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Intake of total and added sugars and nutrient dilution in Australian children and adolescents

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Abstract

This analysis aimed to examine the association between intake of sugars (total or added) and nutrient intake with data from a recent Australian national nutrition survey, the 2007 Australian National Children's Nutrition and Physical Activity Survey (2007ANCNPAS). Data from participants (n 4140; 51 % male) who provided 2× plausible 24-h recalls were included in the analysis. The values on added sugars for foods were estimated using a previously published ten-step systematic methodology. Reported intakes of nutrients and foods defined in the 2007ANCNPAS were analysed by age- and sex-specific quintiles of %energy from added sugars (%EAS) or %energy from total sugars (%ETS) using ANCOVA. Linear trends across the quintiles were examined using multiple linear regression. Logistic regression analysis was used to calculate the OR of not meeting a specified nutrient reference values for Australia and New Zealand per unit in %EAS or %ETS. Analyses were adjusted for age, sex, BMI z-score and total energy intake. Small but significant negative associations were seen between %EAS and the intakes of most nutrient intakes (all $P < 0{\cdot}001$). For %ETS the associations with nutrient intakes were inconsistent; even then they were smaller than that for %EAS. In general, higher intakes of added sugars were associated with lower intakes of most nutrient-rich, 'core' food groups and higher intakes of energy-dense, nutrient-poor 'extra' foods. In conclusion, assessing intakes of added sugars may be a better approach for addressing issues of diet quality compared with intakes of total sugars.

Key words: Total sugars: Added sugars: Nutrient dilution: Australian children and adolescents

The role of sugars in the modern diet has always been a controversial topic[1–9]. 'Sugar' is a term that can refer to a food mostly used in a culinary sense, an ingredient in prepared foods and beverages such as bakery items and soft drinks, or to a set of compounds (sugars) naturally occurring as part of the carbohydrate component of mostly plant foods (e.g. fructose in fruit and lactose in milk). A 'total sugars' value is a problematic marker of diet quality[10] because this reflects the sugar content of nutritious foods such as fruit and dairy products, which contain naturally occurring sugars, as well as added or culinary sugar, which serves only to add energy (kcal/kJ) without concomitant nutrients. Public health agencies have been suggesting for some time that people limit or moderate their intake of added sugars to reduce their total energy intake (EI)[11–13]. In support of these recommendations, a recent systematic review[14] has concluded that in *ad libitum* conditions, increased added sugar consumption is associated with a 0·75 kg weight gain.

High diet quality remains the target for health, and this is evaluated in terms of nutrients delivered for a given energy value. There is some concern that the sugar content may dilute diet quality, that is, the more sugar, the less nutrients for a given energy value. However, the evidence regarding the association between sugar intake (total or added) and nutrient intake is less consistent[15–19]. This may be due to the different use of analytical methods, including different methods for energy adjustment[20]. To date, no study had found that a higher intake of added sugars is associated with improved nutrient intake after adjusting for total EI, and this suggests that the sugar content of the diet may be contributing to nutrient dilution.

Previous analyses of the 1995 Australian national nutrition survey[15,19] revealed that in children and adolescents a higher added/refined sugar intake was associated with poorer nutrient intake. However, recent data suggest that the apparent consumption of refined sugars in Australia has declined in recent years[1,21]. Using a more up-to-date data set from the 2007 Australian National Children's Nutrition and Physical Activity Survey (2007ANCNPAS)[22], the aim of our study was to test whether a higher total or added sugar intake was associated with nutrient dilution (where 'sugar' refers to common chemical forms of sugar). We hypothesise that a higher intake of added

Abbreviations: 2007 ANCNPAS, the 2007 Australian National Children's Nutrition and Physical Activity Survey; EI, energy intake; %EAS, %energy from added sugars; %ETS, %energy from total sugars; NRV, nutrient reference values; PAL, physical activity level.

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sugar but not total sugar is consistently associated with nutrient dilution in the diets of Australian children and adolescents.

Methods

The 2007 Australian National Children's Nutrition and Physical Activity Survey

The 2007 ANCNPAS was commissioned in 2007 by the Australian Government Department of Agriculture, Fisheries and Forestry and the Australian Food and Grocery Council[22]. The methodology of the 2007ANCNPAS has been described in detail elsewhere[23]. In brief, the survey measured the dietary intakes of food and beverages as well as use of supplements using two multiple-pass 24-h recalls collected 7–21 d apart. These data were collected on children aged 2–16 years (n 4834) between 22 February and 30 August 2007. Dietary data were collected from the primary-care giver on children aged 2–8 years; children aged 9 years and older reported their own dietary intake. Nutrient intake from supplements was not considered in the current study.

Added sugars analyses

Dietary intake data were entered into a purpose-built database, with nutrition compositions based on the AUSNUT2007 database[24]. Using this database, the content of added sugars, defined as all refined sugars added during cooking or manufacturing, of foods was estimated on the basis of a ten-step methodology previously published[25]. Briefly, the ten steps are as follows:

Step 1: Assign 0 g added sugar to foods with 0 g total sugars.

Step 2: Assign 0 g added sugar to foods identified as no-added-sugar food groups.

Step 3: Assign 100 % of total sugars as added sugar for foods in 100 %-added-sugar food groups.

Step 4: Calculate added sugar value on the basis of standard recipe used in the food composition database – proportioning method where added sugar contents of ALL ingredients were available from steps 1–3.

Step 5: Calculate added sugar value on the basis of comparison to values from unsweetened variety.

Step 6: Decide on proportion of added sugar on the basis of analytical data.

Step 7: Use borrowed values from similar products from steps 1 to 6 or from overseas.

Step 8: Subjectively estimate added sugar content on the basis of ingredients and/or common recipes (e.g. obtained from popular recipe books).

Step 9: Calculate added sugar content on the basis of standard recipe, which includes ingredients with values assigned at steps 5–8, using the proportioning method.

Step 10: Assign 50 % of total sugars as added sugars.

More details about the steps could be found in the original paper[25].

Data cleaning

Data from children who completed only one 24-h recall (n 179) were excluded from the analyses. The plausibility of data from the remaining sample was assessed using the Goldberg cut-off for specific physical activity level (PAL)[26]. A default PAL of 1·55 was assigned to children aged 8 years or below as no physical activity data were available. We excluded data from 339 extreme under-reporters (EI:BMR ratio: 0·3–1·5; PAL: 1·2–2·8; 47 % male) and 129 extreme over-reporters (EI:BMR ratio: 2·2–4·7; PAL: 1·1–2·3; 51 % male) on the basis of this method. An additional forty-seven subjects were excluded because weight and/or height were not recorded and as the plausibility of the data could not be assessed. The final data set included data from 4140 participants (51 % male) who provided 2 × 24-h recalls.

Comparison to the nutrient reference values of Australia and New Zealand

Usual intakes of energy and macro- and micronutrients were calculated using the multiple source method (MSM)[27] to account for intra-personal variability. The usual nutrient intakes of the participants were compared with the latest Nutrient reference values (NRV) for Australia and New Zealand[28] using criteria relevant to available standards. Thus, for the group of nutrients with an estimated average requirement (EAR) (Ca, Fe, I, Zn, Mg, P, vitamin A (as retinol equivalents), thiamin, riboflavin, dietary folate equivalents and vitamin C), intakes lower than the EAR were considered not meeting the NRV. For nutrients with an adequate intake (AI) value (K, long chain n-3 PUFA (LC n-3 PUFA), dietary fibre, vitamin D and vitamin E), intakes lower than the AI were considered not meeting the NRV. Upper limits and suggested targets were considered for nutrients known to be consumed in excess. Thus, intakes higher than the upper level (UL) for Na were considered not meeting the NRV, and EI from SFA >10 % were considered not meeting the SFA NRV.

Comparison with food pattern intakes

The values for intakes of sugars were compared with reported intakes of food groups reported in the AUSNUT2007 database. Nutrient-rich, core and discretionary 'extra' foods were referred to as defined by the Australian Dietary Guidelines[29] and Rangan *et al.*[30,31]. In brief, core foods included fruits, most vegetables, legumes, nuts, seeds, eggs, fish, most meats and poultry and most dairy foods; and 'extras' were nutrient-poor foods and beverages. A detailed list of how food groups were classified is available as online Supplementary Table S1.

Statistical analysis

Data were weighted to account for over- or under-sampling to enable representation of the Australian population aged 2–16 years in terms of age group, sex and region. BMI z-scores of the subjects were calculated using the WHO Anthro SPSS macro (version 3.1, June 2010). Intakes of nutrients and foods from broad food groups used in the 2007ANCNPAS[23] by age- and sex-specific quintiles of usual %energy from added sugars (%EAS) or %energy from total sugars (%ETS) were calculated using ANCOVA, adjusted for BMI z-score and total EI. The linear trends across the quintiles were examined using multiple linear regression, with %EAS or %ETS as a continuous independent variable and the nutrient intake as a continuous dependent variable, adjusted for age, sex, BMI z-score and total EI.

Pearson's χ^2 test was used to test for difference in the proportion of subjects not meeting the NRV for Australia and New Zealand across the quintiles. Logistic regression analysis was used to calculate the OR of not meeting the NRV for Australia and New Zealand per unit increase in %EAS or %ETS, adjusted for age, sex, BMI z-score and total EI. For the NRV comparisons with %EAS as the independent variable, sources of added sugars were further stratified as from 'core' foods or from 'extra' foods.

To test whether the data collection method – namely, parental *v.* self-report – may have biased the findings, sensitivity analyses were performed where the sample was stratified into 8 years old or below (parental report) and 9 years old or above (self-report).

Values were presented as means and 95 % CI for continuous variables and as percentages for categorical variables. Because a large number of tests were conducted, $P<0·01$ was considered to indicate marginal statistical significance, and $P<0·001$ was considered significant to reduce the chance of type I error. All statistical analyses were carried out using Statistical Packages for Social Science version 22.0 (IBM Corporation, 2010).

Results

Values for usual intake of added sugars (as %EAS) were negatively associated with all nutrient intakes (all $P_{trend}<0·001$) except of course for total carbohydrate and sugar intake, which were positively associated ($P<0·001$). It was also associated with a slight increase in EI (β: 17·7 (SE 5·0); $P_{trend}<0·001$). The association with SFA (absolute or expressed as % of energy) intake was not significant (Table 1). The associations were of small magnitude (a change of approximately 1 % or less in intake per unit increase in %EAS). Similar results were found for associations with %ETS (Table 2), but the magnitude of association was even smaller than that for %EAS in most cases except Na, and the direction of associations was less consistent. There was no linear relationship between total EI and %ETS.

When the associations between intakes of total and added sugars and likelihood of meeting the NRV for Australia and New Zealand were examined (Tables 3 and 4), a higher %EAS was consistently associated with poorer micronutrient intake (all $P_{trend}<0·001$) except vitamin C ($P_{trend}=0·103$) and Na ($P_{trend}=0·082$). For each unit increase in %EAS, the increase in risk for not meeting the NRV for Australia and New Zealand ranged from 5 % for I to 37 % for riboflavin. Stratifying the source of added sugars revealed that this negative relationship between %EAS and likelihood of not meeting the NRV only existed for added sugars from 'extra' food in most cases. The association between %ETS and likelihood of not meeting the NRV is less consistent in direction. A higher %ETS was associated with a greater likelihood of not meeting the NRV for LC n-3 PUFA, Fe and vitamin E and a lesser likelihood of not meeting the NRV for vitamin C, K, I and Na (all $P_{trend}<0·001$).

In general, higher intakes of added sugars were associated with lower intakes of most 'core' foods and a concurrent increase in most 'extra' foods (Table 5). The biggest reductions in 'core' foods (β (SE) per unit increase in %EAS; all $P_{trend}<0·001$) observed were for non-alcoholic beverages (−18·4 (SE 2·5) g), cereal grains and cereal products (−12·9 (SE 0·8) g), fruit and fruit-based products (−10·9 (SE 0·8) g), dairy products (−8·2 (SE 1·3) g) and vegetables (−6·3 (SE 0·7) g); however, the biggest increases in 'extra' foods observed (all $P_{trend}<0·001$) were for sugar-sweetened beverages 43·7 (SE 1·2) g), dairy products (6·1 (SE 0·5) g), confectionery (3·9 (SE 0·2) g) and cereal-based products (3·6 (SE 0·6) g). Total sugar intake was positively associated with both 'core' and 'extra' dairy products, fruits, fruit juices, sugar-sweetened beverages, sugars and confectionery but negatively associated with meat, seafood, eggs, seeds and nuts, legumes, 'extra' vegetables and savoury snacks (Table 6; all $P_{trend}<0·001$).

Sensitivity analyses (see online Supplementary Tables S2–S13) revealed that the associations between usual intakes of added or total sugars and that of macro- and micronutrients were consistent between subjects with parental reports of dietary intake and those who self-reported their dietary intake. However, the magnitude of the association was generally larger among respondents who self-reported their intake, as shown by the larger β (SE). The same is true for the association between % EAS and intake of food groups. More inconsistencies were observed when the likelihood of not meeting the NRV and intake of food groups were assessed according to %ETS quintiles. Nonetheless, these observed inconsistencies were generally minor and, for the NRV analysis, were likely a result of reduced sample size for this analysis.

Discussion

This analysis supports the hypothesis that a higher intake of added sugars, but not total sugars, is associated with nutrient dilution in the diets of Australian children and adolescents. In addition, this association was only observed for added sugars from 'extra' foods in most cases. Using a more recent data set, our results confirm previous findings by Cobiac *et al.*[19] that the intake of total sugars is poorly correlated with micronutrient intake of Australian children and adolescents. Our results on added sugars are similar to other studies on children and adolescents around the world. In one study involving 1035 Irish children and adolescents using a 7-d weighed food record, Joyce & Gibney[18] found that a higher added sugar consumption was associated with decreased dietary density of Mg, Ca, Zn, vitamin B_{12} and vitamin C, as well as an increased likelihood of intake below recommendations for some nutrients such as folate and Zn, depending on age and sex. Here, patterns of intakes from different food groups were similar to those observed by us, for example, the negative association between decreased milk intake and added sugar intake. In another study on 1688 British children and adolescents, Gibson & Boyd[32] found that higher intakes of added sugar were negatively associated with intakes of most nutrients (as % reference nutrient intake), where the reductions ranged from 14 to 24 %. They also found that subjects with higher %EAS were more likely to have intakes below the EAR, and that subjects with a higher %EAS had lower intakes of most core foods.

Table 1. Mean* intake† of energy and nutrient according to age- and sex-specific quintiles of percentage energy (%E) from added sugars
(Mean values and 95 % confidence intervals; β coefficients with their standard errors)

	%E from added sugars													
	Q1		Q2		Q3		Q4		Q5					
Nutrients	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	β‡	SE	R^2	P_{trend}‡
Added sugars (g)	36·1	35·6, 36·7	47·2	46·7, 47·8	55·8	55·3, 56·3	65·3	64·7, 65·8	82·5	81·9, 83·0	4·6	0·0	0·662	<0·001
From core foods§	8·8	8·4, 9·3	11·3	10·9, 11·7	12·3	11·9, 12·7	12·4	12·0, 12·8	13·2	12·8, 13·6	0·4	0·0	0·112	<0·001
From extra foods§	27·6	26·8, 28·3	36·7	36·0, 37·5	43·7	43·0, 44·4	53·9	52·3, 53·7	69·0	68·2, 68·7	4·2	0·0	0·860	<0·001
%E added sugars	7·0	6·9, 7·1	9·6	9·5, 9·7	11·4	11·3, 11·5	13·5	13·4, 13·6	17·2	17·1, 17·3	–	–	–	–
From core foods§	1·9	1·8, 1·9	2·3	2·3, 2·5	2·7	2·6, 2·7	2·7	2·6, 2·8	2·8	2·8, 2·9	0·1	0·0	0·089	<0·001
From extra foods§	5·2	5·1, 5·4	7·3	7·1, 7·4	8·8	8·7, 9·0	10·8	10·7, 11·0	14·2	14·1, 14·4	0·9	0·0	0·842	<0·001
Energy (kJ)	7847·9	7721·3, 7974·6	8093·7	7966·1, 8221·3	8185·6	8058·6, 8312·6	8187·5	8061·3, 8313·7	8226·9	8100·7, 8353·1	17·7	5·0	0·589	<0·001
Protein (g)	84·6	83·9, 85·2	81·6	81·0, 82·3	80·5	79·8, 81·1	77·7	77·0, 78·3	73·7	73·1, 74·4	−1·1	0·0	0·797	<0·001
%E protein	17·6	17·5, 17·8	17·1	17·0, 17·3	16·9	16·8, 17·0	16·4	16·3, 16·5	15·7	15·5, 15·8	−0·2	0·0	0·190	<0·001
Total fat (g)	68·9	68·5, 69·4	68·3	67·9, 68·8	68·2	67·7, 68·7	68·2	67·7, 68·6	66·4	65·9, 66·9	−0·3	0·0	0·831	<0·001
%E total fat	31·0	30·8, 31·3	30·7	30·4, 31·0	30·6	30·4, 30·8	30·6	30·4, 30·8	299	29·7, 30·1	−0·1	0·0	0·046	<0·001
SFA (g)	30·4	30·1, 30·7	30·7	30·4, 31·0	30·8	30·5, 31·2	30·9	30·6, 31·2	30·4	30·1, 30·7	−0·0	0·0	0·703	0·241
%E SFA	13·7	13·6, 13·9	13·8	13·6, 13·9	13·9	13·7, 14·0	13·9	13·8, 14·0	13·6	13·5, 13·8	−0·0	0·0	0·025	0·123
MUFA (g)	24·2	24·0, 24·4	23·8	23·6, 24·0	23·6	23·4, 23·8	23·7	23·5, 23·9	23·0	22·8, 23·2	−0·1	0·0	0·787	<0·001
PUFA (g)	9·0	8·9, 9·1	8·8	8·7, 8·9	8·7	8·6, 8·8	8·6	8·5, 8·7	8·3	8·2, 8·4	−0·1	0·0	0·602	<0·001
LC *n*-3 PUFA (mg)	128·1	124·6, 131·7	120·7	117·1, 124·3	120·3	116·8, 123·9	110·7	107·1, 114·2	103·6	100·1, 107·2	−2·5	0·2	0·163	<0·001
Total carbohydrate (g)	235·2	233·9, 236·5	241·0	239·6, 242·3	243·5	242·2, 244·8	247·8	246·5, 249·1	257·2	255·9, 258·5	2·2	0·1	0·888	<0·001
%E carbohydrates	49·9	49·7, 50·2	51·1	50·8, 51·3	51·5	51·2, 51·7	52·2	52·0, 52·4	53·9	53·7, 54·1	0·4	0·0	0·187	<0·001
Total sugars (g)	102·4	101·2, 103·6	112·7	111·5, 113·9	119·3	118·1, 120·5	125·0	123·8, 126·1	139·7	138·5, 140·9	3·6	0·1	0·729	<0·001
%E total sugars	22·0	21·7, 22·2	24·1	23·8, 24·3	25·4	25·2, 25·7	26·4	26·2, 26·7	29·3	29·1, 29·6	0·7	0·0	0·450	<0·001
Starch (g)	129·6	128·4, 130·8	126·0	124·8, 127·2	122·2	121·0, 123·4	121·0	119·8, 122·2	115·5	114·3, 116·7	−1·3	0·1	0·741	<0·001
%E starch	27·2	27·0, 27·5	26·5	26·3, 26·8	25·6	25·4, 25·9	25·4	25·2, 25·7	24·3	24·0, 24·5	−0·3	0·0	0·115	<0·001
Fibre (g)	22·3	22·0, 22·6	21·5	21·2, 21·7	20·6	20·3, 20·8	19·4	19·1, 19·6	17·9	17·6, 18·2	−0·4	0·0	0·512	<0·001
Ca (mg)	871·2	857·2, 885·3	900·3	886·2, 914·5	877·8	863·8, 891·9	846·4	832·5, 860·4	797·8	783·8, 811·8	−9·1	0·8	0·419	<0·001
Fe (mg)	11·5	11·3, 11·6	11·3	11·1, 11·4	11·0	10·9, 11·2	10·8	10·7, 11·0	10·3	10·2, 10·5	−0·1	0·0	0·619	<0·001
Thiamin (mg)	1·9	1·9, 2·0	1·9	1·9, 1·9	1·8	1·8, 1·8	1·7	1·7, 1·8	1·7	1·6, 1·7	−0·0	0·0	0·312	<0·001
Vitamin C (mg)	115·5	111·6, 119·4	114·9	111·0, 118·8	110·7	106·8, 114·5	102·3	98·5, 106·2	96·7	92·8, 100·5	−2·1	0·2	0·095	<0·001
Vitamin A RE (µg)	793·7	777·4, 810·0	762·1	745·7, 778·5	760·7	744·4, 777·0	720·2	704·0, 736·4	683·3	667·1, 699·6	−11·2	1·0	0·204	<0·001
Riboflavin (mg)	2·6	2·5, 2·6	2·7	2·6, 2·7	2·6	2·5, 2·6	2·4	2·4, 2·5	2·4	2·3, 2·4	−0·0	0·0	0·294	<0·001
DFE (µg)	508·2	496·4, 519·9	506·3	494·5, 518·2	486·7	474·9, 498·4	448·9	437·2, 460·6	424·9	413·2, 436·6	−8·9	0·7	0·149	<0·001
Vitamin D (µg)	3·3	3·2, 3··3	3·3	3·2, 3·4	3·2	3·1, 3·3	3·0	2·9, 3·1	2·7	2·7, 2·8	−0·1	0·0	0·293	<0·001
Vitamin E (mg)	6·1	6·0, 6·2	5·9	5·8, 5·9	5·8	5·7, 5·9	5·6	5·5, 5·7	5·2	5·1, 5·3	−0·1	0·0	0·519	<0·001
P (mg)	1414·8	1403·7, 1425·9	1400·6	1389·4, 1411·8	1371·4	1360·2, 1382·5	1330·4	1319·3, 1341·4	1254·5	1243·5, 1265·6	−16·7	0·7	0·781	<0·001
Mg (mg)	297·2	294·6, 299·9	290·7	288·1, 293·4	281·1	278·5, 283·8	269·5	266·9, 272·2	254·2	251·6, 256·9	−4·4	0·2	0·702	<0·001
Zn (mg)	10·8	10·7, 10·9	10·5	10·3, 10·6	10·1	10·0, 10·2	9·8	9·7, 9·9	9·4	9·3, 9·5	−0·1	0·0	0·693	<0·001
K (mg)	2827·0	2800·4, 2853·5	2753·3	2726·6, 2780·1	2700·3	2673·7, 2727·0	2614·2	2587·7, 2640·6	2471·0	2444·6, 2497·5	−36·1	1·6	0·647	<0·001
I(µg)	134·2	131·7, 136·8	1345·8	133·2, 138·3	131·8	129·2, 134·3	128·3	125·8, 130·8	122·0	119·5, 124·6	−1·4	0·2	0·346	<0·001
Na (mg)	2495·7	2469·7, 2521·7	2438·3	2412·2, 2464·4	2408·7	2382·7, 2434·7	2398·5	2372·6, 2424·3	2337·9	2312·0, 2363·8	−12·4	1·6	0·704	<0·001

LC *n*-3 PUFA, long chain *n*-3 PUFA; RE, retinol equivalents; DFE, dietary folate equivalents.
* Values are estimated marginal means calculated using ANCOVA, with total energy intake and BMI *z* scores as covariates except for energy, where only BMI z score was included as a covariate.
† Usual intake calculated using the multiple source method[27]. Because of the transformation, the sum of added sugars from core foods and extra foods is slightly different from total usual added sugar intake.
‡ β and P_{trend} calculated using linear regression with nutrient as the dependent variable, %E from added sugars as a continuous independent variable and age, sex, total energy intake and BMI z-scores as covariates.
§ 'Core' and 'extra' foods as defined by Rangan *et al.*[30,31].

Table 2. Mean* intake† of energy and nutrient according to age- and sex-specific quintiles of percentage energy (%E) from total sugars
(Mean values and 95 % confidence intervals; β coefficients with their standard errors)

	%E from total sugars													
	Q1		Q2		Q3		Q4		Q5					
Nutrients	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	β‡	SE	R^2	P_{trend}‡
Total sugars (g)	90·6	90·0, 91·3	109·0	108·3, 109·6	120·3	119·7, 121·0	131·5	130·8, 132·1	147·8	147·2, 148·5	5·0	0·0	0·967	<0·001
%E total sugars	19·5	19·4, 19·6	23·3	23·2, 23·4	25·5	25·4, 25·6	27·7	27·6, 27·8	31·2	31·1, 31·3	–	–	–	–
Energy (kJ)	7989·8	7862·0, 8117·7	8141·6	8015·0, 8268·1	8204·6	8078·3, 8330·9	8176·9	8050·2, 8303·7	8026·3	7898·9, 8153·7	–0·0	4·5	0·587	0·994
Protein (g)	84·3	83·6, 84·9	81·3	80·7, 82·0	79·2	78·5, 79·9	78·2	77·5, 78·9	75·0	74·3, 75·7	–0·8	0·0	0·787	<0·001
%E protein	17·6	17·5, 17·7	17·1	16·9, 17·2	16·7	16·6, 16·8	16·5	16·4, 16·6	15·9	15·8, 16·0	–0·1	0·0	0·148	<0·001
Total fat (g)	71·5	71·0, 72·0	69·8	69·3, 70·2	68·7	68·3, 69·2	66·4	65·9, 66·8	63·6	63·1, 64·0	–0·7	0·0	0·855	<0·001
%E total fat	32·2	32·0, 32·4	31·3	31·1, 31·5	30·9	30·7, 31·1	29·8	29·6, 30·0	28·6	28·4, 28·8	–0·3	0·0	0·199	<0·001
SFA (g)	31·1	30·8, 31·4	31·1	30·8, 31·4	31·2	0·9, 31·5	30·3	30·0, 30·7	29·5	29·2, 29·9	–0·2	0·0	0·709	<0·001
%E SFA	14·0	13·9, 14·1	14·0	13·8, 14·1	14·0	13·9, 14·2	13·6	13·5, 13·8	13·2	13·1, 13·4	–0·1	0·0	0·046	<0·001
MUFA (g)	25·4	25·2, 25·6	24·4	24·2, 24·6	23·9	23·7, 24·0	22·9	22·7, 23·1	21·7	21·5, 21·9	–0·3	0·0	0·827	<0··001
PUFA (g)	9·6	9·4, 9·7	9·1	9·0, 9·2	8·7	8·6, 8·8	8·3	8·2, 8·4	7·8	7·7, 7·9	–0·2	0·0	0·653	<0·001
LC *n*-3 PUFA (mg)	134·7	131·2, 138·3	120·5	117·0, 124·0	114·3	110·8, 117·8	110·1	106·6, 113·6	103·7	100·2, 107·3	–2·8	0·2	0·176	<0·001
Total carbohydrate (g)	229·8	228·6, 231·0	238·2	237·0, 239·4	243·8	242·6, 252·3	251·1	249·9, 252·3	261·7	260·5, 262·9	2·8	0·1	0·909	<0·001
%E carbohydrates	49·0	48·8, 49·2	50·5	50·3, 50·7	51·5	51·2, 51·7	52·8	52·6, 53·0	54·8	54·6, 55·1	0·5	0·0	0·358	<0·001
Added sugars (g)	43·1	42·1, 44·1	51·0	50·0, 52·0	57·7	56·8, 58·7	62·3	61·3, 63·3	73·1	72·1, 74·1	2·6	0·1	0·662	<0·001
From core foods§	9·4	8·9, 9·8	10·7	10·3, 11·2	11·7	11·3, 12·1	12·9	12·5, 13·3	13·3	12·9, 13·7	0·4	0·0	0·120	<0·001
From extra foods§	34·1	33·0, 35·2	40·6	39·6, 41·7	46·1	45·1, 47·2	49·8	48·7, 50·8	59·7	58·7, 60·8	2·2	0·1	0·570	<0·001
%E added sugars	8·6	8·4, 8·8	10·4	10·2, 10·6	11·8	11·6, 12·0	12·8	12·6, 13·0	15·2	14·9, 15·4	0·6	0·0	0·438	<0·001
From core foods§	2·0	1·9, 2·1	2·3	2·2, 2·4	2·5	2·4, 2·6	2·7	2·7, 2·8	2·9	2·8, 2·9	0·1	0·0	0·093	<0·001
From extra foods§	6·7	6·5, 7·0	8·2	8·0, 8·4	9·3	9·1, 9·5	10·1	9·8, 10·3	12·2	12·0, 12·4	0·5	0·0	0·356	<0·001
Starch (g)	135·2	134·1, 136·3	127·0	125·8, 128·1	121·8	120·6, 122·9	118·1	117·0, 119·2	112·3	111·2, 113·4	–2·0	0·1	0·778	<0·001
%E starch	28·5	28·3, 28·7	26·7	26·5, 26·9	25·5	25·3, 25·8	24·8	24·6, 25·1	23·5	23·3, 23·8	–0·4	0·0	0·255	<0·001
Fibre (g)	20·4	20·1, 20·7	20·7	20·4, 21·0	20·3	20·0, 20·6	20·4	20·1, 20·7	19·8	19·5, 20·0	–0·0	0·0	0·433	0·003
Ca (mg)	781·9	767·8, 796·0	855·1	841·2, 869·0	869·8	855·9, 883·7	896·3	882·4, 910·3	888·5	874·5, 902·5	8·3	0·7	0·420	<0·001
Fe (mg)	11·1	10·9, 11·2	11·1	11·0, 11·3	11·0	10·8, 11·1	11·1	11·0, 11·3	10·6	10·5, 10·7	–0·0	0·0	0·607	<0·001
Thiamin (mg)	1·81	1·78, 1·85	1·84	1·80, 1·88	1·81	1·77, 1·84	1·81	1·78, 1·85	1·72	1·68, 1·76	–0·0	0·0	0·288	<0·001
Vitamin C (mg)	86·9	83·1, 90·7	102·8	99·0, 106·6	105·5	101·7, 109·3	118·4	114·6, 122·2	126·2	122·4, 130·0	3·8	0·2	0·142	<0·001
Vitamin A RE (μg)	697·7	681·1, 714·2	750·2	733·8, 766·6	755·4	739·1, 771·7	764·2	747·8, 780·6	750·9	734·4, 767·4	4·5	0·9	0·184	<0·001
Riboflavin (mg)	2·29	2·24, 2·35	2·53	2·48, 2·58	2·56	2·51, 2·61	2·63	2·58, 2·68	2·57	2·52, 2·63	0·0	0·0	0·291	<0·001
DFE (μg)	437·9	426·0, 449·9	475·7	463·8, 487·5	480·5	468·6, 492·3	499·0	487·2, 510·9	480·2	468·3, 492·2	3·9	0·7	0·125	<0·001
Vitamin D (μg)	3·00	2·93, 3·07	3·16	3·09, 3·24	3·15	3·08, 3·22	3·15	3·08, 3·22	2·99	2·91, 3·06	–0·0	0·0	0·256	0·132
Vitamin E (mg)	6·13	6·05, 6·22	5·87	5·79, 5·95	5·64	5·55, 5·72	5·63	5·55, 5·71	5·26	5·18, 5·34	–0·1	0·0	0·513	<0·001
P (mg)	1358·3	1346·5, 1370·1	1378·7	1367·1, 1390·4	1350·1	1348·4, 1371·7	1354·5	1342·9, 1366·2	1318·0	1306·3, 1329·7	–4·4	0·6	0·751	<0·001
Mg (mg)	277·0	274·1, 279·8	282·2	279·4, 285·0	277·5	274·7, 280·4	281·4	278·6, 284·3	274·3	271·4, 277·1	–0·2	0·2	0·649	0·325
Zn (mg)	10·5	10·4, 10·6	10·4	10·2, 10·5	10·1	10·0, 10·2	9·9	9·8, 10·0	9·7	9·6, 9·8	–0·1	0·0	0·672	<0·001
K(mg)	2542·6	2515·1, 2570·1	2640·2	2613·0, 2667·5	2675·1	2647·9, 2702·2	2757·6	2730·3, 2784·8	2746·3	2718·9, 2773·8	19·3	1·5	0·620	<0·001
I (μg)	115·7	113·2, 118·2	130·2	127·7, 132·7	130·1	127·6, 132·6	136·5	134·0, 139·0	139·4	136·9, 141·9	1·8	0·1	0·361	<0·001
Na (mg)	2581·0	2555·6, 2606·4	2461·8	2436·7, 2487·0	2415·8	2390·7, 2440·9	2350·7	2325·5, 2375·9	2269·5	2244·2, 2294·9	–27·1	1·3	0·726	<0·001

%E, percentage energy; LC *n*-3 PUFA, long-chain *n*-3 PUFA; RE, retinol equivalents; DFE, dietary folate equivalents.
* Values are estimated marginal means calculated using ANCOVA, with total energy intake and BMI *z*-scores as covariates except for energy, where only BMI z-score was included as a covariate.
† Usual intake calculated using the multiple source method[27]. Because of the transformation, the sum of added sugars from core foods and extra foods is slightly different from total usual added sugar intake.
‡ β, R^2 and P_{trend} calculated using linear regression with nutrient as the dependent variable, %E from added sugars as a continuous independent variable and age, sex, total energy intake and BMI z-scores as covariates.
§ 'Core' and 'extra' foods as defined by Rangan *et al.*[30,31].

Table 3. Percentage of subjects not meeting nutrient reference values (NRV) for Australia and New Zealand* according to age- and sex-specific quintiles (Q) of percentage energy (%E) from added sugars, stratified by source
(Odds ratios and 95 % confidence intervals)

		%E from added sugars										
Nutrients	Source of added sugars†	Q1	Q2	Q3	Q4	Q5	χ^2	P‡	OR§	95 % CI	R^2	P_{trend}§
SFA	All foods	94·3	96·3	96·9	97·5	96·6	13·4	0·010	1·04	1·00, 1·09	0·039	0·065
	From core foods only	96·5	97·6	96·7	96·5	94·2	15·0	0·005	0·83	0·74, 0·92	0·045	<0·001
	From extra foods only	93·5	96·5	96·3	98·6	96·6	30·6	<0·001	1·10	1·04, 1·15	0·047	<0·001
LC *n*-3 PUFA	All foods	7·9	8·8	6·5	8·6	10·7	9·7	0·045	1·04	1·01, 1·07	0·223	0·016
	From core foods only	8·5	7·8	8·0	8·2	10·1	3·5	0·474	1·10	1·00, 1·20	0·222	0·043
	From extra foods only	8·9	8·2	7·5	8·4	9·5	2·4	0·656	1·02	0·99, 1·05	0·220	0·248
Fibre	All foods	38·2	42·5	46·7	55·4	66·7	170·2	<0·001	1·17	1·15, 1·19	0·239	<0·001
	From core foods only	54·3	47·0	47·3	47·6	53·6	17·7	0·001	1·05	0·99, 1·10	0·164	0·090
	From extra foods only	38·7	45·6	45·8	52·9	66·7	149·7	<0·001	1·17	1·15, 1·19	0·235	<0·001
Ca	All foods	35·1	26·5	29·9	32·0	40·7	43·7	<0·001	1·10	1·07, 1·13	0·587	<0·001
	From core foods only	41·7	36·1	32·9	26·6	26·9	61·7	<0·001	0·71	0·65, 0·77	0·590	<0·001
	From extra foods only	30·8	28·8	28·0	32·9	43·6	59·7	<0·001	1·15	1·12, 1·18	0·599	<0·001
Fe	All foods	0·2	0·8	0·7	0·8	1·3	6·3	0·175	1·24	1·13, 1·37	0·527	<0·001
	From core foods only	1·3	0·6	0·6	0·6	0·9	4·2	0·381	1·00	0·74, 1·36	0·467	0·986
	From extra foods only	0·5	0·2	0·8	1·1	1·2	7·1	0·128	1·20	1·10, 1·31	0·508	<0·001
Thiamin	All foods	0·1	0·2	0·2	0·5	0·8	7·2	0·125	1·28	1·15, 1·42	0·380	<0·001
	From core foods only	0·8	0·4	0·0	0·7	0·1	10·9	0·027	0·79	0·50, 1·27	0·284	0·336
	From extra foods only	0·1	0·2	0·1	0·5	1·0	11·0	0·026	1·27	1·14, 1·42	0·365	<0·001
Vitamin C	All foods	0·7	0·2	0·2	0·0	0·2	8·0	0·090	0·88	0·75, 1·03	0·118	0·103
	From core foods only	1·1	0·0	0·2	0·2	0·0	21·4	<0·001	0·36	0·17, 0·79	0·156	0·011
	From extra foods only	0·5	0·4	0·2	0·2	0·2	1·2	0·872	0·97	0·84, 1·12	0·103	0·647
Vitamin A RE	All foods	6·0	5·5	4·6	6·1	10·9	32·3	<0·001	1·11	1·07, 1·15	0·286	<0·001
	From core foods only	9·1	7·2	5·1	4·1	7·7	21·7	<0·001	0·94	0·84, 1·05	0·265	0·246
	From extra foods only	6·7	4·8	5·2	5·3	11·2	37·1	<0·001	1·11	1·07, 1·15	0·286	<0·001
Riboflavin	All foods	0·0	0·0	0·5	0·0	0·5	12·1	0·017	1·37	1·16, 1·62	0·526	<0·001
	From core foods only	0·4	0·2	0·1	0·0	0·2	3·3	0·513	0·58	0·26, 1·29	0·419	0·179
	From extra foods only	0·0	0·0	0·4	0·1	0·5	8·3	0·081	1·46	1·20, 1·78	0·554	<0·001
DFE	All foods	3·1	2·9	3·9	5·3	9·0	44·8	<0·001	1·18	1·14, 1·23	0·370	<0·001
	From core foods only	8·3	5·2	4·4	3·5	2·8	33·5	<0·001	0·68	0·59, 0·80	0·340	<0·001
	From extra foods only	2·8	2·4	4·0	5·7	9·4	57·4	<0·001	1·21	1·16, 1·26	0·385	<0·001
Vitamin D	All foods	90·9	91·9	91·8	95·5	97·6	44·9	<0·001	1·20	1·15, 1·25	0·262	<0·001
	From core foods only	93·3	93·4	93·1	93·9	93·9	0·7	0·951	1·03	0·92, 1·15	0·216	0·645
	From extra foods only	90·3	91·0	93·6	95·3	97·4	48·3	<0·001	1·20	1·15, 1·26	0·263	<0·001
Vitamin E	All foods	77·3	82·3	81·5	87·1	91·0	69·1	<0·001	1·15	1·12, 1·18	0·180	<0·001
	From core foods only	83·4	81·9	82·5	85·2	86·3	8·3	0·083	1·10	1·03, 1·18	0·139	0·006
	From extra foods only	77·8	81·1	85·7	84·0	90·8	58·7	<0·001	1·15	1·12, 1·18	0·175	<0·001
P	All foods	4·4	3·0	2·4	3·3	5·6	14·5	0·006	1·12	1·07, 1·18	0·425	<0·001
	From core foods only	5·4	3·6	3·3	3·7	2·7	9·8	0·044	0·81	0·69, 0·95	0·412	0·010
	From extra foods only	3·1	4·1	3·0	2·7	5·7	14·0	0·007	1·13	1·08, 1·18	0·427	<0·001
Mg	All foods	7·9	8·7	8·7	10·5	16·4	42·6	<0·001	1·19	1·15, 1·24	0·618	<0·001
	From core foods only	11·9	9·9	10·8	9·5	10·1	3·1	0·546	0·88	0·79, 0·99	0·586	0·030
	From extra foods only	7·5	8·9	8·7	10·6	16·3	42·7	<0·001	1·20	1·16, 1·25	0·622	<0·001
Zn	All foods	0·6	0·7	1·2	0·8	2·4	15·9	0·003	1·17	1·08, 1·26	0·535	<0·001
	From core foods only	0·6	1·4	1·1	1·6	1·1	4·1	0·398	1·05	0·82, 1·34	0·504	0·716
	From extra foods only	1·0	0·5	0·6	1·4	2·2	14·2	0·007	1·14	1·05, 1·23	0·525	<0·001
K	All foods	37·0	36·4	35·8	44·2	55·2	92·9	<0·001	1·14	1·11, 1·16	0·302	<0·001
	From core foods only	50·3	41·3	40·0	38·6	38·3	33·5	<0·001	0·89	0·84, 0·93	0·263	<0·001
	From extra foods only	34·5	36·6	39·0	41·0	57·4	113·0	<0·001	1·16	1·14, 1·19	0·317	<0·001
I	All foods	8·5	5·7	6·5	5·9	9·8	16·0	0·003	1·05	1·02, 1·08	0·221	0·004
	From core foods only	12·2	7·6	6·5	5·2	5·0	42·5	<0·001	0·71	0·64, 0·80	0·236	<0·001
	From extra foods only	7·1	6·2	5·8	6·6	10·8	20·1	<0·001	1·08	1·04, 1·11	0·228	<0·001
Na	All foods	94·0	93·4	94·8	94·5	94·4	1·8	0·773	0·97	0·93, 1·00	0·312	0·082
	From core foods only	92·6	96·3	94·0	94·7	93·3	11·9	0·018	1·01	0·90, 1·14	0·310	0·823
	From extra foods only	93·8	93·6	94·8	94·2	94·5	1·5	0·830	0·97	0·93, 1·01	0·312	0·090

LC *n*-3 PUFA, long-chain *n*-3 PUFA; RE, retinol equivalents; DFE, dietary folate equivalents.

* For Ca, Fe, I, Zn, Mg, P, vitamin A RE, thiamin, riboflavin, DFE and vitamin C, intakes lower than the estimated average requirement were considered as not meeting the NRV; for K, LC *n*-3 PUFA, dietary fibre, vitamin D and vitamin E, intakes lower than the adequate intake were considered as not meeting the NRV; for Na, intakes higher than the upper level were considered as not meeting the NRV; for SFA, %E >10 % was considered as not meeting the NRV.

† 'Core' and 'extra' foods as defined by Rangan *et al.*[30,31].

‡ P value tested using Pearson's χ^2 test.

§ Odds ratios and P_{trend} calculated using logistic regression with %E from added sugars as a continuous independent variable and age, sex, total energy intake and BMI z-scores as covariates.

Table 4. Percentage of subjects not meeting nutrient reference values (NRV) for Australia and New Zealand* according to age- and sex-specific quintiles (Q) of percentage energy (%E) from total sugars
(Odds ratios and 95 % confidence intervals)

	%E from total sugars										
Nutrients	Q1	Q2	Q3	Q4	Q5	χ^2	P†	OR‡	95 % CI	R^2	P_{trend}‡
SFA	96·0	96·3	97·7	96·9	94·8	11·0	0·027	0·98	0·94, 1·02	0·036	0·282
LC n-3 PUFA	5·8	8·6	6·0	9·5	12·6	33·3	<0·001	1·07	1·04, 1·10	0·232	<0·001
Fibre	51·4	49·8	46·9	47·1	54·6	13·7	0·008	1·00	0·98, 1·01	0·122	0·541
Ca	41·3	35·3	29·0	27·3	31·2	47·5	<0·001	0·94	0·92, 0·96	0·418	<0·001
Fe	0·7	0·5	0·5	0·6	1·6	9·2	0·057	1·15	1·06, 1·25	0·497	<0·001
Thiamin	0·5	0·2	0·2	0·4	0·7	3·4	0·501	1·13	1·01, 1·25	0·301	0·027
Vitamin C	1·1	0·1	0·2	0·1	0·0	20·6	<0·001	0·73	0·63, 0·84	0·218	<0·001
Vitamin A RE	9·7	5·4	5·9	4·6	7·5	21·9	<0·001	0·96	0·94, 1·00	0·268	0·022
Riboflavin	0·2	0·0	0·2	0·2	0·2	2·0	0·734	1·13	0·97, 1·31	0·420	0·121
DFE	8·0	3·4	3·9	4·7	4·3	24·0	<0·001	0·95	0·92, 0·99	0·105	0·011
Vitamin D	94·3	92·0	93·1	93·0	95·1	8·0	0·092	1·03	0·99, 1·06	0·217	0·104
Vitamin E	76·1	79·7	86·3	84·9	92·3	95·7	<0·001	1·12	1·09, 1·14	0·171	<0·001
P	4·7	3·5	2·8	3·4	4·4	5·7	0·224	1·02	0·98, 1·06	0·407	0·419
Mg	10·9	9·4	9·3	10·0	12·6	6·7	0·152	1·02	0·99, 1·05	0·585	0·266
Zn	1·2	0·5	0·8	1·3	1·8	7·5	0·110	1·09	1·01, 1·18	0·513	0·028
K	54·3	42·0	41·0	33·0	38·3	84·2	<0·001	0·92	0·90, 0·93	0·285	<0·001
I	11·7	6·5	7·4	6·1	4·7	34·3	<0·001	0·93	0·90, 0·95	0·231	<0·001
Na	96·7	94·0	94·8	93·4	92·1	18·0	<0·001	0·92	0·89, 0·95	0·326	<0·001

LC n-3 PUFA, long-chain n-3 PUFA; RE, retinol equivalents; DFE, dietary folate equivalents.
* For Ca, Fe, I, Zn, Mg, P, vitamin A RE, thiamin, riboflavin, DFE and vitamin C, intakes lower than the estimated average requirement were considered as not meeting the NRV; for K, LC n-3 PUFA, dietary fibre, vitamin D and vitamin E, intakes lower than the adequate intake were considered as not meeting the NRV; for Na, intakes higher than the upper level were considered as not meeting the NRV; for SFA, %E > 10 % was considered as not meeting the NRV.
† P value tested using Pearson's χ^2 test.
‡ Odds ratios and P_{trend} calculated using logistic regression with %E from total sugars as a continuous independent variable and age, sex, total energy intake and BMI z-scores as covariates.

The magnitude of the associations observed in our study, although statistically significant, was small. This likely reflects the complexity of the food supply and in particular the influence of processed, manufactured foods that may have added vitamins and minerals as well as sugar in their ingredients lists. Alexy *et al.*[33] has suggested that nutrient fortification of foods may mask the real magnitude of the association between intakes of added sugars and micronutrients. The issue may be of relevance to our study as many breakfast cereal products in Australia include added vitamins and minerals in their ingredient lists and were classified as 'core' foods[34–36], although at the same time contain significant amount of added sugars[37]. To put this in perspective, a sub-analysis of the 2007ANCNPAS found that breakfast cereals (including breakfast cereal bars) provided approximately 6·4 % of all added sugars consumed by the respondents of 2007ANCNPAS[38]; so the impact would only be incremental. Fortification, however, may have less of an impact on nutrients in general as Australia has very strict food standards, which limits the types of foods that could be fortified[39].

The inconsistent direction of associations between %ETS and the likelihood of not meeting the NRV highlights the limitation of using total sugars as a marker of diet quality. Our results showed a reduced likelihood of not meeting the NRV for Ca, vitamin C, K, I and Na when %ETS increased. These associations, apart from that for Na, are likely a result of the coexistence of natural sugars and these nutrient in foods, such as Ca and I in dairy foods (a source of lactose), vitamin C and K in fruits with natural sugars, etc. However, the observation that subjects with higher %ETS are less likely to exceed to UL of Na is interesting. A possible explanation lies in the characteristics of high-salt foods, that most of them are low in sugar – for example, potato crisps and processed meat.

Moving to the food pattern analysis is informative. Clearly, an increase in added sugar intake was consistently associated with a decrease in intake of nutrient-dense 'core' foods such as vegetables, dairy foods, meat and fruit, although being positively associated with the intake of nutrient-poor 'extra' foods such as cakes, biscuits, sugar-sweetened beverages, savoury snacks and confectionery. With this in mind, it suggests that limiting the intake of energy-dense nutrient-poor foods with high levels of added sugar may improve diet quality, which is supported by our findings when the sources of added sugars (from 'core' food *v.* from 'extra' foods) were taken into account. In contrast, the natural sugar content of some nutrient-rich foods is implicated in the results for the total sugars analyses. The positive association between %ETS and intakes of fruit ($P_{trend} < 0·001$) and dairy products ($P_{trend} <0·001$) confirms the inherent limitation of using total sugars in analyses of diet quality, as explained above.

From a beverages perspective, there is likely to be an even greater issue with variation in nutrient content. The subgroup analysis revealed that %EAS was strongly positively associated with the intake of sugar-sweetened beverages, whereas negatively associated with intakes of other beverages. This suggests that sugar-sweetened beverages are significant contributors to the intakes of added sugars (as %energy), and they may displace other beverages with low added sugar contents such as

Table 5. Mean consumption level of various food groups according to age- and sex-specific quintiles (Q) of usual* percentage energy (%E) from added sugars
(Mean values and 95 % confidence intervals; β coefficients with their standard errors)

	%E from added sugars													
	Q1		Q2		Q3		Q4		Q5					
Food groups	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	β†	SE	R^2	P_{trend}†
'Core' food														
Non-alcoholic beverages (g)‡	1156·8	1116·4, 1197·2	1152·5	1111·9, 1193·1	1110·0	1069·5, 1150·4	1047·8	1007·6, 1087·9	985·5	945·3, 1025·7	−18·4	2·5	0·143	<0·001
Fruit and vegetable juices (g)	176·6	162·0, 191·2	171·9	157·2, 186·6	163·0	148·3, 177·6	141·9	127·5, 156·4	136·2	121·7, 150·7	−4·4	0·9	0·027	<0·001
Cereal grains and products (g)§	375·8	363·4, 388·3	336·7	324·2, 349·2	317·9	305·4, 330·4	292·0	279·6, 304·3	244·3	231·9, 256·7	−12·9	0·8	0·202	<0·001
Cereal-based products (g)‖	57·8	49·2, 66·4	72·1	63·5, 80·8	62·5	53·9, 71·7	73·1	64·5, 81·6	67·5	58·9, 76·0	0·5	0·5	0·032	0·341
Fish, sea foods and products (g)	30·4	26·2, 34·5	25·5	21·3, 29·7	29·1	24·9, 33·3	19·0	14·9, 23·2	17·6	13·5, 21·8	−1·4	0·3	0·013	<0·001
Fruits and fruit-based products (g)	296·7	282·8, 310·6	280·7	266·7, 294·7	267·1	253·2, 281·1	233·6	219·7, 247·4	192·3	178·4, 206·1	−10·9	0·8	0·070	<0·001
Eggs and egg-based products (g)	16·5	14·1, 18·9	14·8	12·4, 17·2	14·1	11·7, 16·4	13·6	11·2, 15·9	11·9	9·6, 14·2	−0·5	0·1	0·007	<0·001
Meat, poultry and game and their products (g)	206·8	196·7, 216·9	189·9	179·8, 200·0	195·1	185·0, 205·2	187·4	177·4, 197·4	170·4	160·4, 180·4	−3·4	0·6	0·207	<0·001
Dairy products (g)¶	464·7	442·8, 486·6	496·8	474·8, 518·8	463·8	441·8, 485·7	454·2	432·4, 476·0	394·0	372·2, 415·8	−8·2	1·3	0·124	<0·001
Dairy products (serves)¶	1·3	1·2, 1·3	1·4	1·3, 1·4	1·4	1·3, 1·5	1·3	1·3, 1·4	1·3	1·2, 1·3	−0·0	0·0	0·120	0·305
Dairy alternatives (g)	13·2	6·9, 19·4	14·9	8·6, 21·2	16·3	10·1, 22·6	17·1	10·9, 23·3	10·9	4·7, 17·1	−0·2	0·4	0·003	0·507
Soups (g)	61·6	51·8, 71·4	56·7	46·8, 66·5	39·2	29·4, 49·0	35·7	26·0, 45·5	29·6	19·9, 39·4	−3·3	0·6	0·021	<0·001
Seeds and nuts and their products (g)	5·9	5·0, 6·8	5·1	4·2, 6·0	4·8	3·9, 5·7	4·2	3·3, 5·1	2·8	1·9, 3·7	−0·3	0·1	0·023	<0·001
Sauces (g)**	25·7	22·2, 29·1	19·9	16·4, 23·3	22·4	19·0, 25·9	20·7	17·3, 24·2	19·2	15·7, 22·6	−0·6	0·2	0·022	0·008
Vegetables (g)††	242·3	230·7, 253·9	212·6	200·0, 224·2	203·2	191·6, 214·8	190·8	179·3, 202·4	176·5	164·9, 188·0	−6·3	0·7	0·072	<0·001
Legumes and legume-based products (g)	19·6	15·9, 23·3	18·5	14·8, 22·2	14·9	11·2, 18·6	11·5	7·8, 15·2	7·4	3·8, 11·1	−1·2	0·2	0·009	<0·001
'Extra' foods														
Non-alcoholic beverages (g)‡	153·4	130·2, 176·7	211·2	197·8, 244·5	282·5	259·2, 305·7	389·4	366·3, 412·5	577·3	554·2, 600·4	43·9	1·4	0·363	<0·001
Tea and coffee (g)	28·7	20·5, 36·9	37·2	29·0, 45·5	33·9	25·7, 42·1	35·3	27·1, 43·4	40·0	31·9, 48·2	−0·1	0·5	0·059	0·825
Sugar-sweetened beverages (g)	90·6	69·8, 111·3	157·3	136·4, 178·1	215·9	195·2, 236·7	329·3	308·6, 349·9	506·9	486·3, 527·6	44·5	1·2	0·356	<0·001
Intensely sweetened beverages (g)	34·2	26·3, 42·0	26·7	18·8, 34·5	32·6	24·8, 40·4	24·9	17·1, 32·6	30·4	22·6, 38·2	−0·5	0·5	0·034	0·306
Cereal grains and products (g)§	3·1	1·8, 4·5	5·5	4·2, 6·8	2·9	1·6, 4·2	4·0	2·7, 5·3	4·7	3·4, 6·0	0·1	0·1	0·005	0·394
Cereal-based products (g)‖	127·0	117·6, 136·5	129·7	120·2, 139·3	141·9	132·4, 151·4	145·9	136·5, 155·3	156·0	146·6, 165·4	3·6	0·6	0·202	<0·001
Fats and oils (g)	12·8	12·0, 13·5	12·2	11·4, 12·9	11·2	10·4, 12·0	11·5	10·7, 12·3	10·3	9·5, 11·1	−0·3	0·0	0·031	<0·001
Meat, poultry and game and their products (g)	1·6	1·1, 2·1	1·5	1·0, 2·0	1·0	0·5, 1·5	1·6	1·1, 2·1	0·9	0·4, 1·3	−0·1	0·0	0·006	0·014
Dairy products (g)¶	26·7	19·4, 34·0	53·4	46·1, 60·8	71·2	63·9, 78·5	70·2	63·0, 77·5	97·7	90·4, 105·0	6·1	0·5	0·075	<0·001
Sauces (g)**	15·6	13·3, 18·0	14·4	12·0, 16·8	19·3	16·9, 21·6	17·8	15·5, 20·2	16·7	14·3, 19·0	0·2	0·1	0·044	0·118
Vegetables (g)††	33·0	28·5, 37·5	34·1	29·6, 38·6	34·5	30·1, 39·0	39·6	35·1, 44·0	43·0	38·6, 47·5	1·1	0·3	0·053	<0·001
Savoury snacks (g)	18·4	16·1, 20·6	17·5	15·3, 19·8	18·4	16·1, 20·6	18·3	16·1, 20·5	18·4	16·2, 20·6	0·2	0·1	0·045	0·248
Sugars (g)	13·3	9·5, 17·1	23·8	20·0, 27·6	28·0	24·2, 31·8	33·1	29·4, 36·9	51·3	47·6, 55·1	3·5	0·2	0·060	<0·001
Confectionery (g)	15·1	12·2, 17·9	21·2	18·3, 24·1	27·2	24·3, 30·0	38·2	35·4, 41·1	56·6	53·7, 59·4	3·9	0·2	0·164	<0·001

Values are estimated marginal means calculated using ANCOVA, with total energy intake and BMI *z*-scores as covariates except for energy, where only BMI *z*-score was included as a covariate.

* Usual intake calculated using the multiple source method[27].

† β, R^2 and P_{trend} calculated using linear regression with the food group intake as the dependent variable, %E from added sugars as a continuous independent variable and age, sex, total energy intake and BMI *z*-scores as covariates.

‡ 'Core' non-alcoholic beverages include: fruit and vegetable juices, plain or mineral water and beverage flavourings made up with milk; 'extra' non-alcoholic beverages include: tea and coffee, fruit drinks, cordial/mixers, carbonated soft drinks, flavoured water, electrolyte drinks, energy drinks and beverage flavourings (dry or made up with water).

§ 'Core' cereal grains and products include: plain grains, plain breads, low fat-filled/topped bread, low-sugar sweet buns/scrolls, flat breads, low-fat tortilla and all breakfast cereals; 'extra' cereal grains and products include: higher fat-filled/topped breads, higher sugar sweet buns/scrolls, higher-fat tortilla/taco and high-fat noodles.

‖ 'Core' cereal-based products include: low-fat savoury biscuits, rice and maize crackers/cakes, low sugar scones, low-fat sandwiches, pasta or noodle dishes, low-sugar/fat waffles and batter-based products and crumpet; 'extra' cereal-based products include: sweet biscuits, high-fat savoury biscuits, cakes and slices, higher sugar scones, cereal-based desserts, pastries, pizza, higher-fat sandwiches, hamburgers, taco/tortilla based dishes, savoury dumplings, higher-sugar/fat batter-based products and doughnuts.

¶ 'Core' dairy products include: fluid milk including lower fat-/sugar-flavoured milk, yoghurts, cheese, lower-fat ice-creams and lower-fat custard; 'extra' dairy products include: condensed milk, cream, higher-fat ice-creams, frozen yoghurts, higher-fat custards, dairy desserts and higher-fat/sugar flavoured milk; dairy servings defined as follows: 250 g milk (including flavoured milk); 200 g yoghurt or custards; 40 g cheese; and 100 g ice cream.

** 'Core' sauces include: lower salt-savoury/pasta sauces and fruit/vegetable-based pickles/chutney; 'extra' sauces include: gravies, higher salt-savoury/pasta sauces, mayonnaise, oil-based salad dressing and bread-based stuffing.

†† 'Core' vegetables include: lower-fat potatoes and potato products, lower-fat carrot and similar root vegetables and all other vegetables; 'extra' vegetables include: higher-fat potatoes and potato products, higher-fat carrot and similar root vegetables.

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Table 6. Mean consumption level of various food groups according to age- and sex-specific quintiles (Q) of usual* percentage energy (%E) from total sugars
(Mean values and 95 % confidence intervals; β coefficients with their standard errors)

	%E from total sugars													
	Q1		Q2		Q3		Q4		Q5					
Food groups	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	β†	SE	R^2	P_{trend}†
'Core' food														
Non-alcoholic beverages (g)‡	1119·3	1078·4, 1160·2	1069·8	1029·3, 1110·2	1073·9	1033·5, 1114·2	1094·2	1053·7, 1134·7	1094·0	1053·5, 1134·7	1·1	2·3	0·132	0·613
Fruit and vegetable juices (g)	90·2	75·9, 104·6	131·1	116·9, 145·4	149·8	135·6, 164·0	189·1	174·8, 203·3	228·7	214·4, 243·0	12·8	0·8	0·080	<0·001
Cereal grains and products (g)§	375·5	362·9, 388·1	331·3	318·8, 343·8	306·2	293·8, 318·7	292·2	279·7, 304·7	260·8	248·2, 273·4	−9·8	0·7	0·186	<0·001
Cereal-based products (g)‖	73·6	64·9, 82·2	63·6	55·1, 72·2	61·1	52·5, 69·6	67·9	59·4, 76·5	66·9	58·3, 75·6	−0·4	0·5	0·032	0·379
Fish, sea foods and products (g)	35·5	31·3, 39·6	25·1	21·0, 29·3	21·9	17·8, 26·1	19·4	15·2, 23·6	19·7	15·6, 23·9	−1·7	0·2	0·018	<0·001
Fruits and fruit-based products (g)	178·7	164·8, 192·5	222·4	208·7, 236·1	255·7	242·0, 269·4	299·6	285·9, 313·3	312·7	298·9, 326·5	12·5	0·8	0·094	<0·001
Eggs and egg-based products (g)	17·9	15·5, 20·2	16·2	13·8, 18·5	13·6	11·3, 16·0	12·3	10·0, 14·7	10·8	8·5, 13·2	−0·7	0·1	0·010	<0·001
Meat, poultry and game and their products (g)	228·4	218·4, 238·4	209·5	199·6, 219·4	185·8	176·0, 195·7	176·3	166·4, 186·2	149·5	139·5, 159·4	−6·5	0·6	0·226	<0·001
Dairy products (g)¶	315·1	293·6, 336·7	435·5	414·2, 456·8	483·3	462·0, 504·6	509·6	488·2, 531·0	527·6	506·1, 549·0	17·1	1·2	0·161	<0·001
Dairy products (serves)¶	1·1	1·0, 1·1	1·3	1·2, 1·3	1·4	1·3, 1·4	1·4	1·4, 1·5	1·5	1·4, 1·5	0·0	0·0	0·144	<0·001
Dairy alternatives (g)	27·3	21·0, 33·6	17·1	10·9, 23·3	11·2	5·0, 17·4	12·2	6·0, 18·4	4·6	−1·7, 10·8	−1·4	0·3	0·008	<0·001
Soups (g)	55·6	45·7, 65·5	41·3	31·5, 51·1	41·2	31·4, 50·9	48·2	38·4, 58·0	36·3	26·5, 46·2	−1·0	0·5	0·015	0·082
Seeds and nuts and their products (g)	5·0	4·1, 5·9	6·1	5·2, 7·0	4·4	3·5, 5·3	4·0	3·1, 4·9	3·3	2·4, 4·2	−0·2	0·0	0·019	<0·001
Sauces (g)**	25·2	21·7, 28·7	19·1	15·6, 22·5	21·6	18·2, 25·1	23·7	20·3, 27·2	18·2	14·8, 21·7	−0·2	0·2	0·055	0·195
Vegetables (g)††	207·9	196·1, 219·7	207·0	195·4, 218·7	204·6	193·0, 216·2	207·1	195·5, 218·8	198·3	186·6, 210·1	−0·4	0·6	0·055	0·505
Legumes and legume-based products (g)	17·0	13·3, 20·7	18·2,	14·5, 21·9	14·7	11·1, 18·4	14·0	10·3, 17·7	7·8	4·1, 11·5	−0·8	0·2	0·006	<0·001
'Extra' foods														
Non-alcoholic beverages (g)‡	234·1	209·2, 259·0	268·4	243·8, 293·0	307·7	283·1, 332·3	346·0	321·3, 370·6	471·9	447·1, 496·7	20·2	1·4	0·251	<0·001
Tea and coffee (g)	38·6	30·4, 46·8	34·8	26·7, 43·0	40·1	32·0, 48·2	33·2	25·0, 41·4	28·3	20·1, 36·5	−0·6	0·5	0·060	0·186
Sugar-sweetened beverages (g)	155·2	132·8, 177·6	205·7	183·5, 227·8	244·4	222·3, 266·5	285·3	263·1, 307·4	413·6	391·3, 435·9	21·9	1·2	0·216	<0·001
Intensely sweetened beverages (g)	40·3	32·4, 48·2	27·9	20·1, 35·7	23·2	15·4, 31·0	27·5	19·7, 35·3	30·0	22·1, 37·8	−1·1	0·4	0·035	0·012
Cereal grains and products (g)§	4·9	3·6, 6·2	5·2	3·9, 6·5	3·6	2·2, 4·9	3·1	1·8, 4·4	3·5	2·2, 4·8	−0·2	0·1	0·007	0·004
Cereal-based products (g)‖	148·8	139·3, 158·4	141·6	132·1, 151·0	144·5	135·1, 153·9	122·9	113·4, 132·3	143·2	133·7, 152·7	−1·6	0·5	0·197	0·002
Fats and oils (g)	13·4	12·6, 14·2	12·5	11·7, 13·3	12·6	11·8, 13·3	10·6	9·8, 11·3	8·9	8·1, 9·7	−0·4	0·0	0·046	<0·001
Meat, poultry and game and their products (g)	1·8	1·3, 2·3	2·1	1·6, 2·5	0·9	0·5, 1·4	1·1	0·6, 1·6	0·6	0·1, 1·2	−0·1	0·0	0·009	<0·001
Dairy products (g)¶	41·5	34·0, 49·0	59·0	51·6, 66·3	62·2	54·8, 69·6	68·0	60·6, 75·5	88·9	81·5, 96·4	4·0	0·4	0·056	<0·001
Sauces (g)**	16·4	14·0, 18·8	17·4	15·0, 19·7	17·6	15·3, 20·0	15·7	13·4, 18·1	16·6	14·2, 19·0	−0·1	0·1	0·044	0·549
Vegetables (g)††	43·4	38·9, 47·9	40·9	36·4, 45·3	42·7	38·3, 47·1	29·5	25·0, 33·9	27·8	23·3, 32·3	−1·5	0·3	0·057	<0·001
Savoury snacks (g)	26·0	23·8, 28·3	17·1	14·9, 19·4	16·9	14·7, 19·1	17·2	15·0, 19·4	13·8	11·5, 16·0	−0·9	0·1	0·056	<0·001
Sugars (g)	16·5	12·7, 20·3	21·4	17·6, 25·1	31·2	27·4, 34·9	33·0	29·2, 36·8	47·9	44·0, 51·7	2·8	0·2	0·049	<0·001
Confectionery (g)	19·1	16·1, 22·1	25·8	22·8, 28·7	33·2	30·3, 36·2	37·5	34·5, 40·5	42·9	39·9, 45·9	2·0	0·2	0·097	<0·001

Values are estimated marginal means calculated using ANCOVA, with total energy intake and BMI *z*-scores as covariates except for energy, where only BMI *z*-score was included as a covariate.
* Usual intake calculated using the multiple source method[27].
† β (SE), R^2 and P_{trend} calculated using linear regression with the food group intake as the dependent variable, %E from added sugars as a continuous independent variable and age, sex, total energy intake and BMI *z*-scores as covariates.
‡ 'Core' non-alcoholic beverages include: fruit and vegetable juices, plain or mineral water and beverage flavourings made up with milk; 'extra' non-alcoholic beverages include: tea and coffee, fruit drinks, cordial/mixers, carbonated soft drinks, flavoured water, electrolyte drinks, energy drinks and beverage flavourings (dry or made up with water).
§ 'Core' cereal grains and products include: plain grains, plain breads, low fat-filled/topped bread, low-sugar sweet buns/scrolls, flat breads, low-fat tortilla and all breakfast cereals; 'extra' cereal grains and products include: higher fat-filled/topped breads, higher-sugar sweet buns/scrolls, higher-fat tortilla/taco and high-fat noodles.
‖ 'Core' cereal-based products include: low fat-savoury biscuits, rice and maize crackers/cakes, low sugar scones, low-fat sandwiches, pasta or noodle dishes, low-sugar/fat waffles and batter-based products and crumpet; 'extra' cereal-based products include: sweet biscuits, high-fat savoury biscuits, cakes and slices, higher sugar scones, cereal-based desserts, pastries, pizza, higher-fat sandwiches, hamburgers, taco-/tortilla-based dishes, savoury dumplings, higher sugar/fat batter-based products and doughnuts.
¶ 'Core' dairy products include: fluid milk including lower fat/sugar flavoured milk, yoghurts, cheese, lower-fat ice-creams and lower-fat custard; 'extra' dairy products include: condensed milk, cream, higher fat ice-creams, frozen yoghurts, higher-fat custards, dairy desserts and higher-fat/sugar flavoured milk; dairy servings defined as follows: 250 g milk (including flavoured milk); 200 g yoghurt or custards; 40 g cheese; and 100 g ice cream.
** 'Core' sauces include: lower salt-savoury/pasta sauces and fruit-/vegetable-based pickles/chutney; 'extra' sauces include: gravies, higher salt savoury/pasta sauces, mayonnaise, oil-based salad dressing and bread-based stuffing.
†† 'Core' vegetables include: lower-fat potatoes and potato products, lower-fat carrot and similar root vegetables, and all other vegetables; 'extra' vegetables include: higher-fat potatoes and potato products, higher fat carrot and similar root vegetables.

fruit juice. This pattern was less apparent when %ETS was considered, as fruit juices are high in total sugars.

One limitation of our study is that micronutrients from supplements were not included in the analyses. Although supplements' use has become more common among Australians[40,41], which may have covered the individual from the shortfalls in dietary micronutrient intake, many argue that nutrients from supplements were not well absorbed. In addition, the aim of our study was to assess how dietary added and total sugar intakes were associated with dietary macro- and micronutrient intake. Excluding nutrients from supplements could therefore enable us to identify levels of added or total sugar intake, which may increase the likelihood of inadequate dietary nutrient intake.

Although a common choice for dietary survey, assessing dietary intake by 24-h recalls is not without limitations. It is reliant on the respondent to correctly recall the foods and beverages consumed in the past 24 h. Although various prompts and the use of a multiple-pass method may have partly improved the respondents' ability to recall, this is still subject to memory bias. In addition, data obtained from two 24-h recalls may not capture the habitual intake of an individual as dietary intake is subject to high day-to-day variance[42,43], especially for items that are not frequently consumed. To allow better estimation of habitual intake in young children (6 years or below) using multiple 24-h recalls, it has been shown that up to 9 d of recalls are required to ensure an 80 % correlation between the observed and true mean nutrient intakes of individuals[44]. Two 24-h recalls are the usual choice in national nutrition surveys[45–48] to balance the accuracy of the dietary data collected against respondent burden. Although the use of the MSM[27] on the two 24-h recalls in this study has accounted for some of the intra-person variability, a more accurate estimation of habitual intake could only be achieved either through combining the food frequency data with the recall data in MSM or by increasing the number of recalls. Unfortunately, these were not available.

The analysis is also limited by general limitations to dietary surveys. It had been previously argued that accurate and reliable dietary assessment in children is especially difficult, regardless of whether the children reported their own intake or parental recall was used. In the 2007ANCNPAS, parental recall of food intake was used for children aged 8 years or below, which is likely to result in under-reporting especially when the reporting parent was working and away from home for a significant period of time[42,49–52]. Our results appear to support this proposition where the energy adjusted nutrient intake from parental reports were generally lower than that were self-reported by the child/adolescent. However, when children report their own food intake, they are also likely to inaccurately recall the type of foods they consume due to unfamiliarity of the food[53] as well as information overload (e.g. large number of foods to report), which is likely to result in omission of foods reported[54]. Nonetheless, by using the Goldberg cut-off for specific PAL method[26], we have excluded under- and over-reporters on the basis of a scientifically accepted methodology to minimise the effect of under- and over-reporting on the results, although it is acknowledged that the cut-offs were conservative and only extreme degrees of misreporting were identified this way. In addition, this method does not allow the distinction of varying degrees of misreporting, meaning that a clear-cut approach was taken[26].

Seasonality is another limitation of dietary surveys, and the data collection period spanned across autumn and winter, which may have affected intakes of seasonal foods. Ice cream and sugary drinks, for example, may be consumed more during the summer months.

Despite these limitations, the use of a published systematic method to estimate the added sugar content of the food items in AUSNUT2007 was a particular strength of our study. The generalisability of the findings was also increased through the use of a nationally representative sample.

Conclusion

Using a national survey on Australian children and adolescents, analyses involving intakes of added sugar provided more consistent associations with micronutrient intakes and diet quality compared with assessments of total sugar intake. Higher intakes of added sugar were associated with micronutrient dilution in the diet.

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J. C. Y. L. and L. C. T. contributed to the conception of the study. J. C. Y. L. performed the statistical analyses and drafted the manuscript. Both authors critically reviewed and interpreted the data, were involved in the subsequent edits of the manuscript and have read and approved the final manuscript. The authors declare that those who carried out the original analysis and collection of the data bear no responsibility for the further analysis or interpretation included in this manuscript.

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Supplementary material

For supplementary material/s referred to in this article, please visit http://dx.doi.org/10.1017/S0007114515003542

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