Original Article

Consumption of Sugar-Sweetened Beverages in Relation to the Metabolic Syndrome among Iranian Adults

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Key Words

Sugar-sweetened beverages • Metabolic syndrome • Food frequency questionnaire • Diet

Abstract

Background: Few data are available linking intake of sugar-sweetened beverages (SSBs) with the metabolic syndrome. Furthermore, findings from these studies are inconsistent and most are from Western societies; no information is available in this regard from Middle Eastern populations. **Objective:** This study was conducted to assess the relationship between SSB consumption and metabolic syndrome in an Iranian adult population. **Methods:** In this cross-sectional study, data from 1,752 people (782 men and 970 women) that were selected with the multistage cluster random sampling method from three counties of Isfahan, Najafabad and Arak were used. A validated food frequency questionnaire was used to assess participants' usual dietary intakes. Consumption of SSBs was calculated by summing up the consumption of 'soft drinks' and 'artificially sweetened fruit juices'. To categorize participants, we used three levels of SSB consumption: <1 time/week, 1–3 times/week, and >3 times/week. Biochemical assessments were done after an overnight fasting. Metabolic syndrome was defined according to the guidelines of Adult Treatment Panel III. **Results:** Subjects with high consumption of SSBs (>3 times/week) were younger than those with low consumption (<1 time/week). Mean BMI was not significantly different across SSB categories. High consumption of SSBs was associated with greater intakes of energy and almost all food groups. We found a significant difference in serum triglyceride levels between men consuming SSBs 1–3

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times/week and those consuming <1 time/week. However, after controlling for potential confounders, this association disappeared. In crude models, no significant associations were found between SSB intake and prevalence of the metabolic syndrome in either gender. After adjustment for potential confounders including BMI, we found that men in the top category of SSB intake were 17% more likely to have the metabolic syndrome (odds ratio (OR) 1.17; 95% confidence interval (95% CI) 0.56–2.46), while women in the highest category were 20% less likely to have the syndrome (OR 0.80; 95% CI 0.46–1.42) as compared with those in the bottom category. However, these associations were not significant in either men or women. **Conclusion:** Our results do not support the previous findings on the association between SSB consumption and metabolic syndrome. Prospective studies are needed to further explore for this association.

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Introduction

The metabolic syndrome is a conglomerate of metabolic abnormalities that raise individual's risk for type 2 diabetes mellitus [1], cardiovascular disease [2], and other chronic diseases [3]. It has been defined to include abdominal obesity, high blood pressure, elevated fasting plasma glucose (FPG) and triglycerides, and low high-density lipoprotein (HDL) cholesterol [4]. Metabolic syndrome is associated with non-alcoholic hepatitis and polycystic ovary disease [5]. A role for metabolic syndrome in the development of some cancers has also been suggested [5]. Due to increasing prevalence of obesity worldwide, the number of individuals with metabolic syndrome is continuing to rise. One out of four Americans is affected by the metabolic syndrome [6]. Recent estimates in Iran have shown that the syndrome is highly prevalent among Iranians such that more than 30% of adults [7] and almost 10% of adolescents [8] are affected.

The metabolic syndrome is strongly related to lifestyle factors including diet [9, 10], smoking [11], and physical activity [12]. Dietary determinants of the metabolic syndrome have been summarized in a recent review [13], indicating that high intakes of fruit and vegetables [9], dairy products [14] and whole grains [15] are associated with lower risk while increased consumption of refined carbohydrates and red meat is associated with greater risk of the syndrome [14, 16].

Recently, consumption of sugar-sweetened beverages (SSBs) has greatly increased in the USA, Europe [17, 18], and even in developing countries [19, 20]. Consumption of soft drinks has been related to the prevalence of obesity and diabetes in children and adolescents and also to the development of hypertension in adults [21, 22]. Added sugars in soft drinks have also been associated with elevated levels of serum triglycerides and insulin resistance [23]. This might be explained by greater caloric intake, less satiety, and greater insulin secretion [24]. Therefore, consumption of soft drinks can cause metabolic dysfunction that lead to the metabolic syndrome. Few data are available linking SSB intake and metabolic syndrome. Furthermore, findings from these studies are inconsistent. Some cross-sectional [14, 25] and prospective studies [26] have demonstrated that intake of 'regular' and 'diet drinks' have been positively related to metabolic syndrome, while a recent prospective study failed to reach a significant association between SSB intake and incidence of metabolic syndrome [13]. All these studies came from Western societies; no information is available in this regard from Middle Eastern populations. Finding associations between SSB intake and metabolic syndrome is particularly relevant for this region because consumption of SSBs in this part of the world has increased tremendously due to the phenomenon of nutrition transition [19, 20]. In addition, prevalence of the metabolic

syndrome among Iranian women has been reported to be among the highest rates in the world [8, 27]. Therefore, examining the association between SSB consumption and the metabolic syndrome in this part of the world might add further information to the knowledge in this field. This study aimed to evaluate the association between consumption of SSBs and metabolic syndrome in a large group of the Iranian population.

Participants and Methods

Participants

This cross-sectional study was based on the first part of Isfahan Healthy Heart Program (IHHP). The IHHP was a community-based program for prevention and control of cardiovascular disease and healthy lifestyle promotion. IHHP started in 1999 and took 7 years until 2006 [20, 28]. This program was conducted by the Isfahan Cardiovascular Research Institute and the Isfahan Provincial Health Office. From three provincial cities of Isfahan, Najafabad and Arak, more than 12,000 men and women older than 19 years were selected. For sampling process which has been described elsewhere in more detail [28, 29], multi-stage cluster random sampling method was used. In the current study, participants of IHHP who had complete data on dietary intakes, anthropometric measures, FPG, and serum lipid profiles as well as data for confounding variables were included. After excluding individuals with a prior history of chronic diseases, those who reported a total energy intake of <800 or >4,200 kcal, and those taking medications, a total of 1,752 people (782 men and 970 women) remained for the current analysis. Each participant provided a signed written informed consent. The study was approved by the Ethics Committee of Isfahan University of Medical Sciences and other relevant national organizations.

Assessment of Dietary Intake

Trained technicians assessed dietary intakes of participants by the use of a 49-item food frequency questionnaire (FFQ). The validity of this questionnaire was confirmed by Medical Education Development Center before being used [28]. Participants were asked to report frequency of consumption for each food item during the last year. These data were collected based on daily (e.g. bread), weekly (e.g. rice, meat), and monthly (e.g. fish) basis. For the present analysis, all data on food items were computed as daily intakes by dividing weekly consumption by 7 and monthly consumption by 30. Consumption of SSBs was calculated by summing up the consumption of 'soft drinks' and 'artificially sweetened fruit juices' (commonly used in Iran). Individuals with 3 or more times/week consumption of SSBs were defined as high consumers. Such definition is different from those reported from Western countries. This discrepancy in definition can be explained by lower consumption of SSBs in Iran compared with Western populations.

Biochemical Assessment

All biochemical measurements were done on a fasting blood sample taken from each participant after an overnight fast. FPG was measured on the day of blood collection by enzymatic colorimetric method using glucose oxidase (Pars Azmoon Inc., Tehran, Iran). For further biochemical analyses, the collected blood samples in each center were frozen at -20 °C until being assayed in the central laboratory of Isfahan Cardiovascular Research Center, a WHO collaborating center. Enzymatic colorimetric method was used to measure serum total cholesterol and triglyceride levels. Dextran sulphate-magnesium chloride was used to remove non-HDL cholesterol. After precipitation of the apolipoprotein B-containing lipoproteins, HDL cholesterol levels were determined by the use of commercially available enzymatic kits. To quantify serum low-density lipoprotein (LDL) cholesterol levels, we used the Friedewald equation [30]. The metabolic syndrome was defined based on Adult Treatment Panel III, such that individuals with 3 or more of the following risk factors were described as having metabolic syndrome: FPG of >100 mg/dl, waist circumference of ≥102 cm for men and ≥88 cm for women, serum triglyceride levels of ≥150 mg/dl, serum HDL cholesterol levels of <40 mg/dl for men and <50 mg/dl for women, and systolic or diastolic blood pressure of ≥130/85 mm Hg.

Assessment of Other Variables

Trained interviewers collected information about socioeconomic and demographic data in a face-to-face method. Data on medical and family history as well as smoking status were collected by the use of

Table 1. Characteristics of the study participants across categories of SSB intake^a

Categories of SSB intake, times/week								
	females				males			
	<1 (n = 495)	1-3 (n = 343)	≥3 (n =132)	p value ^b	<1 (n = 285)	1-3 (n = 317)	≥3 (n = 180)	p value ^b
Age, years	39.4 ± 14.2	36.0 ± 13.7	33.8 ± 13.3	<0.001	41.6 ± 16.7	39.3 ± 14.9	33.1 ± 13.2	<0.001
Weight, kg	66.0 ± 12.5	66.0 ± 12.0	66.2 ± 13.6	0.98	71.7 ± 11.9	71.0 ± 11.5	74.0 ± 13.7	<0.05
BMI, kg/m ²	27.0 ± 5.1	26.7 ± 5.0	26.8 ± 5.7	0.67	24.8 ± 4.0	24.3 ± 3.8	24.8 ± 4.3	0.24
BMI ≥ 25 kg/m ² , %	62.9	61.2	57.4		46.3	46.5	42.4	0.64
Physical activity, MET-min/day	663.0 ± 383.5	653.4 ± 379.2	726.2 ± 425.7	0.17	996.5 ± 506.9	1,122 ± 524.7	1,098 ± 516.7	<0.001
Education, %								
0-5 years	57.6	48.8	35.5	<0.001	42.7	38.7	20.5	<0.001
6-12 years	36.6	47.0	55.6	<0.001	44.5	48.7	59.1	<0.001
>12 years	5.8	4.2	8.9	<0.001	12.8	12.6	20.5	<0.001
Smoking, %	1.2	1.7	2.3	0.63	20.7	22.7	31.7	<0.05

^aData are means $\pm$ standard deviation unless indicated.

^bObtained from ANOVA for continuous variables and chi-square for categorical variables

Table 2. Energy and dietary intakes of study participants across categories of SSB intake^a

Categories of SSB intake, times/week								
	females				males			
	<1 (n = 495)	1-3 (n = 343)	≥3 (n = 132)	p value ^b	<1 (n = 285)	1-3 (n = 317)	≥3 (n = 180)	p value ^b
Energy, kcal	1,760 ± 781	1,879 ± 836	1,902 ± 947	0.06	2,171 ± 1,021	2,328 ± 967	2,553 ± 946	<0.001
Fruit, times/week	7.1 ± 4.8	7.4 ± 4.2	9.3 ± 4.5	<0.001	6.4 ± 4.1	7.1 ± 3.8	7.9 ± 3.8	<0.001
Vegetable, times/week	6.3 ± 4.0	6.6 ± 3.8	7.6 ± 4.4	<0.05	5.9 ± 3.7	6.4 ± 3.1	7.0 ± 3.5	<0.05
Dairy, times/week	0.4 ± 1.4	0.4 ± 1.3	0.9 ± 2.8	<0.05	0.6 ± 1.4	0.7 ± 1.6	1.0 ± 2.1	<0.05
Meat, times/week	6.3 ± 3.5	7.0 ± 3.4	8.3 ± 4.0	<0.001	5.6 ± 2.9	6.5 ± 3.1	7.0 ± 2.7	<0.001
HHVO*, times/week	10.5 ± 5.7	12.5 ± 6.1	13.2 ± 6.7	<0.001	10.6 ± 6.3	11.5 ± 6.0	13.1 ± 6.0	<0.001
Non-HVO, imes/week	2.1 ± 4.0	2.2 ± 3.9	4.2 ± 5.7	<0.001	2.6 ± 3.9	2.8 ± 3.9	3.0 ± 3.8	0.50
Pulses, times/week	23.2 ± 6.0	23.4 ± 6.6	22.9 ± 7.7	0.71	24.7 ± 5.3	24.2 ± 5.7	23.5 ± 5.7	0.17

^aData are means $\pm$ standard deviation.

^bObtained from ANCOVA. Data for energy intake are adjusted for age. Data for food groups are adjusted for age and total energy intake.

^cHydrogenated vegetable oil.

pretested questionnaires. Physical activity levels of participants were assessed using the Baecke questionnaire [31]. A secured metal ruler was used to measure height in barefoot. A calibrated scale was used to measure weight in light clothing. BMI was calculated as weight in kilogram divided by height in meters squared. Waist circumference was taken as the smallest circumference around costal margin and hip circumference was taken at the greatest circumference. Blood pressure was measured twice in a seated position after a 5-min rest. The average of two measurements was considered as the final systolic and diastolic blood pressure.

Statistical Methods

Data analysis was done separately by sex. To categorize participants, we used three levels of SSB consumption: <1 time/week, 1–3 times/week and >3 times/week. General characteristics of the study participants across categories of SSB intake were assessed by the use of analysis of variance (for continuous variables) and chi-square tests (for categorical variables). We used analysis of covariance for comparing dietary intakes across categories of SSB consumption with age and total energy intake as covariates. Multivariate-adjusted means of metabolic risk factors across categories of SSB intake were obtained by the use of analysis of covariance with age (continuous), daily physical activity (continuous), smoking status (current, non-current), total energy intake (kcal/day), and consumption of meats, fruits, vegetables, pulses, dairy, hydrogenated and non-hydrogenated vegetable oils (all as continuous) as covariates. To determine the association of SSB intake with the metabolic syndrome, we used logistic regression analysis. Besides a crude model in this analysis, we constructed three other models with adjustment for age and total energy intake in the first model. We further controlled for daily physical activity (continuous), smoking status (current, non-current), and consumption of meats, grains, fruits, vegetables, pulses, dairy, hydrogenated and non-hydrogenated vegetable oils (all as continuous) in the second model. Finally, additional adjustment for BMI was done to explore if the associations are mediated through obesity. The logistic regressions were first constructed for the whole population; then the stratified analysis was performed according to BMI ($\text{BMI} < 25$ and $\text{BMI} \geq 25 \text{ kg/m}^2$) to determine the discrepancy of associations among normal-weight ($\text{BMI} < 25 \text{ kg/m}^2$) and overweight ($\text{BMI} \geq 25 \text{ kg/m}^2$) participants. In all logistic regression models, the first category of SSB intake (<1 time/week) was considered as a reference. Mantel-Haenszel extension chi-square test was used to examine the overall trend of odds ratios across categories of SSB intake. Statistical Package for Social Science (SPSS Inc., Chicago IL, USA; Version 16.0) was used for all statistical analyses.

Results

The characteristics of the study participants across categories of SSB consumption are shown in table 1. Males and females with high consumption of SSBs (>3 times/week) were younger than those with low consumption (<1 time/week) ($p < 0.001$). Mean BMI was not significantly different across SSB categories; however, high SSB consumption was associated with higher weight in men ($p < 0.05$), but not in women. Males in the highest category of SSB intake were more likely to be current smokers and physically active ($p < 0.05$). The distribution of individuals in terms of educational level was significantly different across categories of SSB intake ($p < 0.001$). Prevalence of overweight and obesity was not associated with SSB consumption in either gender.

Dietary intakes of study participants across categories of SSB intake are provided in table 2. High consumption of SSBs was associated with greater intakes of energy and almost all food groups. Women in the highest category of SSB intake consumed higher amounts of fruits, vegetables, dairy, meat as well as hydrogenated and non-hydrogenated vegetable oils as compared with those in the lowest category. This was also the case for total energy intake; however, the association was marginally significant ($p = 0.06$). Except for consumption of pulses and non-hydrogenated vegetable oils, men in the top category of SSB intake had higher intakes of energy and all food groups as compared with those in the bottom category ($p < 0.001$).

Table 3. Means and standard deviations of cardiovascular risks across categories of SSB intake^a

	Categories of SSB intake, times/week				
	females		males		
	<1 (n = 495)	1-3 (n = 343)	≥3 (n = 132)	p value ^b	
Fasting plasma glucose, mg/dl					
Crude	82.3 ± 1.1	81.1 ± 0.8	78.0 ± 1.1	0.11	
Model 1 ^c	82.9 ± 2.7	82.7 ± 2.5	80.4 ± 3.2	0.46	
LDL-cholesterol, mg/dl					
Crude	117.1 ± 1.7	118.4 ± 2.0	120.2 ± 4.3	0.74	
Model 1	119.0 ± 5.0	123.5 ± 5.2	126.8 ± 5.9	0.08	
HDL-cholesterol, mg/dl					
Crude	75.0 ± 0.4	47.0 ± 0.6	47.3 ± 1.0	0.44	
Model 1	45.6 ± 1.4	45.1 ± 1.4	45.7 ± 1.6	0.57	
Total-cholesterol, mg/dl					
Crude	196.8 ± 2.2	195.8 ± 3.2	196.0 ± 4.5	0.95	
Model 1	198.1 ± 6.0	202.1 ± 6.1	206.6 ± 6.9	0.14	
Systolic blood pressure, mm Hg					
Crude	116.1 ± 0.9	112.0 ± 1.0	110.7 ± 1.7	<0.05	
Model 1	114.2 ± 2.2	112.6 ± 2.2	112.4 ± 2.6	0.32	
Diastolic blood pressure, mm Hg					
Crude	76.9 ± 0.5	73.6 ± 0.6	73.2 ± 1.0	<0.001	
Model 1	76.3 ± 1.4	74.1 ± 1.4	74.1 ± 1.6	<0.05	
Serum triglyceride levels, mg/dl					
Crude	161.7 ± 4.9	152.5 ± 5.2	145.6 ± 7.1	0.19	
Model 1	166.8 ± 13.0	165.4 ± 13.3	165.3 ± 15.1	0.98	
Odds ratios for metabolic syndrome ^d					
Crude	1.00	1.79 (1.15–2.78)	1.02 (0.64–1.63)	0.19	
Model 1 ^e	1.00	1.29 (0.79–2.09)	0.86 (0.51–1.44)	0.46	
Model 2 ^f	1.00	1.18 (0.71–1.97)	0.79 (0.46–1.35)	0.55	
Model 3 ^g	1.00	1.21 (0.70–2.09)	0.80 (0.46–1.42)	0.59	

^aData are means ± standard error. ^bObtained from ANCOVA for means and from Mantel-Haenszel extension chi-square test for odds ratios. ^cAdjusted for age, total energy intake, daily physical activity and dietary intakes of meats, grains, fruits, vegetables, dairy, pulses, Non-HVOs and HVOs (hydrogenated vegetable oil). ^dMetabolic syndrome was defined according to the guidelines of ATP III. ^eAdjusted for age and total energy intake. ^fFurther adjusted for smoking, physical activity, dietary intakes of meat, grains, pulses, fruits, vegetables, dairy, HVOs and Non-HVOs. ^gAdditionally controlled for BMI.

Crude and multivariate-adjusted means of metabolic risk factors across SSB categories are indicated in table 3. Surprisingly, in crude models we reached significant inverse associations between SSB intake and blood pressure in either gender, such that those in the highest category of SSB intake had lower systolic and diastolic blood pressure as compared with those in the lowest category. However, means of both systolic and diastolic blood pressure in all categories of SSB intake were in the normal range. When the analyses were controlled for potential confounders, the associations disappeared, except for the association of SSB intake with diastolic blood pressure among females. Besides blood pressure, we also found a significant difference in serum triglyceride levels between men consuming SSBs 1-3 times/week and those consuming <1 time/week. However, after controlling for potential confounders, this association disappeared. No overall significant differences were found in other metabolic risk factors across categories of SSB intake. Multivariate-adjusted odds ratios indicated no significant associations between SSB intake and prevalence of the metabolic syndrome in either gender (table 3). Adjustment for age and total energy intake slightly altered the odds ratios, but the associations were still nonsignificant. Additional control for dietary intakes did not affect the associations in either gender. After further adjustment for BMI, we found that men in the top category of SSB intake were 17% more likely to have the metabolic syndrome, while women in the highest category were 20% less likely to have the syndrome as compared with those in the bottom category. However, these associations were not significant in either men or women. No increasing or decreasing trend in the odds ratios of metabolic syndrome were found with increased consumption of SSBs. When a stratified analysis was conducted according to the BMI, the same findings were obtained. This was also the case when the analyses were performed separately by gender (data not shown).

Discussion

In this cross-sectional study on an Iranian adult population, we failed to find any significant association between SSB intake and metabolic syndrome. Lack of significant associations was persisted even after controlling for potential confounders.

Several potential reasons might explain these findings. The FFQ we used for dietary data collection had no information on portion size, and we had collected data about consumption frequency. Therefore, lack of accuracy on the assessment of SSB intake is a concern in this study. Furthermore, we had not validated our measurements of blood pressure and biochemical indicators. Lifestyle characteristics of the study population with low levels of SSB consumption might also provide additional reasons.

SSBs are carbonated or noncarbonated beverages that contain high amounts of sugar and flavored with natural or artificial additives [32]. Due to the provision of just calorie to the diet, SSBs are usually considered as caloric beverages with harmful effects to human health [33, 34]. These kinds of beverages are full of calories and in general are consumed as additional food intake [35]. Recently, SSB consumption has been associated with increased risk of obesity and the metabolic syndrome. However, findings about these associations are inconsistent. In the current study we did not find any significant association between SSB consumption and metabolic syndrome. It must be kept in mind that we defined SSB intake as the sum of 'soft drinks' and 'artificially sweetened fruit juices'. Artificially sweetened fruit juices in Iran are both natural and industrial fruit juices with added sugars. There might be other sugar-containing beverages not considered in our analysis. However, other sugar-containing products such as beverages made with powdered flavoring, non-juice fruit-flavored drinks, sports drinks or sweetened coffee drinks are not of usual intake

among Iranian general population. These findings are in line with other studies. In a well-designed prospective study Lutsey et al. [13] showed that consumption of SSBs was not associated with incident metabolic syndrome among middle-aged adults. Findings from a meta-analysis have also indicated that the association between SSB intake and BMI is near zero [36]. Recent reviews have also reached to the conclusion that there is no strong evidence for this association [37–39]. Lack of significant association between SSB consumption and weight gain has also been reported by others [21, 40, 41]. Some other studies also reported that there is no convincing evidence to link SSB consumption and obesity [42–45] and diabetes risk [46]. In contrast, others found that high intake of SSBs is positively associated with metabolic syndrome [25, 47, 48], obesity [49–51], related cardio metabolic diseases [52], insulin resistance [42], type 2 diabetes [35, 53, 54], low levels of HDL cholesterol [55], and increased serum triglyceride levels [56]. Consumption of more than one soft drink per day, as compared with less than one drink a day, has been linked with the high prevalence of metabolic syndrome [35]. This has also been shown by a cross-sectional study among young adults [17]. SSB intake in our study is much lower than one serving per day. The SSB intake in the highest category is >3 times per week, which is not necessarily the same as once per day. This might explain, to some extent, the discrepancy in findings between this study and earlier ones. Inconsistent findings in different studies might also be explained by different study designs, sample size, or lack of control for confounding variables in some studies [49]. Other factors like different range of BMI studied in different publications as well as the age group of participants might provide some additional reasons for conflicting results [35].

Several mechanisms have been suggested through which SSB consumption might affect risk of the metabolic syndrome. Less satiety-inducing effects of beverages than those of solid foods has been documented as a possible mechanism. Therefore, consumption of energy-containing beverages like SSBs would result in overconsumption [40]. The other mechanism is related to the glycemic effects of the SSBs. SSBs are a high-glycemic-index foods that contain greater amounts of carbohydrates that could rapidly be absorbed and lead to increments in postprandial glucose levels [57]. The association between glycemic index and metabolic syndrome has long been demonstrated [58]. It seems that components other than sugar content of SSBs (for instance additives) might play a role in this association because even the artificially sweetened beverages have been linked with incident metabolic syndrome in the Framingham Heart Study [25] and the Atherosclerosis Risk in Communities Study [13].

Several limitations should be considered in the interpretation of our findings:

First is the cross-sectional design of the study that prohibits inferring causal relationship between SSB intake and the metabolic syndrome. Future longitudinal studies are required to confirm the association. However, it must be kept in mind that the current study comes from a developing country where only limited sources of funding are available for conducting research. Cohort studies are too expensive to be afforded by a developing country. Furthermore, although the association between SSB intake and metabolic syndrome has been reported from Western countries, limited data are available from non-Western populations, particularly from the understudied region of Middle East. In addition, appropriate analysis of cross-sectional data represents a valuable initial step in identifying relationships between diet and disease. Moreover, prospective cohort studies and clinical trials have their own weaknesses.

Second, as we used a FFQ for assessing dietary intakes, misclassification is a major concern in our study as in any other epidemiologic studies. This is of particular importance given that we considered the frequency of SSB consumption instead of its quantity. The FFQ we used for dietary data collection had no information on portion size, and we had collected

data about consumption frequency. However, it must be kept in mind that putting information on portion size in the FFQ does not add so much, particularly in the case of foods that come in natural units (like SSBs). In addition most of the variations in dietary intake of foods have been shown to be explained by frequency of use rather than their portion size, therefore, data on portion size are relatively unimportant. Furthermore, portion sizes are positively correlated with frequency of use meaning that some of the information on portion size is already accounted for by frequency of use. The potential contribution of additional questions on portion size in the FFQ deserves further investigation; however, available data suggest that such questions do not add substantially to the assessment of dietary intake.

Third, some lifestyle factors that might confound the association between SSB intake and the metabolic syndrome may not have been accurately captured and controlled in our analysis, resulting in residual confounding.

Fourth, the risk estimates obtained in our study were not adjusted for all dietary intakes. However, the associations we observed are unlikely to be confounded significantly by other dietary variables because the extensive adjustments we made had minimal impact on the odds ratios.

Fifth, we excluded individuals taking medications that would affect serum lipid profiles. This might affect the interpretation of our findings.

In conclusion, we failed to find evidence supporting the previous findings on the association between SSB consumption and metabolic syndrome. Prospective studies are needed to further explore for this association.

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Disclosure Statement

The authors declared no conflicts of interest.

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