Dietary intake and food sources of added sugar in the Australian population

[1]Linggang Lei, [1]Anna Rangan, [2,3]Victoria M Flood, [1]Jimmy Chun Yu Louie

[1]School of Molecular Bioscience and Charles Perkins Centre, The University of Sydney NSW 2006 Australia
[2]Faculty of Health Sciences, The University of Sydney NSW 2006 Australia
[3]St Vincent's Hospital, Darlinghurst NSW Australia

Abstract

Previous studies in Australian children/adolescents and adults examining added sugar (AS) intake were based on now out-of-date national surveys. We aimed to examine the AS and free sugar (FS) intake and the main food sources of AS among Australians, using plausible dietary data collected by a multiple-pass 24h recall, from the 2011-12 Australian Health Survey respondents (n = 8202). AS and FS intake were estimated using a previously published method, and as defined by the World Health Organization (WHO), respectively. Food groups contributing to the AS intake were described and compared by age group and sex by one way ANOVA. Linear regression was used to test for trend across age groups. Usual intake of FS (as percentage energy; % EFS) was computed using a published method, and compared to the WHO cut-off of <10%EFS. The mean ± SD AS intake of the participants was 60.3 ± 52.6 g/d. Sugar-sweetened beverages accounted for the greatest proportion of the AS intake of the Australian population (21.4 ± 30.1%), followed by sugar and sweet spreads (16.3 ± 24.5%) and cakes, biscuits pastries and batter based products (15.7 ± 24.4%). More than half of the study population exceeded the WHO's cut-off for FS, especially children and adolescents. Overall 80-90% of the daily AS intake came from high sugar energy-dense and/or nutrient-poor foods. To conclude, the majority of Australian adults and children exceed the WHO recommendation for FS intake. Efforts to reduce AS intake should focus on energy-dense and/or nutrient-poor foods.

Keywords: total sugars, added sugar, free sugar, food sources, Australian, national survey, Australian Health Survey
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Introduction

'Added sugar' is commonly defined as sugars added to foods during processing and preparation. It has become a prime focus of nutrition intervention and research in recent years, as it provides energy with no or little associated nutrients, the so-called 'empty calories' (1; 2). Studies have shown that excessive added sugar intake can dilute the nutrient content of the diet (3; 4; 5; 6) and increase total energy intake (7), ultimately leading to weight gain (8). Hence dietary guidelines around the world consistently recommend limiting the intake of added sugar (9; 10; 11; 12). Recently the World Health Organization (WHO) released a set of revised sugars guidelines (13), which recommends a limit of < 10% energy from 'free sugars' (i.e. added sugar plus honey, syrups, and sugars in fruit juices). Although the WHO acknowledged the evidence supporting the association between added sugars and obesity and other health outcomes is limited at this stage, it concluded that the clear association between high or frequent consumption of free sugars and increased risk of dental caries (9) warrants a stricter limit (13).

To inform public health policy decisions, data on the current intake of added sugar are much needed as the 1995 Australian National Nutrition Survey (NNS) is now out-of-date (6). While our group has published more recent data on Australian children and adolescents based on a national survey conducted in 2007 (14), the food supply and dietary patterns of the Australian population may have substantially changed in the past 10 - 20 years. Furthermore Australian apparent consumption data (15) suggest there has been a declining trend in added sugar intake over the past 40 years. This trend was similar to that observed in other developed countries (16; 17; 18; 19).

To fill this important gap in the literature, this study aims to describe the intake and food sources of added sugar of the Australian population, using data from the most recent national nutrition survey, the 2011-12 Australian Health Survey (AHS) (20). We also aimed to examine age and gender differences in added sugar intake and food sources. To benchmark the population intake of Australians, we also examined the intake of free sugars as defined by the WHO (13).

Method

Data source

Data from the National Nutrition and Physical Activity Survey (NNPAS) component of the 2011-2012 AHS was used (20). The 2011-12 NNPAS was conducted by the Australian Bureau of Statistics in 2011 and 2012. It measured the consumption of foods, beverages and dietary supplements, as well as information on dietary behaviors. Dietary data were collected using a computer-assisted, multiple-pass 24-hour recall on 12,153 individuals aged 2 years and over in a face-to-face interview. Where possible, at least 8 days after the first interview, respondents were contacted to participate in a second 24-hour dietary recall via telephone interview (n = 7735) (20). Data from this second recall were excluded from the primary analyses, and were only used to generate usual intake data (see Statistical analysis). Food and beverage intakes were then translated into energy and nutrient intake using the AUSNUT2011-2013 food composition database (21).

Anthropometric measurements

Weight and height were measured without shoes and heavy clothing where possible, using a digital scale (to the nearest 0.1 kg) and a stadiometer (to the nearest 0.1 cm), respectively. Body mass index (BMI) was calculated as weight in kg divided by the square of height in meters. Subjects were then classified into underweight, normal weight, overweight or obese based on their BMI. For children and adolescents (2-18 years), age- (in half yearly intervals) and sex-specific BMI cut-offs (22) were used. For adults (19+ years) the following cut-offs (23) were used: underweight (≤ 18.5 kg/m^2); normal weight (18.5 – 24.99 kg/m^2), overweight (25.0 – 29.99 kg/m^2) and obese (≥ 30.0 kg/m^2).

Non dietary variables

Information on household income was collected from an adult respondent within each of the sampled households, which represents the combined income of all household members aged 15 years and over. This was then classified into deciles. The Socio-economic Indexes for Areas (SEIFAs) (24), a ranking of socio-economic status based on regions/areas, was derived based on the geographical location of the household. SEIFA quintiles were created where the highest quintile represents the most advantaged areas. Urbanity of the household location was classified based on the Australian Standard Geographical Classification remoteness classification (25), and in this study households classified as located in "major cities of Australia" and "inner regional Australia" were considered as urban. Respondents reported their country of birth, which was classified into "Australia", "major English speaking countries" and "other countries".

Data cleaning

The plausibility of the food intake data was assessed using the Goldberg cut-off (26) for specific physical activity level (PAL).

Table 1 – Demographics of the subjects

	2-3 years	4-8 years	9-13 years	14-18 years	19-30 years	31-50 years	51-70 years	71+ years	*P* value*	*P* value†
n	214	552	630	481	1523	2345	1792	666	-	-
Female (%)	48.8	47.3	49.2	49.7	44.0	47.3	48.7	53.6	<0.006	0.39
BMI (kg/m²)‡	16.9 (2.1)	16.6 (2.4)	19.4 (3.6)	22.0 (3.5)	24.8 (4.8)	26.9 (5.0)	28.2 (5.1)	27.2 (4.7)	<0.001	<0.001
Underweight (%)	6.1	4.7	3.7	8.6	3.5	1.1	1.2	1.5		
Normal weight (%)	65.7	74.9	69.8	71.8	55.8	37.7	26.9	30.0	<0.001	<0.001
Overweight (%)	22.1	14.0	21.6	16.3	29.0	38.8	40.5	45.1		
Obese (%)	6.1	6.4	4.9	3.3	11.7	22.4	31.4	23.3		
% in the highest SEIFA quintile (%)	20.2	25.7	26.5	24.7	23.3	25.3	22.5	19.2	0.013	0.13
% in the highest decile of household income (%)§	3.5	8.2	6.3	6.2	10.6	14.8	12.7	2.8	<0.001	<0.001
Lives in urban area (%)	71.0	67.6	67.5	66.3	79.1	72.8	63.7	69.7	<0.001	0.002
Country of birth										
Australia (%)	94.8	92.9	87.6	87.7	70.6	68.9	68.3	71.8		
Major English speaking countries (%)	1.9	2.7	7.5	6.0	7.8	12.2	13.8	12.5	<0.001	<0.001
Others (%)	3.3	4.3	4.9	6.2	21.6	19.8	17.9	15.8		

Values were presented as mean (SD) for continuous variables and as percentages for categorical variables. Data were weighted to account for over- or under-sampling to enable representation of the general Australian population.
*P values represent P for trend by age group for continuous variables, and for categorical variables the p values were tested by χ^2 test.
†P values for difference between children and adolescents (2-18 years) *vs.* adults (19+ years). For continuous variables the difference was tested using one-way ANOVA, while Pearson's χ^2 was used for categorical variables.
‡n = 213, 549, 629, 479, 1522, 2340, 1787, 649, 1870, 6298, 8168 respectively due to missing data
§n = 199, 515, 584, 388, 1184, 2227, 1649, 598, 1685, 5657, 7344 respectively due to missing data

Since PAL data were not available from the survey, we assigned a standard PAL of 1.55 to all respondents per the advice of the Australian Bureau of Statistics (20), and similar to previous studies (27; 28; 29). Participants with an energy intake:basal metabolic rate ratio outside the 95% CI were excluded from the analysis. We excluded 1847 extreme low reporters and 2104 extreme high reporters based on this method. The final dataset included 8202 participants, of which 47.8% were female. The demographic characteristics of the participants are summarized in Table 1.

Method for estimating added sugar and free sugar content of foods

In this paper, the term 'added sugar' refers to 'sugars and syrups that are added to foods or beverages when they are processed or prepared' (30), which is the definition used by the USDA (31).

A method developed by our group (30) was used to estimate the added sugars content of the 5740 foods in the AUSNUT2011-2013 food composition database (21). Briefly, the 10 steps are:

Step 1: Assign 0 g added sugar to foods with 0 g total sugars (n = 1329).

Step 2: Assign 0 g added sugar to foods in food groups that are either unprocessed or minimally processed with no added sugar (n = 1369).

Step 3: Assign 100% of total sugar as added sugar for foods in food groups that contain no naturally-occurring sugars (n = **462).**

Step 4: Calculation based on standard recipe used in the food composition database (n = 772).

Step 5: Calculation based on comparison with values from the unsweetened variety (n = 63).

Step 6: Decision based on analytical data, e.g. all lactose in dairy foods was considered naturally-occurring (n = 131).

Step 7: Use borrowed values from similar products from steps 1 to 6 or from overseas databases (n = 130).

Step 8: Subjective estimation on the basis of ingredients and/or common recipes (n = 277).

Step 9: Calculation based on the standard recipe that includes ingredients with values assigned at steps 5-8, using the proportion method (n = 1182).

Step 10: Assign 50% of total sugars as added sugar to foods that are not included in steps 1-9 (n = 25).

Free sugars content of foods were defined based on the WHO definition, as 100% of added sugar for non-fruit juice sources (including honey and syrups), and 100% of total sugars for fruit juices and drinks (13). The added and free sugar values were then linked to the NNPAS database to generate the intake of added and free sugar of individual respondents.

Food groupings

To determine the food sources of added sugar of the population, foods considered likely to contain added sugar were classified into the following categories: sugar-sweetened beverages (fruit drinks, cordial/mixer, soft drinks, energy drinks and other sweetened beverages); cakes, biscuits, pastries and batter-based products (sweet and savory biscuits, cakes, buns, pastries, muffins and scones); sugar and sweet spreads (sugar, honey, jam, syrup and other sweet spreads); chocolate and confectionary (chocolate, chocolate-based confectionary and other confectionary); sweetened dairy products (flavored or condensed milk, yoghurt, frozen yoghurt and custard); bread and cereals (bread, breakfast cereal and bars); ice cream and ice confection (ice cream, frozen desserts and ice confection). All other food groups were grouped into "other food sources" (detailed food grouping decision could be found in **Supplemental Table 1**).

Statistical analyses

All statistical analyses were performed with SPSS version 22.0 (IBM, California, USA), and weighting factors were applied in all analyses. All results were presented as mean ± SD for continuous variables, and as percentages for categorical variables. Data were weighted to control for under- and/or over-sampling in particular categories of persons and households, which may occur due to the random nature of sampling or non-response (20). This enables representation of the general Australian population aged 2 years or above. Usual percentage energy from free sugars (%EFS) of the participants, computed by the Multiple Source Method (32) to account for intra-personal variability by taking into account the data from the second 24h recall, was compared to the WHO recommendation for 'free sugar' intake (<10% of total energy intake from free sugar per day). A further reduction to below 5% of total energy from free sugars per day is suggested for additional health benefits (13). Pearson's χ^2 test was used to test for differences in categorical variables across the age groups, and between children and adolescents vs. adults.

Per capita analysis included all respondents with plausible intake data, and represents the mean intake of the population. Per consumer analysis included only subjects who had reported the consumption of food item(s) in the food groups tested (**Supplemental Table 2**). The differences in percentage contribution of added sugar from major added sugar contributing food groups between genders, and the differences in continuous variables between children and adolescents vs. adults were tested by one way ANOVA. For all analyses, linear regression with age (years, continuous) as the independent variable was used to test for trend across age groups. Due to the number of comparisons made, $p < 0.01$ was considered to indicate marginal statistical significance, and $p < 0.001$ was

Table 2 – Daily intake of energy, macronutrients, *added* sugar and *free* sugars by age group

	2-3 years		4-8 years		9-13 years		14-18 years		19-30 years		31-50 years		51-70 years		71+ years		P value*	P value†
n	214		552		630		481		1523		2345		1792		666		-	-
	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD		
Energy (kJ/d)	5894	1540	6976	1956	8945	2351	9975	2844	10342	3063	9839	3095	9351	2851	8086	2326	0.03	<0.001
Energy from protein (%)	16.6	4.3	15.3	3.8	16.1	4.4	16.6	4.8	17.4	5.7	18.0	5.6	18.0	5.5	17.9	5.1	<0.001	<0.001
Energy from fat (%)	29.9	6.8	30.3	6.8	31.9	6.5	32.7	7.4	31.8	9.1	31.4	8.3	31.2	8.7	30.7	8.3	0.05	0.99
Energy from CHO (%)	50.4	8.1	51.4	7.7	49.4	7.2	48.0	8.4	45.0	10.0	43.0	10.4	41.3	10.8	43.6	9.7	<0.001	<0.001
Total sugars (g/d)	92.8	35.5	103.0	43.3	124.6	53.6	132.2	68.1	124.7	67.7	115.1	65.0	106.0	61.0	102.9	51.1	<0.001	0.06
Energy from total sugars (%)	25.2	7.0	23.7	7.4	22.2	7.2	21.0	8.3	19.4	8.5	18.9	8.8	18.2	8.4	20.3	8.0	<0.001	<0.001
Added sugar (g/d)	35.3	28.5	49.9	34.9	68.2	44.0	81.9	59.2	73.3	61.3	60.7	53.5	51.1	49.8	47.9	40.5	<0.001	0.03
Proportion of sugar as *added* sugar (%)	36.3	20.4	45.9	19.9	52.3	20.5	58.4	20.9	53.6	25.2	48.1	23.6	42.3	23.1	43.5	21.1	<0.001	<0.001
Energy from *added* sugar (%)	9.8	6.6	11.9	7.2	12.7	7.1	13.6	8.2	11.9	8.8	10.4	8.1	9.0	7.5	9.8	7.1	<0.001	<0.001
Free sugars (g/d)	41.2	29.8	55.2	36.1	73.6	44.7	88.2	60.9	79.4	64.1	65.1	54.7	54.9	51.1	51.4	42.7	<0.001	0.005
Proportion of sugar as *free* sugars (%)	42.5	20.6	50.9	20.3	56.8	20.0	66.3	19.3	58.1	24.9	52.0	23.4	46.8	22.8	46.3	21.4	<0.001	<0.001
Energy from *free* sugars (%)	11.5	6.9	13.2	7.5	13.8	7.3	14.7	8.3	12.9	9.1	11.2	8.4	9.7	7.6	10.5	7.4	<0.001	<0.001
Energy from *free* sugars‡ ≥ 10% (%)	60.6		70.8		76.2		75.9		61.0		51.7		41.9		46.4		<0.001	<0.001
Energy from *free* sugars‡ ≥ 5% (%)	93.4		96.2		97.5		96.7		90.0		89.2		84.8		90.4		<0.001	<0.001

Values were presented as mean ± SD for continuous variables and as percentages for categorical variables. Data were weighted to account for over- or under-sampling to enable representation of the general Australian population.
*P values represent P for trend for continuous variables, and for categorical variables the *p* values were tested by χ^2 test.
†P values for difference between children and adolescents (2-18 years) *vs.* adults (19+ years). For continuous variables the difference was tested using one-way ANOVA, while Pearson's χ^2 was used for categorical variables.
‡Usual intake calculated by the Multiple Source Method [32].

considered statistically significant.

Results

The demographics of the subjects were summarized in **Table 1**. There was a higher proportion of males than females among the included subjects (52.2% *vs.* 47.8%). A higher proportion of adults were classified as overweight or obese (60.1% *vs.* 23.2%; $p < 0.001$) and lower portion of adults were born in Australia (69.1% *vs.* 90.0%; $p < 0.001$) compared with children and adolescents.

Table 2 shows the daily intake of energy, macronutrients, and added- and free-sugars by age groups. Intakes of fat and protein (as percentage energy) appear to increase with age ($p_{trend} = 0.05$ and < 0.001, respectively), with a concurrent decrease in percentage energy from carbohydrates ($p_{trend} < 0.001$). The estimated mean ± SD daily intake of total-, added- and free-sugar of the study population were 114.2 ± 61.8, 60.3 ± 52.6 and 65.1 ± 54.3 g/d, contributing 19.8 ± 8.5%, 10.8 ± 8.0% and 11.7 ± 8.3% of the total daily energy intake, respectively. Males had a significantly higher mean daily intake of total- (124.6 ± 68.5 vs. 103.0 ± 51.4 g/d; p <0.001), added- (68.0 ± 58.8 *vs.* 51.9 ± 43.4 g/d; $p < 0.001$) and free-sugar (73.5 ± 60.5 *vs.* 56.0 ± 44.9 g/d; $p < 0.001$) than females. Added- and free- sugar accounted for 48.2 ± 23.5% and 52.2 ± 23.2% of total sugars in the Australian population respectively. People in the age group of 9-13, 14-18 and 19-30 had more than half of their total sugars as added sugar (52.3 ± 20.5%, 58.4 ± 20.9% and 53.6 ± 25.2%, respectively). More than half (55.7%) of the study population had higher usual intake of free sugar than the WHO's recommendation, and children and adolescents were more likely to exceed the two cut-offs compared with adults (72.7% *vs.* 50.6%; $p < 0.001$). Children aged 9-13 years had the highest proportion (76.2%) exceeding 10%EFS. Those aged 14-18 years had the highest mean daily intake of total-, added- and free-sugar (132.12 ± 68.1, 81.9 ± 59.2 and 88.2 ± 60.9 g/d, respectively) as well as the highest mean proportion of energy intake from added sugar (13.6 ± 8.2%) and %EFS (14.7 ± 8.3%).

Table 3 summarized the per capita percentage contribution of added sugar from the major added sugar contributing food groups, stratified by age. Sugar-sweetened beverages accounted for the greatest proportion of added sugar intake of the Australian population (21.4 ± 30.1%), followed by sugar and sweet spreads (16.3 ± 24.5%) and cakes, biscuits, pastries and batter based products (15.7 ± 24.4%). For children aged 2-3 years, cakes, biscuits, pastries and batter-based products contributed the largest proportion of daily added sugar intake (20.3 ± 26.5%). But sugar-sweetened beverages were the largest contributors of added sugar in those aged 4-8, 9-13, 14-18, 19-30 and 31-50 years (22.5 ± 27.8%, 28.1 ± 29.1%, 33.9 ± 32.9%, 31.8 ± 34.2% and 20.3 ± 30.0%, respectively). Sugar and sweet spreads were the main contributor to added sugar among older Australians aged 51 years or above. Children and adolescents had a significantly higher proportion of their added sugar intake from sugar-sweetened beverages (26.8 ± 30.0 *vs.* 19.8 ± 29.9; $p < 0.001$), cakes, biscuits, pastries and batter-based products (17.4 ± 24.2 *vs.* 15.2 ± 24.4; $p < 0.001$), sweetened dairy products (9.0 ± 18.4 *vs.* 6.2 ± 16.5; $p < 0.001$), bread and cereals (9.2 ± 17.3 *vs.* 7.9 ± 17.4; $p = 0.004$), and ice-cream and ice confection (7.9 ± 16.3 *vs.* 4.3 ± 13.4; $p < 0.001$); and had a lower proportion of their added sugar intake from sugar and sweet spreads (9.2 ± 17.0 *vs.* 18.4 ± 25.9; $p < 0.001$) than adults.

The per consumer percentage contribution of added sugar from the major added sugar contributing food groups were summarized in **Table 4**. Consumers of sugar-sweetened beverages derived 50.3 ± 25.9% of their daily added sugar intake from this food group. Among sugar-sweetened beverage consumers, those aged 19-30 years had the greatest proportion of energy contributed by added sugar (57.8 ± 24.8%), followed by those aged 14-18 years (54.2 ± 25.0%). Except for consumers aged over 71 years, all sugar-sweetened beverage consumers had more than 40% of added sugar from this food group. Consumers of sweetened dairy products and ice-cream and ice confection aged 4-8 years derived 35.3 ± 24.8% and 31.7 ± 20.3% of their daily added sugar intake from these two food groups, respectively.

Figures 1a and **1b** present data on the per capita percentage contribution of added sugar from major added sugar contributing food groups, stratified by age group and gender. No significant sex differences were observed for children aged 8 years or below. For children aged 9-13 years, males obtained a higher proportion of added sugar from breads and cereals than females (11.6 ± 20.0% *vs* 7.5 ± 15.0%; $p = 0.003$). Boys aged 14-18 years had a higher proportion of added sugar from sugar-sweetened beverages (40.2 ± 33.8% *vs.* 27.6 ± 30.6%; $p < 0.001$), cakes, biscuits, pastries and batter-based products (11.2 ± 19.8% *vs.* 16.9 ± 25.3%; $p = 0.006$), and lower proportion of added

Table 3 – Per-capita percentage contribution of *added* sugar from major *added* sugar contributing food groups, stratified by age

Food groups*	2-3 years		4-8 years		9-13 years		14-18 years		19-30 years		31-50 years		51-70 years		71+ years		*P*value†	*P*value‡
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Sugar-sweetened beverages	18.0	27.3	22.5	27.7	28.1	29.1	33.9	32.9	31.8	34.1	20.3	30.0	12.7	24.9	10.2	20.8	<0.001	<0.001
Cakes, biscuits, pastries and batter-based products	20.3	26.5	17.9	23.7	18.6	24.7	14.0	22.9	12.1	23.0	14.6	24.0	17.0	25.8	19.5	24.3	0.006	<0.001
Sugar and sweet spreads	13.1	25.0	10.6	17.5	7.8	14.1	7.6	14.9	12.3	22.0	18.4	25.3	20.8	27.6	25.8	28.6	<0.001	<0.001
Chocolate and confectionary	10.3	18.6	9.5	17.6	9.7	17.8	9.3	17.8	8.1	18.8	9.1	19.8	9.3	20.3	7.7	17.0	0.28	0.09
Sweetened dairy products	13.5	21.6	10.3	20.9	7.9	16.9	7.0	15.2	6.1	15.6	6.4	17.1	6.4	16.8	5.8	15.5	<0.001	<0.001
Bread and cereals	8.4	16.5	9.9	17.1	9.6	17.8	8.3	17.4	7.3	16.8	7.8	17.4	8.5	17.9	8.6	17.0	0.60	0.004
Ice-cream and ice confection	5.6	15.1	10.1	18.7	8.8	16.3	5.3	13.2	3.4	11.6	3.8	13.4	5.0	14.1	6.0	15.2	<0.001	<0.001
Other food sources	10.0	18.0	9.0	15.2	9.4	15.1	14.6	21.8	18.5	25.8	19.2	27.3	19.6	28.0	16.1	23.2	<0.001	<0.001

Values were presented as mean (SD). Data were weighted to account for over- or under-sampling to enable representation of the general Australian population. P < 0.01 was considered to indicate marginal statistical significance, and p < 0.001 was considered statistically significant to minimize type I error.
*Food groups considered likely to contain added sugar include: sugar-sweetened beverages (fruit drinks, cordial/mixer, soft drinks, energy drinks and other sweetened beverages); cakes, biscuits, pastries and batter-based products (sweet and savory biscuits, cakes, buns, muffins and scones); sugar and sweet spreads (sugar, honey, jam, syrup and other sweet spreads); chocolate and confectionary (chocolate, chocolate-based confectionary and other confectionary); sweetened dairy products (flavored or condensed milk, yoghurt, frozen yoghurt and custard); bread and cereals (bread, breakfast cereal and bars); ice cream and ice confection (ice cream, frozen desserts and ice confection). All other food groups were grouped into "other food sources".
†*p* for trend across age group calculated by linear regression with age (years; continuous) as the independent variable.
‡*p* values for difference between children and adolescents (2-18 years) vs. adults (19 + years), tested by one-way ANOVA.

Table 4 – Per-consumer percentage contribution of *added* sugar from major added sugar contributing food groups, stratified by age

Food groups*	2-3 years		4-8 years		9-13 years		14-18 years		19-30 years		31-50 years		51-70 years		71+ years		*P* value†	*P* value‡
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Sugar-sweetened beverages	42.4	26.9	42.2	24.8	44.1	25.0	54.2	25.0	57.8	24.8	52.4	25.3	47.9	25.6	36.1	24.5	0.003	<0.001
Cakes, biscuits, pastries and batter-based products	27.2	27.4	24.8	24.7	27.8	25.6	26..3	25.6	29.0	27.9	28.9	27.0	30.1	28.0	28.1	24.7	0.013	0.003
Sugar and sweet spreads	41.4	28.3	24.2	19.1	22.3	15.7	21.4	18.1	29.2	25.6	33.0	25.8	36.9	27.5	40.7	26.1	<0.001	<0.001
Chocolate and confectionary	28.7	21.0	24.2	20.7	26.1	20.6	26.2	21.2	31.3	25.2	32.1	25.4	32.3	26.4	28.1	22.0	0.001	<0.001
Sweetened dairy products	32.4	22.5	35.3	24.8	27.4	21.3	28.0	18.3	28.2	22.6	28.9	26.2	28.5	25.2	24.7	23.7	0.003	0.04
Bread and cereals	8.9	16.8	10.4	17.4	10.6	18.4	10.2	18.7	9.0	18.3	9.1	18.5	9.4	18.6	8.9	17.2	0.20	0.04
Ice-cream and ice confection	31.5	21.7	31.7	20.3	27.6	17.8	26.6	17.8	26.0	20.8	30.1	25.1	30.2	20.9	28.7	21.3	0.38	0.97
Other food sources	10.0	18.0	9.0	15.2	9.4	15.1	14.6	21.8	18.5	25.8	19.2	27.3	19.6	28.0	16.1	23.2	<0.001	<0.001

Values were presented as mean (SD). Data were weighted to account for over- or under-sampling to enable representation of the general Australian population. *P* < 0.01 was considered to indicate marginal statistical significance, and *p* < 0.001 was considered statistically significant to minimize type I error.
*Food groups considered likely to contain *added* sugar include: sugar-sweetened beverages (fruit drinks, cordial/mixer, soft drinks, energy drinks and other sweetened beverages); cakes, biscuits, pastries and batter-based products (sweet and savory biscuits, cakes, buns, muffins and scones); sugar and sweet spreads (sugar, honey, jam, syrup and other sweet spreads); chocolate and confectionary (chocolate, chocolate-based confectionary and other confectionary); sweetened dairy products (flavored or condensed milk, yoghurt, frozen yoghurt and custard); bread and cereals (bread, breakfast cereal and bars); ice cream and ice confection (ice cream, frozen desserts and ice confection). All other food groups were grouped into "other food sources".
†*p* for trend across age group calculated by linear regression with age (years; continuous) as the independent variable.
‡*p* values for difference between children and adolescents (2-18 years) *vs.* adults (19 + years), tested by one-way ANOVA.

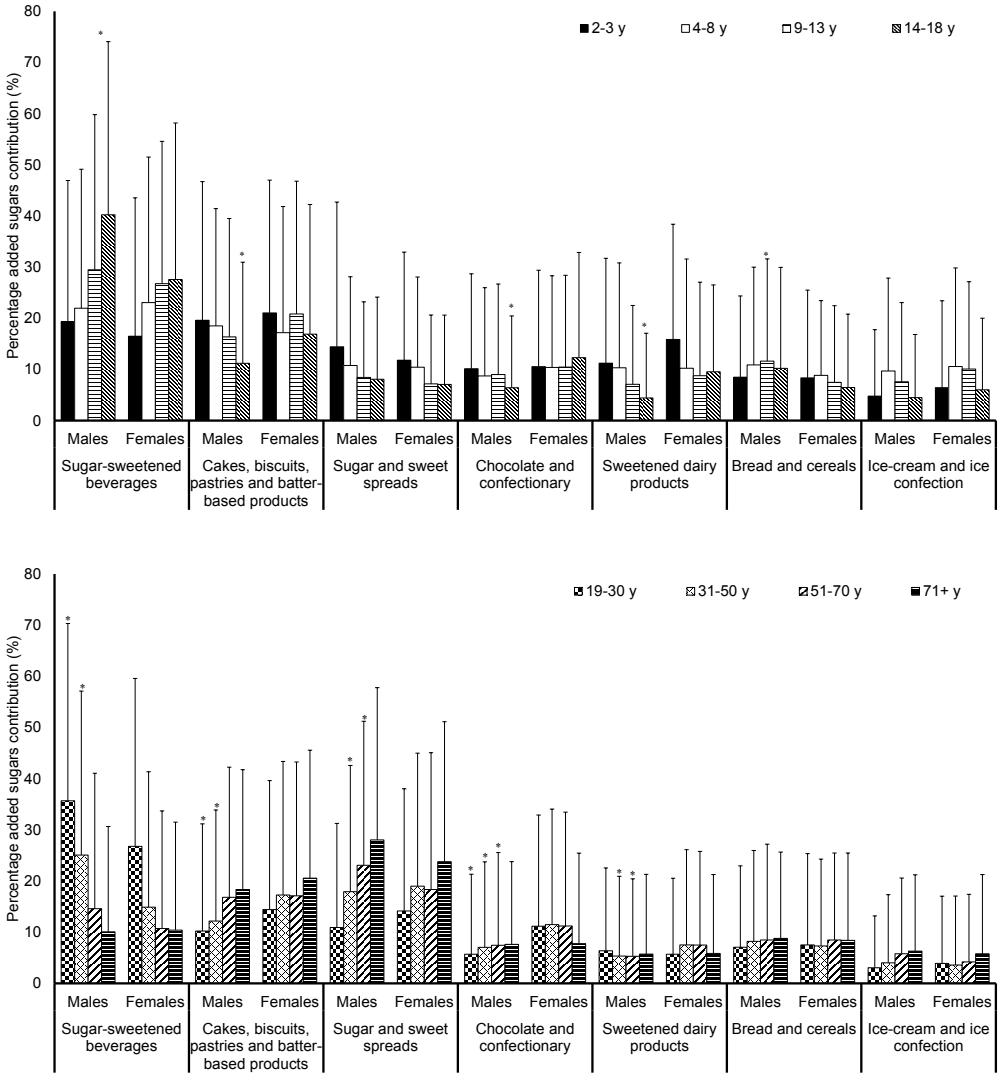

Figure 1. Per capita percentage contribution of added sugar from major added sugar contributing food groups, stratified by sex and age group – (a) children and adolescents (2 – 18 years) only; and (b) adults (19+ years) only. Data were weighted to account for over- or under-sampling to enable representation of the general Australian population. Data were presented as mean (SD). Food groups considered likely to contain added sugar include: sugar-sweetened beverages (fruit drinks, cordial/mixer, soft drinks, energy drinks and other sweetened beverages); cakes, biscuits, pastries and batter-based products (sweet and savory biscuits, cakes, buns, muffins and scones); sugar and sweet spreads (sugar, honey, jam, syrup and other sweet spreads); chocolate and confectionary (chocolate, chocolate-based confectionary and other confectionary); sweetened dairy products (flavored or condensed milk, yoghurt, frozen yoghurt and custard); bread and cereals (bread, breakfast cereal and bars); ice cream and ice confection (ice cream, frozen desserts and ice confection). All other food groups were grouped into "other food sources". *$p < 0.001$ when compared with females in the same age group.

sugar from chocolate and confectionary (6.4 ± 14.0% *vs.* 12.3 ± 20.6%; $p < 0.001$), and sweetened dairy products (4.4 ± 12.6% vs. 9.5 ± 17.0%; $p < 0.001$) than girls of the same age. Similar patterns were observed in adults below 70 years of age. Boys aged 2-18 years had higher proportion of added sugar from sugar -sweetened beverages (28.8 ± 31.0% *vs.* 23.5 ± 31.7%; $p < 0.001$), cakes, biscuits, pastries and batter-based products (16.1 ± 22.9% *vs.* 13.5 ± 22.9%; $p = 0.002$), sweetened dairy products (7.9 ± 17.3% *vs.* 5.6 ± 15.6%; $p < 0.001$), breads and cereals (10.7 ± 19.2% *vs.* 8.0 ± 17.5%; $p < 0.001$), and ice-cream and ice confection (7.1 ± 15.5% *vs.* 4.5 ± 13.2%; $p < 0.001$); and had lower proportion of added sugar from sugar and sweet spreads (9.7 ± 17.9% *vs.* 18.5 ± 25.8%; $p < 0.001$) than men aged 19 years or above. Similar patterns were seen for girls *vs.* women, except no significant differences were observed between the two groups for cakes, biscuits, pastries and batter-based products, and breads and cereals.

Figures 2a and **2b** outline the per consumer food sources of added sugar, stratified by age and sex. No trends across age group were observed. For sugar-sweetened beverages, only males aged 19-30 years and 31-50 years obtained a significantly higher proportion of added sugar from sugar-sweetened beverages than females of the same age (**Figure 2b**). Men aged 31-50 years also had a significantly higher proportion of added sugar from cakes, biscuits, pastries and batter-based products, and lower proportion of added sugar from chocolate and confectionary than women of the same age (all $p < 0.001$).

Discussion

This study presents current data on the dietary intake and food sources of added sugar in the Australian population using data from the most recent national nutrition survey. The mean daily total-, added- and free-sugar intake of the study population were 114 g, 60 g and 65 g, contributing 20%, 11% and 12% of total daily energy intake, respectively. Alarmingly, more than half of the study population exceeded the WHO's cut-off for 'free sugar', especially children and adolescents. Sugar-sweetened beverages, sugar and sweet spreads, and cakes, biscuits pastries and batter based products accounted for more than 50% of the daily added sugar intake. Overall 80-90% of the daily added sugar intake came from high sugar energy-dense and/or nutrient -poor foods, commonly referred to as 'extra' or 'discretionary' foods in dietary guidelines (9; 33).

A previous analysis based on the 1995NNS conducted by Cobiac et al (6) found that the estimated mean intake of added sugar for the Australian population (adults and children) was 66.0 g/d, approximately 11% of the total energy intake. This is 5.7 g/d higher than our findings from the 2011-2012 NNPAS but the percentage energy from added sugar is similar between the two surveys. Studies from other developed countries also report a declining trend in added sugar consumption (16; 18; 34; 35). For example, using data from the National Health and Nutrition

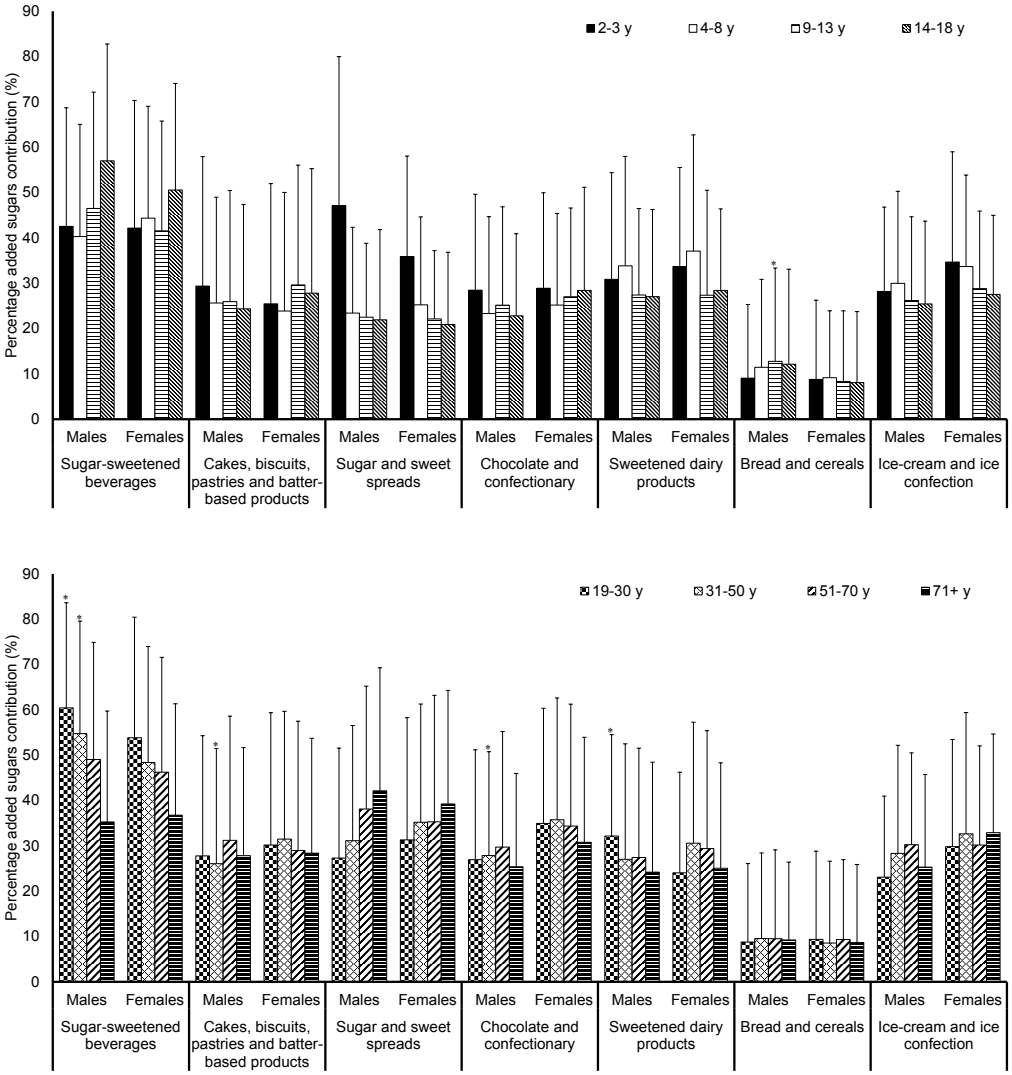

Figure 2. Per consumer percentage contribution of added sugar from major added sugar contributing food groups, stratified by sex and age group – (a) children and adolescents (2 – 18 years) only; and (b) adults (19+ years) only. Data were weighted to account for over- or under-sampling to enable representation of the general Australian population. Data were presented as mean (SD). Food groups considered likely to contain added sugar include: sugar-sweetened beverages (fruit drinks, cordial/mixer, soft drinks, energy drinks and other sweetened beverages); cakes, biscuits, pastries and batter-based products (sweet and savory biscuits, cakes, buns, muffins and scones); sugar and sweet spreads (sugar, honey, jam, syrup and other sweet spreads); chocolate and confectionary (chocolate, chocolate-based confectionary and other confectionary); sweetened dairy products (flavored or condensed milk, yoghurt, frozen yoghurt and custard); bread and cereals (bread, breakfast cereal and bars); ice cream and ice confection (ice cream, frozen desserts and ice confection). All other food groups were grouped into "other food sources". *$p < 0.001$ when compared with females in the same age group.

Examination Survey (NHANES) in the U.S., Welsh et al (16) observed a 23.4 g/d decrease in added sugar intake between 1999-2000 and 2007-2008 amongst U.S. residents aged 2 years or above. However, the magnitude of change observed was larger, possibly due to the higher intake reported in the earlier NHANES (100.1 g/d), leaving more room for improvement.

It is interesting to note that adolescents were found to be the highest consumers of added sugar among all age groups in both the current analysis and the 1995 NNS (6). Previous analysis by our group of the more recent 2007 Australian National Children's Nutrition and Physical Activity Survey (2007ANCNPAS) (14) showed similar results, with children and adolescents aged 9-16 years having the highest added sugar intake, mainly from increased sugar-sweetened beverage consumption.

Our results revealed that sugar-sweetened beverages were the greatest source of added sugar in the Australian population (21.5%), followed by sugar and sweet spreads (16.4%), and cakes, biscuits, pastries and batter-based products (15.8%). In the 1995NNS, the greatest source of added sugar was non-alcoholic beverages (6), the same as observed in the present study, with a different name for the beverage type. Based on data from the three Australian national nutrition surveys (6; 14; 36), the per capita percentage contribution of added sugar from sugar -sweetened beverages among adolescents aged 14-18 years appears to have decreased from almost 50% in the 1995NNS to 24.1% in the 2007ANCNPAS (data for adolescents aged 14-16 years only), then increased to 33.9% in the 2011-12 NNPAS. While the lack of data from older adolescents in the 2007ANCNPAS may have influenced the trend, the current pattern of added sugar contribution from sugar-sweetened beverages among Australian youths is still a public health concern.

Health professionals and consumer groups have regularly criticized the food manufacturers for 'blurring' the line between 'core' and 'discretionary' foods (37; 38), by producing food products high in added sugar such as breakfast cereals and sweetened dairy products that are traditionally considered 'core' foods (39). The current analyses revealed, however, these products only accounted for ~15% of the daily added sugar intake of Australians. This suggests that strategies focussing on reducing the added sugar content in these foods may not be the most effective approach for reducing the added sugar intake of the population. Our results showed that the top 3 sources of added sugar in the Australian population were sugar-sweetened beverages, cakes, biscuits, pastries and batter-based products, and sugar and sweet spreads, which are all energy-dense and/or nutrient-poor 'discretionary' foods (9). Hence, interventions aimed at reducing added sugar intake should focus on these foods, especially sugar-sweetened beverages. Since sugar-sweetened beverages contributed half of the added sugar among consumers, reducing the consumption of sugar-sweetened beverages, such as by replacement with water or other low calorie beverages (40; 41), may lead to a considerable decrease in added sugar intake in the Australian population.

The WHO strongly recommends that free sugars, i.e. added

sugar (including honey and syrups) plus sugars in fruit juices, should be less than 10% of daily total energy intake. A further reduction to less than 5% of daily total energy intake was proposed (13). A commonly used alternative recommendation by the Institute of Medicine (IOM) (42), has proposed a dietary intake of ≤ 25% of energy from added sugars. Using the IOM cut -off, we found only less than 2% exceeded this guideline (data not shown). However, Linos and Bassett (43) argued that this cut-off was not intended to be used as a recommended intake level; rather it represents a cut-off where there is evidence to suggest intake higher than this may lead to inadequate intake of essential nutrients (43). Therefore it appears unsatisfactory to use this lenient cut-off as a benchmark for population intake, particularly in terms of reducing risk for dental caries as has been the focus of the WHO guideline (13). In contrast, Erickson and Slavin (44) suggest that the proposed free sugars recommendation from the WHO is likely to be too restrictive and unachievable for most Americans. Our results showed this may also be the case for Australians with more than half exceeding the 10%EFS cut-off and less than 10% meeting the newly proposed recommendation of 5%EFS. Nonetheless, compared with data from the 2007ANCNPAS (14), there appears to be an improvement in this benchmark where more Australian children and adolescents in 2011-2012 are meeting the <10%EFS guideline (27.3% *vs.* 14.7%).

Our study has several strengths: First, the use of sample weighting enabled the findings to be generalized to the general Australian population. Another strength of the study is the use of a published, reproducible method for estimating added sugar contents of foods (30). Although the methodology has not been formally validated, and hence the accuracy of the estimated values was unknown, the method has passed a vigorous peer-review process, which established its face validity. The method was also clearly described which increased the transparency in the estimation process for further review by peers, and we have recently shown it has good reliability when applied to AUSNUT2011-2013 (45). This is in contrast to methods proposed/used by other researchers which are often inadequately described (46). Based on this method, we assigned added sugar content to most of the 5740 foods in AUSNUT2011-2013 using an objective step or a recipe-based step, and an assumption of 50% total sugars as added sugar was only used in less than 0.5% of the foods (45).

However, there are several limitations of this study. First, although the 24-hour recall is a suitable dietary assessment method for a large number of subjects, the use of this method in children remains doubtful, and it has been argued that it is especially difficult to assess the dietary intake among children accurately (47). Parental recall of food intake has been suggested to be likely to result in under-reporting and may contribute to inaccuracy at an individual level (48; 49; 50; 51). Children who reported their own food intake were also likely to inaccurately recall their food intake, which could be a result of incorrect identification of foods (52; 53), and/or unfamiliarity of the food (54), both of which may lead to misreporting. Information overload (e.g. large number of foods to report) may also bias the recall of food intake (55). By using the Goldberg cut-off for a specific PAL method (26), we have excluded extreme under- and over-reporters to increase the plausibility of the findings of this study, although it is acknowledged that the cut-offs were conservative and are only able to identify extreme degrees of misreporting (56).

Second, dietary intake is likely to vary from day to day, and therefore data obtained from one 24 hour recall may not be representative of the usual intake of an individual (57), although it was deemed appropriate by the National Cancer Institute for estimating population means (58). The ideal method to obtain usual dietary intake data of individuals would be a 7-day food record, but the large number of participants of the 2011-12 NNPAS renders this impractical. The heavy respondent load is another issue for the 7-day food record which may result in a low response rate. Where estimates were calculated for a proportion of subjects (such as comparisons with the WHO cut-offs) that require dietary information at an individual level, we utilized the Multiple Source Method (32) to generate the usual intake to minimize errors.

Conclusions

Our results indicated that added sugar intake appeared to be similar to that reported from the 1995 NNS. Adolescents aged 14 -18 years had the highest added sugar intakes, which is concerning. More than half of the Australian population had more free sugars than the WHO's recommendation. Energy-dense nutrient-poor foods such as sugar-sweetened beverages, and cakes, biscuits, pastries and batter-based products accounted for the greatest proportion of added sugar in the Australian population. Efforts on reducing added sugar intake should focus on reducing the consumption of these energy-dense nutrient-poor foods, with clear messages about minimizing the frequent consumption of discretionary foods, and promotion of water and healthy core foods.

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Statement of authors' contribution to manuscript

J.C.Y.L., A.R. and V.M.F. designed the research. J.C.Y.L. and L.L. assigned the added sugar values to AUSNUT2011-2013; J.C.Y.L. and L.L. analyzed data; all authors were involved in the interpretation of the data; L.L. and J.C.Y.L. wrote the first draft of the manuscript. All authors were involved in the subsequent edits of the manuscript. J.C.Y.L. had primary responsibility for final content. All authors have read and approved the final manuscript.

Reference

1. Perlmutter R (2011) Labeling Solid Fats and Added Sugars As Empty Calories. *J Am Diet Assoc* 111, 222-223.
2. Reedy J, Krebs-Smith SM (2010) Dietary Sources of Energy, Solid Fats, and Added Sugars among Children and Adolescents in the United States. *J Am Diet Assoc* 110, 1477-1484.
3. Joyce T, Gibney MJ (2008) The impact of added sugar consumption on overall dietary quality in Irish children and teenagers. *J Hum Nutr Diet* 21, 438-450.
4. Rennie KL, Livingstone MBE (2007) Associations between dietary added sugar intake and micronutrient intake: a systematic review. *Br J Nutr* 97, 832-841.
5. Forshee RA, Storey ML (2001) The role of added sugars in the diet quality of children and adolescents. *J Am Coll Nutr* 20, 32-43.
6. Cobiac L, Record S, Leppard P et al. (2003) Sugars in the Australian diet: Results from the 1995 National Nutrition Survey. *Nutr Diet* 60, 152-173.
7. Drewnowski A (2007) The real contribution of added sugars and fats to obesity. *Epidemiol Rev* 29, 160-171.
8. Te Morenga L, Mallard S, Mann J (2013) Dietary sugars and body weight: systematic review and meta-analyses of randomised controlled trials and cohort studies. *BMJ* 346, e7492.
9. National Health and Medical Research Council (Australia) (2013) Australian Dietary Guidelines - Providing the scientific evidence for healthier Australian diets. Canberra, ACT, Australia: NHMRC, DoHA.
10. US Department of Health and Human Services, US Department of Agriculture (2011) 2010 Dietary Guidelines for Americans. Washington, DC: Government Printing Office.
11. Food Standards Agency (2007) FSA nutrient and food based guidelines for UK institutions London, UK: Food Standards Agency.
12. Health Canada (2011) Eating Well with Canada's Food Guide - A Resource for Educators and Communicators. Ottawa, Ontario: Health Canada.
13. World Health Organization (2015) Guideline: Sugars intake for adults and children. Geneva, Switzerland: World Health Organization.
14. Louie JCY, Moshtaghian H, Rangan AM et al. (2015) Intake and food sources of added sugars among Australian children and adolescents. *Eur J Nutr* [Epub ahead of print].
15. McNeill TJ, Shrapnel WS (2015) Apparent consumption of refined sugar in Australia (1938-2011). *Eur J Clin Nutr* [Epub ahead of print].
16. Welsh JA, Sharma AJ, Grellinger L et al. (2011) Consumption of added sugars is decreasing in the United States. *Am J Clin Nutr* 94, 726-734.
17. Vorster HH, Kruger A, Wentzel-Viljoen E et al. (2014) Added sugar intake in South Africa: findings from the Adult Prospective Urban and Rural Epidemiology cohort study. *Am J Clin Nutr* 99, 1479-1486.
18. Brisbois TD, Marsden SL, Anderson GH et al. (2014) Estimated intakes and sources of total and added sugars in the Canadian diet. *Nutrients* 6, 1899-1912.
19. Whitton C, Nicholson SK, Roberts C et al. (2011) National Diet and Nutrition Survey: UK food consumption and nutrient intakes from the first year of the rolling programme and comparisons with previous surveys. *Br J Nutr* 106, 1899-1914.
20. Australian Bureau of Statistics (2013) Australian Health Survey: Users' Guide, 2011-13 http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/74D87E30B3539C53CA257BBB0014BB36?opendocument (accessed 2 June 2015)
21. Food Standards Australia New Zealand (2014) AUSNUT2011-2013 - Food Composition Database. http://www.foodstandards.gov.au/science/monitoringnutrients/ausnut/pages/default.aspx (accessed 14th May 2015)
22. Cole TJ, Lobstein T (2012) Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatr Obes* 7, 284-294.
23. World Health Organization (2015) Body mass index - BMI. http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi (accessed 4th Aug 2015)

24. Australian Bureau of Statistics (2013) Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA), Australia, 2011. Canberra, ACT, Australia: Australian Bureau of Statistics.
25. Australian Bureau of Statistics (2013) Australian Statistical Geography Standard (ASGS): Volume 5 - Remoteness Structure, July 2011 Canberra, ACT, Australia: Australian Bureau of Statistics.
26. Goldberg G, Black A, Jebb S et al. (1991) Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. *Eur J Clin Nutr* 45, 569-581.
27. Louie JCY, Buyken AE, Heyer K et al. (2011) Dietary glycaemic index and glycaemic load among Australian children and adolescents. *Br J Nutr* 106, 1273-1282.
28. Tornaritis MJ, Philippou E, Hadjigeorgiou C et al. (2014) A study of the dietary intake of Cypriot children and adolescents aged 6-18 years and the association of mother's educational status and children's weight status on adherence to nutritional recommendations. *BMC Public Health* 14, 13.
29. Ferrari P, Slimani N, Ciampi A et al. (2002) Evaluation of under- and overreporting of energy intake in the 24-hour diet recalls in the European Prospective Investigation into Cancer and Nutrition (EPIC). *Public Health Nutr* 5, 1329-1345.
30. Louie JC, Moshtaghian H, Boylan S et al. (2015) A systematic methodology to estimate added sugar content of foods. *Eur J Clin Nutr* 69, 154-161.
31. U.S. Department of Agriculture What are added sugars? http://www.choosemyplate.gov/weight-management-calories/calories/added-sugars.html (accessed 1 June 2015)
32. Harttig U, Haubrock J, Knuppel S et al. (2011) The MSM program: web-based statistics package for estimating usual dietary intake using the Multiple Source Method. *Eur J Clin Nutr* 65 Suppl 1, S87-91.
33. U.S. Department of Agriculture, U.S. Department of Health & Human Services (2015) Scientific Report of the 2015 Dietary Guidelines Advisory Committee - Advisory Report to the Secretary of Health and Human Services and the Secretary of Agriculture. Wasghinton, DC, USA: USDA.
34. Ervin RB, Kit BK, Carroll MD et al. (2012) Consumption of Added Sugar among US Children and Adolescents, 2005-2008. *NCHS Data Brief*. No. 87. National Center for Health Statistics.
35. Ervin RB, Ogden CL (2013) Consumption of added sugars among US adults, 2005-2010. *NCHS data brief*, 1-8.
36. Australian Bureau of Statistics (2014) Australian Health Survey: Nutrition First Results - Foods and Nutrients, 2011-12 [Australia Bureau of Statistics]. Canberra, ACT, Australia: ABS.
37. Stiles J (2015) The best and worst breakfast cereals revealed. http://thenewdaily.com.au/news/2015/05/04/every-cereal-ranked-health/ (accessed 15th Sep 2015)
38. Clemons R (2015) Breakfast cereal buying guide. https://www.choice.com.au/food-and-drink/bread-cereal-and-grains/cereal-and-muesli/buying-guides/breakfast-cereal (accessed 15th Sep 2015)
39. Louie JC, Dunford EK, Walker KZ et al. (2012) Nutritional quality of Australian breakfast cereals. Are they improving? *Appetite* 59, 464-470.
40. Stookey JD, Constant F, Gardner CD et al. (2007) Replacing Sweetened Caloric Beverages with Drinking Water Is Associated with Lower Energy Intake. *Obesity* 15, 3013-3022.
41. Tate DF, Turner-McGrievy G, Lyons E et al. (2012) Replacing caloric beverages with water or diet beverages for weight loss in adults: main results of the Choose Healthy Options Consciously Everyday (CHOICE) randomized clinical trial. *Am J Clin Nutr* 95, 555-563.
42. Institute of Medicine Panel on Macronutrients (2005) Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington, DC, USA: National Academy Press.
43. Linos N, Bassett MT (2015) Added sugar intake and public health. *JAMA* 314, 187-187.
44. Erickson J, Slavin J (2015) Total, added, and free sugars: are restrictive guidelines science-based or achievable? *Nutrients* 7, 2866-2878.
45. Louie JCY, Lei L, Rangan AM (2015) Reliability of a systematic methodology to estimate added sugars content of foods when applied to a recent Australian food composition database. *J Food Comp Anal* In Press.
46. Kelly SA, Moynihan PJ, Rugg-Gunn AJ et al. (2003) Review of methods used to estimate non-milk extrinsic sugars. *J Hum Nutr Diet* 16, 27-38; quiz 39-41.
47. Livingstone MB, Robson PJ (2000) Measurement of dietary intake in children. *Proc Nutr Soc* 59, 279-293.
48. Klesges R, Klesges L, Brown G et al. (1987) Validation of the 24-hour dietary recall in preschool children. *J Am Diet Assoc* 87, 1383-1385.
49. Eck L, Klesges R, Hanson C (1989) Recall of a child's intake from one meal: are parents accurate? *J Am Diet Assoc* 89, 784-789.
50. Basch CE, Shea S, Arliss R et al. (1990) Validation of mothers' reports of dietary intake by four to seven year-old children. *Am J Public Health* 80, 1314-1317.
51. Baranowski T, Sprague D, Baranowski JH et al. (1991) Accuracy of maternal dietary recall for preschool children. *J Am Diet Assoc* 91, 669-674.
52. Samuelson G (1970) An epidemiological study of child health and nutrition in a northern Swedish county. *Ann Nutr Metab* 12, 321-340.
53. Emmons L, Hayes M (1973) Accuracy of 24-hr. recalls of young children. *J Am Diet Assoc* 62, 409.
54. Warren JM, Henry CJK, Livingstone MBE et al. (2003) How well do children aged 5–7 years recall food eaten at school lunch? *Public Health Nutr* 6, 41-47.
55. Baranowski T, Dworkin R, Henske JC et al. (1986) The accuracy of children's self-reports of diet: Family Health Project. *J Am Diet Assoc* 86, 1381-1385.
56. Goldberg GR, Black AE, Jebb SA et al. (1991) Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. *Eur J Clin Nutr* 45, 569-581.
57. Biro G, Hulshof K, Ovesen L et al. (2002) Selection of methodology to assess food intake. *Eur J Clin Nutr* 56, S25-32.
58. National Cancer Institute (2015) Dietary Assessment Primer. Summary Tables: Recommendations on Potential Approaches to Dietary Assessment for Different Research Objectives Requiring Group-level Estimates. http://dietassessmentprimer.cancer.gov/approach/table.html (accessed 21st May