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Added sugar intake that exceeds current recommendations is associated with nutrient dilution in older Australians

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Added sugar intake that exceeds current recommendations is associated with nutrient dilution in older Australians

Abstract

Objectives A nutrient dilution effect of diets high in added sugar has been reported in some older populations but the evidence is inconsistent. The aim of this study was to investigate the association between added sugar intakes (according to recommended guidelines) and nutrient intake, food consumption and Body Mass Index (BMI). **Method** A cross-sectional analysis of data collected in 2007-09 from participants of the Blue Mountains Eye Study 4 was performed (n = 879). Dietary intake was assessed using a semi-quantitative food frequency questionnaire. Added sugar content of foods was determined by applying a systematic step-wise method. BMI was calculated from measured weight and height. Food and nutrient intakes and BMI were assessed according to categories of percentage energy from added sugar (EAS% <5%, EAS% = 5-10%, EAS% >10%) using ANCOVA for multivariate analysis. **Results** Micronutrient intake including retinol equivalents, vitamins B6, B12, C, E and D, and minerals including calcium, iron and magnesium showed a significant inverse association with EAS% intakes (Ptrend <0.05). In those people with the lowest intake of added sugars (<5% energy) intake of alcohol, fruits, and vegetables were higher and intake of sugar sweetened beverages was lower compared to other participants (all Ptrend <0.001). BMI was similar across the three EAS% categories. **Conclusion** Energy intake from added sugar above the recommended level of 10% is associated with lower micronutrient intakes, indicating micronutrient dilution. Conversely, added sugar intakes below 5% of energy intake are associated with higher micronutrient intakes. This information may inform dietary messages targeted at optimising diet quality in older adults.

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Added sugar intake that exceeds current recommendations is associated with nutrient dilution in older Australians

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Author Contributions

H. M. conducted the research, estimated added sugar values, analysed the data and drafted the manuscript. V.M.F. and P.M. were involved in collection of original BMES data. HM, J.C.Y. L, K.E.C, Y.C. P, B. G and V.M. F were involved in critical review and subsequent editing of the manuscript. All authors approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest

Abstract

Objectives: A nutrient dilution effect of diets high in added sugar has been reported in some older populations but the evidence is inconsistent. The aim of this study was to investigate the association between added sugar intakes (according to recommended guidelines) and nutrient intake, food consumption and Body Mass Index (BMI).

Method: A cross-sectional analysis of data collected in 2007-09 from participants of the Blue Mountains Eye Study 4 was performed (n = 879). Dietary intake was assessed using a semi-quantitative food frequency questionnaire. Added sugar content of foods was determined by applying a systematic step-wise method. BMI was calculated from measured weight and height. Food and nutrient intakes and BMI were assessed according to categories of percentage energy from added sugar (EAS% < 5%, EAS% = 5–10%, EAS% > 10%) using ANCOVA for multivariate analysis.

Results: Micronutrient intake including retinol equivalents, vitamins B₆, B₁₂, C, E and D, and minerals including calcium, iron and magnesium showed a significant inverse association with EAS% intakes ($P_{\text{trend}} < 0.05$). In those people with the lowest intake of added sugars (< 5% energy) intake of alcohol, fruits, and vegetables were higher and intake of sugar sweetened beverages was lower compared to other participants (all $P_{\text{trend}} < 0.001$). BMI was similar across the three EAS% categories.

Conclusion: Energy intake from added sugar above the recommended level of 10% is associated with lower micronutrient intakes, indicating micronutrient dilution. Conversely, added sugar intakes below 5% of energy intake are associated with

- 23 higher micronutrient intakes. This information may inform dietary messages targeted
24 at optimising diet quality in older adults.

Introduction

Nutrient dilution is the term that applies to displacement of nutrients due to the poor quality of diet (1). High intake of energy dense, nutrient poor foods can result in low intake of micronutrients that are essential for optimal body functioning across life stages. Compared to energy requirements, the requirements for many nutrients increases with advancing age because of chronic illnesses and intakes of various medications (2), thus, placing older adults at risk of malnutrition. Food choices that result in nutrient dilution are particularly problematic in older adults who may have an accompanying decreased appetite and reduced food intake (3).

There is some evidence that a diet high in added sugar (AS) contributes to nutrient dilution in vulnerable populations, including children and older adults (4-7). In children and adolescents, a high AS intake has been associated with low intake of some micronutrients, including calcium and zinc (8-10). In older age groups, however, findings are inconsistent. Micronutrient dilution has been shown to be associated with high levels of AS intake in older African women (11), but this was not evident in older British adults (2). Additionally, high AS consumers have been noted to have low fruit and vegetable intakes, coupled with more energy dense, nutrient poor foods (6, 9, 12), but this trend has not been investigated in older populations.

Typically, the term AS includes sugars and syrups that have been added to foods during processing and preparation (13). It is recommended that AS intake to be limited to a maximum of 10% of daily energy intake and for additional health benefits

reduce this intake to 5% (14, 15) despite limited evidence for the latter recommendation (16). No studies thus far have assessed the impact on nutrient dilution in older adults according to these cut-off points, in particular the 5% recommendation. Hence, we aimed to investigate whether there is an association between the recommended levels of AS consumption, and food and nutrient intakes in a sample of older Australians. Differences in Body Mass Index (BMI) according to categories of recommended AS intake were investigated as a secondary objective.

Methods

Subjects

Data from participants of the Blue Mountains Eye Study (BMES) were used. Details of BMES have been described elsewhere (17). Briefly, BMES is a population-based cohort study of older Australians, aged 49 years and over at baseline, who lived in the Blue Mountains area, in New South Wales, Australia. The BMES was conducted over 4 waves. The first wave of the BMES (BMES1) commenced in 1992 to 1994 and data collection has occurred every five years (BMES 2-4). In BMES4 (2007-09), 1149 participants (55.4% of survivors) attended eye examinations. For the purpose of the current analysis, cross-sectional data from participants of the BMES4 who had plausible data (n=879) were used, reflecting the most recent dietary intake data from this ageing cohort.

BMES has ethics approval from the Sydney West Area Health Services and the University of Sydney Human Research Ethics Committees. Written informed consent was obtained from all participants.

Data collection:

BMES4 participants' characteristics were collected using comprehensive questionnaires. Questionnaires included questions on demographic, quality of life, eye and general health, and medication use. Weight was measured and height from the BMES3 was used for the calculation of BMI. BMI was calculated as weight (kg) divided by height squared (m^2). BMI $< 18.5 \text{ kg/m}^2$ and BMI $\geq 30 \text{ kg/m}^2$ were considered as underweight and obese, respectively (18).

Dietary data were collected using a 145-item semi-quantitative food frequency questionnaire (FFQ). Validity and reproducibility of the BMES FFQ has been previously reported in this population (19). Dietary data were analysed for nutrient content using the NUTTAB2010 food composition database (20). Since AS content of foods cannot be determined analytically for inclusion in the food composition database, a systematic stepwise method (21) was used to estimate the AS values of food items in the FFQ. This stepwise method includes identification of natural foods and 100% sugar products; use of recipes, analytical data and food labels; comparison of sweetened and unsweetened products; and borrowed data from foreign databases (21).

To exclude under and over reporters, participants with implausible energy and nutrient intakes were excluded according to the BMES data cleaning protocol. For example, extreme energy intake was considered as $<1800\text{kJ}$ or $>2500\text{kJ}$ and extreme AS intake was considered as $\text{mean} \pm 4\text{SD}$. After data cleaning, 971 participants had plausible dietary data, and of these 879 participants had complete data for BMI and confounding variables.

Food grouping in the BMES was based on the 1995 Australian National Nutrition Survey food hierarchy (22) and details of this process have been discussed elsewhere (23). Food groups included in this analysis were fruit (fresh, dried and canned), vegetables including legumes, sugar sweetened beverages (sweetened juices, cordial and soft drink), cereal products (breakfast cereals, bread, rice and pasta), cereal-based products and dishes (biscuits, cakes, buns and scones, pastries, mixed dishes), dairy product and dishes (milk, cheese, yoghurt, custard, ice-cream, cream and dairy-based desserts), sugar products and dishes (discretionary sugar, honey, jam and syrup) and confectionary (lollies and chocolate).

Statistical analyses

Statistical analyses were conducted using SPSS (version 21, SPSS Inc., Chicago, IL, USA). Percentage of energy from AS (EAS%) was classified into three

categories: category 1 (C1): <5%, category 2 (C2):5%-10% and category 3 (C3): >10%. Data were log transformed where they were not normally distributed. The association between EAS% intake and participants' characteristics were investigated using a chi-square test. Differences in food and nutrient intake and BMI across the three EAS% categories were assessed using ANOVA for unadjusted and ANCOVA for adjusted data. For energy adjustment, food and micronutrient data were expressed as a function of energy (per 1MJ/day). In addition, these data were adjusted for age, gender and BMI. Macronutrient data were reported based on percentages of total energy intake and adjusted for age, gender and BMI. The adjusted model for BMI included energy intake, age and gender as covariates. Regression was used to determine the association between EAS% intake and food, nutrients and BMI. Statistical significance was set at $P < 0.05$.

Results

Participants' mean (SEM) intake of AS in C1, C2 and C3 were 16.81(0.58), 40.13 (0.68) and 74.76 (1.59) g/day, respectively. Baseline characteristics of the BMES4 participants are summarised in Table 1. Participants in the highest EAS% category (C3) found to be older than participants in the other EAS% categories. There were fewer men and less married participants in the lowest EAS% category (C1) compared to other categories. A higher proportion of participants with the lowest EAS% intake had diabetes and/or were classified as obese, compared to other EAS% categories. Despite a higher prevalence of underweight in the lowest EAS% category compared to the middle and highest categories, this association was not significant ($P=0.35$). A lower proportion of participants rated their health as poor in

the lowest EAS% category, compared to other categories although the association was not statistically significant.

Nutrient intake across categories of EAS% intake is shown in Table 2. Energy and carbohydrate (E%) intake increased significantly across categories of EAS% ($P_{\text{trend}} < 0.001$), whereas, protein (E%), alcohol (E%), LCn-3 PUFA and fibre intake decreased significantly ($P_{\text{trend}} < 0.001$). For micronutrient intakes, retinol equivalents, vitamins B₆, C and E decreased significantly across EAS% categories ($P_{\text{trend}} < 0.05$). Intakes of vitamin B₁₂ and magnesium were quadratic across EAS% categories ($P_{\text{trend}} < 0.05$). After adjusting for relevant covariates, findings remained the same for majority of nutrients except riboflavin, dietary folate equivalents, vitamins D, B₁₂, calcium, iron and magnesium where intake decreased significantly across EAS% categories. In the multivariate adjusted model, energy and iodine intakes were quadratic across EAS% categories.

Significant differences were observed in intakes of a range of macro and micronutrients between the three categories of EAS% intake. In the adjusted model, intakes of protein (E%), fibre, retinol equivalents, vitamin B₁₂, riboflavin, C, E, zinc and magnesium were significantly lower in the participants of the highest intake category (C3), compared to the other two categories ($P < 0.05$). Participants in the lowest EAS% category (C1) had the lowest energy intake but also the highest alcohol (E%) intake, compared to other categories.

Intake of various food groups, as well as BMI, according to categories of EAS% intake are shown in Table 3. Consumption of the main food sources of AS including sugar products and dishes, confectionary, sugar sweetened beverages and cereal-based products increased significantly across EAS% categories ($P_{\text{trend}} < 0.001$). Fruit, vegetable and fish intake decreased as EAS% increased ($P_{\text{trend}} < 0.001$). In multivariate analyses, findings remained the same for most food groups except for dairy products, meat and fats. After adjusting for covariates, EAS% intake found to be associated with consumption of dairy products and meat, however, the association between EAS% intake and fats did not remain significant. In the adjusted model, participants with the lowest EAS% intake had the highest fruit, vegetable and fish intake compared to the other two categories ($P < 0.05$). They also had the lowest intake of sugar products and dishes, confectionary, sugar sweetened beverages and cereal-based products compared to the other categories ($P < 0.05$). BMI was similar across the three EAS% categories.

Discussion

This is the first study to demonstrate that older adults who adhere to recommended added sugar intakes have improved nutrient intakes, compared to other consumers. The higher intake of nutrients is a result of higher consumption of nutrient dense foods in place of nutrient poor foods that are high in AS, such as sugar sweetened beverages, sugar products and confectionary. Conversely, those with EAS% intakes above the 10% recommendation were more likely to have poorer nutrient intakes.

Our findings from an Australian sample of older adults adds to the limited evidence in this age group. However, our results differ to findings from other studies in terms of types of nutrients affected by the AS-related nutrient dilution (2, 12, 24). In older South Africans, nutrient dilution was observed for a wide range of vitamins and minerals (11), whereas, in an older British population, nutrient dilution was observed only for vitamin C (in men) and calcium (in women) (2), presumably because of an overall better quality diet, regardless of sugar intake, in the latter. The data from the BMES showed a dilution effect for the majority of nutrients including protein, fibre, calcium, retinol equivalents, vitamin C and E. Differences between studies may be related to differences in the definition of AS versus other definitions such as non-milk extrinsic sugar which include natural sugars in fruit juice in their definitions. Alternatively, differences in the use of AS within cuisines, either added to foods as a sweetening agent, or included as part of a processed food product, or through beverage consumption, may have contributed to differences in major sources of AS. Another explanation for inconsistent findings could be use of different dietary data collection methods. While we used a semi-quantitative FFQ, other studies used 24-hour recalls (11) and weighed food records (2).

The role of mandatory or voluntary nutrient fortification used by the food industry is important to consider in the assessment of dietary patterns that are relevant in the nutrient dilution context. Food product fortification may improve the nutritional quality and disguise the nutrient displacement for essential nutrients (25). In Australia, fortification of wheat flour with folate, iodine and thiamin is mandatory, resulting in bread and other cereal products made with wheat flour being a significant source of

these nutrients (26). Voluntary fortification of breakfast cereals by the food industry (26) may also contribute to a higher micronutrient intake in consumers of high sugar breakfast cereals, and thereby, offset nutrient displacement to a certain degree. Additionally, some sweetened dairy products that are fortified with vitamin D, as is permitted under the voluntary fortification scheme (27), may similarly provide vitamin D at the same time as AS, thus confounding the association.

More stringent restriction of guidelines to reduce EAS% intake to 5% has received criticism regarding a lack of evidence related to beneficial dietary and/or health outcomes (28). It has previously been demonstrated that nutrient intakes are similar between low and intermediate EAS% consumers (2, 11). Gibson argues that even a moderately high intake of EAS (8%-15%) does not compromise adequacy of nutrient intakes in older adults (2). Findings from our analyses demonstrate that very low EAS% intake is associated with a significantly higher intake of most nutrients except for calcium, dietary folate equivalents and vitamin D. It is worth noting that the significance of difference between low and middle EAS% categories became evident for most nutrients once the analysis was adjusted for covariates, particularly energy intake. Due to lack of adjustment in other studies, in particular those that included older populations, comparison of our results with published studies is not possible. In a few studies of younger adults, where energy-adjusted results were reported, the statistical difference between intakes according to categories of EAS% has not been discussed (29, 30).

In our sample, low EAS% consumers had higher intakes of nutrient dense foods such as fruit and vegetables, while high EAS% consumers had higher intakes of energy dense, nutrient poor foods such as sugar products, confectionery and sugar sweetened beverages. Other studies have reported higher intakes of fruit, vegetables, fish and dairy in low EAS% consumers (31) and higher intakes of confectionery and sugar sweetened beverages in high EAS% consumers (9, 10). Interestingly, we found that those with the lowest AS intakes had significantly higher alcohol intakes, which suggests that these beverages may be replacing sugar sweetened beverages. Similarly, in African adults, high alcohol consumption was observed in low EAS% consumers (32).

BMI was not significantly different between categories of EAS% intake, despite a lower reported energy intake in the lowest EAS% category. Similar results were observed in South African, British and Australian studies where there were inconsistencies between trends of BMI and energy intakes across categories of EAS% intake (2, 11, 29). A possible explanation for this result may be a higher level of physical activity in high EAS% consumers and/or a higher degree of dietary under-reporting in low EAS% consumers. Misreporting, in particular, under-reporting of sweetened foods and beverages is known to be a methodological constraint within the nutrient density context (24), and is mostly observed in overweight and obese individuals (33). In our cohort, a higher proportion of obese subjects were in the lowest EAS% category compared to other categories. Under-reporting may attenuate the association between AS and nutrient intake (24). However, since we minimised this limitation by excluding participants with implausible intakes during the data

cleaning stage, it is likely that the significant findings observed in this study are a true reflection of association.

Our findings have demonstrated that older adults who have AS intakes in line with the recommendation of less than 5% of total energy have higher intakes of micronutrients, fibre, protein, but also alcohol, compared to those with higher AS intakes. We also found that fewer men reported AS consumption of less than 5% of energy. This suggests that messages to limit AS consumption could be particularly targeted toward men.

Strengths of this study include availability of a relatively large sample size, consideration of nutrients as well as food groups for the analysis, and use of a comprehensive estimation method to assess AS intake. This study had some limitations. Firstly, although participants in the lowest EAS% category consumed more nutrient dense foods, we could not assess whether they met the requirements or had nutrient deficiencies. It was not possible to compare absolute food and micronutrient intake against Australian dietary guidelines (34) and nutrient reference values (35) due to the use of semi-quantitative FFQ. The FFQ is a dietary assessment method that is able to rank consumers according to their intake of food and nutrients but it is not an appropriate tool for estimating absolute dietary intake of individuals (36). Secondly, this study focused only on dietary intake of micronutrients in relation to EAS%, and did not include the use of vitamin or mineral supplements. The percent of people reporting consuming multivitamin supplements did not differ

across the categories of EAS% which suggests that the consumption of multivitamins are not likely to alter the results across categories, nevertheless, this warrants further investigation in other populations.

In conclusion, an intake of added sugars that comprises less than 5% of total energy intake is associated with higher intakes of micronutrients, protein and fibre, while intakes above the 10% of recommendation are associated with lower intakes of these nutrients. Healthier food choices were observed in those with a low proportion of energy provided by AS compared to high consumers, except for alcohol intake, which suggests replacement of sugar sweetened beverages with alcoholic beverages. This study provides evidence of nutrient dilution with increasing intake of added sugars, and suggests that older adults should be encouraged to avoid intakes of AS above 10% of energy. This information may inform dietary messages targeted at optimising diet quality in older adults.

References:

1. Forshee RA, Storey ML. Controversy and Statistical Issues in the Use of Nutrient Densities in Assessing Diet Quality. *The Journal of Nutrition*. 2004;134(10):2733-7.
2. Gibson S. Dietary sugars and micronutrient dilution in normal adults aged 65 years and over. *Public Health Nutrition*. 2001;4(06):1235-44.
3. Engel JH, Siewerdt F, Jackson R, Akobundu U, Wait C, Sahyoun N. Hardiness, Depression, and Emotional Well-Being and Their Association with Appetite in Older Adults. *Journal of the American Geriatrics Society*. 2011;59(3):482-7.
4. Gibson SA. Dietary sugars intake and micronutrient adequacy: a systematic review of the evidence. *Nutrition Research Reviews*. 2007;20(02):121-31.
5. Livingstone MBE, Rennie KL. Added sugars and micronutrient dilution. *Obesity Reviews*. 2009;10:34-40.
6. Louie JCY, Tapsell LC. The impacts of total and added sugars on food and nutrient intake: a systematic literature review. *Nutrition Review* 2015 (In press):doi: 10.1093/nutrit/nuv044.
7. Louie JCY, Tapsell LC. Intake of total and added sugars and nutrient dilution in Australian children and adolescents. *British Journal of Nutrition*. 2015;FirstView (Supplement -1):1-12.
8. Øverby NC, Lillegaard IT, Johansson L, Andersen LF. High intake of added sugar among Norwegian children and adolescents. *Public Health Nutrition*. 2004;7(02):285-93.
9. Joyce T, Gibney MJ. The impact of added sugar consumption on overall dietary quality in Irish children and teenagers. *Journal of Human Nutrition and Dietetics*. 2008;21(5):438-50.
10. Ruottinen S, Niinikoski H, Lagström H, Rönnemaa T, Hakanen M, Viikari J, et al. High Sucrose Intake Is Associated With Poor Quality of Diet and Growth Between 13 Months and 9 Years of Age: The Special Turku Coronary Risk Factor Intervention Project. *Pediatrics*. 2008;121(6):e1676-e85.
11. Charlton KE, Kolbe-Alexander TL, Nel JH. Micronutrient dilution associated with added sugar intake in elderly black South African women. *Eur J Clin Nutr*. 2005;59(9):1030-42.
12. Forshee RA, Storey ML. The role of added sugars in the diet quality of children and adolescents. *Journal of the American College of Nutrition*. 2001;20(1):32-43.
13. Institute of Medicine. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids. Washington, D.C: National Academies Press; 2005.
14. Johnson RK, Appel LJ, Brands M, Howard BV, Lefevre M, Lustig RH, et al. Dietary Sugars Intake and Cardiovascular Health: A Scientific Statement From the American Heart Association. *Circulation*. 2009;120(11):1011-20.
15. US Department of Agriculture and US Department of Health and Human Services. Scientific Report of the 2015 Dietary Guidelines Advisory Committee 2015 [25 July 2015]. Available from: https://ods.od.nih.gov/About/2015_DGAC_Report.aspx.
16. World Health Organization. Guideline: Sugars intake for adults and children. Geneva: 2015.
17. Flood VM, Smith W, Rochtchina E, Wang JJ, Mitchell P. Assembling a nutrient database for a large cohort study: The Blue Mountains Eye Study. *Food Australia*. 2008;60(1-2):37-40.

18. World Health Organization. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. Geneva 1995.
19. Smith W, Mitchell P, Reay EM, Webb K, Harvey PWJ. Validity and reproducibility of a self-administered food frequency questionnaire in older people. *Australian and New Zealand Journal of Public Health*. 1998;22(4):456-63.
20. Food Standards Australia New Zealand. NUTTAB 2010. Canberra, Australia, FSANZ. 2010.
21. Louie JCY, Moshtaghian H, Boylan S, Flood VM, Rangan AM, Barclay AW, et al. A systematic methodology to estimate added sugar content of foods. *Eur J Clin Nutr*. 2015;69(2):154-61.
22. McLennan W, Podger A. National Nutrition Survey Nutrient Intakes and Physical Measurements. Canberra: Australian Bureau of Statistics 1998.
23. Louie JCY, Flood VM, Rangan AM, Burlutsky G, Gill TP, Gopinath B, et al. Higher regular fat dairy consumption is associated with lower incidence of metabolic syndrome but not type 2 diabetes. *Nutrition, Metabolism and Cardiovascular Diseases*. 2013;23(9):816-21.
24. Rennie KL, Livingstone MBE. Associations between dietary added sugar intake and micronutrient intake: a systematic review. *British Journal of Nutrition*. 2007;97(05):832-41.
25. Alexy U, Sichert-Hellert W, Kersting M. Fortification Masks Nutrient Dilution due to Added Sugars in the Diet of Children and Adolescents. *The Journal of Nutrition*. 2002;132(9):2785-91.
26. Food Standards Australia New Zealand. Vitamins and minerals added to food 2012 [30 August 2015]. Available from: <http://www.foodstandards.gov.au/consumer/nutrition/vitaminadded/Pages/default.aspx>.
27. Food Standards Australia New Zealand. Australia New Zealand Food Standards Code - Standard 1.3.2 - Vitamins and Minerals 2014 [31 August 2015]. Available from: <https://www.comlaw.gov.au/Details/F2014C01184>.
28. Erickson J, Slavin J. Total, Added, and Free Sugars: Are Restrictive Guidelines Science-Based or Achievable? *Nutrients*. 2015;7(4):2866-78.
29. Cobiac L, Record S, Leppard P, Syrette J, Flight I. Sugars in the Australian diet: results from the 1995 National Nutrition Survey. 2003;60(3):152-73.
30. Marriott BP, Olsho L, Hadden L, Connor P. Intake of Added Sugars and Selected Nutrients in the United States, National Health and Nutrition Examination Survey (NHANES) 2003—2006. *Critical Reviews in Food Science and Nutrition*. 2010;50(3):228-58.
31. Kranz S, Smiciklas-Wright H, Siega-Riz AM, Mitchell D. Adverse effect of high added sugar consumption on dietary intake in American preschoolers. *The Journal of Pediatrics*. 2005;146(1):105-11.
32. Vorster HH, Kruger A, Wentzel-Viljoen E, Kruger HS, Margetts BM. Added sugar intake in South Africa: findings from the Adult Prospective Urban and Rural Epidemiology cohort study. *The American Journal of Clinical Nutrition*. 2014;99(6):1479-86.
33. Krebs-Smith SM, Graubard BI, Kahle LL, Subar AF, Cleveland LE, Ballard-Barbash R. Low energy reporters vs others: a comparison of reported food intakes. *European Journal Of Clinical Nutrition*. 2000;54(4):281-7.
34. National Health Medical Research Council. Dietary guidelines for Australians. Canberra: Australian Govt. Pub. Service, 2013 Contract No.: N55a.
35. Australian Commonwealth Department of Health and Ageing, National Health and Medical Research Council (Australia). Nutrient reference values for Australia and New Zealand: including recommended dietary intakes: Canberra, A.C.T., NHMRC.; 2006.

- 391 36. Wrieden W, Peace H, Armstrong J, Barton K, editors. A short review of dietary
392 assessment methods used in National and Scottish Research Studies. Briefing Paper Prepared
393 for: Working Group on Monitoring Scottish Dietary Targets Workshop Edinburgh; 2003.

Table 1. Background characteristics of participants of Blue Mountain Eye Study 4.

	Percentage energy from added sugar (EAS%)						P ¹
Characteristics	C1: < 5.00%		C2: 5%-10%		C3: >10%		
n	181		406		292		
	Mean	SEM	Mean	SEM	Mean	SEM	
Age (y)	75.33	0.50	75.61	0.32	77.60	0.39	0.004
	n	%	n	%	n	%	
Women	111	61.33	242	59.61	149	51.03	0.034
Smoking	84	46.41	171	42.12	136	46.58	0.682
Employed	17	9.44	37	9.16	19	6.55	0.641
Poor self-health rated	4	2.21	11	2.71	14	4.79	0.293
Married	85	47.75	260	64.20	165	56.90	0.001
Qualification after leaving school	117	66.10	271	68.78	192	68.09	0.817
Home ownership	162	90.00	357	88.15	264	90.41	0.625
Living alone	78	43.33	119	29.38	100	34.25	0.087
Hypertension	112	61.88	222	54.68	153	52.40	0.121
Hypercholesterolemia	87	48.07	187	46.06	136	46.58	0.903
Diabetes	43	23.76	44	10.84	20	6.85	<0.001
Obesity	51	28.18	109	26.85	54	18.49	0.016
Underweight	4	2.21	7	1.72	2	0.68	0.351
Multivitamin use	76	41.99	158	38.92	112	38.36	0.760

¹ All P values were assessed using Pearson Chi square except for age where p for trend was assessed using linear regression.

Table 2. Nutrients intake in Blue Mountain Eye Study 4 participants according to categories of energy from added sugar (EAS%)¹

	Unadjusted analyses								Multi-variate adjusted analyses ²							
	Percentage energy from added sugar (EAS%)								Energy from added sugar (EAS%)							
	C1: < 5.00%		C2: 5%-10%		C3: >10%		β coefficient*	P _{trend}	C1: < 5.00%		C2: 5%-10%		C3: >10%		β coefficient*	P _{trend}
n	181		406		292				181		406		292			
	Mean	SEM	Mean	SEM	Mean	SEM			Mean	SEM	Mean	SEM	Mean	SEM		
Energy intake (kJ)	8211.28 ^a	196.46	9001.23	121.37	9113.03 ^c	153.05	0.118	<0.001	8277.27 ^a	186.40	9039.64	124.42	9018.73 ^c	147.93	0.102	<0.001
Carbohydrate (E%)	39.32 ^a	0.57	43.02	0.31	46.27 ^{b,c}	0.33	0.398	<0.001	39.39 ^a	0.47	43.06	0.31	46.18 ^{b,c}	0.37	0.390	<0.001
Fat (E%)	32.28	0.49	32.03	0.29	32.51	0.32	-0.014	0.675	32.27	0.44	32.02	0.29	32.52	0.35	-0.014	0.989
Protein (E%)	19.78 ^a	0.27	18.37	0.15	16.47 ^{b,c}	0.16	-0.387	<0.001	19.66 ^a	0.22	18.30	0.15	16.65 ^{b,c}	0.18	-0.362	<0.001
Alcohol (E%)	4.59 ^a	0.48	3.24	0.23	2.38 ^c	0.21	-0.146	<0.001	4.66 ^a	0.34	3.28	0.23	2.28 ^{b,c}	0.27	-0.152	<0.001
Fiber (g)	32.70	0.99	32.68	0.59	28.81 ^{b,c}	0.61	-0.144	<0.001	4.03 ^a	0.07	3.65	0.05	3.20 ^{b,c}	0.06	-0.338	<0.001
LCn-3 PUFA (mg)	559.80	39.03	466.42	20.96	377.63 ^{b,c}	16.65	0.176	<0.001	67.63 ^a	3.12	51.17	2.09	42.41 ^{b,c}	2.48	-0.230	<0.001
Thiamin (mg)	1.70	0.05	1.81	0.03	1.73	0.05	0.003	0.939	0.21	0.01	0.20	0.00	0.19 ^{b,c}	0.00	-0.083	0.059
Vitamin B ₁₂ (μg)	3.37	0.13	3.44	0.08	3.13 ^b	0.09	-0.081	0.016	0.41 ^a	0.01	0.38	0.01	0.35 ^{b,c}	0.01	-0.196	<0.001
Riboflavin (mg)	2.30	0.07	2.37	0.05	2.19 ^b	0.05	-0.055	0.103	0.28 ^a	0.01	0.26	0.00	0.25 ^{b,c}	0.00	-0.159	<0.001
Vitamin B ₆ (mg)	1.28	0.04	1.23	0.02	1.08 ^{b,c}	0.02	-0.156	<0.001	0.16 ^a	0.00	0.14	0.00	0.12 ^{b,c}	0.00	-0.351	<0.001
Retinol equivalent (μg)	2004.58	152.24	1810.00	53.02	1654.07 ^{b,c}	100.99	-0.143	<0.001	239.98 ^a	15.86	203.03	10.58	197.06 ^{b,c}	12.58	-0.212	<0.001
Vitamin C (mg)	189.59 ^a	8.78	162.11	4.25	138.50 ^{b,c}	4.42	-0.192	<0.001	23.36 ^a	0.72	18.25	0.48	15.59 ^{b,c}	0.57	-0.279	<0.001
Vitamin E (mg)	8.70	0.29	8.64	0.18	8.14	0.23	-0.070	0.039	1.07 ^a	0.03	0.97	0.02	0.89 ^{b,c}	0.02	-0.183	<0.001
Vitamin D (μg)	1.09	0.07	1.10	0.04	1.01	0.05	-0.066	0.051	0.13	0.01	0.12	0.00	0.11 ^c	0.01	-0.108	0.0001
Dietary folate equivalents (μg)	636.00	17.93	673.96	11.87	665.30	15.71	0.035	0.300	79.69	1.86	76.29	1.24	74.41 ^c	1.48	-0.078	0.044
Iron (mg)	13.06	0.33	13.69	0.21	12.75 ^b	0.25	-0.040	0.238	1.61 ^a	0.02	1.53	0.02	1.41 ^{b,c}	0.02	-0.237	<0.001
Calcium (mg)	972.23	34.84	1032.31	22.44	942.21 ^b	23.99	-0.022	0.510	117.85	2.95	114.61	1.97	104.48 ^{b,c}	2.34	-0.130	<0.001
Zinc (mg)	12.97	0.34	13.53	0.20	12.51 ^b	0.24	-0.062	0.067	1.58 ^a	0.02	1.51	0.01	1.39 ^{b,c}	0.02	-0.279	<0.001
Magnesium (mg)	369.58	9.16	377.03	5.59	340.79 ^{b,c}	6.54	-0.104	0.002	45.30 ^a	0.52	42.05	0.35	37.67 ^{b,c}	0.41	-0.377	<0.001
Iodine (μg)	112.28 ^a	4.22	126.17	2.64	119.06	3.18	0.032	0.338	13.70	0.38	14.10	0.25	13.09 ^b	0.30	-0.057	0.008

¹ Difference between categories was assessed using ANOVA for unadjusted analyses and ANCOVA for multivariate analyses. P_{trend} was assessed using linear regression.

^a Difference between C1 and C2 p<0.05

^b Difference between C3 and C2 p<0.05

^c Difference between C3 and C1 p<0.05

² All data were adjusted for energy (nutrient/1000kJ), age, gender and BMI except for intakes of energy, carbohydrate (E%), fat (E%), protein (E%), and alcohol (E%) which were adjusted for age, gender and BMI.

*Standardised β coefficient

Table 3. Food group intake and BMI in the Blue Mountain Eye Study 4 participants according to categories of energy from added sugar (EAS%)¹

	Unadjusted analyses								Multi-variate adjusted analyses ²							
	Percentage energy from added sugar (EAS%)								Percentage energy from added sugar (EAS%)							
	C1: < 5.00%		C2: 5%-10%		C3: >10%		β coefficient*	P _{trend}	C1: < 5.00%		C2: 5%-10%		C3: >10%		β coefficient*	P _{trend}
n	181		406		292				181		406		292			
	Mean	SEM	Mean	SEM	Mean	SEM			Mean	SEM	Mean	SEM	Mean	SEM		
Food groups intake (g)																
Vegetables	503.34	17.27	492.37	10.56	429.31 ^{b,c}	11.67	-0.147	<0.001	62.27 ^a	1.68	55.47	1.12	48.85 ^{b,c}	1.33	-0.224	<0.001
Fruit	520.73	29.80	425.44	14.65	339.28 ^{b,c}	13.65	-0.158	<0.001	62.92 ^a	2.33	47.40	1.56	37.61 ^{b,c}	1.85	-0.228	<0.001
Cereal Products	193.35	9.44	216.24	6.68	206.87	8.28	0.106	0.002	24.02	1.03	24.27	0.69	22.34	0.82	0.026	0.001
Cereal-based products and dishes	19.52 ^a	1.25	36.70	1.52	46.76 ^{b,c}	2.00	0.400	<0.001	2.45 ^a	0.20	4.00	0.14	4.95 ^{b,c}	0.16	0.372	<0.001
Sugar sweetened beverages	23.89 ^a	3.15	37.14	2.63	93.30 ^{b,c}	7.44	0.320	<0.001	2.71 ^a	0.72	4.06	0.48	10.79 ^{b,c}	0.57	0.327	<0.001
Dairy product and dishes	355.09 ^a	20.56	389.75	14.64	347.77	14.13	0.028	0.403	42.97	2.21	43.36	1.48	38.79	1.76	-0.012	0.005
Meat	144.58	6.36	147.74	3.72	138.54	4.41	-0.043	0.204	17.45	0.56	16.40	0.37	15.47 ^c	0.44	-0.105	<0.001
Fish	29.48 ^a	2.50	24.65	1.45	18.30 ^{b,c}	1.29	-0.178	<0.001	3.58 ^a	0.22	2.69	0.15	2.08 ^{b,c}	0.18	-0.216	<0.001
Alcoholic beverages	203.51	26.86	146.68	14.39	98.49 ^{b,c}	10.87	-0.095	0.005	25.19	2.16	16.36	1.44	10.13 ^{b,c}	1.71	-0.121	<0.001
Confectionary	3.96 ^a	0.45	13.37	0.73	28.74 ^{b,c}	1.97	0.443	<0.001	0.48 ^a	0.16	1.44	0.11	3.02 ^{b,c}	0.13	0.431	<0.001
Sugar product and dishes	5.44 ^a	0.51	19.83	0.61	41.69 ^{b,c}	1.50	0.694	<0.001	0.65 ^a	0.14	2.24	0.09	4.64 ^{b,c}	0.11	0.695	<0.001
Fats	12.07	0.70	13.47	0.51	14.41 ^c	0.55	0.116	0.001	1.49	0.08	1.53	0.06	1.64	0.07	0.075	0.218
BMI (kg/m ²)	27.59	0.38	27.37	0.25	26.59	0.26	-0.051	0.129	27.37	0.35	27.31	0.24	26.81	0.28	-0.023	0.490

¹ Difference between categories was assessed using ANOVA for unadjusted analyses and ANCOVA for multivariate analyses. P_{trend} was assessed using linear regression.

^a Difference between C1 and C2 $p < 0.05$.

^b Difference between C3 and C2 $p < 0.05$.

^c Difference between C3 and C1 $p < 0.05$

² All food groups were adjusted for energy (grams/1000kJ), BMI, age and gender. BMI was adjusted for age, gender and energy intake

*Standardised β coefficient

Highlights

- We assessed the association between added sugar, and food and nutrient intake in older Australians
- Intake of >10% of energy from added sugar was associated with higher energy intake
- High added sugar consumers had lower protein, vitamin C, E and zinc intake
- Low added sugar consumers had higher intake of alcohol, fruit, vegetable and fish