Sugar-sweetened beverage intake and its associations with cardiometabolic risks among adolescents

D. A. Loh¹, F. M. Moy¹, N. L. Zaharan², M. Y. Jalaludin³ and Z. Mohamed²

Summary

Background: Investigations on sugar-sweetened beverage (SSB) intake and cardiometabolic risks among Asians are scant.

Objectives: This study aimed to examine associations between SSB intake and cardiometabolic risks among Malaysian adolescents.

Methods: Anthropometric data, blood pressure (BP), fasting blood glucose (FBG), lipid profiles and insulin levels measured involved 873 adolescents (aged 13 years). SSB intake, dietary patterns and physical activity level (PAL) were self-reported.

Results: Mean SSB consumption was 177.5 mL day⁻¹ with significant differences among ethnicities (Malay, Chinese, Indians and Others) (p < 0.05). SSB intake was deleteriously associated with increased waist circumference, elevated triglycerides, FBG, insulin, insulin resistance and low HDL-cholesterol, independent of PAL, body mass index and dietary patterns. Significant U-shaped and inverse trends were noted between SSB intake and LDL-cholesterol and BP, respectively.

Conclusion: Sugar-sweetened beverage intake was unfavourably associated with cardiometabolic health outcomes among young adolescents. Concerted efforts towards healthy hydration are imperative to mitigate risk of cardiometabolic events.

Keywords: Adolescents, metabolic syndrome, obesity, sugar-sweetened beverages.

Introduction

Three-fifths of global sugar-sweetened beverage (SSB) consumption including soft drinks, fruit drinks, energy drinks, flavoured milk and cordials now come from low-income and middle-income countries (1). Increased SSB intake is deleteriously linked to obesity, type 2 diabetes and metabolic syndrome (2,3).

Past studies demonstrated that the weak satiating and non-compensatory effect of SSBs result in greater subsequent energy intake (2). Considerable evidence suggest that glucose increases dietary glycaemic load, while fructose elevates visceral adiposity and promotes metabolic complications (2,4). However, investigations into SSB consumption and cardiometabolic risks remain largely in Western populations (5). This study aims to examine associations between SSB intake and cardiometabolic risks among Malaysian adolescents.

Methods

This cross-sectional study involved 13-year-olds recruited between February and June 2012 from 23 national secondary schools in Kuala Lumpur via multi-stage sampling. Eligible participants included adolescents literate in Malay, undiagnosed with chronic diseases and not on long-term medication.

The Medical Ethics Committee of University of Malaya Medical Centre, Malaysia (MEC 896.123) approved the study. Participating schools granted written permission. Informed parental consent with
demographic information and adolescent assent were obtained prior to data collection.

Height and weight of participants, in light clothing and shoes removed, were measured with a stadiometer (SECA 217, Hamburg, Germany) and a digital floor scale (SECA 813) to the nearest 0.1 cm and 0.1 kg, respectively, by trained enumerators. Body mass index (BMI) in kg m\(^{-2}\) were categorized using International Obesity Task Force (6) and World Health Organization criteria (7). Waist circumference was measured to the nearest 0.1 cm at the midway between the 10th rib and iliac crest using a measuring tape (SECA 203).

Fasting venous blood samples were drawn after an overnight fast of at least 8 h. Serum triglycerides (TG), high-density lipoprotein cholesterol (HDL-C) and plasma glucose were analysed with Dimension RxL Max, whereas insulin was measured by ADVIA Centaur assay XP (Siemens Healthcare Diagnostics Inc., Deerfield, IL, USA). Low-density lipoprotein cholesterol (LDL-C) was calculated with the Friedewald equation (8). Homeostasis model assessment of insulin resistance was calculated; a value of 3 indicated insulin resistance (9). Resting systolic and diastolic blood pressure (BP) was measured. Metabolic syndrome was defined using International Diabetes Federation criteria (10): WC ≥ 90th percentile with ≥2 of the following: TG ≥ 1.7 mmol L\(^{-1}\), HDL-C < 1.03 mmol L\(^{-1}\), BP ≥ 130 mmHg systolic or ≥ 85 mmHg diastolic or FBG ≥ 5.6 mmol L\(^{-1}\). Pubertal stage was self-assessed using coloured Tanner stages illustrations. Physical activity level (PAL) was self-reported with the nine-item Physical Activity Questionnaire for Children; a summary score of 1 (low PAL) and 5 (high PAL) (11). Dietary patterns including intake, health behaviour, attitude, environment and knowledge were assessed using a validated, adapted Malay version of the modified Child Nutrition Questionnaire. Overall, a higher summary score indicated healthier dietary patterns (12).

Sugar-sweetened beverage referred to carbonated drinks, sugar-sweetened fruit drinks, non-dairy beverages or tetra-packed drinks. Each participant was asked “How many times in the past 7 days did you drink SSBs (1 cup = 250 mL)?” to calculate mean daily SSB intake.

Complex samples (CS) univariate analyses were performed on weighted data. CS general linear models determined associations between SSB intake (continuous variable) and each cardiometabolic risk adjusted for gender, ethnicity, maternal education (as a proxy for socio-economic status and indexed as none, primary, secondary or tertiary education level), pubertal stage and PAL (Model 1), additional adjustment for BMI (Model 2) and dietary patterns (Child Nutrition Questionnaire scores) (Model 3). Data were analysed with SPSS 22.0 (IBM Corp., Armonk, NY, USA) (13) with statistical significance set at \(p < 0.05\).

**Results**

The study involved 873 participants, predominantly Malays (76%) followed by Chinese (12%), Indians (10%) and other ethnicities (2%). Sample characteristics of participants by mean SSB intake and tertiles are presented (Table 1). SSB intake was significantly different among the ethnicities \(p < 0.05\). Average SSB consumption was 0.71 servings/day (177.5 mL daily), highest among Malays (190 mL day\(^{-1}\)) followed by Indians (138 mL day\(^{-1}\)) and Chinese (110 mL day\(^{-1}\)). Mean BMI was 20.73 ± 0.29 kg m\(^{-2}\) with 19% overweight and 10% obese (International Obesity Task Force criteria) or 19% overweight and 15% obese adolescents (World Health Organization cutoffs). Higher SSB consumption corresponded with high levels of TG, FBG, insulin, homeostasis model assessment of insulin resistance and low HDL-C; however, these did not reach statistical significance. While unfavourable cardiometabolic effects were observed across the SSB tertiles, none of these were statistically significant except for ethnic differences.

Multivariate analyses showed that all metabolic parameters were significantly associated with SSB intake when adjusted for confounders (Table 2). U-shaped and inverse trends were noted between SSB intake and LDL-C and BP, respectively. Statistical significance persisted after additional adjustments for BMI and dietary patterns.

**Discussion**

This study presents associations between SSB intake and cardiometabolic risks among Malaysian adolescents. Average SSB consumption was 177.5 mL day\(^{-1}\), lower than Australian (436 mL day\(^{-1}\)) (14) and European adolescents (227.7 mL day\(^{-1}\)) (15). Given the escalating paediatric obesity rates in Malaysia (16), underestimation of SSB intake is plausible (17).

Ethnic differences in SSB consumption may be attributed to their varying sociocultural practices and dietary habits (18). This merits further investigations to identify risk factors of disease patterns.

Higher SSB consumption corresponded with elevated TG, FBG, insulin, insulin resistance and low HDL-C, however, were statistically insignificant. When adjusted for confounders, most metabolic parameters were deleteriously associated with SSB...
intake, independent of PAL, BMI and dietary patterns. U-shaped and inverse trends were noted between SSB intake and LDL-C and BP, respectively. These metabolic consequences may be associated with the calorie-sweetened beverages consumption and the fructose therein (3), exacerbated by obesity (19). Causality could not be established because of the study design. Under-reporting and recall bias in

<table>
<thead>
<tr>
<th>Characteristics/clinical parameters</th>
<th>Categories</th>
<th>n (%)</th>
<th>SSB intake (serving&lt;sup&gt;#&lt;/sup&gt;)&lt;sup&gt;†&lt;/sup&gt; (mean ± SE)</th>
<th>p</th>
<th>SSB tertiles (mean ± SE)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
<td>249 (27.2)</td>
<td>0.68 ± 0.08</td>
<td>0.79</td>
<td>0.13 ± 0.01</td>
<td>0.50 ± 0.01</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>632 (72.8)</td>
<td>0.67 ± 0.03</td>
<td>0.67 ± 0.01</td>
<td>0.12 ± 0.01</td>
<td>0.49 ± 0.01</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>Malay</td>
<td>666 (66.4)</td>
<td>0.76 ± 0.04</td>
<td>0.03</td>
<td>0.12 ± 0.01</td>
<td>0.48 ± 0.01</td>
</tr>
<tr>
<td></td>
<td>Chinese</td>
<td>100 (19.1)</td>
<td>0.44 ± 0.05</td>
<td>0.40 ± 0.01</td>
<td>0.11 ± 0.02</td>
<td>0.52 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>Indian</td>
<td>90 (12.1)</td>
<td>0.55 ± 0.10</td>
<td>0.11 ± 0.02</td>
<td>0.53 ± 0.02</td>
<td>1.36 ± 0.20</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>25 (2.3)</td>
<td>0.63 ± 0.21</td>
<td>0.07 ± 0.03</td>
<td>0.15 ± 0.05</td>
<td>0.56 ± 0.21</td>
</tr>
<tr>
<td>Maternal education</td>
<td>Primary</td>
<td>63 (11.0)</td>
<td>0.62 ± 0.07</td>
<td>0.17</td>
<td>0.12 ± 0.03</td>
<td>0.48 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>Secondary</td>
<td>383 (61.4)</td>
<td>0.74 ± 0.05</td>
<td>0.12 ± 0.01</td>
<td>0.49 ± 0.01</td>
<td>1.49 ± 0.10</td>
</tr>
<tr>
<td></td>
<td>Tertiary</td>
<td>143 (27.6)</td>
<td>0.61 ± 0.06</td>
<td>0.10 ± 0.02</td>
<td>0.48 ± 0.01</td>
<td>1.43 ± 0.21</td>
</tr>
<tr>
<td>Body mass index&lt;sup&gt;†&lt;/sup&gt; (kg m&lt;sup&gt;2&lt;/sup&gt;/C0&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>Underweight</td>
<td>81 (8.3)</td>
<td>0.61 ± 0.09</td>
<td>0.48</td>
<td>20.82 ± 0.35</td>
<td>20.72 ± 0.26</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>543 (61.2)</td>
<td>0.71 ± 0.04</td>
<td>0.17</td>
<td>20.72 ± 0.26</td>
<td>20.40 ± 0.31</td>
</tr>
<tr>
<td></td>
<td>Overweight</td>
<td>169 (20.5)</td>
<td>0.62 ± 0.06</td>
<td>0.10</td>
<td>20.72 ± 0.26</td>
<td>20.40 ± 0.31</td>
</tr>
<tr>
<td></td>
<td>Obese</td>
<td>88 (10.0)</td>
<td>0.63 ± 0.07</td>
<td>0.10</td>
<td>20.72 ± 0.26</td>
<td>20.40 ± 0.31</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>&lt;90th percentile</td>
<td>751 (84.9)</td>
<td>0.70 ± 0.04</td>
<td>0.77</td>
<td>70.04 ± 0.83</td>
<td>69.05 ± 0.64</td>
</tr>
<tr>
<td></td>
<td>≥90th percentile</td>
<td>121 (15.1)</td>
<td>0.68 ± 0.07</td>
<td>0.68 ± 0.07</td>
<td>0.68 ± 0.07</td>
<td>0.68 ± 0.07</td>
</tr>
<tr>
<td>Triglycerides (mmol L&lt;sup&gt;−1&lt;/sup&gt;)</td>
<td>Normal</td>
<td>763 (94.2)</td>
<td>0.68 ± 0.03</td>
<td>0.13</td>
<td>0.94 ± 0.02</td>
<td>1.00 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>47 (5.8)</td>
<td>0.87 ± 0.12</td>
<td>0.94 ± 0.02</td>
<td>1.00 ± 0.02</td>
<td>0.99 ± 0.03</td>
</tr>
<tr>
<td>HDL cholesterol (mmol L&lt;sup&gt;−1&lt;/sup&gt;)</td>
<td>Normal</td>
<td>782 (87.3)</td>
<td>0.70 ± 0.03</td>
<td>0.46</td>
<td>1.38 ± 0.02</td>
<td>1.43 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>96 (12.7)</td>
<td>0.71 ± 0.09</td>
<td>1.38 ± 0.02</td>
<td>1.43 ± 0.02</td>
<td>1.44 ± 0.02</td>
</tr>
<tr>
<td>LDL cholesterol (mmol L&lt;sup&gt;−1&lt;/sup&gt;)</td>
<td>Normal</td>
<td>881 (100.0)</td>
<td>2.72 ± 0.02</td>
<td>2.72 ± 0.02</td>
<td>2.69 ± 0.04</td>
<td>2.75 ± 0.04</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0 (0.0)</td>
<td>—</td>
<td>2.77 ± 0.05</td>
<td>2.69 ± 0.04</td>
<td>2.75 ± 0.04</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>Normal</td>
<td>856 (98.2)</td>
<td>0.70 ± 0.03</td>
<td>0.20</td>
<td>105.05 ± 0.77</td>
<td>103.87 ± 0.62</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>20 (1.8)</td>
<td>0.45 ± 0.10</td>
<td>20.45 ± 0.10</td>
<td>20.45 ± 0.10</td>
<td>20.45 ± 0.10</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>Normal</td>
<td>852 (97.9)</td>
<td>0.70 ± 0.03</td>
<td>0.31</td>
<td>63.96 ± 0.62</td>
<td>63.28 ± 0.48</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>24 (2.1)</td>
<td>0.49 ± 0.09</td>
<td>63.96 ± 0.62</td>
<td>63.28 ± 0.48</td>
<td>63.39 ± 0.61</td>
</tr>
<tr>
<td>Fasting blood glucose (mmol L&lt;sup&gt;−1&lt;/sup&gt;)</td>
<td>Normal</td>
<td>867 (98.2)</td>
<td>0.70 ± 0.03</td>
<td>0.96</td>
<td>4.63 ± 0.03</td>
<td>4.69 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>14 (1.8)</td>
<td>0.75 ± 0.14</td>
<td>4.63 ± 0.03</td>
<td>4.69 ± 0.02</td>
<td>4.70 ± 0.03</td>
</tr>
<tr>
<td>HOMA-IR</td>
<td>Normal</td>
<td>545 (60.0)</td>
<td>0.68 ± 0.04</td>
<td>0.27</td>
<td>3.26 ± 0.25</td>
<td>3.14 ± 0.13</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>323 (40.0)</td>
<td>0.73 ± 0.05</td>
<td>3.26 ± 0.25</td>
<td>3.14 ± 0.13</td>
<td>3.05 ± 0.12</td>
</tr>
<tr>
<td>Insulin (uU mL&lt;sup&gt;−1&lt;/sup&gt;)</td>
<td>Normal</td>
<td>709 (78.2)</td>
<td>0.69 ± 0.03</td>
<td>0.90</td>
<td>15.73 ± 1.11</td>
<td>15.01 ± 0.65</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>159 (21.8)</td>
<td>0.72 ± 0.07</td>
<td>15.73 ± 1.11</td>
<td>15.01 ± 0.65</td>
<td>14.46 ± 0.57</td>
</tr>
</tbody>
</table>

*Missing data present.
*<sup>1</sup> serving = 250 mL.
*<sup>2</sup>BMI was categorized according to International Obesity Task Force criteria.
HDL, high-density lipoprotein; HOMA-IR, homeostasis model assessment of insulin resistance; LDL, low-density lipoprotein; SE, standard error; SSB, sugar-sweetened beverage.
Table 2 Associations between cardiometabolic risks and SSB intake among adolescents using different models of regression (n = 881)

<table>
<thead>
<tr>
<th>Clinical parameters</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SE</td>
<td>95% CI</td>
<td>p</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>68.9 ± 0.6</td>
<td>67.5–70.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Triglycerides (mmol L⁻¹)</td>
<td>0.99 ± 0.19</td>
<td>0.54–1.43</td>
<td>0.001</td>
</tr>
<tr>
<td>HDL cholesterol (mmol L⁻¹)</td>
<td>1.10 ± 0.24</td>
<td>0.55–1.64</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LDL cholesterol (mmol L⁻¹)</td>
<td>3.25 ± 0.28</td>
<td>2.62–3.89</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>104 ± 2</td>
<td>100–109</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>63 ± 1</td>
<td>60–66</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Glucose (mmol L⁻¹)</td>
<td>4.74 ± 0.16</td>
<td>4.37–5.11</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HOMA-IR</td>
<td>2.83 ± 0.19</td>
<td>2.39–3.28</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Insulin (uU mL⁻¹)</td>
<td>13.50 ± 0.90</td>
<td>11.42–15.57</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Missing data present.

1 Complex samples general linear models were performed. Model 1 was adjusted for gender, ethnicity, maternal education, pubertal stage and physical activity; Model 2 was adjusted for Model 1 and for BMI; Model 3 was adjusted for Model 2 and for the Malay Child Nutrition Questionnaire scores.

BP, blood pressure; CI, confidence interval; HDL, high-density lipoprotein; HOMA-IR, homeostasis model assessment of insulin resistance; LDL, low-density lipoprotein; SE, standard error; SSB, sugar-sweetened beverage.

Acknowledgements

The authors have no conflicts of interest to declare.

References

7. Culpable efforts from public health practitioners, policy makers and beverage industries are imperative to encourage consumption of healthier beverages and reduce the cardiometabolic effects of SSB intake among young adolescents. Adverse cardiometabolic health outcomes linked to SSB are emerging among young adolescents.
8. Our appreciation to all teachers, school principals and students involved. The authors received funding from the Ministry of Higher Education, Malaysia to conduct this research. This study was funded by the High Impact Research (HIR) Grant from the Ministry of Higher Education (HIR MOHE). The funders had no role in the study design, data collection, data analysis, data interpretation, critically reviewed the manuscript and had final approval of the submitted version.

Table 2: Associations between cardiometabolic risks and SSB intake among adolescents using different models of regression (n = 881)

The authors have no conflicts of interest to declare.
11. Kowalski KC, Crock PR, Donen RM. The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) manual 2004; 87.