, tree nut, and other food allergies

Fig 2 describes the number of students with multiple food allergies to peanut, any tree nut, or any other foods. Clinic-defined tree nut allergy and peanut allergy coexisted in 41.5% (56 of 135) of the peanut-allergic students. Among the students with any clinic-defined current food allergy, 7.6% (17 of 224) were allergic to all of peanut, tree nut, and another non-nut food.

Self-reported peanut and tree nut allergy was coexistent in 55.1% (70 of 127) of the peanut-allergic students in the questionnaire group, and 13.8% (35 of 253) of students with any self-reported food allergy reported multiple allergy to peanut, any tree nut, and any other food.

Details of the OFCs

We performed a total of 266 OFCs among 200 participants. Table VI describes the reactions observed in the 91 OFCs that were positive at day 1. Cardiovascular and lower respiratory tract reactions were observed in 2 (2.2%) and 22 (24.2%) OFCs, respectively, and a total of 6 (6.6%) cases received adrenaline. The challenges requiring adrenaline treatment were to peanut, cashew, pecan, and shrimp and 2 challenges to sesame. Persistent itchy mouth or tongue was the most commonly reported reaction, which was recorded in 47% of the OFCs, followed by skin reactions, which were observed in 44.0% of all OFCs.

Reweighting clinic-defined current food allergy prevalence to general population

The rate of self-reported food allergy by the student questionnaire was higher among the students in the clinic group than in the questionnaire group (7.0% vs 5.5%, data not shown). The ICSEA score had a difference in its distribution between the 2 groups (Table III), and also showed an association with the prevalence of clinic-defined food allergy ($P < .01$, data not shown). Thus, the prevalence of clinic-defined food allergy was reweighted to the whole study population including nonparticipants (n = 20,965) using the ICSEA score. This produced an estimated prevalence of 4.2% (95% CI, 3.6-4.8).

DISCUSSION

This is the first study reporting the population prevalence of clinic-defined food allergy among early adolescents in Australia, a country with high rates of food allergy. The prevalence of clinic-evaluated food allergy was 4.5% (95% CI, 3.9-5.1). Peanut and tree nuts were the major allergens among this age group, with each having a prevalence over 2%.

The strengths of this study are the large population-based data set and the thorough clinic evaluation that included OFC to confirm food allergy diagnosis. We contacted not only the students who reported current food allergy but also those who had been previously food allergic, had any reaction from food, or had never eaten specific foods (possibility of unrecognized allergy) with the goal of capturing the “true” prevalence of current food allergy. In addition, by evaluating a full panel of allergens including multiple tree nuts, we have been able to investigate the population prevalence of tree nut allergy, which has not previously been well described.

A previous UK study in 2002 among 11- and 15-year-old adolescents using a similar method, defining current food allergy by the presence of a positive OFC result, convincing history of previous reactions in the presence of a positive SPT result, or a physician's diagnosis, reported a prevalence of current food allergy to all foods as 2.3% for each age group.⁷ Other population-based studies investigating the prevalence of food allergy in adolescents include a Turkish study in 2011 of 11- to 15-year-old adolescents that reported a challenge-proven prevalence of 0.15% to all foods, where the most common allergen was peanut (0.05%) and tree nuts (0.05%).⁸ A Swedish study in 2010 reported the prevalence of clinic-defined food allergy to milk, egg, cod, and wheat as 1.4%, which used history of reactions and evidence of sensitization as the diagnostic criteria.⁹ There are methodological differences mainly around the use of OFC and assessed foods between these previous studies

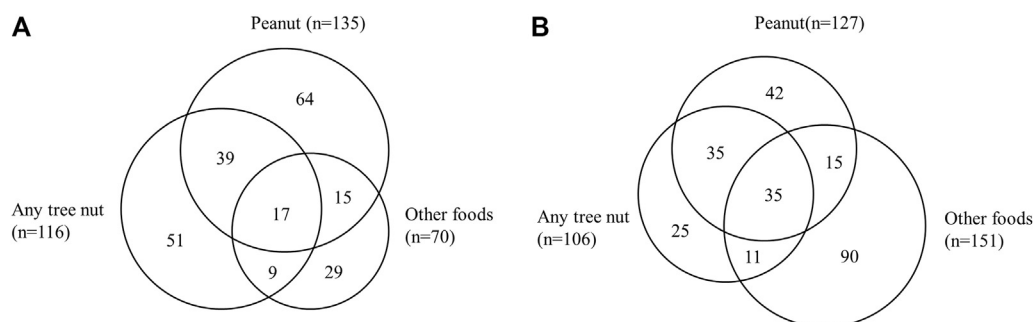
TABLE V. Number of students with clinic-defined current allergy diagnosed by each criterion and children with inconclusive food allergy

Food	Clinic-defined current food allergy, n	Challenge positive, %*	Deemed allergic due to SPT wheal size of ≥ 8 mm, %*	SPT wheal size of ≥ 3 mm and < 8 mm, deemed allergic from history, %*	Inconclusive food allergy, n
Any core food†	224	34.8	59.8	14.0	25
Peanut	135	21.3	75.0	3.7	9
Tree nut (any tree nut)‡	116	31.9	80.2	8.6	37
Individual tree nut					
Cashew	82	26.8	69.5	3.7	12
Pistachio	48	8.3	91.7	0	34
Walnut	34	23.5	73.5	3.0	25
Hazelnut	34	5.9	85.3	8.8	19
Macadamia	11	0	90.9	9.1	13
Pecan	9	22.2	77.8	0	21
Almond	4	0	50.0	50.0	34
Brazil nut	4	25.0	75.0	0	15
Pine nut	6	0	83.3	16.7	29
Sesame	9	44.4	55.6	0	10
Egg	26	23.1	42.3	34.6	5
Cow's milk	12	25.0	66.7	8.3	2
Shellfish	15	33.3	53.3	13.3	24
Fish	8	12.5	75.0	12.5	2
Soy	1	100	0	0	6
Wheat	3	33.3	66.7	0	4
Kiwi	7	14.3	85.7	0	6
Banana	0	0	0	0	1
Avocado	3	0	66.7	33.3	4

*The proportion of students in each category among the total number of children with clinic-defined allergy to that food.

†The total number of children who had a challenge-proven allergy, not challenged but had a SPT wheal size of ≥ 8 mm, or deemed allergic from history to any core food is greater than the number of students with any clinic-defined core food allergy, because there were students with multiple clinic-defined core food allergy by different reasons.

‡The total number of students who had a challenge-proven allergy to any tree nut, not challenged but had a SPT wheal size of ≥ 8 mm to any tree nut, or deemed allergic to any tree nut from history is greater than the number of students with any clinic-defined tree nut allergy, because there were students with multiple tree nut allergy by different reasons.

**FIG 2.** Coexistence of peanut, tree nut, and other food allergies. **A**, Number of students with clinic-defined allergy to peanut/any tree nut/other foods ($n = 224$). **B**, Number of students with self-reported allergy to peanut/any tree nut/other foods ($n = 253$).

and the SchoolNuts study that limit direct comparison. However, our results are in line with a systematic review reporting the prevalence of tree nut allergy to be around 2% in childhood.¹⁹

Although there is a difference in the age group, our results are also similar to those of a statewide survey in Victoria, Australia, among children at school entry who had parent-reported peanut or tree nut allergy prevalence of approximately 3%.²⁰ The results are also in line with our HealthNuts study, which has shown the rate of challenge-proven food allergy to be 3.0% to peanut for 1-year-old children.¹² In addition, egg allergy contributed significantly to our previously reported prevalence of food allergy at age 1 year (10%) of which 50% had resolved by age 2 years²¹ and 80% by age 4 years,²² but in contrast only 20% of peanut allergy in the HealthNuts cohort had resolved by age 4 years.²³

Some limitations need to be considered. Schools were randomly selected with no consistent characteristic differences between participating and nonparticipating schools. Thus, participating schools are likely to be broadly representative of schools in Melbourne, Australia. However, the participation rate of 46.1% among eligible students might have led to a selection bias. To address the low participation rate, we trialed an opt-out consent method for parents of secondary students among 5 non-Catholic schools (1660 eligible students), where the participation rate was significantly higher compared with the students participating in the opt-in method (opt-out vs opt-in schools: 70.2% vs 44.4%). Among the opt-out group, the prevalence of student-reported current food allergy was lower than the prevalence in the opt-in group after adjusting for age, sex,

TABLE VI. Reactions observed in the positive OFCs*

Reactions	No. of OFCs with reaction	% among the total positive OFCs (N = 91)	% among the total reactions (N = 140†)
Skin reactions			
Hives/erythema/angioedema‡	40	43.9	28.6
Gastrointestinal reactions			
Itchy mouth/throat§	47	51.6	33.6
Vomiting/diarrhea	6	6.6	4.3
Abdominal pain/nausea§	16	17.6	11.4
Upper respiratory tract reactions			
Persistent sneezing/rhinorrhea	6	6.6	4.3
Lower respiratory tract reactions			
Persistent cough/wheeze	6	6.6	4.3
Tightness in throat/difficulty talking or breathing§	17	18.7	12.1
Cardiovascular reaction			
Hypotension	2	1.5	1.4

Six students (1 hypotension, 5 lower respiratory tract reactions) received adrenaline for the treatment of the reaction.

*n = 3 had a positive reaction including objective signs at the subsequent home challenge and deemed positive (not included in this table).

†The total number of reactions (n = 140) is more than the number of positive OFC test results (n = 91) because, on average, each individual had 1.6 reactions.

‡Hives more than 3 and lasting more than 5 min, >50% generalized erythema, and perioral or periorbital angioedema were treated as positive skin reactions.

§These subjective symptoms were treated as positive reactions only when persistent for more than 40 min or when recurred on 3 doses.

and the ICSEA score in the 2 groups (opt-out vs opt-in: 4.7% vs 6.8%), suggesting that nonallergic students were less likely to participate by the opt-in method. Therefore, we conducted a sensitivity analysis, reweighting the prevalence of clinic-defined current food allergy to the whole study population on the basis of the distribution of the ICSEA score, which decreased the estimated prevalence only slightly from 4.5% (95% CI, 3.9-5.1) to 4.2% (95% CI, 3.6-4.8).

The other limitation is the lower participation rate of parents than students, leading to evaluating half of the participating students by the student questionnaire results alone without clinic-defined food allergy status available. However, despite the slight difference between the overall clinic-defined prevalence and self-reported prevalence to any core food, the prevalence of current food allergy to both peanut and tree nuts was surprisingly similar. Peanut and tree nut allergies are most commonly IgE-mediated reactions, with a low probability of achieving tolerance, especially in older ages.¹⁹ This may make self-reported allergy diagnosis to these foods more reliable than for other foods such as milk, where lactose intolerance is commonly mistaken as allergy, which might explain the slightly higher prevalence of milk allergy in the questionnaire group.^{20,24}

In this study, open OFCs rather than double-blind placebo-controlled OFCs were used and persistent subjective symptoms were included as positive criteria. This might have led to some false-positive OFC results. To minimize this risk, we adopted strict criteria for the inclusion of subjective symptoms as a positive reaction by evaluating the persistence and recurrence of the symptom, as previously suggested.¹⁴ Most of the positive OFCs (72%, 68 of 94) had some objective sign or respiratory reaction; among those who did not (n = 26), more than half (n = 14) were challenged because of no history of ingesting the challenged food with a SPT wheal size of 8 mm or more, which suggests that they were likely to have true allergy (data not shown).

In conclusion, 4% to 6% of early adolescents in Melbourne, Australia, had current food allergy to any food. Peanut and tree nut allergy accounted for the majority of food allergy in this age

group. This study provides further evidence for the high prevalence of food allergy in Australia, and at least partly explains the recently identified rising rates of food-induced anaphylaxis in Australia. It also underscores the importance of future investigation into the risk factors for food allergy among this age group.

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Key messages

- The prevalence of current food allergy was 4% to 6% in early adolescents in Melbourne, Australia.
- Peanut and tree nut were the most common allergies, with each affecting 2% to 3% of adolescents.

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OFC PROTOCOL

OFC dosage protocols were consistent with those of the Australian Society of Clinical Immunology and Allergy using graded, incremental doses administered at 15- to 20-minute intervals.

Peanut: Peanut butter

Dose number every 20 minutes:

1. Smear inside lip (not to touch outside lip)
2. 1/16 teaspoon
3. 1/8 teaspoon
4. 1/4 teaspoon
5. 1/2 teaspoon
6. 1 teaspoon

Tree nut: Crushed nut

Dose number every 20 minutes:

1. Smear inside lip (not to touch outside lip)
2. 1/16 teaspoon
3. 1/8 teaspoon
4. 1/4 teaspoon
5. 1/2 teaspoon
6. 1 teaspoon

Cow's milk: Full cream cow's milk

Dose number every 20 minutes:

1. 0.1 mL (not to touch outside lip)
2. 1 mL
3. 5 mL
4. 15 mL
5. 40 mL
6. 100 mL

Soy: Soy milk

Dose number every 20 minutes:

1. 0.1 mL (not to touch outside lip)
2. 1 mL
3. 5 mL
4. 15 mL
5. 40 mL
6. 100 mL

Egg white: Raw egg white

Dose number every 15 minutes:

1. Drop inside lip (not to touch outside lip)
2. 0.5 mL
3. 1 mL
4. 2 mL
5. 5 mL
6. 10 mL
7. Remainder of the 60 g egg white (usually 10-15 mL)

Sesame: Unhulled tahini

Dose number every 20 minutes:

1. Drop inside lip (not to touch outside lip)
2. 0.31 mL
3. 0.62 mL
4. 1.25 mL
5. 2.5 mL
6. 5 mL

Wheat: Plain wheat flower 40 mL (24 g of wheat) mixed with 80 mL of milk or juice

Dose number every 20 minutes:

1. Drop inside lip (not to touch outside lip)
2. 1 mL
3. 2 mL
4. 5 mL
5. 10 mL
6. 20 mL
7. 40 mL

Other foods: A total amount of an age-appropriate 1 serving of the food divided into 5 doses.

Dose number every 15 minutes:

1. Crumb
2. 1/12 of 1 serving
3. 1/6 of 1 serving
4. 1/4 of 1 serving
5. 1/2 of 1 serving

STOPPING CRITERIA OF AN OFC

Cessation of challenge occurred either when an objective unequivocal allergic reaction occurred (challenge deemed positive) or when patient refused to complete challenge (challenge deemed inconclusive) or completed top dose of challenge (challenge deemed negative). In some instances, there was an equivocal reaction that required repeat administration of the same dose as outlined below.

Equivocal reaction

If there was suspicion of an acute allergic reaction (eg, a transient area of erythema or urticaria) but no objective or persistent evidence of the below signs and symptoms, then the previous dose of the challenge protocol was readministered after 15 to 20 minutes had elapsed since the previous dose. For example, the same dose was repeated if only 1 or 2 urticaria particularly was transient (<5 minutes).

Signs and symptoms of a positive challenge ^{E1-E3}

- Three or more concurrent noncontact urticaria persisting for at least 5 minutes
- Perioral or periorbital angioedema
- Vomiting/diarrhea
- Evidence of circulatory or respiratory compromise.

When the student did not show objective signs, but had the following subjective symptoms continuing up to the timing of the next dose, the previous dose was repeated. If the below symptoms persisted for a total of more than 40 minutes or reoccurred on 3 doses, it was recorded as a positive reaction.

- Itchy mouth or throat
- Abdominal pain or nausea
- Tightness in throat
- Difficulty talking or difficulty breathing

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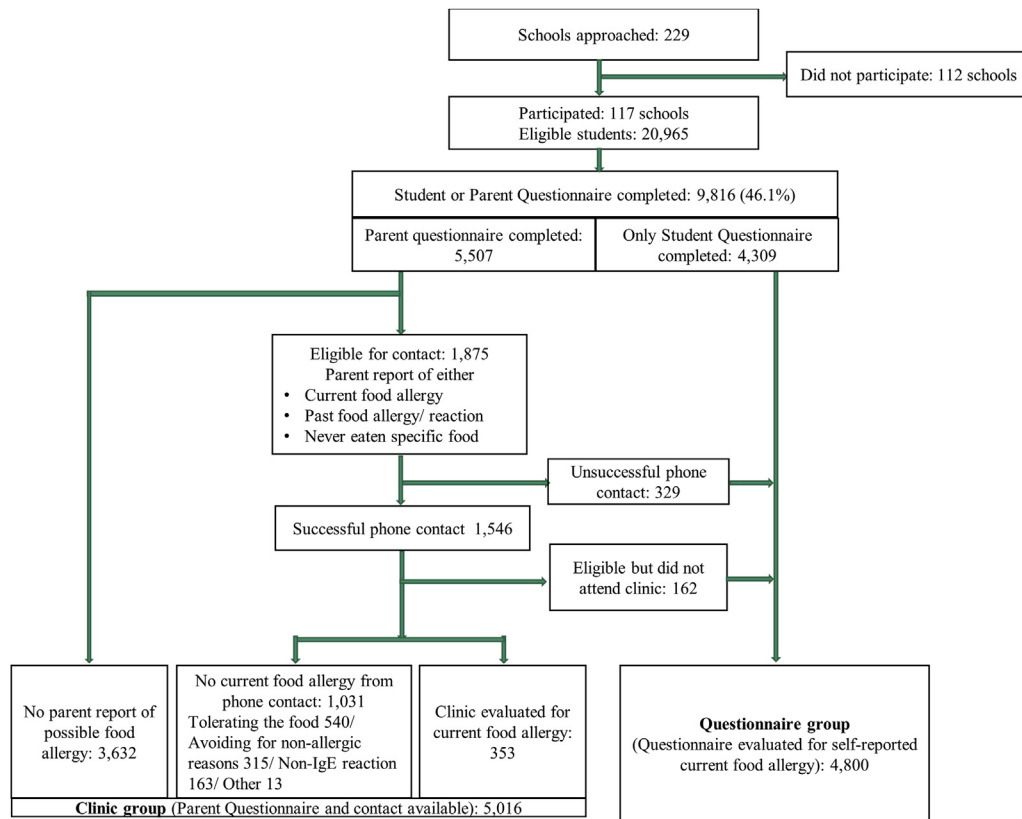


FIG E1. School, student, and parent participation.

TABLE E1. Differences between participating schools and those that declined participation

Characteristic	Participated	Declined	<i>P</i> value (Wilcoxon-Mann-Whitney test)
Government: primary	N = 31	N = 22	
ICSEA,* median (SD)	1018 (61.6)	1033 (69.8)	.03
Size, no. of students—median (SD)	386 (188.0)	419 (210.8)	.22
Government: secondary	N = 19	N = 25	
ICSEA,* median (SD)	977 (46.5)	968 (53.0)	.45
Size, no. of students—median (SD)	736 (491.8)	642 (346.5)	.96
Catholic: primary	N = 32	N = 26	
ICSEA,* median (SD)	1055 (56.3)	1078 (64.9)	.17
Size, no. of students—median (SD)	263 (118.2)	345 (152.9)	.11
Catholic: secondary	N = 8	N = 18	
ICSEA,* median (SD)	1017 (77.8)	1029 (56.1)	.45
Size, no. of students—median (SD)	890 (445.2)	778 (307.2)	.87
Independent: both	N = 15	N = 11	
ICSEA,* median (SD)	1151 (51.3)	1152 (57.6)	.42
Size, no. of students—median (SD)	759 (483.2)	859 (640.6)	.55

*The ICSEA is a scale of socioeducational advantage generated from student-level parent occupation and education, remoteness, and percent indigenous student enrolment. Lower scores indicate more disadvantage.