

ORIGINAL ARTICLE

Epidemiology of Allergic Disease

Asian children living in Australia have a different profile of allergy and anaphylaxis than Australian-born children: A State-wide survey

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Abstract

Background: Asian children born in Australia have higher rates of eczema and nut allergy than non-Asian children. However, it is not known whether this country of birth differential exists for other allergies or anaphylaxis risk.

Objective: We investigated the influence of maternal and child's country of birth on the prevalence of parent-reported eczema, asthma, food allergy and being diagnosed by a doctor as being "at risk of anaphylaxis."

Methods: We assessed the relationship between mother and child country of birth and allergies using the 2010 School Entrant Health Questionnaire, completed for 57 005 5-year old children (85.8% response rate) in Victoria, Australia. Analyses were conducted using logistic regression with results presented as odds ratios (OR) with 95% confidence intervals (CIs).

Results: Children born in Australia to Asian-born mothers were more likely to have parent-reported food allergy (OR 2.33, 95%CI 1.96-2.77) and eczema (OR 2.04, 95% CI 1.73-2.41), but not more likely to have asthma (OR 0.87, 95% CI 0.74-1.02) than non-Asian children. By contrast, children born in Asia who subsequently migrated to Australia had a lower risk of food allergy (OR 0.33, 95%CI 0.20-0.55), eczema (OR 0.37, 95%CI 0.24-0.57) and asthma (OR 0.29, 95% CI 0.21-0.40). Patterns of anaphylaxis risk differed depending on the trigger. Compared with Australian-born non-Asian children, Australian-born Asian children were more likely to be diagnosed as being at risk of both food-induced and non-food-induced anaphylaxis. For children born in Asia, risk was lower for anaphylaxis to milk, peanut and tree nuts compared to non-Asian children, but higher for soy, wheat and non-food triggers.

Conclusions and Clinical Relevance: Patterns of allergy/anaphylaxis risk and their triggers differed according to both ethnicity and country of birth, suggesting a gene-environment factor is in play. The difference in patterns for asthma compared with other atopic diseases is surprising and warrants further exploration.

KEYWORDS

anaphylaxis, Asian, country of birth, ethnicity, food allergy, paediatrics

1 | INTRODUCTION

The burden of food allergy in children is increasing in terms of prevalence and hospitalizations in both developed and developing countries.¹ We recently reported that 10% of infants in Melbourne, Australia had challenge-proven food allergy, the highest food allergy population prevalence yet reported.² An increasing trend of anaphylaxis incidence has been consistently reported in various countries.^{3,4} Most studies confirmed food as the major trigger for anaphylaxis in children⁴⁻⁶ and food allergy, in particular, drove the rapid increase in anaphylaxis admissions in Australian children reported between 1998 to 2012.³

Australia has a high proportion of residents that are of Asian descent, and our studies have shown that Australian-born infants with Asian ethnicity were more likely to have nut allergy and eczema compared to Caucasian ethnicity⁷ while children born in Asia living in Australia at age 5 years had a lower prevalence of nut allergy compared with Australian-born non-Asian children.⁸ This indicates that both genetic and environmental factors likely alter the development of nut allergy. However, less is known about other allergies and anaphylaxis among these groups. Seafood (fish and shellfish) and wheat have been reported to be the main triggers of food allergy and anaphylaxis in some Asian countries,⁹⁻¹³ but little is known about the prevalence of these allergies in Asian children living in other countries.

Using data from the state-wide compulsory School Entrant Health Questionnaire (SEHQ) completed for nearly 60 000 children in 2010 at the time of school entry, we aimed to investigate the influence of maternal and child's country of birth on the prevalence of parent-reported eczema, asthma, food allergy to a range of foods and risk of anaphylaxis by comparing children born in Asia (the largest non-Caucasian immigrant group in Victoria¹⁴), Australian-born Asian children and Australian-born non-Asian children. We also investigated other demographic and environmental factors associated with the prevalence of food-induced and non-food induced-anaphylaxis risk.

2 | METHODS

2.1 | Study design and population

This study utilized data from the School Entrant Health Questionnaire (SEHQ), which is a state level questionnaire completed by the parent or guardian of all children entering primary school (preparatory grade students). Children commence school in Victoria at approximately 5 years of age. The survey has been distributed annually to children enrolled in primary schools in Victoria, Australia since mid-1997.¹⁵ In 2010, the survey included questions on allergy and anaphylaxis which are used in the present analysis.

2.2 | Demographic, environmental exposures and confounders

The following variables from the questionnaire were considered in our analysis: mother's country of birth (father's country of birth was

not asked in the questionnaire), children's age and gender, child's country of birth (age of migration was not available for children born overseas), whether the child had very low birthweight (<1500 g) (VLBW), whether the child lives with siblings, postcode of residence, mother's education level, father's education level and region of residence.

The socio-economic status for children in our study was calculated using Socio-Economic Indexes for Areas (SEIFA) by matching postcodes of residence with SEIFA data from the Australian Bureau of Statistics. SEIFA takes into account economic and social conditions of people and households within an area, including both relative advantage and disadvantage measures.⁸

2.3 | Definitions of allergic outcomes

The following food allergy and anaphylaxis questions were asked in the survey:

1. Has your child ever been told by a doctor that your child has an allergy problem? If yes, parents were instructed to check boxes indicating which food or substance the child was allergic to. Options provided in checkboxes were milk, eggs, peanuts, tree nuts, soy, wheat, fish/shellfish, bee/insect stings, other.
2. Have you ever been told by a doctor that your child's allergy may result in anaphylaxis? Parents were also instructed to check boxes indicating which food or substance the child was anaphylactic to (options as defined above).

Parent-reported food allergy (hereafter referred to as "food allergy") was defined as a report of allergy caused by any of the eight listed foods/food groups (milk, eggs, peanuts, tree nuts, soy, wheat, fish, shellfish). These foods collectively account for more than 90% of IgE-mediated food allergies in children.¹⁶

A student was defined as being at risk of anaphylaxis if the parent reported being told by a doctor that their child's allergy may result in anaphylaxis for any of the listed foods or substances. If a food trigger was selected, children were classified as being at risk of food-induced anaphylaxis (FIA). Those at risk of anaphylaxis are likely to be those with IgE-mediated food allergy rather than non-IgE-mediated food allergy or intolerances. Non-food-induced anaphylaxis (Non-FIA) was defined as any other trigger (bee/insect sting or other trigger, details of "other" triggers were not available). Separate categories were created for risk of anaphylaxis to bee/insect stings and other triggers.

Asthma: An affirmative response to "Have you ever been told by a doctor that your child has asthma."

Eczema: An affirmative response to "Does your child have ongoing eczema (with daily effects)?"

No additional information on symptoms of allergy or method of diagnosis was collected. The survey did not collect information on allergic rhinitis or hay fever.

2.4 | Definitions of maternal and child country of birth and ethnicity

Parents were asked to indicate where the child was born and where the child's mother was born. Checkboxes were provided for the following countries: Australia, New Zealand, England, South Africa, China, Philippines, India, USA, South Korea, Hong Kong (SAR of China) and "other," with answers for other countries recorded in a free text field. Answers recorded in this free text field were not available and individuals who answered "other" were therefore excluded from the analysis.

We further classified country of birth as "East Asia" if the mother/child was born in China, the Philippines, South Korea or Hong Kong (SAR of China).

For the primary analysis, we combined East Asia and India into a single category ("Asia"). We also conducted a sensitivity analysis which considered East Asia and India as separate categories.

The term "children born in Asia" was applied if the children were born in Asia to Asian-born mothers. "Australian-born Asian children" refers to children born in Australia with Asian-born mothers. "Australian-born non-Asian children" refers to children born in Australia with Australian-born mothers. A combined variable with the categories Australia-Australia, Asia-Australia, Asia-Asia referring to maternal-child country of birth was generated for the analysis.

2.5 | Statistical analysis

We described the prevalence of allergic outcomes (food allergy, asthma, eczema, food-induced anaphylaxis, non-food anaphylaxis) within categories of maternal and child's country of birth (Australia-Australia; Asia-Australia; Asia-Asia) as the observed proportion with 95% confidence intervals (95% CIs) for the population prevalence calculated using the normal approximation to the binomial distribution.

Adjusted logistic regression models were used to examine the association between maternal or child country of birth and allergic outcomes, with results presented as odds ratios (OR) with 95% CIs. Potential confounders considered in our analysis were factors that have been reported to be associated with allergic disease in previous studies.^{7,8} Potential confounders considered in the models were children's age and gender, region of residence, whether child had very low birthweight (<1500 g) (VLBW), whether child lives with any siblings, mother's education level, father's education level and SEIFA. Each model was adjusted for the potential confounder only if its inclusion in the model altered an OR by >10%.

Separate adjusted logistic regression models examined the association between other demographic factors (child's sex, the presence of siblings, region, parental education and socioeconomic status) and allergic outcomes.

All data were analysed using Stata version 15.0 (StataCorp, College Station, TX, USA).

2.6 | Ethics approval

Ethics approval was granted by the human research ethics committees of the Royal Children's Hospital (HREC# 34168) and the Victorian Department of Education and Early Childhood Development.

3 | RESULTS

In 2010, 57 005 of 66 444 (85.8%) eligible children returned the questionnaire and were therefore included in this study. The demographics of these children have been reported elsewhere⁸ and are summarized in online repository Table S1. Among participants, the number of Australian-born non-Asian children was 39 585, Australian-born Asian children was 1657 (representing the largest non-Caucasian ethnic group) and children born in Asia was 1005. The mean age of participating children was 4.9 years (range 4-7 years).

3.1 | Patterns of food allergy, eczema and asthma according to ethnicity and country of birth

The prevalence of food allergy, eczema and asthma by maternal and child country of birth is illustrated in Figure 1. Australian-born Asian children were more likely to have food allergy (aOR 2.33, 95%CI 1.96-2.77, $P < 0.001$) and eczema (aOR 2.04, 95%CI 1.73-2.41, $P < 0.001$), but were not more likely to have asthma (aOR 0.87, 95%CI 0.74-1.02, $P = 0.08$) compared to Australian-born non-Asian children (online repository Table S2). By contrast, children born in Asia who subsequently migrated to Australia had a lower risk of food allergy (aOR 0.33, 95%CI 0.20-0.55, $P < 0.001$), eczema (aOR 0.41, 95%CI 0.28-0.62, $P < 0.001$) and asthma (aOR 0.29, 95%CI 0.21-0.40, $P < 0.001$) compared to Australian-born non-Asian children.

Among children with Asian-born mothers, those born in Australia had a greatly increased risk of food allergy (aOR 6.97, 95%CI 4.14-11.74, $P < 0.001$), eczema (aOR 5.50, 95%CI 3.50-8.66, $P < 0.001$) and asthma (aOR 2.99, 95%CI 2.12-4.22, $P < 0.001$) compared to those who were born in Asia.

3.2 | Patterns of anaphylaxis risk and its triggers according to ethnicity and country of birth

The prevalence of FIA and non-FIA risk by maternal and child country of birth is shown in Figure 2. The overall prevalence of FIA, bee/insect stings anaphylaxis and other anaphylaxis risk in our study was 2.81% (95%CI 2.67-2.94), 0.23% (95%CI 0.26-0.35) and 1.31% (95%CI 1.21-1.40), respectively. Compared to Australian-born non-Asian children, Asian children were more likely to be diagnosed as at risk of FIA (aOR 1.50, 95%CI 1.16-1.94, $P = 0.002$) if they were born in Australia but they had a lower risk (aOR 0.28, 95%CI 0.14-0.56, $P < 0.001$) if they were born in Asia (Figure 2, online repository Table S2). Interestingly, Asian children were more likely

than Australian-born non-Asian children to be diagnosed as at risk of anaphylaxis with a non-food trigger regardless of where they were born.

In online repository Figure S1, we show the results with Asia further divided into East Asia and India. Both showed similar patterns although the numbers in some groups were small.

Patterns of FIA risk among ethnicity groups differed depending on the food trigger (Figure 3, online repository Table S3). Australian-born Asian children were more likely to be at risk of anaphylaxis to peanut and tree nuts compared to Australian-born non-Asian children. By contrast, children born in Asia who migrated to Australia were less likely to be at risk of anaphylaxis to peanut, tree nuts and milk compared to Australian-born non-Asian children. Interestingly, Asian children had a higher risk of anaphylaxis to soy, wheat and seafood (fish/shellfish) compared to Australian-born non-Asian children regardless of where they were born.

Among Asian children, those born in Australia were more likely to be at risk of anaphylaxis to milk (aOR 3.06, 95%CI 1.17-8.04, $P = 0.023$), peanut (aOR 14.14, 95%CI 3.42-58.46, $P < 0.001$) and tree nuts (aOR 9.43, 95%CI 2.25-39.59, $P = 0.002$) compared to those who were born in Asia.

3.3 | The association between demographic factors and anaphylaxis risk

The association between various demographic factors and risk of anaphylaxis (food induced and non-food induced) are summarized in Table 1.

Boys were more likely to be at risk of FIA than girls, but there was less evidence of a difference in non-FIA between genders (Table 1). Children born with very low birthweight (VLBW) were less likely to be at risk of FIA, while there was little evidence of a

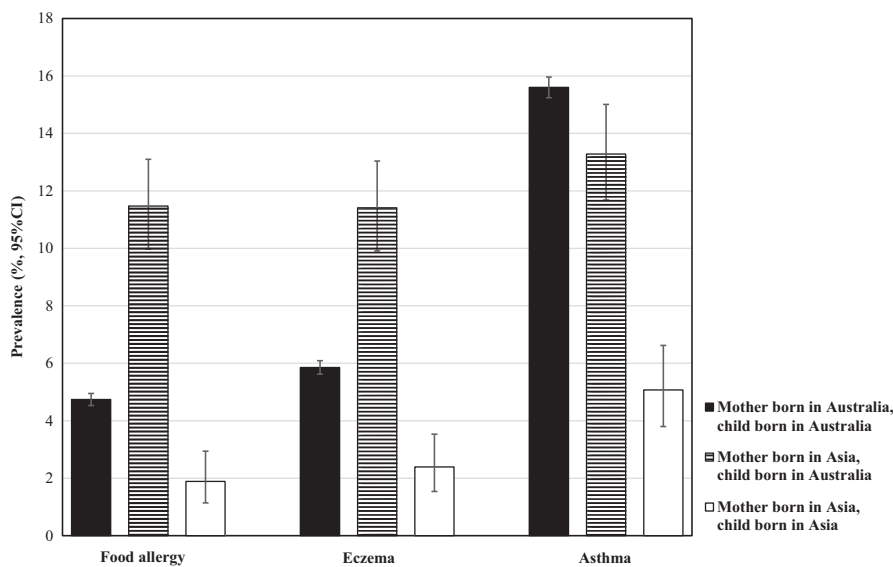


FIGURE 1 Prevalence (%; 95%CI) of food allergy, eczema and asthma categorized by mother's versus child's country of birth

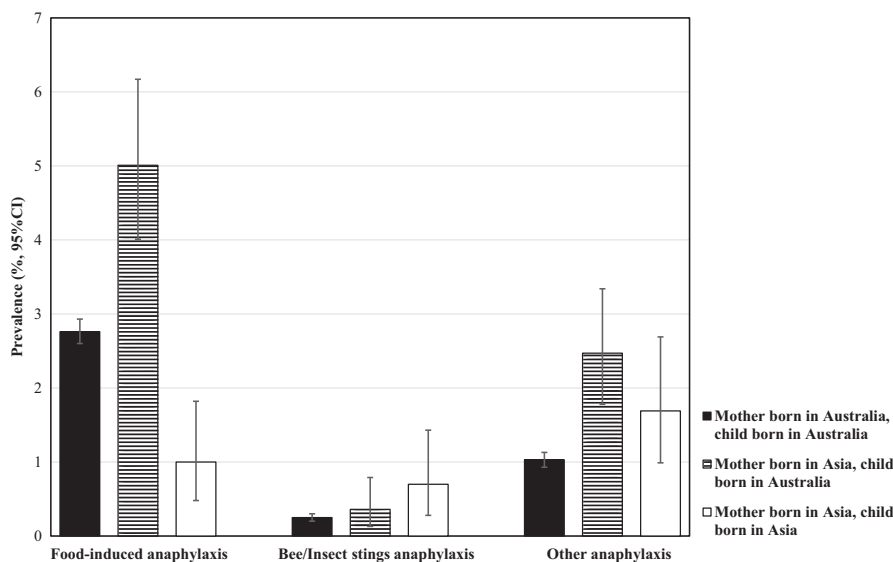


FIGURE 2 Prevalence (%; 95%CI) of food-induced anaphylaxis and non-food anaphylaxis risk by mother's versus child's country of birth

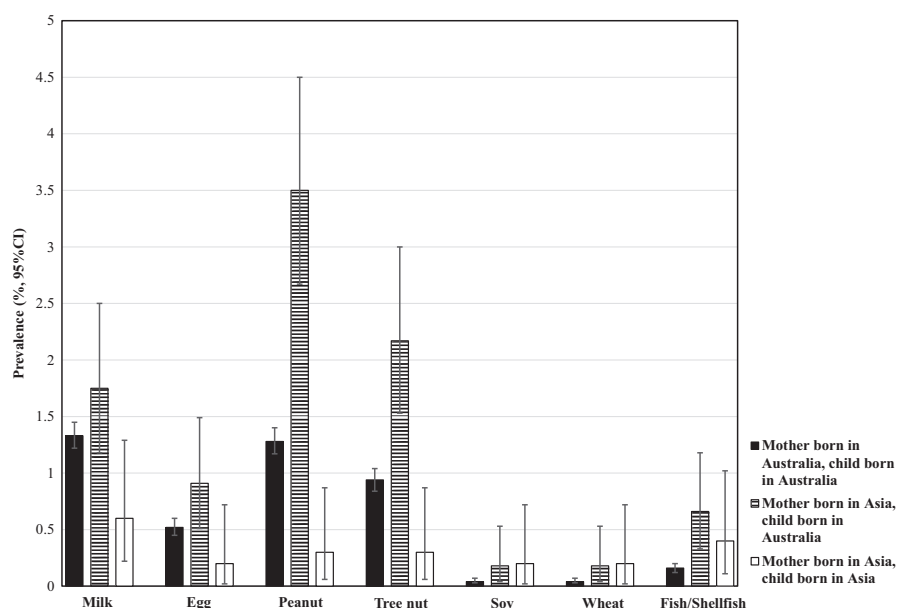


FIGURE 3 Prevalence (%; 95%CI) of individual food triggers for anaphylaxis risk by mother's versus child's country of birth

difference in non-FIA. Living with siblings was associated with less risk of non-FIA while there was no association for FIA. There was little difference between regions, except for a slightly lower rate of FIA risk in Gippsland. Children whose mothers had a higher education level were more likely to be at risk of FIA reported by parents, but less likely to be at risk of non-FIA.

4 | DISCUSSION

In a large state-wide survey of more than 57 000 children entering school (age 5 years), we found children with Asian-born mothers who were themselves born in Australia had a higher prevalence of most food allergies, anaphylaxis risk and eczema compared with Australian-born non-Asian children, while children born in Asia had a lower risk. In addition, we found that the patterns of anaphylaxis risk in ethnicity groups differed depending on the trigger. Asian children were more likely than non-Asian children to be at risk of anaphylaxis elicited by soy, wheat, seafood and non-food triggers regardless of whether the Asian child was born in Australia or Asia.

The strengths of this study are the large sample size and population-based data set collecting information from 86% of school entrant children in Victoria in a single year. This dataset provides a range of valuable demographics and health status for children across the whole state. Limitations include the use of parent-reported allergy outcomes. The questionnaire captured information on whether the child was ever considered as at potential risk of anaphylaxis, rather than acute anaphylaxis onset. As expected, the prevalence of anaphylaxis in our study is therefore higher than the reported hospital admission rates for anaphylaxis in Australia³ and in European countries.¹⁷ In a previous study, Loke et al¹⁸ reported that 1.6% of Victorian government school students in the first year of school were currently at risk of anaphylaxis (from any trigger) in

2010. In that study, students at risk of anaphylaxis were defined as those prescribed an adrenaline auto-injectors by their doctors and with a current Australasian Society of Clinical Immunology and Allergy Anaphylaxis Management Plan. Factors that may have contributed to the higher prevalence reported by us in comparison with Loke et al include that our criteria captured past history of anaphylaxis risk as well as current cases and therefore will include a proportion of children who may have outgrown their food allergies early in life. In addition, our questionnaire did not record whether the child carried a current adrenaline auto-injector and over-reporting of anaphylaxis risk in our study is also possible. The relatively high prevalence of "other anaphylaxis" risk in our study might be because this group combined all other triggers together, including medications/drug, serum, latex and other potential triggers. It is also possible that some rare food triggers were misclassified as "other" triggers, although we think this is unlikely to be a large contributor to this group, as the most common foods responsible for IgE-mediated food allergy and anaphylaxis were captured in the food-induced anaphylaxis group. Another potential limitation is that there might be differences in healthcare utilization according to maternal country of birth and length of time spent in Australia that could contribute to the differences observed (eg families recently migrated from Asia may be less likely to seek medical diagnosis of asthma), but this also seems unlikely to completely explain our findings as the patterns were not the same for all allergic diseases. Another limitation is the use of maternal country of birth as an indirect marker of ethnicity as other information on ethnicity was not collected. However, in our previous population-based study in Victoria, we found that parental country of birth was highly correlated (more than 93.0%) with genetically determined Asian or Caucasian ancestry.¹⁹

In our study, children born in Asia who subsequently migrated to Australia had a lower risk of food allergy and eczema compared with

TABLE 1 Association between demographic variables and risk of food-induced and non-food-induced anaphylaxis

Variable category	FIA		Non-FIA	
	Adjusted OR ^a (95%CI)	P-value ^b	Adjusted OR ^a (95%CI)	P-value ^b
Sex of child				
Female	Reference		Reference	
Male	1.31 (1.17, 1.48)	<0.001	1.14 (0.96, 1.34)	0.127
VLBW				
No	Reference		Reference	
Yes	0.41 (0.20, 0.83)	0.013	0.68 (0.32, 1.45)	0.321
Live with sibling				
No	Reference		Reference	
Yes	1.02 (0.89, 1.15)	0.83	0.69 (0.56, 0.85)	0.001
Region of residence ^d				
North	Reference		Reference	
West	1.01 (0.81, 1.25)	0.939	1.12 (0.84, 1.49)	0.444
South	0.93 (0.77, 1.12)	0.426	0.98 (0.76, 1.27)	0.898
East	0.99 (0.82, 1.20)	0.839	1.11 (0.83, 1.48)	0.492
Barwon South West	0.90 (0.69, 1.17)	0.509	0.85 (0.57, 1.26)	0.425
Gippsland	0.67 (0.47, 0.97)	0.033	1.04 (0.67, 1.61)	0.871
Grampians	1.09 (0.80, 1.48)	0.572	0.76 (0.45, 1.26)	0.281
Hume	0.86 (0.64, 1.20)	0.413	0.78 (0.49, 1.23)	0.280
Loddon Mallee	0.86 (0.64, 1.15)	0.312	0.97 (0.64, 1.46)	0.887
Mother's education				
Some high school	Reference		Reference	
Completed high school or equivalent	1.28 (1.02, 1.60)	0.034	1.00 (0.78, 1.29)	0.997
TAFE trade certificate or diploma	1.42 (1.13, 1.79)	0.003	0.86 (0.65, 1.14)	0.285
University/tertiary institute degree including post-grad	1.64 (1.31, 2.05)	<0.001	0.69 (0.52, 0.91)	0.010
Father's education				
Some high school	Reference		Reference	
Completed high school or equivalent	1.14 (0.92, 1.41)	0.245	0.98 (0.75, 1.27)	0.885
TAFE trade certificate or diploma	1.30 (1.07, 1.58)	0.010	0.90 (0.70, 1.16)	0.406
University/tertiary institute degree including post-grad	1.20 (0.97, 1.48)	0.096	0.78 (0.59, 1.04)	0.088
SEIFA quintile ^c				
1 (most advantage)	Reference		Reference	
2	1.03 (0.86, 1.25)	0.732	0.86 (0.67, 1.10)	0.231
3	1.06 (0.86, 1.30)	0.583	1.04 (0.79, 1.35)	0.801
4	1.16 (0.96, 1.39)	0.119	0.89 (0.69, 1.15)	0.373
5 (least advantage)	1.24 (0.97, 1.58)	0.084	0.90 (0.62, 1.31)	0.593

^aAll factors were included in the model simultaneously, and models were additionally adjusted for mother and child country of birth and child's age.

^bP-values <0.05 are highlighted in bold font.

^cSEIFA: Socio-economic Indexes for Areas: most disadvantaged = 1, least disadvantaged = 5.

^d"North" was the baseline category to compare with other regions of residence.

Australian-born both Asian and non-Asian children. Similar findings have been reported in previous studies from America and the International Study of Asthma and Allergies in Childhood (ISAAC), which found that immigrants had lower risk of eczema and food allergy,^{20,21} although no information was provided on the immigrant's country of origin. This could be explained by the hygiene hypothesis that either infections or microbial exposures in early

childhood may protect against atopic diseases.²⁰ Alternatively, higher relative humidity and higher UV exposure in some Asian regions such as Philippines and Hong Kong compared with Victoria, Australia, could have contributed to lower rates of eczema in early life. Subsequently, this may have reduced the likelihood of food sensitization occurring through the skin and thus reduce the risk of food allergy.^{22,23} Differences in Vitamin D exposure might also contribute

to differences in allergy rates between growing up in Asia and those growing up in Australia.²⁴

While both eczema and food allergy were around twice as common in Australian-born Asian children as in non-Asian children, the prevalence of asthma was not similarly increased, suggesting a different pathogenesis between asthma and other allergic diseases. This is consistent with previous study by Buka et al²⁵ reporting that rates of asthma were similar between children of South Asian origin and white British populations living in Britain.

In addition, children born in Asia who migrated to Australia subsequently had a much lower risk of asthma compared with both Australian-born Asian and non-Asian children. Previous studies have suggested that the asthma prevalence of migrants tends to become more similar to the prevalence in the native population over time.^{21,26} Unfortunately, there was no information on the duration of residence time in Australia for the Asian children in our questionnaire although it had to be less than their age which ranged from 4 to 7 years. Therefore, we are unable to comment on the impact of length of stay of the children and/or their adaptation of lifestyle and dietary habits.²⁷ The difference in asthma prevalence observed in our study may change over time, as the children age and spend a longer time in the Australian environment.

Our finding of a higher prevalence of food-induced anaphylaxis risk in Australian-born Asian children is consistent with recently published studies in the United States and New Zealand that reported that Asian children had higher rates of hospital presentations for food-induced anaphylaxis.^{28,29} However, these studies did not capture information on place of birth, which we found to be important in determining risk of food-induced anaphylaxis in the Asian population. Previous studies reported wheat and seafood as the most common food to elicit anaphylaxis in Asian countries.^{12,13} In our study, children with Asian ancestry more often reported risk of anaphylaxis triggered by soy, wheat and seafood regardless of where they were born. Reasons for this higher prevalence of anaphylaxis risk to soy, wheat and seafood require further study, but may reflect differences in dietary patterns in the Asian population, including potentially differences in timing of introduction of these foods into the infant diet.³⁰

5 | CONCLUSIONS

In conclusion, we found different profiles of allergy and anaphylaxis risk between children born in Asia, Australian-born Asian children and Australian-born non-Asian children. The observed patterns might be explained by a gene–environment interaction, whereby a risk factor present in the Australian environment has a greater effect on allergy risk among those with an Asian ancestry who are exposed to this risk factor early in life. The different pattern of asthma (lower in Asian children born in Australia) compared with other allergic diseases is surprising and warrants further exploration, while bearing in mind the potential for cultural differences in health seeking behaviour.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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REFERENCES

1. Prescott SL, Pawankar R, Allen KJ, et al. A global survey of changing patterns of food allergy burden in children. *World Allergy Organ J*. 2013;6(1):21.
2. Osborne NJ, Koplin JJ, Martin PE, et al. Prevalence of challenge-proven IgE-mediated food allergy using population-based sampling and predetermined challenge criteria in infants. *J Allergy Clin Immunol*. 2011;127(3):668–676 e1–2.
3. Mullins RJ, Dear KB, Tang ML. Time trends in Australian hospital anaphylaxis admissions in 1998–1999 to 2011–2012. *J Allergy Clin Immunol*. 2015;136(2):367–375.
4. Lee S, Hess EP, Lohse C, Gilani W, Chamberlain AM, Campbell RL. Trends, characteristics, and incidence of anaphylaxis in 2001–2010: a population-based study. *J Allergy Clin Immunol*. 2017;139(1):182–188 e2.
5. White MV, Silvia S, Muniz R, Herrem C, Hogue SL. Prevalence and triggers of anaphylactic events in schools. *Allergy Asthma Proc*. 2017;38(4):286–293.
6. Grabenhenrich LB, Dolle S, Moneret-Vautrin A. Anaphylaxis in children and adolescents: The European Anaphylaxis Registry. *J Allergy Clin Immunol*. 2016;137(4):1128–1137 e1.
7. Koplin JJ, Peters RL, Ponsonby AL, et al. Study, Increased risk of peanut allergy in infants of Asian-born parents compared to those of Australian-born parents. *Allergy*. 2014;69(12):1639–1647.
8. Panjari M, Koplin JJ, Dharmage SC, et al. Nut allergy prevalence and differences between Asian-born children and Australian-born children of Asian descent: a state-wide survey of children at primary school entry in Victoria, Australia. *Clin Exp Allergy*. 2016;46(4):602–609.
9. Liew WK, Chiang WC, Goh AE, et al. Paediatric anaphylaxis in a Singaporean children cohort: changing food allergy triggers over time. *Asia Pac Allergy*. 2013;3(1):29–34.
10. Chan CF, Chen PH, Huang CF, Wu TC. Emergency department visits for food allergy in Taiwan: a retrospective study. *Pediatr Neonatol*. 2014;55(4):275–281.
11. Lee SY, Ahn K, Kim J, et al. A Multicenter retrospective case study of anaphylaxis triggers by age in Korean children. *Allergy Asthma Immunol Res*. 2016;8(6):535–540.
12. Jiang N, Yin J, Wen L, Li H. Characteristics of anaphylaxis in 907 Chinese patients referred to a tertiary allergy center: a retrospective study of 1,952 episodes. *Allergy Asthma Immunol Res*. 2016;8(4):353–361.
13. Smit DV, Cameron PA, Rainer TH. Anaphylaxis presentations to an emergency department in Hong Kong: incidence and predictors of biphasic reactions. *J Emerg Med*. 2005;28(4):381–388.
14. Australian Bureau of Statistics, migration, Australia. <http://www.abs.gov.au/ausstats/abs@.nsf/mf/3412.0>. Accessed January 25, 2018.
15. Edgecombe GA, Avant KC, Griffin P, Corneille K. School nurse assessment of primary school children: analysis of data from the school entrant health questionnaire. *Int J Nurs Pract*. 1998;4(1):40–50.
16. Allen KJ, Koplin JJ. The epidemiology of IgE-mediated food allergy and anaphylaxis. *Immunol Allergy Clin North Am*. 2012;32(1):35–50.

17. Panesar SS, Javad S, de Silva D, et al. The epidemiology of anaphylaxis in Europe: a systematic review. *Allergy*. 2013;68(11):1353-1361.
18. Loke P, Koplin J, Beck C, et al. Statewide prevalence of school children at risk of anaphylaxis and rate of adrenaline autoinjector activation in Victorian government schools, Australia. *J All Clin Immunols*. 2016;138(2):529-535.
19. Ashley SE, Tan HTT, Vuillermine P, et al. The skin barrier function gene SPINK5 is associated with challenge-proven IgE-mediated food allergy in infants. *Allergy*. 2017;72(9):1356-1364.
20. Silverberg JI, Simpson EL, Durkin HG, Joks R. Prevalence of allergic disease in foreign-born American children. *JAMA Pediatr*. 2013;167(6):554-560.
21. Garcia-Marcos L, Robertson CF, Ross H, et al. Does migration affect asthma, rhinoconjunctivitis and eczema prevalence? Global findings from the international study of asthma and allergies in childhood. *Int J Epidemiol*. 2014;43(6):1846-1854.
22. Silverberg JI, Hanifin J, Simpson EL. Climatic factors are associated with childhood eczema prevalence in the United States. *J Invest Dermatol*. 2013;133(7):1752-1759.
23. Li A, Fan L, Xie L, Ren Y, Li L. Associations between air pollution, climate factors and outpatient visits for eczema in West China Hospital, Chengdu, south-western China: a time series analysis. *J Eur Acad Dermatol Venereol*. 2018;32(3):486-494.
24. Koplin JJ, Suaini NH, Vuillermine P, et al. Polymorphisms affecting vitamin D-binding protein modify the relationship between serum vitamin D (25[OH]D3) and food allergy. *J Allergy Clin Immunol*. 2016;137(2):500-506.
25. Buka RJ, Crossman RJ, Melchior CL, et al. Anaphylaxis and ethnicity: higher incidence in British South Asians. *Allergy*. 2015;70(12):1580-1587.
26. Leung RC, Carlin JB, Burdon JG, Czarny D. Asthma, allergy and atopy in Asian immigrants in Melbourne. *Med J Aust*. 1994;161(7):418-425.
27. Wood LG, Lagleva M, Shah S, et al. Dietary changes in migrant adolescents with increasing length of stay in Australia and associated risk of wheeze—a retrospective, cross sectional study. *BMC Pediatr*. 2015;15:102.
28. Speakman S, Kool B, Sinclair J, Fitzharris P. Paediatric food-induced anaphylaxis hospital presentations in New Zealand. *J Paediatr Child Health*. 2018;54(3):254-259.
29. Dyer AA, Lau CH, Smith TL, Smith BM, Gupta RS. Pediatric emergency department visits and hospitalizations due to food-induced anaphylaxis in Illinois. *Ann Allergy Asthma Immunol*. 2015;115(1):56-62.
30. Wang Y, Allen KJ, Koplin JJ. Dietary intervention for preventing food allergy in children. *Curr Opin Pediatr*. 2017;29(6):704-710.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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Appendices

Figures

Online Repository Figure S1. Sensitivity analysis for East Asia and India groups.

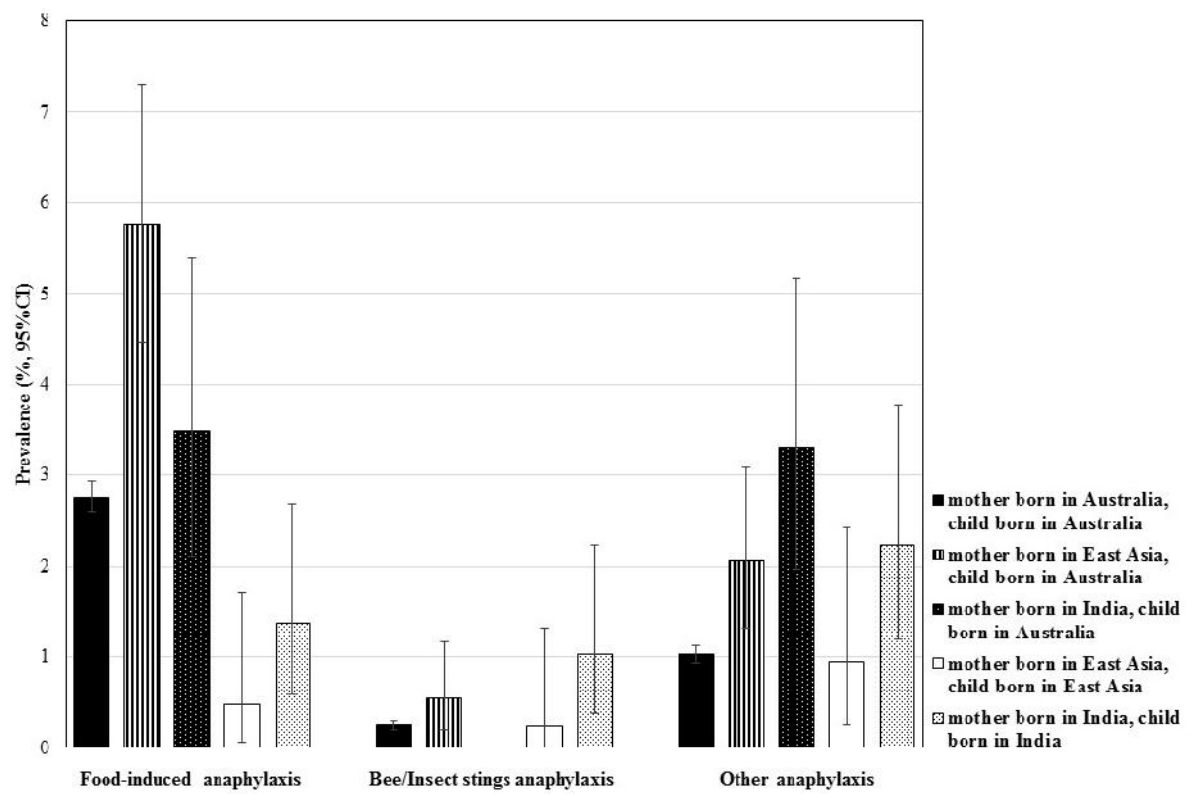
Tables

Online Repository Table S1. Demographics of Victorian children completing School Entrant Health Questionnaire (N=57,005)

Online Repository Table S2. Results of logistic regression analysis showing odds of presenting with allergic outcomes according to maternal-child country of birth

Online Repository Table S3. Results of logistic regression analysis showing odds of presenting with anaphylaxis risk according to maternal-child country of birth

Online Repository Table S4. Results of logistic regression analysis showing odds of allergy and anaphylaxis risk among children with Asian-born mothers according to country of birth of the child



Online Repository Figure S1. Sensitivity analysis for East Asia and India groups.

Online Repository Table S1. Demographics of Victorian children completing School Entrant

Health Questionnaire (N=57,005)

Variable category	N (%)
Child age	
Mean (range) years	4.94 (4.00-7.00)
Maternal age at child birth	
Mean (range) years	30.93 (11.00-55.00)
Sex of child	
Female	27 169 (48.83)
Male	28 476 (51.17)
Very Low Birth Weight (VLBW)	
No	55 960 (98.17)
Yes	1 045 (1.83)
Live with sibling	
No	42 527 (74.60)
Yes	14 478 (25.40)
Mother's country of birth	
Australia	40 118 (70.38)
New Zealand	1 046 (1.83)
England	1 412 (2.48)
East Asia	1 657 (2.91)
India	1 274 (2.23)
USA	193 (0.34)
South Africa	381 (0.67)
Other unknown (free text data)	9 381 (16.46)
Missing	1 543 (2.71)
Maternal age at immigration (mother's country of birth was not Australia)	
Mean (range) years	22.34 (1.00-50.00)
Child's country of birth	
Australia	51 439 (90.24)
New Zealand	471 (0.83)
England	512 (0.90)
East Asia	506 (0.89)
India	593 (1.04)
USA	170 (0.30)
South Africa	114 (0.20)
Other unknown (free text data)	2 202 (3.86)

Missing	998 (1.75)
Region of residence[‡]	
North	9 973 (17.49)
West	6 814 (11.95)
South	13 003 (22.81)
East	10 708 (18.78)
Barwon South West	4 198 (7.36)
Gippsland	2 910 (5.10)
Grampians	2 615 (4.59)
Hume	3 199 (5.61)
Loddon Mallee	3 585 (6.29)
Mother's education	
Some high school	9 175 (16.10)
Completed high school or equivalent	12 302 (21.58)
TAFE trade certificate or diploma	10 704 (18.78)
University/tertiary institute degree including post-grad	19 684 (34.53)
Missing	5 140 (9.02)
Father's education	
Some high school	10 151 (17.81)
Completed high school or equivalent	9 139 (16.03)
TAFE trade certificate or diploma	15 021 (26.35)
University/tertiary institute degree including post-grad	16 275 (28.55)
Missing	6 419 (11.26)
SEIFA quintile[^]	
1 (most advantage)	14 411 (25.28)
2	10 060 (17.65)
3	6 756 (11.85)
4	14 861 (26.07)
5 (least advantage)	4 441 (7.79)
Missing	6 476 (11.36)

[^]SEIFA: Socio-economic Indexes for Areas: most disadvantaged = 1, least disadvantaged = 5.

Online Repository Table S2. Results of logistic regression analysis showing odds of presenting with allergic outcomes according to maternal-child country of birth

	Odds Ratio (95%CI)	P-value
Food allergy		
New Zealand-Australia	0.94 (0.64, 1.39)	0.775
New Zealand-New Zealand	0.68 (0.28, 1.66)	0.399
England-Australia	0.82 (0.59, 1.13)	0.221
England-England	1.05 (0.55, 2.00)	0.878
Asia-Australia	2.33 (1.96, 2.77)	<0.001
Asia-Asia	0.33 (0.20, 0.55)	<0.001
Eczema		
New Zealand-Australia	1.12 (0.83, 1.53)	0.456
New Zealand-New Zealand	1.53 (0.94, 2.50)	0.086
England-Australia	0.97 (0.73, 1.28)	0.806
England-England	0.28 (0.09, 0.86)	0.027
Asia-Australia	2.04 (1.73, 2.41)	<0.001
Asia-Asia	0.37 (0.24, 0.57)	<0.001
Asthma		
New Zealand-Australia	1.11 (0.90, 1.38)	0.315
New Zealand-New Zealand	1.14 (0.77, 1.69)	0.516
England-Australia	0.86 (0.71, 1.04)	0.126
England-England	0.82 (0.53, 1.29)	0.398
Asia-Australia	0.87 (0.74, 1.02)	0.080
Asia-Asia	0.29 (0.21, 0.40)	<0.001
Food-induced anaphylaxis risk		
New Zealand-Australia	0.84 (0.49, 1.43)	0.511
New Zealand-New Zealand	1.22 (0.50, 2.98)	0.666
England-Australia	0.86 (0.57, 1.28)	0.455
England-England	1.38 (0.68, 2.83)	0.372
Asia-Australia	1.50 (1.16, 1.94)	0.002
Asia-Asia	0.28 (0.14, 0.56)	<0.001
Non-food anaphylaxis risk		
New Zealand-Australia	1.43 (0.76, 2.70)	0.266
New Zealand-New Zealand	2.71 (1.11, 6.66)	0.030
England-Australia	0.59 (0.26, 1.32)	0.195
England-England	1.59 (0.50, 5.01)	0.434
Asia-Australia	2.50 (1.75, 3.57)	<0.001
Asia-Asia	2.28 (1.41, 3.69)	0.001

95%CI, 95% confidence interval; OR was adjusted for maternal age at the child's birth, mother's education level, father's education level and SEIFA; Mother (left) and child (right) country of birth; Australia-Australia group is the reference. Significant P-values bold.

Note: Some country of birth groups (eg. USA or South Africa) were not included in our analysis as there were limited participants in those groups.

Online Repository Table S3. Results of logistic regression analysis showing odds of presenting with anaphylaxis risk according to maternal-child country of birth

	Odds Ratio (95%CI)	P-value
Anaphylaxis triggered by milk		
New Zealand-Australia	1.15 (0.59, 2.25)	0.673
New Zealand-New Zealand	0.53 (0.07, 3.77)	0.523
England-Australia	0.89 (0.50, 1.59)	0.701
England-England	1.93 (0.78, 4.74)	0.152
Asia-Australia	1.18 (0.78, 1.80)	0.427
Asia-Asia	0.39 (0.16, 0.95)	0.037
Anaphylaxis triggered by egg		
New Zealand-Australia	0.32 (0.04, 2.26)	0.252
New Zealand-New Zealand	2.44 (0.60, 10.02)	0.214
England-Australia	1.08 (0.48, 2.45)	0.854
England-England	0.92 (0.13, 6.64)	0.933
Asia-Australia	1.28 (0.70, 2.34)	0.427
Asia-Asia	0.36 (0.09, 1.46)	0.151
Anaphylaxis triggered by peanut		
New Zealand-Australia	0.63 (0.26, 1.52)	0.302
New Zealand-New Zealand	1.48 (0.47, 4.67)	0.506
England-Australia	0.14 (0.04, 0.58)	0.006
England-England	NA	
Asia-Australia	2.02 (1.45, 2.79)	<0.001
Asia-Asia	0.14 (0.04, 0.58)	0.006
Anaphylaxis triggered by tree nut		
New Zealand-Australia	0.17 (0.02, 1.21)	0.077
New Zealand-New Zealand	2.01 (0.63, 6.37)	0.236
England-Australia	0.76 (0.38, 1.55)	0.455
England-England	0.49 (0.07, 3.49)	0.473
Asia-Australia	1.71 (1.15, 2.53)	0.008
Asia-Asia	0.18 (0.04, 0.73)	0.017
Anaphylaxis triggered by soy		
New Zealand-Australia	4.08 (0.52, 31.92)	0.181
New Zealand-New Zealand	14.82 (1.80, 122.39)	0.012
England-Australia	NA	
England-England	NA	
Asia-Australia	7.39 (1.87, 29.21)	0.004
Asia-Asia	9.61 (1.80, 51.23)	0.008
Anaphylaxis triggered by wheat		
New Zealand-Australia	NA	
New Zealand-New Zealand	20.81 (2.50, 173.04)	0.005
England-Australia	NA	
England-England	NA	
Asia-Australia	7.67 (1.93, 30.40)	0.004

Asia-Asia	9.13 (1.73, 48.15)	0.009
Anaphylaxis triggered by seafood		
New Zealand-Australia	NA	
New Zealand-New Zealand	10.59 (2.50, 44.92)	0.001
England-Australia	0.68 (0.09, 4.93)	0.699
England-England	3.26 (0.44, 24.18)	0.248
Asia-Australia	3.17 (1.36, 7.39)	0.007
Asia-Asia	2.88 (0.98, 8.50)	0.055

95%CI, 95% confidence interval; OR was adjusted for mother's education level, father's education level and SEIFA; Mother (left) and child (right) country of birth; Australia-Australia group is the reference. NA refers to categories where OR was unable to be obtained due to low numbers in the group. Significant P-values bold.

Online Repository Table S4. Results of logistic regression analysis showing odds of allergy and anaphylaxis risk among children with Asian-born mothers according to country of birth of the child

	Odds Ratio (95%CI)	P-value
Food allergy		
Child born in Asia	<i>reference</i>	
Child born in Australia	6.97 (0.78, 1.80)	<0.001
Eczema		
Child born in Asia	<i>reference</i>	
Child born in Australia	5.50 (3.50, 8.66)	<0.001
Asthma		
Child born in Asia	<i>reference</i>	
Child born in Australia	2.99 (2.12, 4.22)	<0.001
Food-induced anaphylaxis		
Child born in Asia	<i>reference</i>	
Child born in Australia	5.40 (2.58, 11.29)	<0.001
Non-food anaphylaxis		
Child born in Asia	<i>reference</i>	
Child born in Australia	1.10 (0.62, 1.93)	0.749
Anaphylaxis triggered by milk		
Child born in Asia	<i>reference</i>	
Child born in Australia	3.06 (1.17, 8.04)	0.023
Anaphylaxis triggered by egg		
Child born in Asia	<i>reference</i>	
Child born in Australia	3.59 (0.80, 16.09)	0.095
Anaphylaxis triggered by peanut		
Child born in Asia	<i>reference</i>	
Child born in Australia	14.14 (3.42, 58.46)	<0.001
Anaphylaxis triggered by tree nut		
Child born in Asia	<i>reference</i>	
Child born in Australia	9.43 (2.25, 39.59)	0.002
Anaphylaxis triggered by soy		
Child born in Asia	<i>reference</i>	
Child born in Australia	0.77 (0.12, 4.75)	0.778
Anaphylaxis triggered by wheat		
Child born in Asia	<i>reference</i>	
Child born in Australia	0.84 (0.14, 5.15)	0.851
Anaphylaxis triggered by seafood		
Child born in Asia	<i>reference</i>	
Child born in Australia	1.10 (0.32, 3.79)	0.879

95%CI, 95% confidence interval; OR was adjusted for maternal age at child birth, mother's education level, father's education level and SEIFA; Mother (left) and child (right) country of birth. Significant P-values bold.