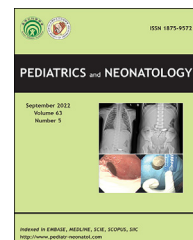


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Original Article

Prevalence, clinical presentation, and associated atopic diseases of pediatric fruit and vegetable allergy: A population-based study

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Key Words

atopic disease;
children;
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Abstract *Background:* In children, fruit and vegetable allergies are often overlooked compared with well-known allergies such as those to eggs, milk, and shellfish. Therefore, this study aimed to analyze fruit and vegetable allergies in children, including prevalence, types of food allergens, clinical presentation, management, and associated comorbid atopic diseases. *Methods:* In 2012, a nationwide, cross-sectional, random sampling questionnaire-based survey for common fruit and vegetable allergies was conducted in Taiwan. Information regarding these plant food allergies was collected. Physicians diagnosed food allergies according to the descriptions of convincing symptoms. Enrolled questionnaires were reviewed by expert pediatricians.

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Results: A total of 9,982 valid questionnaires were analyzed. The overall prevalence of fruit and vegetable allergies was 5.6% (n = 560) and 3.0% (n = 304), respectively. The most common fruit allergen was mango, followed by kiwifruit, whereas taro and bamboo shoot were the most common vegetable allergens. Meanwhile, most allergic symptoms were of the mucocutaneous tissue, followed by the upper airway and gastrointestinal tract. Most only required avoidance of allergens and not medical treatment. Children with fruit or vegetable allergies had a higher percentage of comorbid atopic dermatitis, allergic rhinitis, and asthma than those without food allergies; additionally, the proportion of comorbid atopic diseases was similar between fruit and vegetable allergies and shellfish allergy. One child developed anaphylaxis due to a corn allergy.

Conclusions: Fruits and vegetables are common food allergens in Taiwanese children who present with diverse and potentially severe symptoms. Children with plant food allergies had a percentage of comorbid atopic diseases similar to that of shellfish allergy, the most common allergen. These findings indicate the importance of considering fruit and vegetable allergies in children.

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1. Introduction

The prevalence of food allergy is gradually increasing worldwide.¹ In young children, the most common food allergens are cow milk, egg, peanuts, and seafood²; considering this, fruit and vegetable allergens are often overlooked. Fruit and vegetable allergies are more common in adolescents and adults; however, they are not rare in children. Particularly, the prevalence of fruit allergy gradually increases as children develop. One European study found that fruits were the second most common allergen during early school age (4–6 years) but they became the most common allergen during teenage years.³ In Korean children, fruits and vegetables are both common food groups that cause immediate-type allergy.⁴

Generally, fruit and vegetable allergic symptoms are mild and transient, but severe reactions such as anaphylaxis can occur and require emergency management.^{5,6} Prompt attention and precise avoidance are crucial for these food allergens. Therefore, detailed studies regarding plant allergens are vital for effective avoidance and nutritional concerns.

Previous studies have confirmed that fruits and vegetables are important food allergens^{7,8}; however, not all studies have focused on detailed allergic food items. Among the studies that discussed allergic fruits and vegetables, significant discrepancies regarding common food allergens were observed, which may result from the diverse dietary habits of consumed fruits and vegetables among tropical, temperate, and frigid countries. Additionally, studies investigating the relationship between fruit and vegetable allergies and atopic diseases remain limited, requiring further evaluation. Large-scale studies are especially important to identify uncommon fruit or vegetable allergens.

This nationwide study aimed to evaluate the prevalence, detailed allergic foods, clinical presentation, and associated comorbid atopic diseases of pediatric fruit and vegetable allergies.

2. Methods

2.1. Study design and population

A nationwide, cross-sectional, random questionnaire-based survey was conducted from February to August 2012. Children were randomly enrolled from selected elementary schools in each stratum of Taiwan, which was designated according to particular ethnic and geographical characteristics of residents using the probabilities proportional to sizes method similar to the research design of the 'Nutrition and Health Survey in Taiwan (2005–2008)'.⁹

Questionnaires are distributed to students at school to be filled out by themselves and their parents. In the questionnaire, we asked about general information, symptoms of food allergy, food allergens, comorbid atopic diseases and diagnostic methods. We also listed common food allergens in the questionnaire. In fruit and vegetable categories, we listed frequently consumed fruits and vegetables in Taiwan. If the interviewees had vegetables or fruits that they were allergic to which were not included in the checklist, they were instructed to specify that allergic food. Children with a positive food allergy history were asked to answer further questions regarding specific allergic foods, allergic manifestations, medical assessment and management. Detailed content of the questionnaire is listed in the supplementary material (Table S1).

The questionnaires were reviewed by pediatricians specializing in gastroenterology and immunology at Taipei Veterans General Hospital, a tertiary medical hospital in Taipei, Taiwan. Participants with incomplete data, equivocal statements, and vague descriptions were excluded. Among the valid questionnaires, questionnaires of subjects allergic to fruits and vegetables were selected for further analysis. Additionally, the comorbid rate of common atopic diseases (atopic dermatitis, allergic rhinitis, and asthma) was investigated. Furthermore, children with shellfish allergy, the most common food allergen in Taiwan,¹⁰ were

included to compare the incidence of comorbid atopic diseases with those of children with fruit or vegetable allergies.

2.2. Statistical analysis

Differences between groups for categorical variables were determined using either the chi-square test or Bonferroni multiple comparison test. Statistical significance was set at two-tailed $p < 0.05$.

3. Results

A total of 10,601 questionnaires were obtained. After review and interpretation by expert physicians, 619 ineligible questionnaires were excluded. Finally, 9,982 participants were included; among them, 4,847 were boys and 5,135 were girls (sex ratio M/F = 0.94) with a mean age of 10.1 years (range: 6–13 years). In this study, the overall prevalence of fruit and vegetable allergies was 5.6% ($n = 560$) and 3.0% ($n = 304$), respectively. Fruit was the second common food allergen category in our study and vegetable was the sixth common food allergen. Common food allergens are listed in the supplementary material (Table S2). Girls had a significantly higher prevalence of fruit allergy than boys ($p < 0.05$; 6.1 vs. 5.1%); however, no sex-based difference was observed in vegetable allergy. Additionally, the prevalence of fruit or vegetable allergies also showed no significant difference between different age groups (Table 1). Among children allergic to fruits, 70.3% were allergic to only one kind of fruit. Similarly, 66.5% of children allergic to vegetables only had one vegetable allergen (Table 2). Mango and kiwifruit were the two most common fruit allergens, and taro and bamboo shoot were the two most common vegetable allergens (Fig. 1).

The frequency and location of symptoms of the fruit and vegetable allergies were similar, with both most commonly manifesting in mucocutaneous tissue, followed by the upper airway and the gastrointestinal tract. Concerning the mucocutaneous tissue, the most common symptom was skin itching, followed by skin rash and eye itching. Concerning the upper airway, sneezing was the most common allergic symptom, followed by rhinorrhea and cough. Concerning the gastrointestinal tract, nausea and vomiting were the most common symptoms, followed by diarrhea and

Table 1 Prevalence of fruit and vegetable allergy in children categorized by sex and age.

	Total	Fruit allergy	Vegetable allergy
Case number	9982	560 (5.6%)	304 (3.0%)
Sex			
Male	4847	245 (5.1%)	136 (2.8%)
Female	5135	315 (6.1%)*	168 (3.3%)
Age (years)			
6–9	3639	208 (5.7%)	101 (2.8%)
10–13	6343	352 (5.5%)	203 (3.2%)

Data presented as case numbers (prevalence %).

* p -value < 0.05 between sex.

Table 2 Number of allergic fruits and vegetables.

Number	Fruit	Vegetable
1	394 (70.3%)	202 (66.5%)
2–3	133 (23.8%)	81 (26.6%)
≥3	33 (5.9%)	21 (6.9%)

Data presented as case numbers (percentage %).

abdominal pain. In severe and systemic presentations, dyspnea was the leading presentation in both allergic groups, with most requiring medical treatment. In this investigation, one child was reported to have anaphylaxis due to a corn allergy (Table 3).

Children with food allergies often have comorbid atopic diseases, such as allergic rhinitis, asthma, and atopic dermatitis. We compared the frequency of these comorbid diseases among children with fruit, vegetable, and shellfish allergy with that of those among children without food allergy. Children with fruit, vegetable, or shellfish allergy had a higher possibility of having these comorbid atopic diseases than those without food allergies (Table 4). Shellfish is a common and well-known food allergen; however, no significant differences were observed in the percentage of children with comorbid atopic diseases between fruit/vegetable- and shellfish-allergic children. The number of allergic foods also affected the prevalence of comorbid atopic diseases. In our study, children with multiple food allergies had a higher prevalence of comorbid atopic dermatitis than did those with a single food allergy only. The comorbid atopic dermatitis prevalence rates in children with single, two and more than three food categories allergy were 21.7%, 27.0% and 39.7%, respectively.

4. Discussion

To our knowledge, this is the first large-scale study to have investigated the relationship between fruit and vegetable allergies and comorbid atopic disease. We identified prevalence, common allergic foods, and allergic presentations; additionally, we confirmed that fruit and vegetable allergies and shellfish allergy had similar rates of comorbid atopic diseases in children.

Previous studies have reported significant variations in the prevalence of fruit and vegetable allergies in children. In a systematic review, the prevalence of fruit and vegetable allergies in young children was 2.2–11.5% and 0.7–3.3%, respectively.⁷ In our study, the prevalence rates of fruit and vegetable allergies in Taiwanese children were 5.6% and 3.0%, respectively, which were consistent with those in previous studies worldwide.

Similarly, previous studies have found significant variations in common fruit and vegetable allergens. This discrepancy is attributable to differences in dietary food and ethnicities worldwide. For example, in Europe, Rosaceae fruits, such as peach, apple, strawberry, and plum, are common fruit allergens.^{7,8,11,12} However, in tropical areas, such as Latin America, banana, guava, and mango are also common fruit allergens besides Rosaceae fruits.¹³ In addition to dietary factors, environmental and

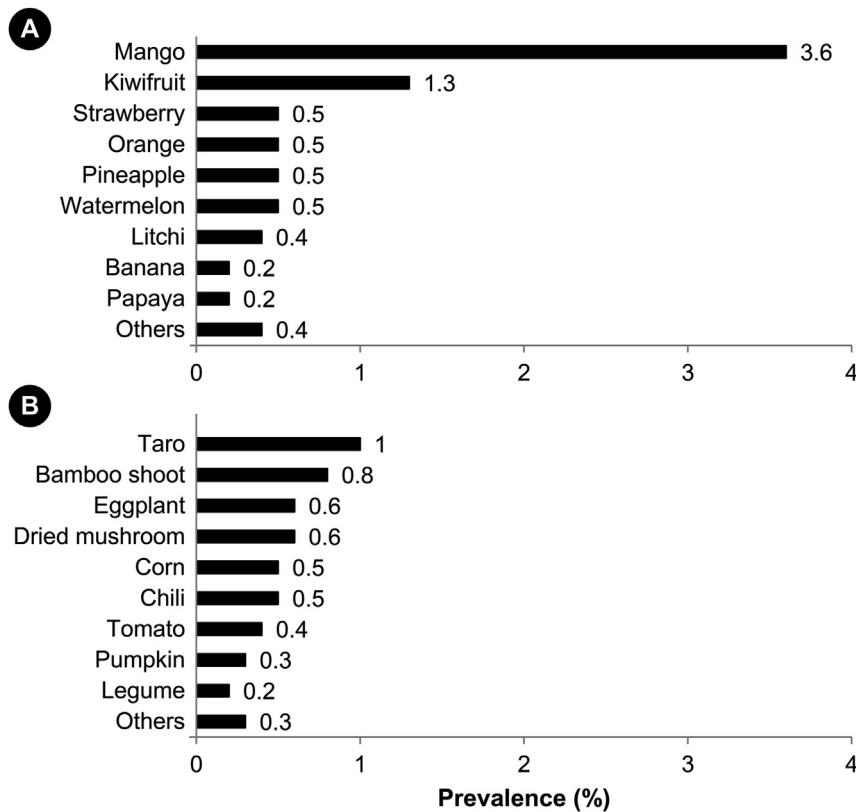


Figure 1 Common allergic fruits (A) and vegetables (B) and their prevalence in Taiwanese children.

Table 3 Clinical presentations of fruit and vegetable allergy in children.

Clinical presentations	Fruit allergy (n = 560)	Vegetable allergy (n = 304)
Mucocutaneous tissue		
Skin itching	357 (63.8%)	177 (58.2%)
Skin rash	216 (38.6%)	119 (39.1%)
Eye itching	216 (38.6%)	114 (37.5%)
Throat itching	94 (16.8%)	50 (16.4%)
Focal edema	79 (14.1%)	38 (12.5%)
Upper airway		
Sneezing	199 (35.5%)	110 (36.2%)
Rhinorrhea	169 (30.2%)	89 (29.3%)
Cough	119 (21.3%)	69 (22.7%)
Gastrointestinal tract		
Nausea and vomiting	46 (8.2%)	39 (12.8%)
Diarrhea	41 (7.3%)	34 (11.2%)
Abdominal pain	46 (8.2%)	30 (9.9%)
Severe reaction		
Dyspnea	34 (6.1%)	27 (8.9%)
Anaphylaxis	0 (0%)	1 (0.3%)

Data presented as case numbers (percentage %).

cultural factors in different areas, such as prevailing allergic pollens,¹⁴ feeding history and family smoking, also increase variety of common food allergens worldwide.

In our study, the most common fruit allergen was mango, which is mainly planted in tropical areas and is not frequently consumed in temperate and frigid regions. Nevertheless, the incidence of mango allergy varied significantly among tropical countries. For example, mango allergy was seldom reported in South Asia¹⁵ but it was common in China¹⁶ and Latin America.¹³ This may be due to racial differences. Additionally, mango allergy was occasionally reported in non-planting, temperate countries such as Germany¹⁷ and Poland.¹⁸ Mango should be particularly noteworthy because it can induce anaphylactic reactions.^{17,18}

Kiwifruit was the second most common allergic fruit in our study. Studies worldwide have shown that kiwifruit allergy is frequent in many countries and regions, such as Japan,¹⁹ Korea,²⁰ the Middle East²¹ and Europe.^{7,11,12} Additionally, kiwifruit is also a common cause of fruit allergy-induced anaphylaxis in Japan¹⁹ and Korea.²⁰

Rosaceae fruits are common allergens in subtropical and temperate zones such as Europe,^{7,8,11,12} the Middle East,^{21,22} and China.¹⁶ In our study, Rosaceae fruits were not significant fruit allergens; however, orange and strawberry allergies were observed. Furthermore, apple and peach are frequently consumed Rosaceae fruits in Taiwan; however, allergies to these two fruits were rare in our study. In contrast, apples and peaches are common allergic fruits in Europe.^{7,8,11,12} These different findings indicate the effect of racial differences in fruit allergies.

In our study, the most common vegetable allergens were taro and bamboo shoot, which is inconsistent with previous

Table 4 Percentage of comorbid atopic diseases in children allergic to different foods and children without food allergy.

Comorbid atopic diseases	Fruit allergy (n = 560)	Vegetable allergy (n = 304)	Shellfish allergy (n = 1313)	Without allergy (n = 7132)
Allergic rhinitis	290 (51.8%)*	151 (49.7%)*	637 (48.5%)*	2300 (32.2%)
Asthma	110 (19.6%)*	55 (18.1%)*	231 (17.6%)*	528 (7.4%)
Atopic dermatitis	199 (35.5%)*	88 (28.9%)*	389 (29.6%)*	541 (7.6%)

Data presented as case numbers (prevalence %).

* p -value < 0.05, compared with those without food allergy.

† p -value < 0.05, comparison between fruit/vegetable and shellfish allergies.

studies. In Europe, tomato, carrot and celery are the most common vegetable allergens.^{7,11,12} In Latin American, onion, chili, garlic, tomato and potato are common vegetable allergens.¹³ However, no studies have reported food allergy caused by bamboo shoot. We found that bamboo shoot is a common food allergen in Taiwan. Symptoms of bamboo shoot allergy occur mostly in the mucocutaneous tissue and upper airway. Fortunately, no severe allergic reactions were observed. Taro allergy was seldom reported in previous studies; only one study in Korea, regarding pollen food allergen syndrome, identified taro and taro stem as food allergens.²³

In our study, eggplant and dried mushroom followed taro and bamboo shoot in frequency of allergies. However, reports of allergies to these two vegetables are limited. One study reported that the prevalence of eggplant allergy in South India was 1.4%.²⁴ One study in Spain reported that dried mushroom intake could cause esophageal symptoms.²⁵ Therefore, the types of allergic vegetables vary greatly worldwide, emphasizing the importance of considering local common vegetable allergens in different regions when evaluating the food allergens of patients. Common allergic fruits and vegetables in different areas are summarized in Table S3.^{7,8,10–13,16,19–24}

Fruit and vegetable allergies are mainly associated with pollen-food allergy syndrome (PFAS) and lipid transfer protein (LTP) syndrome. PFAS is a common immunoglobulin E (IgE)-mediated allergic disease caused by a cross-reaction between pollen and plant foods. The allergens of PFAS are generally labile and cannot withstand high temperatures of food processing and proteolytic enzymes in the digestive tract.⁸ Therefore, PFAS is induced by intake of raw, unprocessed fruits and vegetables. PFAS is also known as oral allergy syndrome (OAS), which manifests as allergic symptoms of the oropharyngeal mucosa, including itching and swelling of the lips, mouth, and throat. These symptoms are usually mild and self-limited and present within 10 min of allergen intake.²⁶ In addition to oropharyngeal mucosa symptoms, PFAS can have systemic presentations, such as widespread urticaria and wheezing. Approximately 1–10% of PFAS cases present systemically.²⁷ Pollinosis and PFAS are more common in adolescents and adults; however, they are not rare in children. The prevalence of PFAS in children with pollinosis is 5–42.7% worldwide.¹⁴

Fruit and vegetable allergies are also frequently associated with LTPs, which may or may not be associated with pollen allergy.²⁸ LTPs are stable plant allergens, which are resistant to heat processing and enzymatic digestion.⁸

Therefore, the LTP syndrome has a higher possibility of developing systemic allergic symptoms than does PFAS.⁸

In addition to PFAS and LTP syndrome, latex-fruit syndrome is another category of fruit or vegetable allergy, which is caused by allergic cross reactions between latex and plant foods. Approximately 30–50% of individuals allergic to natural rubber latex have concomitant hypersensitivity to some plant-derived foods, especially freshly consumed fruits, such as banana, avocado, and kiwifruit.²⁹ Additionally, they can be allergic to vegetables, such as potato, celery, and carrot.³⁰

In our study, the most common presentations of fruit or vegetable allergies were located in the mucocutaneous tissue, followed by the upper airway and gastrointestinal tract, which was compatible with common presentations of PFAS and LTP syndrome.

Fruit and vegetable allergic presentations are usually mild and transient; however, the risk for severe allergic reactions remains, such as respiratory distress, hypotension, and anaphylactic shock. A study in Taiwan found that fruit allergy accounted for 6.8% of severe food allergies in emergency department visits caused by food allergy.³¹ Additionally, a study in Europe showed that 11% of anaphylaxis in children and adolescents was caused by fruit and vegetable allergies.⁵ Similarly, a study in China found that fruits and vegetables accounted for 20% of anaphylactic reactions.⁶ In this study, we found a case of corn-induced anaphylaxis, which was reported in a previous study.³²

This study found a higher prevalence of fruit allergy in girls than in boys; however, no sex-based difference was found in vegetable allergy. Several studies support our findings. A study in Sweden showed that female adolescents had a significantly higher rate of fruit allergy than males.³³ Similarly, a study in Germany found that the incidence of citrus-fruit allergy was significantly higher in female adults than in males.³⁴ Generally, girls have a higher prevalence of food allergy than boys after puberty³⁵; however, sex differences in food allergies during childhood showed inconsistent results.³⁶ Studies investigating sex differences in childhood fruit and vegetable allergies remain lacking and further studies are needed.

We also found children with multiple food allergies had higher tendency to have comorbid atopic dermatitis diseases than those with a single food allergy. These differences were not obvious in comorbid allergic rhinitis and asthma because airway allergy may be most frequently induced by aeroallergens.

Avoidance is the main strategy employed for preventing fruit and vegetable allergies. For those with OAS caused by fruits or vegetables, dietary avoidance of raw allergic foods is sufficient. However, strict restriction of allergic foods is recommended for patients presenting with severe or systemic allergic symptoms. However, for Rosaceae fruits, most LTPs are located in the peel³⁷; therefore, patients suffering from LTP syndrome may tolerate the allergic symptoms after peeling the fruits.³⁸ For those with allergic symptoms that interfere with respiration, such as laryngeal swelling or respiratory compromise, strict avoidance of allergic foods and prescription with an auto-injected epinephrine are advised.³⁹ Complete investigations in local areas with correct education can reduce the risk of over-avoidance of many safe foods. These are important, so children can effectively obtain diversified nutrients and reduce the risk of food allergy.

In the present study, we collected and analyzed large-scale nationwide data. This large data reduced the possibility of personal bias and enabled the detection of low-frequency food allergens and anaphylaxis. However, it is difficult to diagnose all children, nationwide, with food allergy using the gold standard examination, double-blind, placebo-controlled food challenge tests (DBPCFC). Therefore, differences may be observed in studies employing questionnaires and those that used DBPCFC. In the future, we may analyze the condition of fruit and vegetable allergies from databases based on DBPCFC. There was another limitation in the present study. It was difficult to differentiate food allergy and intolerance accurately in a retrospective study. We will try to conduct a prospective study with detailed history evaluation and laboratory study before participant enrollment.

In conclusion, we elucidated that the prevalence of fruit and vegetable allergies in children was 5.6% and 3.0%, respectively. The most common allergic presentations are located in the mucocutaneous tissue, followed by the upper airway and gastrointestinal tract. Mango and kiwifruit are the most frequent fruit allergens, while taro and bamboo shoot were the most common vegetable allergens. Children with a fruit or vegetable allergy had a similar percentage of comorbid atopic diseases with those allergic to the most common allergen, shellfish. If a child has symptoms of atopic diseases, but no specific allergen is identified among common allergic foods, vegetable or fruit allergy should be considered and evaluated. Plant allergens also have the risk of inducing acute or severe allergic reactions. Different studies have inconsistent findings regarding common plant allergens; therefore, further studies worldwide are required to synthesize these conflicting results.

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Declaration of competing interest

No conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pedneo.2022.03.019>.