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Original Article

Sugar-Sweetened Beverage Consumption and Risk of General and Abdominal Obesity in Iranian Adults: Tehran Lipid and Glucose Study

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Abstract

Background: General and abdominal obesity are major global health problems. This cross-sectional study was conducted to evaluate the association between consumption of sugar-sweetened beverages (SSBs) and body mass index and waist circumference status in 5852 Iranian adults within the framework of the Tehran Lipid and Glucose Study (TLGS).

Methods: Intakes of SSBs including carbonated drinks and synthetic fruit juices were measured using a validated food frequency questionnaire. The association between body mass index, waist circumference and body adiposity index in each quartile category of SSB consumption were determined using the multivariable linear regression models. The odds ratio (OR) of general and abdominal obesity in each quartile of SSB consumption was also determined using the multivariable logistic regression models.

Results: Mean dietary intake of SSBs was 48.9 g/d or 0.25 servings/d. After adjustment for all potential confounding variables, significant associations were observed between SSB consumption and BMI (β: 0.49, 95% CI: 0.13-0.86), and waist circumference (β: 1.28, 95% CI: 0.40-2.16) in the fourth quartile. There was no significant association between SSB consumption and body adiposity index. Participants who consumed > 57.1 g/d of SSBs had 22% higher risk of general obesity (OR: 1.22, 95% CI: 1.00-1.48) and 35% higher risk of abdominal obesity (OR: 1.35, 95% CI: 1.12-1.61), compared with those in the lowest quartile of SSB consumption.

Conclusion: Higher intakes of SSBs were associated with the higher risk of general and abdominal obesity in adults suggesting that limiting the consumption of SSBs may be a practical approach to prevent and manage obesity.

Keywords: Sugar-sweetened beverages, Obesity, Abdominal obesity, Iran

Introduction

General and abdominal obesity, major global health problems, are associated with increased risk of non-communicable diseases such as diabetes, metabolic syndrome, nonalcoholic fatty liver disease and cardiovascular complications (1-3). Increased consumption of industrial food products such as sugar sweetened beverages (SSBs), which include carbonated drinks and synthetic fruit juices may contribute to the growing epidemic of obesity. Sugars added during the processing or preparation of foods play an important role in the amount of energy consumption (4). Sugar sweetened beverages are the greatest source of added sugar intake and their consumption has increased over the last decades, tracking closely with the sharp increase of obesity (5).

Current data regarding the association between SSB consumption and obesity are still inconsistent. Most cross-sectional and longitudinal epidemiological studies indicate that regular consumption of SSBs can lead to weight gain and increased risk of chronic diseases (6-10). However, one meta-analysis has established no relationship between body mass index (BMI) and SSB consumption (11).

Several possible mechanisms may explain the association between obesity and consumption of SSBs. Consumption of SSBs is associated with overconsumption of calories as a result of low satiety of liquid foods (12-14). Moreover, high-fructose corn syrup, the sweetener used in SSBs, promotes weight gain because of its adverse effects on insulin secretion and leptin release and reduces the body's normal inhibitory effect on food intake (15, 16). The fructose content of these beverages may also promote the accumulation of visceral adiposity (17).

For better understanding of the SSB consumption status of Iranian adults and its relationship with obesity risk, the current study was conducted to evaluate the association between SSB consumption and BMI and waist circumference status in a representative sample of Tehranian adults.

Materials and Methods

Study population

This study was conducted within the framework of the Tehran Lipid and Glucose Study (TLGS). Briefly, TLGS is a community-based prospective study being conducted to investigate and prevent non-communicable diseases, in a representative sample of residents of district 13 of Tehran, the capital city of Iran. The first phase of the TLGS began in March 1999 and data collection is ongoing at three-year intervals (18, 19).

For the current study, 6672 men and women aged 19-70 years, who participated in the fourth phase of TLGS (2009-2011) were recruited. We excluded participants if they had no information on sex and anthropometric measurements (n=132), if they were underweight (n=110), if they were under- or over reporters of dietary intakes (less than 800 kcal/d or more than 4200 kcal/d, respectively) (n=435), if they were on specific diets (n=130), or if they had reported cancer or stroke (n=13). After exclusions, the final analysis was conducted on data of 5852 participants.

Informed written consents were obtained from all participants and the study protocol was approved by the research council of the Research Institute for Endocrine Sciences (RIES), Shahid Beheshti University of Medical Sciences, Tehran, Iran. The study was conducted according to the Declaration of Helsinki and was approved by the ethical committee of the Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences.

Dietary assessment

Dietary data were collected using a validated semi-quantitative food frequency questionnaire (FFQ) with 168 food items, developed for the TLGS. Trained dietitians asked participants their intake frequency for each food item consumed during the past year on a daily, weekly, or monthly basis. The validity and reliability of the FFQ for food group intakes were assessed and were acceptable (20). Because the Iranian Food Composition Table (FCT) is incomplete and has limited data on nutrient content of foods, we used the US Department of Agriculture (USDA) Food Composition Table to analyze foods and beverages (21); however, the Iranian FCT was used for some national foods and beverages, which are not listed in the USDA FCT (22). The USDA database for added sugar was used to identify the added sugar contents of food items. Intake of added sugar was calculated in percent of energy per day (21, 23).

The FFQ included questions on the frequency of consumption and usual portion size of SSBs including carbonated drinks and synthetic fruit juices, both of which were combined to estimate the daily intake of SSBs. Portion sizes of consumed SSBs reported in household measures were then converted to grams, and their intakes were categorized by using quartile cutoffs (<6.7, 6.7-21.8, 21.9-57.1, >57.1 g/d). Participants with dietary SSB intakes <6.7 g/d were considered as the reference group. The average intake of SSBs (g/day) was converted to practical serving sizes, with the assumption that one serving was equivalent to 1 cup or 200 grams.

Lifestyle and anthropometric measurements

Trained interviewers collected the participants' characteristics using a questionnaire. Information on age (years), educational level (illiterate, primary education and academic education), smoking behavior (yes/no), and physical activity level (MET-hr/wk) were also assessed. Participants who smoked daily or occasionally were considered current smokers, and those who had never smoked or those who stopped smoking were considered non-smokers. Physical activity level was assessed using the Persian translated Modifiable Activity Questionnaire (MAQ) (24). High reliability and relatively moderate validity were reported for the Persian translated MAQ in Tehranian adults (25). The frequency and time spent on light, moderate, hard and very hard intensity activities according to the list of common activities of daily life over the past year were documented. Physical activity was calculated as metabolic equivalent hours per week (METs h/wk), and was then categorized to low, moderate and high activity groups (26).

Weight was measured to the nearest 100 g using digital scales, while the participants were minimally clothed, without shoes. Height was measured to the nearest 0.5 cm using a tape meter, in a standing position without shoes. Body mass index was calculated as weight (kg) divided by square of the height (m^2). Waist circumference was measured to the nearest 0.1 cm, at the umbilical level and hip circumference was measured at the maximum level, over light clothing, using a tape meter. Body adiposity index was calculated as (hip (cm)/height (m) $^{1.5}$)-18 (27). Body mass index ≥ 30 kg/m^2 was classified as general obesity and waist circumference ≥ 95 cm for both sexes was classified as abdominal obesity (28).

Statistical analysis

All statistical analyses were conducted using SPSS (Version 15.0; SPSS Inc, Chicago, IL), and *P* values < 0.05 were considered significant. Participant characteristics were compared across quartiles of SSB intakes using the general linear model, adjusted for sex and age or the Chi-square test. Dietary intakes of participants were compared across quartiles of SSB intakes, using One-way analysis of variance or Kruskal-Wallis test. The odds ratio (OR) of general and abdominal obesity in each quartile of SSB intake was determined using the multivariable logistic regression models. Logistic regression models included a dichotomous outcome (obesity (yes or no) or abdominal obesity (yes or no)) and quartiles of SSB intakes as the main predictor of interest, adjusted for age, sex, physical activity, smoking status, education status and energy intake. Because total energy intake could be in the casual pathway between SSB intakes and obesity risk, energy intake was included in an additional model. Data are presented as OR with 95% confidence interval (CI). To assess the overall trends of odds ratio across increasing quartiles of SSB intakes, the median SSB intakes of each quartile was used as a continuous variable in logistic regression models. The association between body mass index, waist circumference and body adiposity index as continuous variables and quartiles of SSB intakes were determined using multivariable linear regression models with adjustment for age, sex, physical activity, smoking status, education status and energy intake. Data are presented as β regression and 95% confidence interval.

Results

Mean age of participants was 40.6 y, and mean BMI was 27.5 kg/m^2. Forty three percent of the participants were men. Mean dietary intake of SSBs was 48.9 g/d or 0.25 servings/d (65.8 and 36.2 g/d, in men and women, respectively). Characteristics of the study participants across quartile categories of SSBs are shown in Table 1.

Table 1: Characteristics of participants according to quartiles of intakes of sugar sweetened beverages

	(n=5852)				
	Q1 (n=1491)	**Q2 (n=1435)**	**Q3 (n=1470)**	**Q4 (n=1456)**	***P*[3]**
Sugar sweetened beverages (g/d)					
	<6.7	6.7-21.8	21.9-57.1	>57.1	
Range	2.6±2.7	13.0±4.3	36.1±10.0	144.7±106.8	
Mean					
Age (y)[1]	45.7±12.7	40.7±12.3	39.7±12.4	36.2±12.4	< 0.001
Men (%)	30.9	37.3	46.0	58.9	< 0.001
BMI (kg/m^2) [2]	26.9±0.13	27.1±0.12	27.6±0.12	27.6±0.12	< 0.001
Waist circumference (cm) [2]	91.7±0.31	92.3±0.29	93.4±0.28	93.7±0.29	< 0.001
Body adiposity index (%)[2]	29.7±0.12	29.8±0.11	30.0±0.11	30.1±0.11	0.03
Physical activity					0.001
Low	67.2	71.8	73.2	73.3	
Moderate	21.1	20.1	16.6	17.2	
High	11.7	8.1	10.2	9.5	
Current smoker (%)	7.0	8.9	12.2	16.5	< 0.001
Education status (%)					0.02
Illiterate	1.1	0.8	1.4	0.8	
Primary education	73.1	69.5	69.7	68.1	
Academic education	25.8	29.7	28.9	31.2	

[1] Data are mean ± SD./ [2] Data are age- and sex-adjusted mean ± SE./ [3] *P* value compared the characteristics of participants across quartiles of sugar sweetened beverage intakes using Chi square test, analysis of variance or analysis of covariance.

The distribution of the men in the upper quartile of SSBs was significantly higher than the lower quartile categories (58.9 *vs.* 30.9%). Participants in the highest compared with the lowest quartile of SSBs, were significantly younger (36.2 *vs.* 45.7 years, *P* <0.01), had higher body mass index (27.6 *vs.* 26.9 kg/m^2), as well as waist circumference (93.7 *vs.* 91.7 cm) and body adiposity index (30.1 *vs.* 29.7 %). Higher consumption of SSBs was observed in participants with lower physical activity (*P*<0.01), higher smoking (*P*<0.01) and higher academic education levels (*P*<0.05). Dietary intakes of participants according to the quartile categories of SSB consumption are presented in Table 2.

Table 2: Dietary intakes of participants according to quartiles of intakes of sugar sweetened beverages

	(n=5852)				
	Q1 (n=1491)	**Q2 (n=1435)**	**Q3 (n=1470)**	**Q4 (n=1456)**	***P***
Sugar sweetened beverages (g/d)					
Range	<6.7	6.7-21.8	21.9-57.1	>57.1	
Mean	2.6±2.7	13.0±4.3	36.1±10.0	144.7±106.8	
Energy (kcal/d)	2207±713	2240±668	2413±678	2712±686	< 0.001
Carbohydrate (% of total energy)	59.1±11.3	58.9±6.67	58.6±6.51	58.6±6.32	0.15
Fat (% of total energy)	30.1±23.4	29.6±6.28	30.3±6.05	30.3±5.9	0.48
Protein (% of total energy)	15.8±10.8	15.0±3.35	14.7±2.90	14.3±2.72	< 0.001
Total fiber (g/1000 kcal)	21.8±27.0	19.9±6.75	19.6±9.94	17.9±6.22	< 0.001
Added sugar (% of total energy)	3.52±2.85	4.41±2.81	5.03±2.74	7.11±3.17	< 0.001
Percentage of added sugar from liquid sources (%)	2.64±5.13	8.59±7.24	16.87±9.95	34.21±17.34	< 0.001

Data are mean±SD./ *P* value compared the dietary intakes of participants across quartiles of sugar sweetened beverages using One-way analysis of variance and Kruskal-Wallis test.

Daily energy intake and energy intake from added sugar were significantly higher in participants with the highest compared to the lowest consumption of SSBs (*P*<0.01). There was a significant decreasing trend in dietary intakes of protein and total fiber across increasing consumption of SSBs (*P*<0.01). Percentage of added sugar from liquid sources was over 12 fold in the highest compared to the lowest consumption of SSBs.

Associations of SSB consumption and anthropometric measures in each quartile category of SSBs are shown in Table 3.

Table 3: The association between sugar sweetened beverage intakes and anthropometric measures (n=5852)

Quartiles of sugar sweetened beverage intake	Body mass index	Waist circumference	Body adiposity index
Q1(<6.7g, reference)			
Q2 (6.7-21.8g)	0.15 (-0.19-0.49)	0.31 (-0.51-1.13)	0.07 (-0.24-0.38)
Q3 (21.9-57.1g)	0.47 (0.13-0.81)	0.99 (0.16-1.81)	0.19 (-0.12-0.51)
Q4 (>57.1g)	0.49 (0.13-0.86)	1.28 (0.40-2.16)	0.25 (-0.09-0.59)

Data are β regression and 95% confidence interval estimated by using linear regression models with adjustment for age, sex, physical activity, smoking status, education status and energy intake.

After adjustment for all potential confounding variables including age, sex, physical activity, smoking status, education status and energy intake, a significant association was observed between SSB consumption and BMI (β: 0.49, 95% CI: 0.13-0.86), and waist circumference (β: 1.28, 95% CI: 0.40-2.16) in the fourth quartile category. No significant association was observed between SSB consumption and body adiposity index.

Odds ratio and 95% confidence interval of general and abdominal obesity across quartile categories of SSB consumption is provided in Table 4.

Table 4: Odds ratio and 95% confidence interval for general and abdominal obesity across quartile categories of sugar sweetened beverage intakes (n=5852)

Quartiles of sugar sweetened beverage intakes	Model 1		Model 2		Model 3	
	OR	95%CI	OR	95%CI	OR	95%CI
Obesity (BMI≥30 kg/m²)						
Q1(<6.7g, reference)						
Q2 (6.7-21.8g)	1.10	0.93-1.31	1.15	0.96-1.37	1.15	0.96-1.37
Q3 (21.9-57.1g)	1.23	1.04-1.45	1.25	1.04-1.50	1.24	1.03-1.48
Q4 (>57.1g)	1.26	1.05-1.51	1.25	1.02-1.50	1.22	1.00-1.48
P for trend	0.02		0.09		0.15	
Abdominal obesity (WC≥ 95 cm)						
Q1(<6.7g, reference)						
Q2 (6.7-21.8g)	1.09	0.93-1.28	1.10	0.93-1.31	1.10	0.93-1.31
Q3 (21.9-57.1g)	1.25	1.06-1.47	1.25	1.06-1.48	1.24	1.05-1.47
Q4 (>57.1g)	1.39	1.18-1.65	1.37	1.15-1.64	1.35	1.12-1.61
P for trend	< 0.001		0.001		0.003	

Model 1: Logistic regression model with adjustment for age and sex.
Model 2: Additional adjustment for physical activity, smoking status and education status.
Model 3: Additional adjustment for energy intake.

After adjustment for confounding variables, participants in the highest compared to the lowest quartile category of SSBs had higher risk of general obesity (OR: 1.25, 95% CI: 1.02-1.50) and abdominal obesity (OR: 1.37, 95% CI: 1.15-1.64); however, these associations became slightly weaker after additional adjustment for energy intake (OR: 1.22, 95% CI: 1.00-1.48) and (OR: 1.35, 95% CI: 1.12-1.61) for general and abdominal obesity, respectively.

Discussion

In this cross-sectional study, higher intake of SSBs was associated with the higher risk of general and abdominal obesity in adults. We also observed that increasing SSB intake was associated with increased BMI and waist circumference. Participants who consumed > 57.1 g/d (0.28 servings/d) of SSBs had 22% higher risk of obesity and 35% higher risk of abdominal obesity, compared with those in the lowest quartile of SSB consumption; these findings support previous observational studies, which have shown that regular consumption of SSBs was associated with an increased risk of obesity and abdominal obesity (6, 29-32). Malik et al, in a meta-analysis of prospective cohort studies provided evidence that one daily serving increment of SSBs was associated with 0.22 kg and 0.12 kg weight gain in adults over 1 year, in random and fixed-effects models, respectively (33). However, other studies have found no association between SSB consumption and obesity (15, 34, 35).

Body adiposity index has been proposed as a new measurement to determine fat mass (27). In the present study, no significant association was found between SSB consumption and body adiposity index, as an indicator for percentage of adiposity; this observation is in agreement with the Odegaard et al. study that showed SSB intakes had no association with overall adiposity, and a significant association was observed only between frequent SSB consumption and more abdominal adiposity in non-Hispanic white adults (36).

In the present study, mean dietary intake of SSBs was about 50 g/d or 0.25 servings/d. The mean intake of daily soft drinks was 56 ml among Iranian university students (37). SSB intake was lower than one serving per day in Iranian adults (38). Moreover, percentage of added sugar from liquid sources in the fourth quartile of SSBs intake in this study was 34%, while the NHANES reported that soft drinks and fruit drinks provided >40% of added sugars and SSBs are the greatest contributor to added sugar intake in the United States (17, 39). These results are in line with differences of dietary habits in various countries indicating that SSBs had lower consumption in Iran, compared to western countries generally.

Results of epidemiological studies are inconsistent. Based on Olsen and Heitman's meta-analysis, high intake of calorically sweetened beverages can be regarded as a determinant for obesity (40); On the other hand, the Sun and Empie meta-analysis found no relationship between BMI and SSB consumption (11). The inconsistency between these results may be explained by the adjustment of different confounders, differences in dietary assessment methods, between-country differences in dietary patterns, variation in definitions of SSBs and different study designs. Furthermore, financial conflicts of interest may bias conclusions of systematic reviews on SSB consumption and weight gain or obesity (41).

Some possible mechanisms may explain the observed associations between consumption of SSBs and obesity; studies have shown that liquid foods have low satiety effect and SSBs are typically consumed as an addition to usual food intake. Therefore, they do not reduce consumption of solid foods in response (12-14). High fructose corn syrup is now used as the sweeteners in SSBs. Results of animal studies indicate that high fructose intake increased lipogenesis and fat storage (42, 43). Dietary fructose reduces circulating insulin and leptin levels and inhibits postprandial suppression of ghrelin. Therefore, fructose increases hunger rating and energy intake (16). Higher dietary fructose intake was significantly associated with the increased risk of abdominal obesity (44).

The consumption of SSBs was associated with reduced vegetables and milk consumption and higher consumption of fast foods (45, 46), imply-

ing that the associations found in this study are results of these unhealthy dietary habits in part.
This study does have some limitations. Due to the cross sectional nature of this study, no causality can be drawn between SSB consumption and obesity. The FFQ was used to estimate typical beverage consumption over the previous year, but like all dietary assessment methods, FFQs have their limitations and underreporting is probable. Moreover, it is possible that seasonal variation will influence fluid consumption. Furthermore, our FFQ did not include all different types of SSBs, which could result in misclassification of exposure. Although we attempted to control for major confounders in the present study, residual confounding cannot be ruled out. However, it is noticeable that at the population level, the importance of minor dietary changes in improving health should not be underestimated.

Conclusion

SSB consumption in this study was lower than in western countries. Despite this, our analysis provided some evidence regarding the association of SSB consumption with higher risk of general and abdominal obesity in adults. Therefore, reducing consumption of SSBs may be a practical approach to reduce energy intake, which in turn could be useful in obesity prevention and management. Limiting intake of SSBs is one simple dietary behavioral change that could have an impact on weight control.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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