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Vegetable intake in Australian children and adolescents: the importance of consumption frequency, eating occasion and its association with dietary and sociodemographic factors

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Abstract

Objective: We aimed to profile vegetable consumption and its association with dietary and sociodemographic factors.

Design: Secondary analysis of a nationally representative nutrition survey. 'Vegetables' refers to non-discretionary 'vegetables and legumes/beans' as defined by the Australian Dietary Guidelines (ADG). Prevalence of vegetable consumption, frequency of intake, proportion meeting ADG recommendations, most popular food groups, intake at each reported eating occasion, and the profile of high and low vegetable consumers (based on the median servings) were determined.

Setting: Australian 2011–2012 National Nutrition and Physical Activity Survey.

Participants: Children and adolescents aged 2 to 18 years (*n* 2812).

Results: Vegetables were consumed by 83·0 % (95 % CI 81·6, 84·4 %) of participants, but the median vegetable servings was less than a third of the ADG recommendations. 'Leaf and stalk vegetables' and 'potatoes' were the most popular vegetable-dense food groups at lunch and dinner, respectively. Sixty-four percent had vegetables once a day, and predominantly at dinner. Vegetable frequency was positively associated with daily vegetable servings and variety. Participants who consumed vegetables twice a day generally had vegetables at both lunch and dinner and had nearly double the servings (2·6, SD 1·9) of those who consumed them once (1·5, SD 1·5). High vegetable consumers were older, had higher total energy, but lower discretionary energy intake and were less likely to be at risk of metabolic complications.

Conclusion: Increasing the frequency of vegetable consumption may assist with increasing daily vegetable servings. A focus on consuming vegetables at lunch may assist with increasing both total servings and variety.

Keywords
Vegetable
Children
Frequency
Dietary intake
National Nutrition Survey
Variety
Eating occasion

Vegetables are fundamental to a healthy diet[1]. In systematic reviews and meta-analyses of cohort studies, increased vegetable consumption was associated with a reduced risk of coronary heart disease[2–4], stroke[4–6] and all-cause mortality[4,7]. Further evidence suggests that higher vegetable consumption may reduce the risk of some cancer types[8], depression[9], type 2 diabetes[10,11] and weight gain[12]. Low fruit and vegetable intake may be attributable to 7·8 million premature deaths worldwide in the year 2013 alone[4]. In Australia, economic modelling reported that if vegetable consumption were just 10 % higher, government health expenditure would reduce by about AU$100 million (2015–2016 dollars)[13].

The Australian Dietary Guidelines (ADG) recommend the consumption of 'plenty of vegetables' in order to satisfy nutritional requirements and minimise diet-related chronic disease risk[14]. This translates to a recommended 2·5 servings of 'vegetables and legumes/beans' for children aged 2–3 years and 4·5–5·5 servings for children aged 4–18 years. More than 99 % of children and adolescents (children) in the 2011–2012 National Nutrition and Physical Activity Survey (NNPAS) had usual intakes below recommendations[15]. Whilst intake was poor across all five ADG food groups, 'vegetables and legume/beans' had the highest proportion of children who failed to meet the recommended servings[15]. Of further concern, a number of

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longitudinal studies have reported that eating behaviour in childhood and adolescence tracks into later life[16,17], including that for vegetable intakes[18,19].

Understanding the context and correlates of vegetable consumption is necessary to help inform interventions and recommendations to increase consumption. A number of determinants are associated with low vegetable and fruit intake in children. These include being male, older, of low socio-economic status[20], lack of appropriate time/occasion/setting for eating fruit and vegetables, and extensive access to unhealthy food[21]. Most of these data combine fruit and vegetables and it is recommended that fruit and vegetable consumption be approached as two separate behaviours, as children are more likely to consume fruit over vegetables[22].

The frequency of vegetable consumption, measured as the number of daily eating occasions (or meals) with vegetables, may be an important determinant of total vegetable intake as meal skipping has been associated with a low vegetable intake[23–25]. Since the timing of vegetable consumption is generally not reported in studies, it is unclear how the types of eating occasion contribute to vegetable intake.

In Australia, vegetable intake among adults has been previously reported, including the timing of consumption[26], the variety of intake[27] and the association with discretionary foods[28], but data for children are limited.

The aim of the current study was to profile vegetable consumption, including the prevalence, quantity, frequency, variety, type and timing of vegetable intake, in a nationally representative sample of Australian children; and to examine the profile of high and low vegetable consumers with respect to their demographic, dietary, socio-economic and anthropometric characteristics.

Methods

Survey methodology

The 2011–2012 NNPAS is a nationally representative survey carried out by the Australian Bureau of Statistics (ABS) that forms part of the 2011–2013 Australian Health Survey. Detailed dietary information and physical activity data were collected for the NNPAS during face-to-face interviews by trained interviewers from the ABS. An Automated Multiple-Pass Method, developed by the Agricultural Research Service of the United States Department of Agriculture, was used by the ABS to capture all foods and beverages consumed by respondents within the 24 h prior to the interview day. For children aged 2–14 years, an adult was interviewed on the child's behalf, although children aged 6–14 years were invited to also participate in the interview. Children aged 15–17 years were personally interviewed with parental consent. Data were collected from 2812 children and adolescents (hereinafter referred to as 'children') aged 2–18 years, 1682 of whom provided dietary data for the second day of recall by telephone interview. To maximise the sample size, only the first day of dietary recall was used for all analyses, and data were weighted to represent the Australian population with weightings provided by the ABS. The interview components of the survey were conducted under the Census and Statistics Act 1905 and ethics approval was not necessary. Further survey details are available online under the Australian Health Survey: Users' Guide, 2011–2013[29].

Dietary intake

Dietary intake data were analysed using the survey specific 2011–2013 Australian Food Composition Database (AUSNUT) developed by Food Standards Australia New Zealand (FSANZ)[30]. The ABS categorised foods and beverages in the survey at the major food group level (2-digit), the sub-major food group level (3-digit), and the minor food group level (5-digit). The quantity of each food consumed was measured in grams and kilojoules.

'Vegetables' were defined as any 'vegetables or legumes/beans' according to the Australian Dietary Guidelines[14]. Total grams of vegetables consumed were calculated using a FSANZ database which details the amounts of each of the Five Food Groups in foods consumed in the NNPAS[31]. The total vegetable intake (grams) was calculated and the prevalence of vegetable consumption was calculated as the number of children who consumed any vegetables (>0 g). The number of vegetable servings was calculated using the ADG definitions for a serve (1 serve = 75 g, apart from vegetable juice where 1 serve = 130 g)[14]. Total vegetable intake and the number of servings were calculated for each sub-major food group. In contrast to some countries and to the WHO guidelines, potatoes are included in the 'vegetables' food group in the ADG. We calculated the percentage of vegetable intake that came from the sub-group 'potatoes' or 'potato mixed dishes' to provide context in comparison with other countries. The number of servings of vegetables and legumes/beans recommended in the ADG varies according to age and sex, from 2·5 among children 2–3 years old, to 5 among girls aged 14–18 years and 5·5 among boys aged 14–18 years[14]. The proportion of children of each age and sex group meeting the ADG recommendations was determined. Foods were classified as vegetable-dense based on whether they were >50 % vegetables by weight. The majority of vegetable-dense foods were sole vegetables (i.e. carrot, lettuce, etc.), however there were also some mixed dishes such as vegetable stew or vegetable lasagne that were vegetable-dense. There are sixty-two sub-major food groups that have foods containing vegetables, and thirty-five of these have foods that are vegetable-dense. Vegetable variety was calculated by determining the number of different vegetable dense sub-major food groups.

Discretionary food and beverages are defined as foods and beverages not necessary for a nutritious diet, and are high in saturated fat, added sugars, added salt, or alcohol and low in fibre[14]. Mean energy intake from discretionary

foods and beverages, mean daily energy intake, and the proportion of total energy intake from discretionary foods and beverages was calculated. In the 2011–2012 NNPAS, discretionary foods and beverages that contained vegetables (e.g. potato chips, hash browns, onion rings, vegetable tempura) contributed 23 % of total vegetable intake among children aged 2–18 years[15]. These foods and beverages were not included in our calculations of vegetable intake.

As part of the survey, respondents were asked to identify the reported eating occasion (REO) as well as the time they began consuming each food or beverage. The available REOs were: breakfast, morning tea, lunch, brunch, afternoon tea, dinner, supper, snack, beverage/drink, extended consumption or other. We defined an eating occasion (EO) as the consumption of one or more foods or beverages at the same time with the same reported eating occasion. For example, if a sandwich was consumed at 13.00 hours with the REO 'lunch', and a juice was also consumed at 13.00 hours but with the REO 'beverage/drink', this would be classified as two EO. Vegetable intake at each REO was determined. Vegetable frequency, defined as the number of eating occasions that contained vegetables, and the percentage contribution of each REO to total vegetable intake, were calculated.

Anthropometric measures and socio-economic status

Physical measurements including weight, height and waist circumference were measured for participating respondents by trained interviewers during the face-to-face interview. BMI *Z*-score, also known as BMI SD score, is a measure of relative weight adjusted for age and sex. The BMI *Z*-score was calculated using the child's age, sex, height, and weight, and the WHO growth reference standards for 2–4 and 5–19-year-old children[32]. The standard normal distribution was then calculated for all children's BMI *Z*-scores. This was used to categorise children as: 'normal weight' (<85 %), 'at risk for overweight' (≥85 to <95 %) or 'overweight' (≥95 %). Waist circumference to height ratio was also calculated for each child. A waist circumference to height ratio of <0·5 is associated with a low risk of metabolic complications, whereas a ratio of ≥0·5 is associated with a higher risk[33].

The Socio-Economic Indexes for Areas (SEIFA)[34] was used to define socio-economic status (SES). SEIFA is a product developed by the ABS that ranks areas in Australia into quintiles according to relative socio-economic advantage or disadvantage.

Statistical analysis

The statistical software package 'IBM SPSS Statistics version 23.0' was used for all analyses. The median number of vegetable servings per capita was used to define low and high vegetable consumers. Low vegetable consumers were defined as less than the median and high consumers as equal to or greater than the median.

Descriptive summaries were calculated for all variables of interest. ANOVA tables were created to calculate SDs, standard errors of the mean, and 95 % CI. Associations between frequency of vegetable intake and other vegetable-related metrics were measured using one-way ANOVA for means and Pearson's Chi-square tests for prevalence. The relationships between low and high vegetable consumers and sociodemographic, dietary, and anthropometric-related measures were also examined using one-way ANOVA and Pearson's Chi-square tests. Bonferroni post-hoc analysis showed pairwise significance between categories of consumers. Owing to the large sample size (n 2812) and the number of tests, P values <0·001 were treated as significant.

Results

Most children consumed vegetables (83 %), and the prevalence was greater among boys compared with girls (Table 1). The lowest prevalence was among 4–8-year-old girls (77·2 %) and the highest among 12–13-year-old boys (87·0 %). The mean daily servings of vegetables was 1·8 per capita, and 2·1 among vegetable consumers. For all age and sex groups, the median daily vegetable servings per capita were less than a third of the ADG recommendations and only 7·9 % of children met the recommendations.

Which reported eating occasions contributed the most to vegetable intake?

Dinner was the most common reported eating occasion for vegetable consumption, with 72·3 % (95 % CI 70·6, 73·9 %) of children having vegetables at dinner, followed by 34·2 % (95 % CI 32·4, 35·9 %) at lunch. Dinner had the highest mean servings of vegetables per capita (1·2 SD 1·5) and among consumers of vegetables at the reported eating occasion (1·7 SD 1·5) (Table 2). Less than 10 % of vegetable consumers had vegetables at each of the eating occasions: breakfast, snack, supper, and morning and afternoon tea (Table 3).

How did vegetable intake differ by frequency of consumption?

The average frequency of vegetable consumption (the mean number of eating occasions with vegetables) among consumers was 1·5 (SD 0·7), and the majority of vegetable consumers (56·6 %) had vegetables once a day (Table 3).

Vegetable frequency had a positive association with daily vegetable servings ($P < 0·001$). Children who had vegetables once a day had a mean of 1·5 servings, those who had it twice a day had a mean of 2·6 servings, and those who had it three or more times a day had a mean of 3·9 servings. Vegetable frequency was also positively associated with meeting vegetable recommendations ($P < 0·001$). Among children who had vegetables once a day, 4·3 % met the ADG recommended number of servings,

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Table 1 Vegetable* intake by age group and sex

		Percentage of children who consumed vegetables (%)		Vegetable servings/d								ADG vegetable serves recommendation		
				Per capita				Per consumer					Percentage of children who met target (%)	
	Sample size, *n*	Median	95 % CI	Mean	SD	Median	IQR	Mean	SD	Median	IQR	Target	Median	95 % CI
All children														
2–18 years	2812	83·0	81·6, 84·4	1·8	1·9	1·2	0·3–2·5	2·1	1·9	1·6	0·7–2·8	2·5–5·5	7·9	6·9, 8·9
2–3 years	331	82·3	78·2, 86·4	1·3	1·5	0·8	0·2–1·8	1·5	1·6	1·0	0·5–2·1	2·5	15·4	11·5, 19·3
4–8 years	809	80·4	77·6, 83·1	1·5	1·7	1·1	0·2–2·2	1·9	1·6	1·5	0·7–2·6	4·5	5·9	4·3, 7·5
9–11 years	511	83·2	80·0, 86·5	1·9	2·1	1·4	0·4–2·8	2·3	2·1	1·7	0·8–3·1	5·0	7·4	5·1, 9·7
12–13 years	389	86·0	82·6, 89·5	1·8	1·7	1·3	0·4–2·6	2·1	1·7	1·5	0·9–2·9	5·0–5·5	5·0	2·9, 7·2
14–18 years	773	84·4	81·8, 86·9	2·1	2·3	1·5	0·4–2·9	2·5	2·3	1·9	0·9–3·3	5·0–5·5	8·7	6·7, 10·7
Boys														
2–18 years	1435	84·2	82·3, 86·1	1·9	2·1	1·3	0·4–2·7	2·2	2·1	1·6	0·7–3·0	2·5–5·5	9·4	7·9, 11·0
2–3 years	172	84·8	79·5, 90·2	1·4	1·7	0·8	0·2–1·9	1·7	1·7	1·0	0·4–2·2	2·5	17·7	12·0, 23·4
4–8 years	418	83·4	79·8, 86·9	1·7	1·8	1·2	0·3–2·5	2·1	1·8	1·6	0·7–2·8	4·5	9·3	6·5, 12·1
9–11 years	257	80·5	75·7, 85·4	2·0	2·3	1·1	0·3–3·1	2·4	2·3	1·8	0·8–3·8	5	6·8	3·7, 9·9
12–13 years	197	87·0	82·3, 91·7	1·9	1·9	1·3	0·7–2·8	2·2	1·8	1·5	0·9–3·1	5·5	6·8	3·3, 10·3
14–18 years	389	85·9	82·4, 89·4	2·2	2·3	1·6	0·4–3·0	2·5	2·3	2·0	0·8–3·4	5·5	9·0	6·1, 11·8
Girls														
2–18 years	1377	81·7	79·7, 83·8	1·6	1·8	1·3	0·3–2·7	2·0	1·8	1·5	0·7–2·7	2·5–5	6·4	5·1, 7·7
2–3 years	159	79·6	73·3, 85·9	1·1	1·3	0·7	0·2–1·6	1·4	1·4	1·0	0·5–2·0	2·5	12·9	7·7, 18·1
4–8 years	391	77·2	73·0, 81·3	1·3	1·4	1·0	0·1–1·9	1·7	1·4	1·3	0·7–2·3	4·5	2·3	0·8, 3·7
9–11 years	253	86·0	81·7, 90·2	1·9	1·9	1·4	0·6–2·7	2·2	1·9	1·7	0·9–2·8	5	8·0	4·7, 11·3
12–13 years	192	85·1	80·0, 90·1	1·7	1·6	1·3	0·4–2·4	1·9	1·6	1·7	0·8–2·7	5	3·2	0·7, 5·7
14–18 years	383	82·8	79·0, 86·6	2·0	2·2	1·3	0·4–2·8	2·4	2·2	1·7	0·9–3·3	5	8·4	5·6, 11·1

ADG, Australian Dietary Guidelines; IQR, inter-quartile range.
*Refers to 'vegetables and legumes/beans' as defined by the Australian Dietary Guidelines, and includes potatoes but excludes discretionary vegetables[14].

Table 2 Vegetable* consumption at reported eating occasions

		Reported eating occasion			
		Breakfast (*n* 2569)	Lunch (*n* 2569)	Dinner (*n* 2696)	Snack (*n* 2101)
Prevalence of children that consumed vegetables, *N*		129	961	2033	195
Per capita	Percentage of children who consumed vegetables (%)	4·6	34·2	72·3	6·9
	95 % CI	3·8, 5·3	32·4, 35·9	70·6, 73·9	6·0, 7·9
	Vegetable servings/d, mean	0·1	0·3	1·2	0·1
	SD	0·4	0·8	1·5	0·4
Per consumer of the REO	Percentage of children who consumed vegetables (%)	5·0	37·4	75·4	9·3
	95 % CI	4·2, 5·8	35·5, 39·3	73·7, 77·0	8·1, 10·5
	Vegetable servings/d, mean	0·1	0·4	1·3	0·1
	SD	0·4	0·8	1·5	0·5
Per vegetable consumer at the REO	Vegetable servings/d, mean	1·2	1·0	1·7	1·0
	SD	1·2	1·1	1·5	1·1

REO, reported eating occasion.
*Refers to 'vegetables and legumes/beans' as defined by the Australian Dietary Guidelines, and includes potatoes but excludes discretionary vegetables[14].

and this was significantly lower than among children with two (12·9 %) or three or more (30·0 %) vegetable eating occasions per day ($P < 0·001$). Vegetable frequency was positively correlated with vegetable variety ($P < 0·001$). Children who had vegetables once a day had, on average, 1·1 vegetable-dense food groups, compared with 2·1 among those who consumed vegetables twice, and 2·7 among those who consumed them three or more times (Table 3).

The proportion of children who consumed vegetables at the different eating occasions, and particularly at lunch, increased with increased vegetable frequency. For children who consumed vegetables once a day, vegetables were eaten at dinner by 82·3 % and at lunch by 13·3 %. For those who consumed vegetables twice a day, this increased to 92·4 % at dinner and 74·6 % at lunch. For those who had vegetables three or more times a day, vegetables were most commonly consumed at dinner (97·2 %) and lunch (88·5 %), and then spread across the other eating occasions.

The most popular vegetable food groups consumed differed when comparing top food groups among children who had vegetables once, twice or three or more times a day. 'Potatoes' were the most popular among those who had vegetables once a day, but did not make the top three among those who had them twice or those who had them three or more times a day. 'Tomato and tomato products' was popular among those who had vegetables three or more times a day, but did not make the top three among the other groups.

Which vegetable-dense food groups were the most popular?

Prevalence and intake of vegetable-dense food groups across the day by the top vegetable eating occasions, lunch and at dinner, are shown in Table 4. Across the day, 'other fruiting vegetables' (pumpkin, mushrooms, zucchini, corn, avocado, capsicum, cucumber, etc.) had the highest prevalence of consumers (21·0 %), followed by 'potatoes' (20·4 %), and 'carrot and similar root vegetables' (20·2 %). The mean vegetable servings per consumer of the ten leading vegetable-dense food groups were all under one serve, apart from 'potatoes' and 'mixed dishes where cereal is the major ingredient' (sandwiches, pizza, pasta and rice dishes, etc.), which were 1·4 and 2·4, respectively. The ten most popular food groups that contained any vegetable can be found in Supplementary Table S1. For these, 'Mixed dishes where cereal is the major ingredient' had the highest prevalence of consumers (39·4 %) and the mean vegetables serve per consumer was 1·1. Approximately 14 % of total vegetable intake among Australian children came from the sub-groups 'potatoes' or 'potato mixed dishes'.

The three most popular vegetable-dense food groups at lunch were 'leaf and stalk vegetables' (lettuce, spinach, celery, etc.) (25·0 %), 'tomato and tomato products' (fresh tomato, tomato paste, sundried tomato, etc.) (21·0 %), and 'other fruiting vegetables' (capsicum, corn, pumpkin, etc.) (16·6 %). At dinner, 'potatoes' (21·1 %) was the most popular (whereas at lunch this category ranked seventh), followed by 'dishes where vegetable is the major component' (salads, vegetable curries, stir-fries casseroles, etc.) (14·3 %), and 'other fruiting vegetables' (13·8 %).

The mean vegetable servings per consumer of the ten most popular vegetable-dense food groups varied widely and were dependent on the food group consumed. At lunch, this ranged from 0·3 ('leaf and stalk vegetables'; 'other vegetables and vegetable combinations') to 3·1 ('mature legume and pulse products and dishes'). At dinner, it ranged from 0·4 ('leaf and stalk vegetables') to 2·5 ('mixed dishes where cereal is the major ingredient').

Table 3 Vegetable* intake by the frequency of consumption

	All vegetable consumers		Number of vegetable eating occasions†						
			1		2		3+		
	Mean or median	SD or 95 % CI or IQR	Mean or median	SD or 95 % CI or IQR	Mean or median	SD or 95 % CI or IQR	Mean or median	SD or 95 % CI or IQR	*P* value‡
Prevalence of children, *N*	2334		1322		807		208		
Percentage of vegetable consumers	83·0	81·6, 84·4	47·0		28·7		7·4		
Vegetable eating occasions/d	1·5	0·7							
Vegetable eating occasions/d	1	1–2							
Vegetable serves/d	2·1	1·9	1·5[a]	1·5	2·6[b]	1·9	3·9[c]	3·0	<0·001
Percentage of children who met the ADG recommendations‡	7·9	6·9, 8·9	4·3	3·2, 5·4	12·9	10·6, 15·2	30·0	23·8, 36·3	<0·001
Number of distinct vegetable-dense§ food groups	1·6	1·4	1·1[a]	1·1	2·1[b]	1·4	2·7[c]	1·4	<0·001
Percentage of children who consumed vegetables at each REO, %									
Breakfast	5·5	4·6, 6·4	0·7	0·3, 1·2	6·7	5·0, 8·5	31·2	24·9, 37·5	<0·001
Lunch	41·2	39·2, 43·2	13·3	11·5, 15·2	74·6	71·6, 77·6	88·5	84·1, 92·8	<0·001
Dinner	87·1	85·7, 88·4	82·3	80·2, 84·3	92·4	90·5, 94·2	97·2	95·0, 99·5	<0·001
Morning tea	3·7	3·0, 4·5	0·3	0·0, 0·7	5·1	3·6, 6·6	19·9	14·5, 25·4	<0·001
Afternoon tea	4·0	3·2, 4·8	0·6	0·2, 1·0	3·6	2·3, 4·9	27·6	21·5, 33·6	<0·001
Snack	8·4	7·2, 9·5	1·8	1·1, 2·5	13·7	11·3, 16·0	29·4	23·2, 35·6	<0·001
Supper	1·4	1·0, 1·9	0·5	0·1, 0·8	2·4	1·3, 3·4	3·8	1·2, 6·4	<0·001
Most popular vegetable-dense§ food groups (% consumers, mean servings)									
1st	Other fruiting vegetables	21·0, 0·9	Potatoes	20·1, 1·4	Carrot and similar root vegetables	28·0, 0·8	Other fruiting vegetables	39·4, 1·2	
2nd	Potatoes	20·4, 1·4	Other fruiting vegetables	14·1, 1·0	Other fruiting vegetables	27·7, 0·8	Carrot and similar root vegetables	37·4, 0·8	
3rd	Carrot and similar root vegetables	20·2, 0·9	Carrot and similar root vegetables	12·8, 1·0	Leaf and stalk vegetables	27·3, 0·3	Tomato and tomato products	37·1, 0·9	

ADG, Australian Dietary Guidelines; IQR, interquartile range; REO, reported eating occasion.
[a,b,c]Mean values within a row with unlike superscript letters were significantly different ($P < 0·001$, *post hoc* Bonferroni).
*Refers to 'vegetables and legumes/beans' as defined by the Australian Dietary Guidelines, and includes potatoes but excludes discretionary vegetables[14].
†An eating occasion is defined as the consumption of one or more foods or beverages at the same time with the same reported eating occasion.
‡*P* values compare number of eating occasions, using one-way ANOVA for means and Chi-square tests for prevalence.
§Vegetable-dense refers to sub-major food groups with more than 50 % vegetable by weight.

Table 4 Most popular vegetable-dense* food groups

	Total day					Lunch					Dinner				
		Prevalence of children who consumed the food group		Vegetable† servings per consumer of the food group			Prevalence of children who consumed the food group		Vegetable† servings per consumer of the food group			Prevalence of children who consumed the food group		Vegetable† servings per consumer of the food group	
Rank	Sub-major food group	*N*	%	Mean	SD	Sub-major food group	*N*	%	Mean	SD	Sub-major food group	*N*	%	Mean	SD
1	Other fruiting vegetables	490	21·0	0·9	0·9	Leaf and stalk vegetables	240	25·0	0·3	0·2	Potatoes	429	21·1	1·3	1·1
2	Potatoes	476	20·4	1·4	1·2	Tomato and tomato products	202	21·0	0·6	0·4	Dishes where vegetable is the major component	290	14·3	0·9	0·9
3	Carrot and similar root vegetables	472	20·2	0·9	0·9	Other fruiting vegetables	159	16·6	0·6	0·6	Other fruiting vegetables	281	13·8	1·0	0·9
4	Dishes where vegetable is the major component	365	15·6	0·9	1·0	Carrot and similar root vegetables	115	12·0	0·6	0·7	Carrot and similar root vegetables	274	13·5	0·9	0·8
5	Leaf and stalk vegetables	363	15·5	0·3	0·3	Dishes where vegetable is the major component	76	7·9	0·8	0·6	Other vegetables and vegetable combinations	273	13·4	0·9	0·8
6	Other vegetables and vegetable combinations	341	14·6	0·8	0·8	Other vegetables and vegetable combinations	60	6·3	0·3	0·4	Cabbage, cauliflower and similar brassica vegetables	211	10·4	0·7	0·7
7	Tomato and tomato products	328	14·0	0·8	1·0	Potatoes	35	3·6	1·9	1·3	Peas and beans	188	9·2	0·5	0·4
8	Cabbage, cauliflower and similar brassica vegetables	231	9·9	0·8	0·7	Mixed dishes where cereal is the major ingredient	32	3·3	1·8	1·5	Leaf and stalk vegetables	84	4·2	0·4	0·5
9	Peas and beans	208	8·9	0·5	0·5	Mixed dishes where beef, sheep, pork or mammalian game is the major component	18	1·8	1·3	1·1	Mixed dishes where cereal is the major ingredient	68	3·3	2·5	1·5
10	Mixed dishes where cereal is the major ingredient	102	4·3	2·4	1·5	Mature legume and pulse products and dishes	16	1·6	3·1	1·8	Mixed dishes where beef, sheep, pork or mammalian game is major component	66	3·2	2·1	1·5

*Vegetable-dense refers to sub-major food groups with more than 50 % vegetable by weight.
†Refers to 'vegetables and legumes/beans' as defined by the Australian Dietary Guidelines, and includes potatoes but excludes discretionary vegetables[14].

Table 5 Sociodemographic, dietary and anthropometric characteristics of low and high vegetable* consumers

	Low vegetable* consumers (*n* 1407)†	High vegetable* consumers (*n* 1405)†	*P* value‡
Vegetable servings/d, mean	0·4	3·1	<0·001
SD	0·4	1·9	
Vegetable servings/d, median	0·3	2·5	
IQR	0·0–0·7	1·7–3·9	
Age (years), mean	9·3	10·6	<0·001
SD	4·9	4·8	
Percentage of children who were female, %	50·7	47·3	0·040
Energy (MJ), mean	7·5	8·5	<0·001
SD	3·0	3·4	
Discretionary energy (MJ)	3·3	2·9	<0·001
SD	2·5	2·3	
Proportion of total energy intake from discretionary foods and beverages (%), mean	41·2	31·9	<0·001
SD	21·1	18·2	
BMI *Z*-score, mean	0·60	0·57	0·488
SD	1·22	1·13	
Weight status§, %			0·148
Normal	66·9	70·0	
At risk of overweight	14·1	11·6	
Overweight	19·0	18·5	
Waist:height ratio, mean	0·48	0·48	0·009
SD	0·06	0·06	
Waist:height category‖, %			<0·001
Not at risk of metabolic complications	63·9	72·4	
Increased risk of metabolic complications	36·1	27·6	
Socio-economic status, %			0·246
Lowest quintile	18·3	16·4	
Highest quintile	22·6	25·8	

IQR, inter-quartile range.
*Refers to 'vegetables and legumes/beans' as defined by the Australian Dietary Guidelines, and includes potatoes but excludes discretionary vegetables[14].
†Low and high consumers defined as below and equal to or above the median intake (1·19 servings/d) respectively.
‡*P* values for means tested by one-way ANOVA and for prevalence tested by Chi-square tests.
§Based on BMI *Z*-score: normal (<85th percentile), at risk for overweight (≥85th percentile, <95th percentile), overweight (≥95th percentile)[33].
‖Based on waist circumference to height ratio: not at risk of metabolic complications (<0·5), increased risk of metabolic complications (≥0·5)[32].

What were the sociodemographic, dietary and anthropometric characteristics of high vegetable consumers?

High vegetable consumers (intake greater than the median of 1·2 vegetable servings/d) were older, had a greater mean total energy intake, and a lower discretionary energy intake (Table 5). The contribution of energy from discretionary foods and beverages was lower among high vegetable consumers (31·9 %) compared with low vegetable consumers (41·2 %). Low vegetable consumers had a higher prevalence of children at increased risk of metabolic complications (36·1 *v.* 27·6 %) and had a similar mean BMI and waist:height ratio. There were no differences in sex, weight status, or SES.

Discussion

The majority of Australian children consumed vegetables, however both the frequency and total daily servings of vegetable were low, with the median vegetable servings less than a third of recommendations. Children most commonly consumed vegetables once per day, at dinner, and those with a higher vegetable frequency had a greater daily intake of vegetables, were more likely to meet vegetable recommendations and had a greater vegetable variety. More than half of vegetable consumers did not have any vegetables at lunch, and those who had vegetables more than once per day generally had them at both dinner and lunch. 'Mixed dishes where cereal is the major ingredient' was the most popular vegetable-containing food group, whilst 'other fruiting vegetables' and 'potatoes' were the most popular vegetable-dense food groups. High vegetable consumers were older, had a greater energy intake but lower discretionary energy intake, and were less likely to be at risk of metabolic complications based on evaluation of waist:height ratio.

Despite the majority of children consuming vegetables in Australia, a low proportion of children met vegetable recommendations. This is consistent with data from the US[35], Canada[36], Europe[37], Mexico[38] and Malaysia[39], where the proportion of children meeting recommendations ranged from 7 to 24 %. Direct comparisons between countries should be made cautiously for several reasons: recommendations are country specific, there is no consensus on whether potatoes and legumes should be included as a vegetable in the literature, and most of these studies grouped vegetables with fruit. In Canada, almost all (97 %) children aged 11–17 years consumed vegetables or fruit, yet only 10 % met national recommendations for

vegetables and fruit combined[36]. In children aged 11 years across ten European countries, 55 % ate vegetables at least once daily but only 24 % of children met the WHO population goal for total fruit and vegetable consumption[37]. Our data suggest that focusing on increasing the amount of daily vegetables consumed, rather than on the percentage of individuals who are consumers, could help to increase vegetable intake towards recommended targets.

In our study, both vegetable servings and frequency were low, with the majority of children having vegetables once per day. Novel to this study, higher vegetable frequency was correlated with higher daily vegetable servings and with increased vegetable variety. Among Australian adults, a similar pattern was observed where those who had five servings of vegetables or more had the highest proportion of consumers across all meals[40]. We found that frequent vegetable consumers ate a wider variety of vegetable-dense food groups. Much of the research for increasing vegetable intake has focused on increasing portion size[41–44]. Evidence from intervention studies in children suggest that this approach is effective but may be limited after reaching a certain portion size, such as 120 g in 3–5-year-olds[45] or 150 g in 5–6-year-olds[46], which is still less than or equal to two standard vegetable servings[14]. There is experimental evidence that increasing variety can increase vegetable intake in school-aged children[47]. Thus, increasing vegetable frequency may also need to be an important target for increasing vegetable intake in children.

Consuming a wider variety of vegetables may also have public health benefits. In adults, greater vegetable variety has been associated with a reduced risk of type 2 diabetes[48], and a greater fruit and vegetable variety was associated with higher micronutrient intakes[49] and lower markers of inflammation[50]. Our correlation between vegetable frequency and variety could be partially explained by differences in the most popular vegetable food groups consumed at lunch and at dinner. Since those with a higher vegetable frequency had vegetables at both lunch and dinner, they are more likely to have consumed different vegetables at these occasions. It is also possible that the correlation between frequency and variety is a direct result of a higher vegetable quantity. Intervention studies are required to determine causality between increasing vegetable frequency and increased vegetable variety and intake, and future studies should determine if such associations with variety are independent of, or related to, total vegetable servings.

We found that vegetables were most commonly consumed at dinner, followed by lunch, but at a much lower prevalence, providing an opportunity to target portion size at dinner and both portion size and consumption at lunch. These findings are in line with evidence from other cross-sectional studies where dinner contributed the most to vegetable intake. An American study that analysed the diets of children aged 2–18 years from the NHANES 2007–2010 reported that dinner provided more than half (52–54 %) of total vegetable intake, followed by lunch (29–31 %), snacking (11–14 %) and breakfast (4–5 %)[51]. Similarly, dinner is the most prevalent eating occasion for vegetable consumption among school-aged children in New Zealand[52], among adolescents in Norway[53] and also among Australian adults[27]. Our finding that vegetables are not popularly consumed at lunch is consistent with other countries. In the USA, a study of children aged 4–11 years reported that only 5 % of children consumed one serving (80 g) of vegetables at lunch[54]. In England, only 19 % of packed lunches for 8–9-year-old children provided vegetables[55]. Our findings that children with a higher frequency of vegetable intake generally had vegetables at both dinner and lunch highlight that interventions designed to increase vegetable frequency could prioritise increasing the percentage of children having vegetables at lunch, whereas dinner recommendations may need to focus on increasing portion size.

Our findings have clinical relevance. A specific focus on frequency and eating occasions may be useful for increasing both total vegetable intake, including the proportion of children meeting vegetable recommendations, and vegetable variety. Recommendations for vegetable intake in children could include frequency messages such as 'enjoy veggies at least 3 times a day'. Given that fewer than 10 % of Australian children currently achieve this, shorter-term frequency messages could be to consume vegetables 'at least 2 times a day', 'at every lunch and dinner' or to 'add veggies as a snack every day', rather than messages on serve sizes. Given the role of vegetable consumption at lunch for greater vegetable frequency, school lunch programmes warrant consideration in Australia. A number of studies in England have shown that children who consumed a lunch as part of a school lunch programme consumed more vegetables or were more likely to consume vegetables at lunch than children who took a packed lunch[56–58], with one study finding a tenfold (81 *v.* 8 %) difference in the prevalence of vegetable consumers[58]. In the US, school lunch programme participation was associated with greater vegetable and lower discretionary food intake[59]. In Denmark, a school lunch increased vegetable consumption in a randomised controlled trial[60], suggesting that the relationship is likely to be causal. Given the overall nutritional quality of the lunch meal in Australia is particularly poor[61], and that a high intake of discretionary foods is consumed in Australian schools[61–63], strategies that address the nutritional quality of the entire lunch meal, not only its vegetable content, are warranted.

'Mixed dishes where cereal is the major ingredient' (e.g. sandwiches, pasta, rice) was by far the most popular vegetable food group in the current study. This finding, while not surprising, is in line with other studies that report children are more likely to consume vegetables mixed with other foods rather than on their own, although reasons for

consuming specific vegetables in school-aged children have been shown not to be generalisable[64]. An analysis of the NHANES 2003–2008 reported that the leading food group contributor to vegetable intake was mixed dishes (approximately 41 %), followed by white and fried potatoes (20·9 % combined)[65]. An analysis of fruit and vegetable intake from the NHANES 2007–2010 reported that only 3–6 % of vegetables were consumed as raw or on their own (e.g. whole or cut-up carrots)[51]. The meal context is likely an important determinant of vegetable consumption. Numerous studies have described taste as the main reason for children not liking vegetables[66–69], and that adding another food or flavour can help to facilitate their consumption[70,71]. The importance of mixed dishes in contributing to total vegetable intake should be taken with some caution since they contribute greatly to children's total energy intake[72] and were not vegetable-dense. We found that 39 % of children consumed mixed dishes that contained vegetables, but only 4 % consumed mixed dishes that were vegetable-dense. In a randomised crossover trial, the incorporation of vegetables into mixed dishes increased the vegetable intake within the meal by 50–73 %[73]. Thus, adding vegetables to mixed dishes to increase their vegetable density, including sandwiches, casseroles, pasta, rice, and soups, may form effective and culturally appropriate meal-based guidelines to increase vegetable intakes in children in Australia.

'Other fruiting vegetables' (e.g. cucumber, capsicum, corn, avocado) and 'potatoes' were the two most popular vegetable-dense food groups, suggesting that these foods may be useful for increasing vegetable intake. It has been demonstrated in randomised trials that increasing the variety of vegetables offered to children within a meal increases total vegetable intake at the meal[47,74]. One strategy to increase vegetable intake may be to encourage adding smaller quantities of less popular vegetables to these more popular ones. For example, adding extra vegetables to a sandwich or wrap; to a roast vegetable tray, to the barbeque, in a stir fry and remembering to have vegetables as snacks. 'Potatoes' were the largest contributor to any single vegetable food group, had the largest vegetable servings per consumer, and were most popular among children with a low vegetable frequency. In New Zealand, children were more likely to consume less popular non-starchy vegetables if they also consumed potato/kumara/taro[52]. The versatility of potatoes means that they are likely to be a useful target to facilitate greater variety in vegetable consumption. Potato-based recipes could include extra vegetables and also different varieties of potatoes (i.e. sweet potato). Further, recommendations could also focus on swapping discretionary potatoes (e.g. French fries) to core potatoes (e.g. baked potato), as discretionary foods are not included in the ADG food groups.

Our finding that high vegetable consumers had a lower energy contribution from discretionary energy is of interest given discretionary food and beverage intake is high in Australian children[15], and is consistent with a number of studies. Among Australian adults, discretionary foods and beverages were shown to be inversely associated with vegetable intake[28]. Cross-sectional studies in Australia have reported that children who met vegetable recommendations had a lower 'junk food' intake[75] and that a more frequent consumption of fast food was associated with a lower fruit and vegetable intake[76]. In the US, an inverse relationship between fast-food intake and vegetable intake is reported[77–79], and increasing the energy intake from fruit and vegetables in school lunches has been associated with reduced energy intake from other sources[80]. There is evidence from intervention studies that increasing vegetable intake directly reduces the intake of other energy sources[81–83]. These findings may be because vegetables generally have a low energy density and that increasing their intake can enhance satiety[82], and raises questions about whether increasing vegetable intake may have a dual benefit in also reducing discretionary energy.

We found that high vegetable consumers had a lower risk of metabolic complications, but not a lower mean BMI *Z*-score or mean waist:height ratio. Similarly, in Australian adults, no association was found between vegetable consumption and BMI[40]. There is limited evidence from longitudinal and experimental studies on a relationship between vegetable intake and adiposity in children[84]. An inverse association has been described in adults in a systematic review and meta-analysis of prospective cohorts[85] and is supported by a meta-analysis of randomised controlled trials that found increased fruit and vegetable consumption favoured weight loss[86]. The nature of our cross-sectional analysis, and that adiposity is multifactorial, means that confounding or reverse causation may influence the observed associations. It is possible that we did not observe an association between vegetable consumption and BMI *Z*-score or waist:height ratio because even the high vegetable consumers in our study had a low total vegetable intake when compared with dietary recommendations. Intervention studies in Australian children are required to better understand the relationship between vegetable consumption, including differing amounts, and adiposity measures.

The strengths of the current study include the use of a large, nationally representative sample of Australian children, with detailed information on a range of consumption factors. The focus was purely on vegetable intake, whereas many cross-sectional studies on vegetable intake group vegetable with fruit, and classify discretionary vegetables as vegetables (i.e. French fries), potentially confounding the true intake profile and associations of vegetable intake. Measuring the intake and prevalence of vegetable consumers at each eating occasion helped to better understand the role of consumption frequency and eatingoccasions in contributing to daily intake. The analysis of food groups with greater than 50 % vegetable by weight gives a deeper insight into how children consume vegetable-dense groups, which need to be encouraged.

The current study has limitations. The data are cross-sectional, meaning causal effects cannot be determined. Under-reporting in nutrition surveys is common[87] and this may impact the observed associations between vegetable intake and other variables. However, we suspect that the effect of under-reporting on vegetable intake is minimal, since the intake is low across all age and sex groups, and there is evidence that healthy foods are less likely to be under-reported[88,89]. Nutritional needs and food choices change with age, and many of our analyses were for all children between 2 and 18 years of age, and hence findings may differ across age groups, including the top vegetable food groups and eating occasions in which vegetables are consumed. The vegetable recommendations from the ADG are age- and sex-specific, and key results such as the prevalence of children meeting ADG recommendations apply to children of all ages. The associations we found with frequency of vegetable intake are also likely to be relevant to all age groups. All vegetables and legumes/beans were grouped together, yet it has been observed that potatoes have an opposite association with body weight gain compared with non-starchy vegetables in adults[90]. For this reason, we excluded all vegetables from discretionary food sources, such as those consumed with fast food, or potatoes that were deep-fried. Vegetable intake in our study is likely to be higher than in studies that report vegetable intake using the WHO guidelines, since potatoes (although non-discretionary only) were included in our analyses and the WHO excludes potatoes as vegetables. Eating occasions were subjectively defined, meaning they may differ between people and may not be consistently representative of a certain time of day. Further, we used 1 d of dietary recall to categorise participants and estimate means, which may not reflect usual intakes. The rationale for using 1 d of dietary recall was to retain a larger sample size, as only 57 % of children provided the second day of recall.

Conclusions

In conclusion, our findings showed that the low vegetable intake in Australian children and adolescents is related to a low frequency of vegetable consumption, and that many children consume vegetables only at dinner. Our analysis suggests that interventions that successfully increase vegetable frequency, particularly by addressing the consumption of vegetables in the lunch meal, may help to increase the total intake and variety of vegetables consumed. Research is needed to confirm the effectiveness of such interventions.

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Supplementary material

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