Original Article

# Increased coffee, tea, or other sugar-sweetened beverage consumption in adolescents is associated with less satisfactory dietary quality, body fatness and serum uric acid profiles over the past 18 years in Taiwan

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**Background and Objectives:** Taiwan has a high density of convenience stores and beverage shops, which makes sugar-sweetened beverages (SSBs) very accessible to teenagers. This study examined the changes and the association between SSBs and biomarkers and nutrient intake, for teenagers over the course of 18 years using a national representative sample. **Methods and Study Design:** This cross-sectional study used data from the Nutrition and Health Survey in Taiwan (NAHSIT). Complete data for teenagers aged 13 to 19 years including a 24-hour dietary recall, anthropometric and clinical measurements, and SSBs from two periods were analyzed (1993-1996: N=1820; 2010-2011: N=2513). SAS callable SUDAAN was used for statistical analysis, adjusting for the sampling scheme. Log transformation was used for non-normal variables before linear models were used. Coffee or tea and SSB (excluding tea or coffee) consumers were categorized as non-drinkers, low (below), or high (above) consumers based on median intake during 1993-1996. **Results:** Intake of coffee or tea increased significantly in the 18 years of this study ($p<0.01$), whereas intake of SSBs (excluding coffee or tea) decreased significantly ($p<0.05$). Intake was significantly higher among second survey and those with high total energy intakes ($p<0.01$). For both coffee/tea and SSB, the high-intake groups had higher serum uric acid and intake of carbohydrates ($p<0.05$), lower intake of protein and phosphorus and lower dietary diversity score ($p<0.05$). **Conclusions:** Consumption of coffee or tea increased in adolescents during the 18 years. High intakes of SSB, coffee or tea was associated with high serum uric acid values and worse dietary quality.

**Key Words: sugar-sweetened beverage, 24-hour dietary recall, serum uric acid, adolescents**

## INTRODUCTION

Energy intake from sugar-sweetened beverages (SSBs) among adolescents trended upwards between 1977 and 1996 in the United States,[1] but in both the United States and Australia this trend appeared to be declining in the last 10–20 years.[2-4] Research performed in the United States has found that, although consumption of soft drinks has decreased, consumption of sweetened coffee, sweetened tea, sports drinks, and energy drinks has increased.[2,4] Despite the decline in soft drink consumption, sugar from SSBs still remains the greatest source of sugar in the diets of adolescents, representing almost 20% of total sugar intake according to research conducted in Australia.[5] The 2015 World Health Organization (WHO) guidelines strongly recommend that free sugar intake should represent only 10% of the total daily energy intake for children and adults. It also conditionally recommends that this intake should be reduced to 5% of the total daily energy intake, with particular attention focused on sugar intake from SSBs.[6] Excessive consumption of SSBs leads to increased risk of the metabolic syndrome,[7,8] weight problems, obesity, gout, cardiovascular disease, and diabetes in children, adolescents, and adults.[9] High SSB intake can also result in nutritional imbalances in adolescents.[10-15]

Taiwan has a very high concentration of convenience stores and beverage shops; at the end of 2017, there were a total of 10,662 convenience stores (including four major chains)[16,17] and 21,346 beverage shops (including juice

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shops, beverage shops, coffee shops and alcoholic beverages shop),[18] or approximately one convenience store per 2211 persons[16,17] and one beverage shop per 1104 persons.[18] Beverages, excluding alcoholic beverages, were the greatest source of income (32.5%) to these convenience stores in 2015.[16] Regulations in Taiwan prohibit the sale of SSBs in elementary and junior high schools, as well as the sale of soft drinks in senior high schools. Despite these provisions, the high density of convenience stores and beverage shops near schools means that SSBs remain very accessible for teenagers. Past research suggests that the closer teenagers are to a convenience store, the higher their chance of purchasing SSBs.[19] In this 18 years, Taiwanese teenagers spent less on original foods and decreased energy intakes. Instead, they spent more money on processed food and ultra-processed food,[20] including SSB since the number of convenience stores and beverage shops has increased over time, and information about SSB intake was scarce, we examined the time trend of SSB intake using national representative samples. Since sweetened tea and coffee become very popular, especially in beverage stores, tea and coffee and other SSB are studied. We also explored the demographic factors associated with tea/coffee and other SSB intake, as well as the consequences of tea/coffee and other SSB intake on biomarkers. Figure 1 shows the concept diagram of this study.

## METHODS

### *Study population*

This study analyzed data from the 1993–1996 and 2010–2011 Nutrition and Health Survey in Taiwan (NAHSIT), and was approved by the Institute Review Board of the National Health Research Institutes. The study population for the 1993–1996 survey included those aged 3 years and older residing in Taiwan. The 1993–1996 survey incorporated a multi-stage stratified cluster sampling scheme to select individuals for face-to-face interviews. The survey divided the whole of Taiwan into 7 strata according to the unique dietary patterns of the residents, the urbanization index, and geographical location. The four groups with unique dietary patterns were: (1) the Hakka people, who consume a lot of preserved food and lard; (2) 80% of residents of mountainous areas, who are aborigines; (3) people living on the eastern coast, isolated from the western areas; and (4) people living on the Peng-Hu islands, who consume a high amount of salt. After these four groups were identified, the remaining area was stratified by the degree of urbanization and geographic location into (5) metropolitan cities, (6) provincial class I townships, and (7) provincial class II townships. Three townships or districts were selected based on the selection probability proportional to its population sizes (PPS) in each of the strata, and each township or district was surveyed in the same season to account for seasonal variation. Each township had a designated number of individuals to be interviewed by age and gender and interviews were conducted in a household setting. The response rate was 74%. Details of the sampling design have been described elsewhere.[21]

The study population for the 2010–2011 survey included students at public and private high schools. A two-stage stratified cluster sampling was adopted for this survey. It first stratified the whole of Taiwan into 5 strata, including 2 northern regions, 1 central region, 1 southern region, and 1 eastern region. Four schools were selected from each stratum with PPS. Twenty students (10 male and 10 female) of each grade from each school were sampled randomly. The response rate was 87% for those in junior high school and 92% for those in senior high school. Further details of the survey sample and sampling methods have been provided elsewhere.[22] All data collection methods were carried out in accordance with relevant guidelines and regulations. All measurement protocols

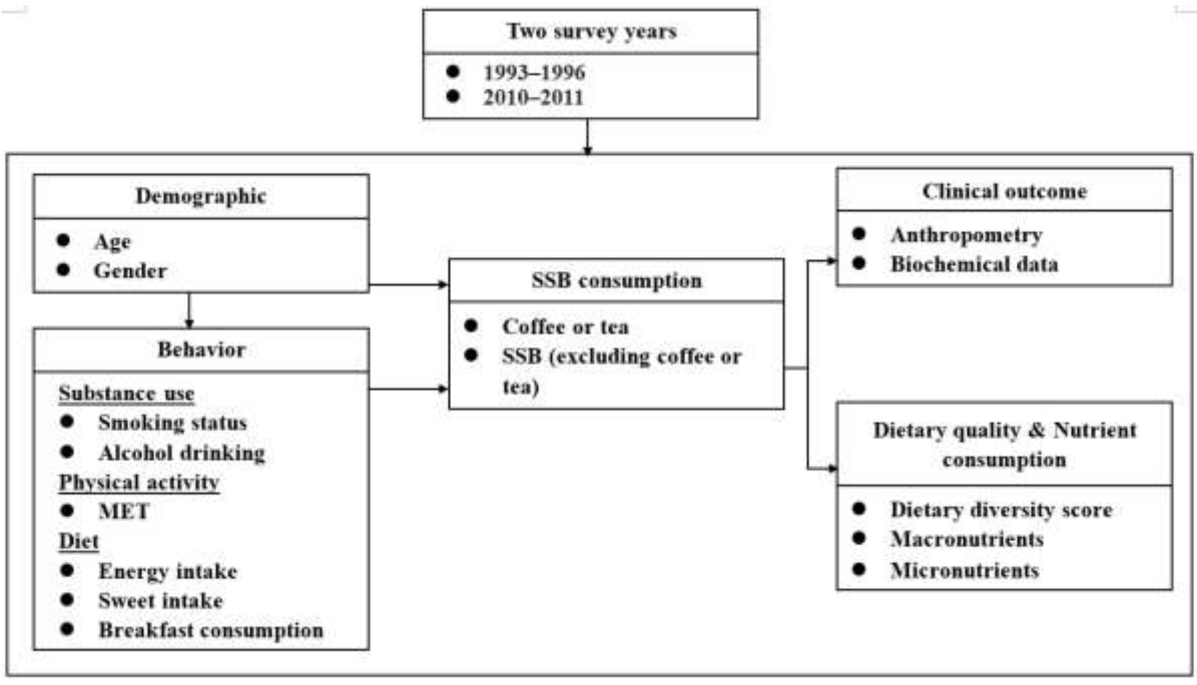


**Figure 1.** Conceptual diagram of study.

were approved by the Internal Review Board of National Health Research Institutes.

Informed consent was obtained after students were selected. Parental consent was also obtained for students younger than 18 years of age. These two surveys resulted in nationally representative samples. In the present study, we included junior and senior high school students aged 13 to 19 years, who could provide complete data for 24-hour dietary recall, anthropometric and clinical measurements, and SSB consumption. After excluding excessively high (≥37656 kJ) or low (<836.8 kJ) total energy intake (N=10)[23], a total of 4333 participants were included in the analysis (1993–1996: N=1820; 2010–2011: N=2513). Ethical approval was not required in 1993-1996. Participants joined the survey if they agreed verbally. The 2010-2011 survey was approved by the National Health Research Institutes Research Ethics Committee.

***Availability of data and material***

The 1993-1996 Nutrition and Health Survey in Taiwan can be download directly at the following website for members: https://srda.sinica.edu.tw/search/fsciitem/1321.

***Dietary assessments***

We used NAHSIT questionnaire data including 24-hour dietary recall, medical history, physical activity, and parental data. SSB and daily nutrient intake data were obtained from the 24-hour dietary recall information. For the purposes of this study, SSBs included sweetened coffee, sweetened tea, carbonated drinks (soft drinks), fruit drinks (including reconstituted juice, fermented fruit and vegetable juice, and other beverages), energy drinks (including sports drinks), and other drinks (cocoa or chocolate drinks, lactic drinks, iced drinks, and scented teas). SSBs did not include 100% juice or fruit wine. We noted that non-sweetened coffee or tea was an available option, although most teens tended to buy sweetened coffee or tea. For the purposes of this study, we therefore chose to consider coffee or tea separately from SSBs (excluding coffee or tea). Daily nutrient intake, were estimated based on the 24-hour dietary recall information and food composition tables from the website of the Food and Drug Administration, Ministry of Health and Welfare,[24] and included both macronutrients (carbohydrates, protein, total fats, saturated fatty acids, and cholesterol) and micronutrients (calcium, phosphorus, iron, sodium, niacin, vitamin B1, vitamin B2, vitamin C, and vitamin E). Individual intake was adjusted for total energy intake to determine % energy for macronutrients and mg/4184 kJ for micronutrients. In addition, based on other local research into SSBs,[25] we also examined the consumption of sweets, including all types of candy, chocolate, and cookies, but not bread or pastries. Adolescents who ate breakfast 7 days per week were considered regular breakfast eaters.

Other variables included age, sex, smoking status (non-smokers and ever-smokers, including former smokers, occasional smokers, and daily smokers), alcohol drinking status (non-drinkers and ever-drinkers, including anyone who had ever consumed alcohol), and physical activity level. Physical activity was measured in weekly metabolic equivalents (MET) based on the research by Ridley et al.[26]

***Dietary quality***

We used Dietary Diversity Score (DDS) to evaluate the dietary quality of adolescents. DDS has been widely used to assess the overall quality of food and nutrient intakes.[27-29] Since there are different food groups in different countries, each country can develop their own DDS. This index used six major food groups that obtained from 24-hr recall. The six major food groups are grains, dairy, beans/fish/eggs/meat, vegetables, fruits, oil and nuts.[28-30] We used two methods, one is giving 1 point for taking half portion of each food group daily (DDS1), the other is giving 1 point for taking 1 portion of each food group daily (DDS2). Both indices ranged 0 to 6 points.

***Anthropometric and clinical measurements***

NAHSIT data included a health examination component, which collected anthropometric data and biochemistry according to 8-hour fasting blood samples. Body mass index (BMI) was calculated as body weight in kilograms divided by the square of body height in meters. Waist circumference (WC) measurements were performed at the midpoint between the lower edge of the rib cage and the top of the iliac crest. Fasting blood was drawn during the morning, immediately after the individuals arrived for health check-ups. Blood samples were centrifuged and stored on dry ice, then delivered to a central laboratory and frozen at −70°C on the same day for further analysis. Blood profiles included high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), total cholesterol (TC), triglycerides (TG), fasting blood glucose, and serum uric acid.

***Statistical analyses***

SAS version 9.4 (SAS Institute Inc.) and SUDAAN version 11.0 were used to perform statistical analyses accounting for the unequal probability of sample selection. Each individual was weighted to reflect representativeness in the population at the time of the interview. Estimated daily intakes for coffee, tea, and SSB (excluding coffee or tea) in grams had a non-normal distribution and were categorized into three categories based on total intake during 1993–1996. These groups were: coffee or tea: non-intake (0 g), low intake (>0 g to < 402 g), and high intake (≥402 g); and SSB (excluding coffee or tea): non-intake (0 g), low intake (>0 g to <379 g), and high intake (≥379 g). Low and high groups were determined based on relation to median of the 1993-1996 survey: low = lower than median, high = higher than median. Descriptive statistics were provided as percentages or means ± standard deviations.

Comparisons between SSB intake groups and between survey dates were tested using the chi-squared test (categorical variables) or t test (continuous variables). Stacked bar charts were used to present patterns of SSBs in different surveys by sex. Because SSB intake was categorized into three groups, multinomial logistic regression was used to identify potential risk factors. Trend analysis was used to examine whether dependent variables increased or decreased in different SSB groups. Multiple regression was used to analyze the association between SSB and anthropometry, biomarkers, and nutrients after adjusting for survey date, age, sex, MET, and total energy. Because nutrient intake had been adjusted for total energy intake, analysis of the relationship between SSB and nutrients did not account for total energy intake. To ensure that the regression fulfilled the criteria of normality, residual analysis was performed, including histogram, box plot, Q–Q plot, and residual plots. Only the residuals of LDL-C, carbohydrate, fat, and SFA remained normal in the regression. All others were log-transformed after excluding outliers. All results of multiple regression included residuals that were normally distributed, with skewness close to 0 and the absolute kurtosis less than 2. Two-sided *p* values < 0.5 were considered significant.

## RESULTS

Table 1 shows the demographic characteristics of the adolescents in the two surveys by gender. The average age for both genders was 15.1 years in 2010–2011, slightly lower than the average of 15.5 years in 1993–1996. The BMI and WC of both genders increased significantly over the course of 18 years ($p$<0.05). The proportion of females in the ever-drink alcohol group increased from 12.9% to 20.7% in 18 years ($p$<0.05). The proportion of total energy intake greater than 1993-1996 median (7464.3 kJ) increased from about 68% to about 82% in high-intake groups of boys and from about 29% to about 56% ($p$<0.001) in girls over the course of 18 years. The consumption of sweets almost doubled for both girls and boys ($p$<0.001).

Figure 2 shows the changes in SSB consumption over the course of 18 years according to beverage type. Average intake of SSBs was 371.2 g (SE=16.7) in 1993-1996, which increased to 413.4 g (SE=22.9) 2010–2012, although this did not reach statistical significance ($p$=0.126; data not shown). The intake of coffee or tea increased from 206.3 g to 311 g ($p$<0.001), and the intake of soda decreased from 76.4 g to 27.2 g ($p$<0.001). Over the 18 years, coffee and tea became a significant type of SSB for adolescents; in 1993–1996, coffee and tea formed approximately 56% of the total SSB intake, while in 2010–2011 this increased to 75% (data not shown).

Table 2 shows the clinical outcome, dietary quality and nutrient consumption of the adolescents in the two surveys by gender. BMI, WC, and fasting glucose increased significantly in 18 years (p<0.05), whereas uric acid decreased significantly ($p$<0.001). TG also increased significantly in boys (p<0.05). Both DDS1 and DDS2 increased significantly ($p$<0.01), indicating improvement of dietary quality. Most nutrient intakes increased ($p$<0.05), except carbohydrates and vitamin C decreased ($p$<0.01). Intakes of calcium and vitamin B-2 decreased significantly in girls ($p$<0.01).

Table 3 shows the characteristics of SSB consumers. Over 50% of teens drank coffee or tea in 2010–2011 (boys 56.3% and girls 49.4%), and consumption for both genders increased significantly from 1993–1996. The proportion of teenagers consuming SSBs (excluding coffee or tea), on the other hand, decreased. For low-intake consumers, intake of both coffee or tea and SSB (excluding coffee or tea) decreased significantly among boys (p<0.05), although only SSB (excluding coffee or tea) intake decreased among girls ($p$=0.015).

Table 4 shows the results of multinomial logistic regression of factors associated with different patterns of SSB intake. In terms of high vs. non-intake of coffee or tea, high intake was significantly associated with the following survey groups: 2010–2011 survey date (OR=1.66,

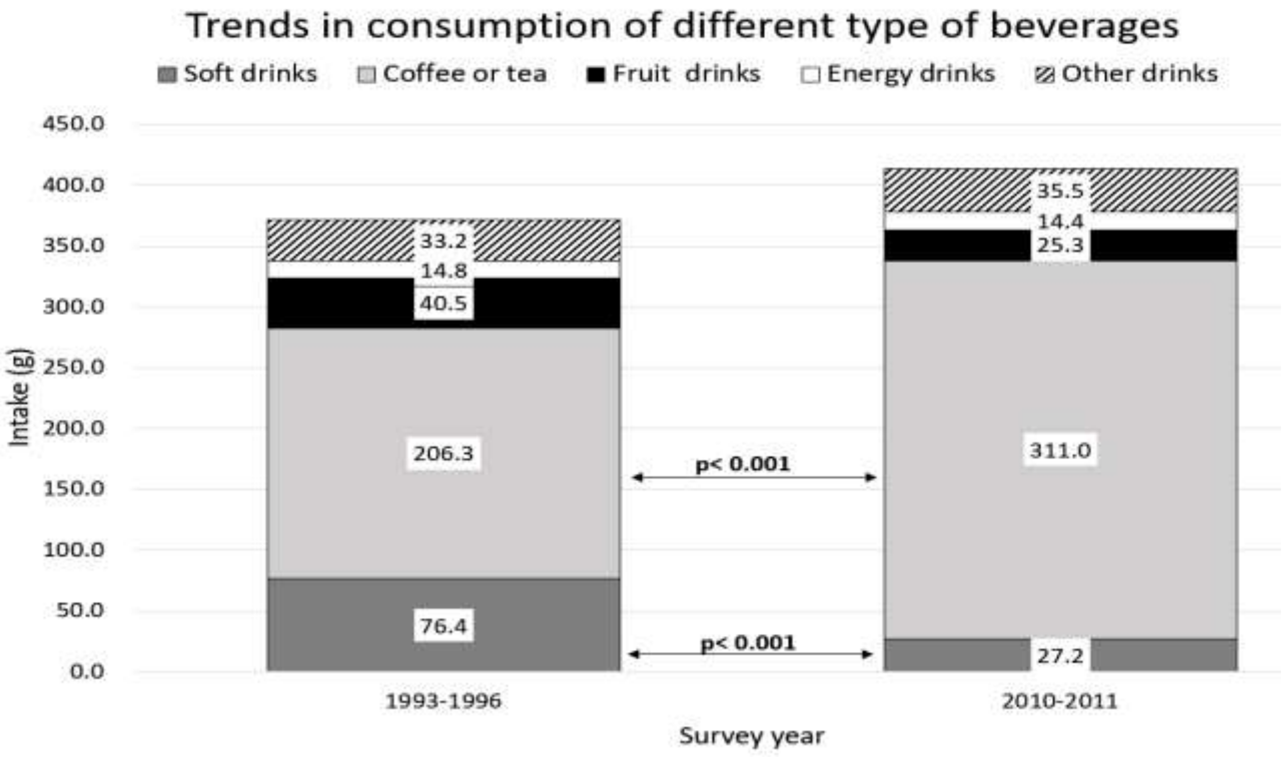


**Figure 2.** Trends in consumption patterns of SSBs in two different surveys.

**Table 1.** Modifications of biochemical parameters

| Variable† | Boys (N= 2158) | | | | | Girls (N=2175) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1993~1996 | | 2010~2011 | | *p* value* | 1993~1996 | | 2010~2011 | | *p* value* |
| | N | Weighted % | N | Weighted % | | N | Weighted % | N | Weighted % | |
| Sample size (n) | 918 | | 1240 | | | 902 | | 1273 | | |
| Age (years) (mean±SE) | 15.5±0.1 | | 15.1±0.1 | | 0.008 | 15.5±0.1 | | 15.1±0.1 | | 0.005 |
| Age, group | | | | | 0.001 | | | | | 0.002 |
| Young (junior high school) | 568 | 49.3 | 718 | 64.0 | | 558 | 48.7 | 747 | 64.9 | |
| Older (senior high school) | 352 | 50.7 | 526 | 36.0 | | 345 | 51.3 | 527 | 35.1 | |
| BMI (kg/m$^2$) (mean±SE) | 20±0.4 | | 21.9±0.2 | | 0.001 | 20.4±0.1 | | 20.9±0.1 | | 0.011 |
| WC (cm) (mean±SE) | 67.5±0.7 | | 77.5±0.5 | | <0.001 | 63.7±0.3 | | 75±0.4 | | <0.001 |
| Smoking status (%) | | | | | 0.023 | | | | | 0.400 |
| Non-smokers | 524 | 80.1 | 821 | 89.0 | | 679 | 97.0 | 914 | 95.3 | |
| Ever-smokers | 125 | 19.9 | 139 | 11.0 | | 24 | 3.0 | 60 | 4.7 | |
| Alcohol drinking status (%) | | | | | 0.089 | | | | | 0.026 |
| Non-drinkers | 564 | 73.9 | 760 | 80.6 | | 667 | 87.1 | 765 | 79.3 | |
| Ever-drinkers | 224 | 26.1 | 201 | 19.4 | | 118 | 12.9 | 208 | 20.7 | |
| MET (kJ/ kg/ h), group (%)‡ | | | | | 0.283 | | | | | 0.125 |
| Low (<127.6) | 264 | 38.7 | 423 | 43.4 | | 474 | 63.0 | 647 | 69.3 | |
| High (≥127.6) | 515 | 61.3 | 536 | 56.6 | | 295 | 37.0 | 316 | 30.7 | |
| Energy intake (%)‡ | | | | | <0.001 | | | | | <0.001 |
| Low (<7464.3kJ) | 361 | 31.9 | 215 | 17.8 | | 634 | 70.9 | 549 | 43.7 | |
| High (≥7464.3kJ) | 557 | 68.0 | 1025 | 82.2 | | 268 | 29.1 | 724 | 56.3 | |
| Dietary behavior (%) | | | | | | | | | | |
| Sweet intake (>0 g /day) | 385 | 41.4 | 1070 | 85.5 | <0.001 | 427 | 47.8 | 1126 | 86.2 | <0.001 |
| Breakfast (7 days/week) | 638 | 74.3 | 865 | 71.0 | 0.276 | 590 | 68.9 | 779 | 62.4 | 0.144 |

BMI: body mass index; WC: waist circumference; SSB: sugar-sweetened beverage; MET: metabolic equivalent task per week.
†Missing value not shown.
‡Based on median from 1993-1996.
**p* value based on t test for continuous variables and *p* value based on chi-square test for categorical variables between the surveys.

**Table 2.** Modifications of biochemical parameters

| Variable | Boys (mean±SE) | | | Girls (mean±SE) | | |
|---|---|---|---|---|---|---|
| | 1993~1996 | 2010~2011 | *p* value* | 1993~1996 | 2010~2011 | *p* value* |
| Sample size (n) | 918 | 1240 | | 902 | 1273 | |
| Anthropometry and biochemical data | | | | | | |
| BMI, kg/m$^2$ | 20.0±0.4 | 21.9±0.2 | 0.001 | 20.4±0.1 | 20.9±0.1 | 0.011 |
| WC, cm | 67.5±0.7 | 77.5±0.5 | <0.001 | 63.7±0.3 | 75.1±0.4 | <0.001 |
| HDL-C, mg/dL | 55.6±1.5 | 52.2±0.5 | 0.056 | 59.6±1.8 | 58.4±0.5 | 0.538 |
| LDL-C, mg/dL | 86.2±2.0 | 88.7±0.9 | 0.280 | 94.4±2.1 | 92.1±1.3 | 0.374 |
| TC, mg/dL | 155±2.0 | 156±0.9 | 0.949 | 168±2.8 | 164±1.5 | 0.264 |
| TG, mg/dL | 66.7±2.0 | 73.0±1.7 | 0.038 | 70.0±2.4 | 69.3±1.0 | 0.789 |
| Fasting blood glucose, mg/dL | 80.8±0.9 | 96.1±0.4 | <0.001 | 79.7±0.9 | 92.9±0.4 | <0.001 |
| Serum uric acid, mg/dL | 7.4±0.1 | 6.7±0.1 | <0.001 | 5.5±0.1 | 4.8±0.0 | <0.001 |
| Dietary quality (range 0-6)† | | | | | | |
| DDS1 | 4.2±0.1 | 4.5±0.0 | 0.003 | 4.1±0.0 | 4.5±0.0 | <0.001 |
| DDS2 | 3.7±0.1 | 4.1±0.0 | <0.001 | 3.7±0.1 | 4.0±0.1 | 0.001 |
| Nutrient consumption | | | | | | |
| Carbohydrates (% energy) | 55.9±0.9 | 51.7±0.52 | 0.002 | 56.4±0.7 | 51.8±0.5 | <0.001 |
| Protein (% energy) | 15.5±0.4 | 15.7±0.2 | 0.681 | 15.5±0.4 | 15.4±0.1 | 0.818 |
| Total fat (% energy) | 28.8±0.9 | 32.9±0.4 | 0.002 | 28.6±0.5 | 33.4±0.4 | <0.001 |
| SFA (% energy) | 10±0.3 | 11.3±0.2 | 0.005 | 9.9±0.2 | 11.6±0.2 | <0.001 |
| Cholesterol (mg/4184 kJ) | 180±5.1 | 187±3.5 | 0.249 | 183±11.4 | 199±6.1 | 0.238 |
| Calcium (mg/4184 kJ) | 220±10.4 | 214±4.5 | 0.625 | 273±11.5 | 229±5.1 | 0.006 |
| Phosphorus (mg/4184 kJ) | 508±13.8 | 553±5.5 | 0.013 | 543±13.8 | 558±5.0 | 0.381 |
| Iron (mg/4184 kJ) | 6.5±0.2 | 7.2±0.1 | 0.011 | 6.8±0.4 | 7.6±0.2 | 0.067 |
| Sodium (g/4184 kJ) | 1.5±0.0 | 1.9±0.0 | <0.001 | 1.7±0.0 | 2.0±0.0 | <0.001 |
| Niacin (mg/4184 kJ) | 8.1±0.3 | 9.1±0.1 | 0.009 | 8.0±0.5 | 9.0±0.2 | 0.083 |
| Vitamin B-1 (mg/4184 kJ) | 0.6±0.0 | 0.6±0.0 | 0.025 | 0.6±0.0 | 0.6±0.0 | 0.037 |
| Vitamin B-2 (mg/4184 kJ) | 0.6±0.0 | 0.6±0.0 | 0.156 | 0.7±0.0 | 0.6±0.0 | 0.004 |
| Vitamin C (mg/4184 kJ) | 64.4±3.1 | 48.1±1.6 | 0.001 | 80.5±5.8 | 58.2±1.7 | 0.004 |
| Vitamin E (mg α-TE/4184 kJ) | 3.1±0.1 | 3.6±0.1 | <0.001 | 3.9±0.2 | 4.0±0.1 | 0.734 |

SSB: sugar-sweetened beverage; BMI: body mass index; WC: waist circumference; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; TC: total cholesterol; TG: triglyceride; DDS: dietary diversity score; SFA: Saturated fatty acids.

†DDS1: participant ate 0.5 serving per group per day; DDS2: participant ate 1 serving per group per day.

**p* value based on t test for continuous variables and *p* value based on chi-square test for categorical variables between the surveys

**Table 3.** Changes of SSB consumption of teens aged 13-19 years between two surveys by sex

| Variable[†] | Boys (mean±SE) | | | Girls (mean±SE) | | |
|---|---|---|---|---|---|---|
| | 1993~1996 | 2010~2011 | *p* value[*] | 1993~1996 | 2010~2011 | *p* value[*] |
| Sample size (n) | 918 | 1240 | | 902 | 1273 | |
| Coffee or tea | | | | | | |
| Intake (g/day) | 232±10.8 | 365±21.4 | <0.001 | 176±15.7 | 254±18.4 | 0.009 |
| Intake by group (g/day) [‡] | | | | | | |
| No intake (0 g) | 0.0 | 0.0 | -- | 0.0 | 0.0 | -- |
| Low (0< to <402 g) | 301±12.2 | 263±6.1 | 0.018 | 281±19.2 | 248±9.7 | 0.149 |
| High (≥402 g) | 773±45.5 | 858±24.9 | 0.191 | 677±21.3 | 725±19.5 | 0.131 |
| Distribution of SSB group[‡] (weighted %) | | | 0.002 | | | 0.030 |
| No intake (0 g) | 57.8 | 43.7 | | 62.7 | 50.6 | |
| Low (0< to <402 g) | 20.1 | 19.9 | | 19.4 | 21.8 | |
| High (≥402 g) | 22.2 | 36.4 | | 17.8 | 27.6 | |
| SSB (excluding coffee or tea) | | | | | | |
| Intake (g) | 208±19.7 | 117±13.8 | 0.004 | 114±5.4 | 87.3±9.2 | 0.032 |
| Intake group (g/day)[‡] | | | | | | |
| No intake (0 g) | 0.0 | 0.0 | -- | 0.0 | 0.0 | -- |
| Low (0< to <379 g) | 258±17.0 | 198±15.5 | 0.028 | 235.3±11.5 | 187±11.8 | 0.015 |
| High (≥379 g) | 754±36.5 | 704±23.1 | 0.275 | 644.9±48.8 | 694±37.5 | 0.441 |
| Distribution of SSB group[‡] (weighted %) | | | 0.022 | | | 0.084 |
| No intake (0 g) | 62.0 | 73.8 | | 71.4 | 75.3 | |
| Low (0< to <379 g) | 15.9 | 13.4 | | 17.2 | 16.6 | |
| High (≥379 g) | 22.2 | 12.8 | | 11.4 | 8.1 | |

SSB: sugar-sweetened beverage.
[†]Missing value not shown.
[‡]Based on median from 1993-1996.
[*]*p* value based on t test for continuous variables and *p* value based on chi-square test for categorical variables between the surveys.

*p*=0.012), senior high (OR=1.46, *p*=0.002), ever-smokers (OR=2.36, *p*=0.004), and high total intake (OR=1.84, *p*=0.009). Those with high MET were associated with the non-intake group (OR=0.76, *p*=0.046). A positive trend in appeared in the second survey among senior high students (vs. junior high students), ever-smokers, and total energy intake (*p* values for trend=0.035, 0.002, 0.011, and 0.014, respectively), indicating that the higher these variables, the higher the chance of being in the high coffee or tea intake group. Regarding SSB (excluding coffee or tea) high vs. non-intake, high total energy intake (OR=2.38, *p*<0.001) was associated with the high SSB group. Teens in the 2010–2011 survey were negatively associated with high SSB intake (OR=0.44, *p*=0.001). The positive trend appeared for boys and total energy intake (*p* values for trend=0.014 and <0.001, respectively) and a negative trend appeared in the second survey compared to the first survey (*p* values for trend=0.002).

The relationships between the different patterns of SSB intake and anthropometry, biomarkers, dietary quality and nutrients are presented in Table 5. For coffee or tea intake, after controlling for age, sex, MET, and total energy intake, BMI (β=0.02, *p*=0.041), WC (β=0.02, *p*=0.013) and serum uric acid (β=0.04, *p*=0.022) were significantly higher in the high intake group compared to the non-intake group. DDS were lower in high intake group than non-drinkers (β=-0.33 to -0.31, *p*<0.01). DDS1 in low intake group also significantly lower than the non-intake group. (β=-0.21, *p*=0.046). Because nutrients were already converted to nutrient density (per 4184 kJ), the variables controlled were survey date, age, sex, and MET. The results showed that the group with a high intake of coffee or tea had higher carbohydrate intake (β=2.62, *p*=0.003), lower protein intake (β=-0.09, *p*=0.003), lower phosphorus intake (β=-0.06, *p*=0.041), and lower vitamin E (β=-0.09, *p*=0.008) intake than the group with no intake of coffee or tea.

The group with a high intake of SSBs (excluding coffee or tea) had a higher serum uric acid (β=0.05, *p*=0.012), a higher intake of carbohydrates (β=6.09, *p*<0.001), and vitamin C (β=0.49, *p*<0.001), but had a lower DDS (β=-0.31 to -0.24, *p*<0.05), a lower intake of protein (β=-0.13, *p*<0.001), total fat (β=-3.79, *p*<0.001), SFA (β=-0.90, *p*=0.027), calcium (β=-0.19, *p*=0.023), phosphorus (β=-0.12, *p*<0.001), and vitamin B1 (β=-0.12, *p*=0.010) than the group with no intake of SSBs (excluding coffee or tea).

## DISCUSSION

This study compared adolescent SSB intake over 18 years using two surveys of national representative samples. We found that tea or coffee, as a variety of SSB, became a major source of sugar consumption for Taiwanese adolescents over the course of 18 years. Both high- and low-SSB intake were significantly associated with survey date and total energy intake. Consuming higher amounts of SSB or coffee or tea was associated with higher values of serum uric acid and higher intake of carbohydrates, as well as lower intake of protein and phosphorous and had a lower DDS.

We found that adolescents in Taiwan consumed more than 400 g of SSBs per day in 2010-2011, which is almost double the amount consumed by 10–17 years old in 13 other countries, which had average intakes of 271 mL/day for boys and 250 mL/day for girls. SSBs in this case included hot beverages (coffee, tea, and other hot beverages), juices, regular soft beverages (sugared and artificially sweetened, carbonated and non-carbonated

**Table 4.** The characteristics of participating chefs and cooks (n=90)

| Variable | Low vs Non-intake† | | | High vs Non-intake† | | | p-trend* |
|---|---|---|---|---|---|---|---|
| | OR | 95% CI | p value | OR | 95% CI | p value | |
| Coffee or tea | | | | | | | |
| Survey year (ref. 1993-1996) | | | | | | | |
| 2010-2011 | 1.22 | 0.85-1.73 | 0.247 | 1.66 | 1.18-2.92 | 0.012 | 0.035 |
| Age group (ref. young) | | | | | | | |
| Older (senior high school) | 0.96 | 0.72-1.28 | 0.739 | 1.46 | 1.19-1.79 | 0.002 | 0.002 |
| Boy (Ref. girl) | 0.97 | 0.69-1.37 | 0.871 | 0.89 | 0.63-1.24 | 0.434 | 0.647 |
| Smoking status (ref. non-smokers) | | | | | | | |
| Ever-smokers | 1.76 | 1.06-2.92 | 0.033 | 2.36 | 1.41-3.96 | 0.004 | 0.011 |
| Alcohol drinking status (ref. non-drinkers) | | | | | | | |
| Ever-drinkers | 0.82 | 0.41-1.63 | 0.534 | 1.16 | 0.89-1.51 | 0.243 | 0.481 |
| MET, group (ref. low) | | | | | | | |
| High (≥127.6 kJ/kg/h)‡ | 0.88 | 0.64-1.20 | 0.386 | 0.76 | 0.58-0.99 | 0.046 | 0.124 |
| Energy intake, group (ref. low) | | | | | | | |
| High (≥7464.3 kJ)‡ | 1.27 | 0.68-2.35 | 0.417 | 1.84 | 1.21-2.80 | 0.009 | 0.014 |
| Dietary behavior | | | | | | | |
| Sweet intake (>0 g/day) (ref. no sweet intake) | 1.02 | 0.61-1.69 | 0.946 | 1.27 | 0.78-2.06 | 0.294 | 0.351 |
| Breakfast (7 days/week) (ref. <7 days/week) | 1.02 | 0.66-1.58 | 0.920 | 0.78 | 0.48-1.27 | 0.286 | 0.530 |
| SSB (excluding coffee or tea) | | | | | | | |
| Survey year (ref. 1993-1996) | | | | | | | |
| 2010-2011 | 0.78 | 0.61-1.01 | 0.061 | 0.44 | 0.30-0.64 | 0.001 | 0.002 |
| Age group (ref. young) | | | | | | | |
| Older (senior high school) | 1.14 | 0.63-2.04 | 0.635 | 1.32 | 0.82-2.12 | 0.224 | 0.455 |
| Boy (Ref. girl) | 0.84 | 0.51-1.39 | 0.466 | 1.48 | 1.00-2.18 | 0.050 | 0.014 |
| Smoking status (ref. non-smokers) | | | | | | | |
| Ever-smokers | 0.84 | 0.49-1.44 | 0.498 | 0.88 | 0.37-2.14 | 0.762 | 0.750 |
| Alcohol drinking status (ref. non-drinker) | | | | | | | |
| Ever-drinker | 1.06 | 0.71-1.59 | 0.740 | 1.00 | 0.51-1.97 | 1.000 | 0.883 |
| MET, group (ref. low) | | | | | | | |
| High (≥127.6 kJ/kg/h)‡ | 1.18 | 0.79-1.78 | 0.374 | 0.89 | 0.46-1.72 | 0.711 | 0.511 |
| Energy intake (%), group (ref. low) | | | | | | | |
| High (≥7464.3 kJ)‡ | 1.42 | 1.00-2.01 | 0.052 | 2.38 | 1.73-3.27 | <0.001 | <0.001 |
| Dietary behavior from FFQ | | | | | | | |
| Sweet intake (>0 g/day) (ref. no sweet intake) | 1.02 | 0.83-1.24 | 0.868 | 1.43 | 0.87-2.34 | 0.138 | 0.314 |
| Breakfast (7 days/week) (ref. <7 days/week) | 1.16 | 0.69-1.93 | 0.540 | 0.69 | 0.44-1.07 | 0.089 | 0.157 |

MET: metabolic equivalent task per week; SSB: sugar-sweetened beverage.
†Intake group in coffee or tea (g): Non-intake, 0; Low, >0 to <402; High, ≥402. Intake group in SSB (excluding coffee or tea) (g): Non-intake, 0; Low, >0 to <379; High, ≥379. The values are based on the median from 1993-1996.
‡Based on median from 1993-1996.
*Tests for linear trend.

soft drinks, energy drinks, sports drinks, and other sugared or artificially sweetened soft drinks), as well as other beverages. Thirty-one Eastern Asia in general has the lowest SSB intake (0.2 servings/day which was about 45 g/day) among 187 countries (including sodas, fruit drinks, sports/energy drinks, pre-sweetened iced tea, and homemade SSB), according to a 2010 survey. In contrast to this, Taiwanese men consumed 1.02 servings/day and women consumed 0.94 servings/day, equivalent to 231 g/day to 213 g/day.[32] This suggests that Taiwanese consumption of SSB was high regardless age. Some countries have recently shown declines in SSB consumption. A 2005–2008 Australian survey found SSB consumption decreased among 4 to 18-year-olds over the course of 2–3 years.[3] In the United States, the number of adolescents consuming SSBs decreased from 87% in 1999–2000 to 77% in 2007–2008, and the energy taken from SSBs also decreased from 363 kcal/day to 286 kcal/day (1518.8 kJ/day to 1196.6 kJ/day).[2] In addition to standard SSBs, coffee and tea consumption was high among Taiwanese adolescents; the proportion drinking coffee and tea already exceeded 50% in 1993–1996 and this increased to 70% in 2010–2011. One possible reason for this increase might be the increased availability of tea and coffee at beverage shops, which sell various sweetened teas, such as black or green tea, and mixed tea, such as pearl milk tea, jelly milk tea, and fruit tea. Along with these teas, some shops also sell coffee, all at a price affordable to teens; these beverage shops rarely sell soda drinks, limiting the availability of that type of SSB.

Many other studies have observed that SSB consumption increases with age, with adolescents consuming more than younger children.[5,10,11,33,34] This agrees with our findings that senior high school students drank more coffee or tea than those in junior high. This may possibly be a factor of the older students' greater disposable income and longer commute to school, which increases both their opportunity and ability to eat in restaurants and purchase

**Table 5.** Regression analysis of clinical outcomes, DDS and daily nutrient intake associated with different pattern of SSB consumption

| Variables† | Coffee or tea | | | | | | SSB (excluding coffee or tea) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low* | | *p* value | High* | | *p* value | Low* | | *p* value | High* | | *p* value |
| | Beta | 95% CI | | Beta | 95% CI | | Beta | 95% CI | | Beta | 95% CI | |
| Anthropometry and biochemical data‡ | | | | | | | | | | | | |
| Log-BMI, kg/m$^2$ | 0.01 | -0.03 to 0.04 | 0.706 | 0.02 | 0.00 to 0.04 | 0.041 | -0.01 | -0.03 to 0.02 | 0.509 | -0.01 | -0.03 to 0.01 | 0.178 |
| Log-WC, cm | 0.00 | -0.01 to 0.02 | 0.621 | 0.02 | 0.00 to 0.03 | 0.013 | -0.01 | -0.02 to 0.01 | 0.210 | -0.01 | -0.02 to 0.00 | 0.114 |
| Log-HDL-C, mg/dL | 0.03 | -0.05 to 0.10 | 0.460 | -0.01 | -0.07 to 0.06 | 0.827 | -0.02 | -0.07 to 0.03 | 0.337 | -0.03 | -0.08 to 0.02 | 0.250 |
| LDL-C, mg/dL | 1.56 | -3.46 to 6.58 | 0.504 | 2.20 | -1.66 to 6.06 | 0.233 | 4.10 | -0.12 to 8.32 | 0.055 | 4.87 | -1.07 to 10.80 | 0.098 |
| Log-TC, mg/dL | 0.01 | -0.03 to 0.05 | 0.456 | 0.01 | -0.01 to 0.04 | 0.272 | 0.02 | -0.01 to 0.05 | 0.267 | 0.02 | -0.02 to 0.06 | 0.337 |
| Log-TG, mg/dL | -0.02 | -0.09 to 0.05 | 0.597 | 0.01 | -0.05 to 0.07 | 0.779 | 0.01 | -0.08 to 0.10 | 0.730 | -0.00 | -0.12 to 0.12 | 0.995 |
| Log-Fasting blood glucose, mg/dL | 0.01 | -0.02 to 0.04 | 0.511 | 0.01 | -0.02 to 0.04 | 0.512 | 0.01 | -0.01 to 0.03 | 0.415 | 0.00 | -0.01 to 0.01 | 0.772 |
| Log-Serum uric acid, mg/dL | 0.01 | -0.03 to 0.04 | 0.727 | 0.04 | 0.01 to 0.08 | 0.022 | -0.01 | -0.04 to 0.03 | 0.734 | 0.05 | 0.01 to 0.09 | 0.012 |
| Dietary quality (range 0-6)‡§ | | | | | | | | | | | | |
| DDS1 | -0.21 | -0.43 to -0.00 | 0.046 | -0.33 | -0.46 to -0.21 | <0.001 | 0.03 | -0.15 to 0.22 | 0.695 | -0.24 | -0.42 to -0.06 | 0.014 |
| DDS2 | -0.26 | -0.52 to 0.00 | 0.053 | -0.31 | -0.50 to -0.13 | 0.004 | 0.02 | -0.17 to 0.20 | 0.825 | -0.31 | -0.49 to -0.13 | 0.003 |
| Nutrient consumption¶ | | | | | | | | | | | | |
| Carbohydrates (% energy) | 0.40 | -2.85 to 3.65 | 0.791 | 2.62 | 1.11 to 4.13 | 0.003 | -0.11 | -3.32 to 3.09 | 0.938 | 6.09 | 4.59 to 7.59 | <0.001 |
| Log-Protein (% energy) | -0.03 | -0.07 to 0.02 | 0.195 | -0.09 | -0.14 to -0.04 | 0.003 | 0.00 | -0.04 to 0.04 | 0.884 | -0.13 | -0.17 to -0.08 | <0.001 |
| Total fat (% energy) | -0.08 | -3.29 to 3.12 | 0.955 | -1.23 | -2.98 to 0.52 | 0.149 | 0.10 | -3.26 to 3.47 | 0.947 | -3.79 | -5.31 to -2.28 | <0.001 |
| SFA (% energy) | 0.23 | -0.98 to 1.45 | 0.677 | 0.05 | -0.86 to 0.96 | 0.908 | 0.44 | -0.60 to 1.47 | 0.371 | -0.90 | -1.66 to -0.13 | 0.027 |
| Log-Cholesterol (mg/4184 kJ) | -0.04 | -0.16 to 0.09 | 0.511 | -0.04 | -0.13 to 0.05 | 0.375 | -0.09 | -0.25 to 0.07 | 0.227 | -0.11 | -0.27 to 0.04 | 0.133 |
| Log-Calcium (mg/4184 kJ) | 0.04 | -0.09 to 0.17 | 0.518 | -0.07 | -0.19 to 0.05 | 0.210 | -0.03 | -0.19 to 0.12 | 0.645 | -0.19 | -0.36 to -0.03 | 0.023 |
| Log-Phosphorus (mg/4184 kJ) | 0.02 | -0.03 to 0.06 | 0.463 | -0.06 | -0.02 to -0.00 | 0.041 | 0.01 | -0.04 to 0.06 | 0.536 | -0.12 | -0.17 to -0.08 | <0.001 |
| Log-Iron (mg/4184 kJ) | 0.04 | -0.07 to 0.14 | 0.426 | 0.07 | -0.01 to 0.15 | 0.093 | -0.00 | -0.06 to 0.06 | 0.884 | -0.03 | -0.10 to 0.04 | 0.300 |
| Log-Sodium (g/4184 kJ) | -0.10 | -0.21 to 0.01 | 0.064 | -0.08 | -0.18 to 0.03 | 0.130 | 0.01 | -0.14 to 0.15 | 0.903 | -0.03 | -0.13 to 0.06 | 0.449 |
| Log-Niacin (mg/4184 kJ) | 0.04 | -0.02 to 0.09 | 0.152 | 0.02 | -0.05 to 0.10 | 0.489 | -0.00 | -0.09 to 0.08 | 0.985 | 0.02 | -0.09 to 0.13 | 0.670 |
| Log-Vitamin B-1 (mg/4184 kJ) | -0.06 | -0.15 to 0.03 | 0.170 | -0.07 | -0.16 to 0.03 | 0.138 | 0.01 | -0.08 to 0.10 | 0.818 | -0.12 | -0.20 to -0.04 | 0.010 |
| Log-Vitamin B-2 (mg/4184 kJ) | 0.04 | -0.04 to 0.13 | 0.279 | 0.05 | -0.06 to 0.15 | 0.346 | 0.01 | -0.06 to 0.08 | 0.752 | -0.01 | -0.07 to 0.05 | 0.740 |
| Log-Vitamin C (mg/4184 kJ) | 0.06 | -0.06 to 0.18 | 0.260 | 0.01 | -0.17 to 0.20 | 0.895 | 0.14 | -0.05 to 0.34 | 0.125 | 0.49 | 0.28 to 0.70 | <0.001 |
| Log-Vitamin E (mg α-TE/4184 kJ) | -0.07 | -0.15 to 0.02 | 0.124 | -0.09 | -0.14 to -0.03 | 0.008 | -0.09 | -0.25 to 0.07 | 0.226 | -0.11 | -0.27 to 0.04 | 0.120 |

SSB: sugar-sweetened beverage; BMI: body mass index; WC: waist circumference; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; TC: total cholesterol; TG: triglyceride; DDS: dietary diversity score; SFA: Saturated fatty acids.

†The log transformation is used for most variables except for LDL-C, carbohydrates, total fat and SFA.

‡The multiple regression model was adjusted for survey year, age, gender, physical activity performed per week (MET), daily energy intake (in kilojoule).

§DDS1: participant ate 0.5 serving per food group per day; DDS2: participant ate 1 serving per food group per day.

¶The multiple regression model was adjusted for survey date, age, gender and physical activity performed (MET) per week.

*Intake group in coffee or tea (g): Non-intake, 0; Low, >0 to <402; High, ≥402. Intake group in SSB (excluding coffee or tea) (g): Non-intake, 0; Low, >0 to <379; High, ≥379.

SSBs. Two surveys of 14-18 year old in the US found that smokers had higher intake of SSBs, which accords with our findings that students in the ever-smoker group had high intakes of SSBs.[35,36] As has been observed in males in many other studies, high total energy intake was associated with high SSB intake.[31,32,37-39]

Adolescents consuming high amounts of SSB or coffee or tea had high serum uric acid values. High consumption of coffee or tea was also associated with higher BMI and WC. Fructose might contribute to this effect. Usually, sucrose or high-fructose corn syrup (HFCS) are added to SSBs; the main contents of these two sweeteners are fructose and glucose. Fructokinase has no negative feedback preventing it from continuing to phosphorylate substrate; as a result, fructose turns into acetyl-CoA and glyceraldehyde, which then accumulate and increase de novo lipogenesis. Eventually, TG are formed. In fructokinase, a large amount of adenosine triphosphate (ATP) is consumed and generates uric acid.[40] The effects of SSB consumption on increasing uric acid values have been observed in a 1999–2004 survey in United States[41] and Taiwan.[42] Uric acid is an independent risk factor for all-cause mortality.[43,44]

The average DDS2 was around 3.7, indicating relative good dietary quality.[29] Steyn et al has shown that when using 6 food groups to calculate DDS, those scored 3 had over 70% micronutrients intakes. That was sufficient. But that study was on children under 9 years old. There has not been appropriate cut-off for adolescents. Nevertheless, we found that higher intakes of SSB would reduce DDS. In other words, SSB intakes reduced dietary quality.[28,29] Only three nutrients were associated with SSB intakes. It was possible due to intakes of ultra- processed food.[20] Past study has shown that high school students have increased more ultra-processed food intakes, and resulted in decrease in many micronutrients.

We found that intakes of carbohydrates increased as both coffee or tea and SSB (excluding coffee or tea) intake increased, and intakes of protein and phosphorus decreased as both pattern of SSB increased. The more SSBs consumed, the higher the sugar (carbohydrate) intake.[11,14,15,45] Furthermore, consuming large amounts of SSBs was associated with the intake of other nutrients.[10-15,45] We found that high consumption of SSBs (excluding coffee or tea) was associated with high vitamin C intake. The increase in vitamin C intake may be due to consumption of fruit drinks or to beverage shops adding fruits such as plums to beverages. A 1994–1996 survey in the United States found that adolescents consuming fruit-flavored drinks had a better chance of fulfilling their daily recommended vitamin C intake, but drinking soda did not help.[12] Canada had similar findings in their 2004 survey.[46] Our study included soft drinks, energy drinks, and fruit drinks; we believe the vitamin C may have come from fruit drinks.

The strength of this study is that it used national representative samples to examine the change in adolescent SSB intake over the course of 18 years. In addition, 24-hour dietary recall was conducted during a face-to-face interview. These surveys were performed periodically to reflect social changes in a timely manner. However, there were some limitations to this study. The cross-sectional nature of the design could not infer a causal relationship. There were some differences in measurement and units of certain nutrients; therefore, some nutrients, such as vitamin A, vitamin D, magnesium, potassium, and zinc, were not included in the analysis. Intake information according to 24-hour recall was used; normally, this might not reflect the usual intake of SSBs. However, we obtained repeated measurements on a subsample (N=325) of participants in 2010–2011. The correlation on total SSBs was 0.48 (0.42 for boys and 0.57 for girls). All reached statistical significance, and the high correlation implied that they consumed SSBs regularly. Furthermore, correlation coefficients could be used to estimate the variance between individuals in dietary data with repeated measurements.[47] The variance between individuals can be estimated as $Sb = S\sqrt{\gamma}$, where S is the total variance. When variance between individuals is reduced, the chance of reaching statistical significance increases. This calculation is, however, beyond the scope of this study. Based on the high correlation of our repeated subsample measurements, we believe our data reflects the usual intake of SSBs in teens.

### *Conclusions*

Coffee or tea has become a major source of SSBs in adolescents in Taiwan. Over 50% of adolescents consumed coffee or tea in 2010–2011. High intake of SSBs (including coffee or tea) was associated with higher uric acid. This suggests that adolescent consumption of SSBs is not trivial and is a habit requiring great effort to change. To promote healthier teen choices regarding SSBs, public health education should take greater care in educating parents on providing a healthy diet with low sugar intake. Schools should teach students how to choose beverages intelligently, encouraging children and teens to choose non-sweetened drinks or water instead of SSBs.


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## AUTHOR DISCLOSURES

The authors declare that there are no competing interests.

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