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

Hanieh Moshtaghian
*University of Wollongong, hm389@uowmail.edu.au*

Jimmy Chun Yu Louie
*University of Sydney, jlouie@uow.edu.au*

Karen E. Charlton
*University of Wollongong, karenc@uow.edu.au*

Yasmine Probst
*University of Wollongong, yasmine@uow.edu.au*

Bamini Gopinath
*University of Sydney, bamini.gopinath@sydney.edu.au*

*See next page for additional authors*

Publication Details

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

Hanieh Moshtaghian Ph.D. candidate\textsuperscript{a}, Jimmy Chun Yu Louie Ph.D.\textsuperscript{b,c}, Karen E Charlton Ph.D.\textsuperscript{a}, Yasmine C Probst Ph.D.\textsuperscript{a}, Bamini Gopinath Ph.D.\textsuperscript{d}, Paul Mitchell Ph.D.\textsuperscript{d}, Victoria M Flood Ph.D.\textsuperscript{e,f}.

\textsuperscript{a}School of Medicine, Faculty of Science, Medicine and Health, University of Wollongong, Wollongong, NSW 2522, Australia

\textsuperscript{b}School of Life and Environmental Sciences, Faculty of Science, University of Sydney, Sydney, NSW 2006, Australia

\textsuperscript{c}School of Biological Sciences, Faculty of Science, The University of Hong Kong, Pokfulam, Hong Kong

\textsuperscript{d}Center for Vision Research, Department of Ophthalmology and Westmead Millennium Institute, University of Sydney, Sydney, NSW2145, Australia

\textsuperscript{e}St Vincent’s Hospital, Sydney, NSW 2010, Australia

\textsuperscript{f}Faculty of Health Sciences, University of Sydney, Sydney, NSW 2141, Australia

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* To whom correspondence should be addressed, e-mail: vicki.flood@sydney.edu.au

Tel.: +612-8382 2402, Fax +612-9351 9001.

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 (Pₜₚₑ₅d<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 Pₜₚₑ₅d <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.
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 measured 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 kg/m$^2$ and BMI $\geq$ 30 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 <1800kJ or >2500kJ and extreme AS intake was considered as mean±4SD. 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 B$_6$, C and E decreased significantly across EAS% categories ($P_{\text{trend}} <0.05$). Intakes of vitamin B$_{12}$ 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, B$_{12}$, 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 B$_{12}$, 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 deceased 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:


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

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>C1: &lt; 5.00%</th>
<th>C2: 5%-10%</th>
<th>C3: &gt;10%</th>
<th>P1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SEM</td>
<td>Mean</td>
<td>SEM</td>
</tr>
<tr>
<td>Age (y)</td>
<td>75.33</td>
<td>0.50</td>
<td>75.61</td>
<td>0.32</td>
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<tr>
<td>Women</td>
<td>111</td>
<td>61.33</td>
<td>242</td>
<td>59.61</td>
</tr>
<tr>
<td>Smoking</td>
<td>84</td>
<td>46.41</td>
<td>171</td>
<td>42.12</td>
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<td>Employed</td>
<td>17</td>
<td>9.44</td>
<td>37</td>
<td>9.16</td>
</tr>
<tr>
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<td>4</td>
<td>2.21</td>
<td>11</td>
<td>2.71</td>
</tr>
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<td>Married</td>
<td>85</td>
<td>47.75</td>
<td>260</td>
<td>64.20</td>
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<td>Qualification after leaving school</td>
<td>117</td>
<td>66.10</td>
<td>271</td>
<td>68.78</td>
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<td>Home ownership</td>
<td>162</td>
<td>90.00</td>
<td>357</td>
<td>88.15</td>
</tr>
<tr>
<td>Living alone</td>
<td>78</td>
<td>43.33</td>
<td>119</td>
<td>29.38</td>
</tr>
<tr>
<td>Hypertension</td>
<td>112</td>
<td>61.88</td>
<td>222</td>
<td>54.68</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>87</td>
<td>48.07</td>
<td>187</td>
<td>46.06</td>
</tr>
<tr>
<td>Diabetes</td>
<td>43</td>
<td>23.76</td>
<td>44</td>
<td>10.84</td>
</tr>
<tr>
<td>Obesity</td>
<td>51</td>
<td>28.18</td>
<td>109</td>
<td>26.86</td>
</tr>
<tr>
<td>Underweight</td>
<td>4</td>
<td>2.21</td>
<td>7</td>
<td>1.72</td>
</tr>
<tr>
<td>Multivitamin use</td>
<td>76</td>
<td>41.99</td>
<td>158</td>
<td>38.92</td>
</tr>
</tbody>
</table>

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%)\(^1\)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>C1: &lt; 5.00%</th>
<th>C2: 5%-10%</th>
<th>C3: &gt;10%</th>
<th>(\beta) coefficient(^*)</th>
<th>(P_{\text{trend}})</th>
<th>C1: &lt; 5.00%</th>
<th>C2: 5%-10%</th>
<th>C3: &gt;10%</th>
<th>(\beta) coefficient(^*)</th>
<th>(P_{\text{trend}})</th>
</tr>
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<tbody>
<tr>
<td>n</td>
<td>181</td>
<td>406</td>
<td>292</td>
<td></td>
<td></td>
<td>181</td>
<td>406</td>
<td>292</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy intake (kJ)</td>
<td>8211.28(^a)</td>
<td>1964.46</td>
<td>9001.23</td>
<td>121.37</td>
<td>9113.03(^c)</td>
<td>153.05</td>
<td>0.118</td>
<td>0.001</td>
<td>8277.27(^a)</td>
<td>186.40</td>
</tr>
<tr>
<td>Carbohydrate (E%)</td>
<td>39.32(^a)</td>
<td>0.57</td>
<td>43.02</td>
<td>0.31</td>
<td>46.27(^b)</td>
<td>0.33</td>
<td>0.398</td>
<td>0.001</td>
<td>39.39(^a)</td>
<td>0.47</td>
</tr>
<tr>
<td>Fat (E%)</td>
<td>32.28</td>
<td>0.49</td>
<td>32.03</td>
<td>0.29</td>
<td>32.51</td>
<td>0.32</td>
<td>-0.014</td>
<td>0.675</td>
<td>32.27</td>
<td>0.44</td>
</tr>
<tr>
<td>Protein (E%)</td>
<td>19.78(^a)</td>
<td>0.27</td>
<td>18.37</td>
<td>0.15</td>
<td>16.47(^c)</td>
<td>0.16</td>
<td>-0.387</td>
<td>0.001</td>
<td>19.66(^a)</td>
<td>0.22</td>
</tr>
<tr>
<td>Alcohol (E%)</td>
<td>4.59(^a)</td>
<td>0.48</td>
<td>3.24</td>
<td>0.23</td>
<td>2.38(^b)</td>
<td>0.21</td>
<td>-0.146</td>
<td>0.001</td>
<td>4.66(^a)</td>
<td>0.34</td>
</tr>
<tr>
<td>Fiber (g)</td>
<td>32.70</td>
<td>0.99</td>
<td>32.68</td>
<td>0.59</td>
<td>28.81(^b)</td>
<td>0.61</td>
<td>-0.144</td>
<td>0.001</td>
<td>4.03(^b)</td>
<td>0.07</td>
</tr>
<tr>
<td>LCn-3 PUFA (mg)</td>
<td>559.80</td>
<td>39.03</td>
<td>466.42</td>
<td>20.96</td>
<td>377.63(^c)</td>
<td>16.65</td>
<td>0.176</td>
<td>0.001</td>
<td>67.63(^a)</td>
<td>3.12</td>
</tr>
<tr>
<td>Thiamin (mg)</td>
<td>1.70</td>
<td>0.05</td>
<td>1.81</td>
<td>0.03</td>
<td>1.73</td>
<td>0.05</td>
<td>0.003</td>
<td>0.939</td>
<td>0.21</td>
<td>0.01</td>
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<tr>
<td>Vitamin B2 (µg)</td>
<td>3.37</td>
<td>0.13</td>
<td>3.44</td>
<td>0.08</td>
<td>3.13(^b)</td>
<td>0.09</td>
<td>-0.081</td>
<td>0.016</td>
<td>0.41(^a)</td>
<td>0.01</td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>2.30</td>
<td>0.73</td>
<td>2.27</td>
<td>0.05</td>
<td>2.19(^b)</td>
<td>0.05</td>
<td>-0.055</td>
<td>0.103</td>
<td>0.28(^a)</td>
<td>0.01</td>
</tr>
<tr>
<td>Vitamin B6 (mg)</td>
<td>1.28</td>
<td>0.04</td>
<td>1.23</td>
<td>0.02</td>
<td>1.08(^b)</td>
<td>0.02</td>
<td>-0.156</td>
<td>0.001</td>
<td>0.16(^a)</td>
<td>0.00</td>
</tr>
<tr>
<td>Retinol equivalent (µg)</td>
<td>2004.58</td>
<td>152.24</td>
<td>1810.00</td>
<td>53.02</td>
<td>1654.07(^b)</td>
<td>100.99</td>
<td>-0.143</td>
<td>0.001</td>
<td>239.98(^a)</td>
<td>15.86</td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
<td>189.59(^a)</td>
<td>8.78</td>
<td>162.11</td>
<td>4.25</td>
<td>138.50(^c)</td>
<td>4.42</td>
<td>-0.192</td>
<td>0.001</td>
<td>23.36(^a)</td>
<td>0.72</td>
</tr>
<tr>
<td>Vitamin E (mg)</td>
<td>8.70</td>
<td>0.29</td>
<td>8.64</td>
<td>0.18</td>
<td>8.14</td>
<td>0.23</td>
<td>-0.070</td>
<td>0.039</td>
<td>1.07(^a)</td>
<td>0.03</td>
</tr>
<tr>
<td>Vitamin D (µg)</td>
<td>1.09</td>
<td>0.07</td>
<td>1.10</td>
<td>0.04</td>
<td>1.01</td>
<td>0.05</td>
<td>-0.066</td>
<td>0.051</td>
<td>0.13</td>
<td>0.01</td>
</tr>
<tr>
<td>Dietary folate equivalents (µg)</td>
<td>636.00</td>
<td>17.93</td>
<td>673.96</td>
<td>11.87</td>
<td>665.30</td>
<td>15.71</td>
<td>0.035</td>
<td>0.300</td>
<td>79.69</td>
<td>1.86</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>13.06</td>
<td>0.33</td>
<td>13.69</td>
<td>0.21</td>
<td>12.79(^b)</td>
<td>0.25</td>
<td>-0.040</td>
<td>0.238</td>
<td>1.61(^a)</td>
<td>0.02</td>
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<tr>
<td>Calcium (mg)</td>
<td>972.23</td>
<td>34.84</td>
<td>1032.31</td>
<td>22.44</td>
<td>942.21(^b)</td>
<td>23.99</td>
<td>-0.022</td>
<td>0.510</td>
<td>117.85</td>
<td>2.95</td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>12.97</td>
<td>0.34</td>
<td>13.53</td>
<td>0.20</td>
<td>12.51</td>
<td>0.24</td>
<td>-0.062</td>
<td>0.067</td>
<td>1.58(^a)</td>
<td>0.02</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>369.58</td>
<td>9.16</td>
<td>377.03</td>
<td>5.59</td>
<td>340.79(^c)</td>
<td>6.54</td>
<td>-0.104</td>
<td>0.002</td>
<td>45.30(^a)</td>
<td>0.52</td>
</tr>
<tr>
<td>Iodine (µg)</td>
<td>112.28(^a)</td>
<td>4.22</td>
<td>126.17</td>
<td>2.64</td>
<td>119.06</td>
<td>3.18</td>
<td>0.032</td>
<td>0.338</td>
<td>13.70</td>
<td>0.38</td>
</tr>
</tbody>
</table>

\(^1\) Difference between categories was assessed using ANOVA for unadjusted analyses and ANCOVA for multivariate analyses. \(P_{\text{trend}}\) 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 \(p<0.05\)

\(^\ast\) Standardised \(\beta\) 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%)  

<table>
<thead>
<tr>
<th>Food groups intake (g)</th>
<th>C1: &lt; 5.00%</th>
<th>C2: 5%-10%</th>
<th>C3: &gt;10%</th>
<th>β coefficient</th>
<th>P&lt;sub&gt;trend&lt;/sub&gt;</th>
<th>C1: &lt; 5.00%</th>
<th>C2: 5%-10%</th>
<th>C3: &gt;10%</th>
<th>β coefficient</th>
<th>P&lt;sub&gt;trend&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unadjusted analyses</strong></td>
<td></td>
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<tr>
<td>n</td>
<td>181</td>
<td>406</td>
<td>292</td>
<td></td>
<td></td>
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<tr>
<td>Mean</td>
<td>503.34</td>
<td>29.80</td>
<td>355.09</td>
<td>144.58</td>
<td>134.74</td>
<td>128.07</td>
<td>203.51</td>
<td>29.48</td>
<td>203.51</td>
<td>29.48</td>
</tr>
<tr>
<td>SEM</td>
<td>17.27</td>
<td>14.65</td>
<td>20.56</td>
<td>6.36</td>
<td>4.41</td>
<td>4.41</td>
<td>14.39</td>
<td>2.50</td>
<td>14.39</td>
<td>2.50</td>
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<tr>
<td><strong>Percentage energy from added sugar (EAS%)</strong></td>
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<tr>
<td>Percentage energy from added sugar (EAS%)</td>
<td>10.56</td>
<td>14.65</td>
<td>14.39</td>
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<tr>
<td><strong>Multi-variate adjusted analyses</strong></td>
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</table>

* Difference between categories was assessed using ANOVA for unadjusted analyses and ANCOVA for multivariate analyses. P<sub>trend</sub> 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