HHS Public Access

Author manuscript

Nutr Health. Author manuscript; available in PMC 2020 February 13.

Published in final edited form as:

Nutr Health. ; : 260106018792409. doi:10.1177/0260106018792409.

Prevalence of low-calorie sweetener intake in South Asian adults

Yichen Jin[1], **Allison C Sylvetsky**[1,2], **Namratha R Kandula**[3], **Alka M Kanaya**[4], and **Sameera A Talegawkar**[1,2]

[1]Department of Exercise and Nutrition Sciences, Milken Institute School of Public Health, The George Washington University, Washington, USA

[2]Sumner M Redstone Global Centerfor Prevention and Wellness, Milken Institute School of Public Health, The George Washington University, Washington, USA

[3]Division of General Internal Medicine, Northwestern University Feinberg School of Medicine, Chicago, USA

[4]Division of General Internal Medicine, Department of Medicine, University of California, San Francisco, USA

Abstract

Background: Consumption of low-calorie sweeteners (LCS) has increased in the US and is associated with cardiometabolic risk. No data exist on LCS consumption in South Asians.

Aim: The aim of this study was to assess the prevalence of LCS use across socio-demographic characteristics, chronic disease status, and cardiometabolic risk factors.

Methods: Cross-sectional analyses were conducted using data from the Mediators of Atherosclerosis in South Asians Living in America study (N = 892; 47% women; mean age = 55 (standard deviation = 9.4) y). Chi-squared and ANOVA tests were used to compare LCS consumption across socio-demographic characteristics and cardiometabolic risk factors.

Results: Twenty-two percent of participants reported LCS use, with higher consumption among men and those with longer residency in the US. LCS use was associated with adiposity and higher odds of hypertension, high cholesterol, and diabetes.

Conclusions: LCS use is prevalent among South Asians, emphasizing the need for long-term, prospective studies to investigate its role in incident cardiometabolic risk in an already metabolically vulnerable population.

Keywords

Low-calorie sweetener; non-nutritive sweetener; South Asian; metabolic risk; adiposity

Corresponding author: Sameera A Talegawkar, Department of Exercise and Nutrition Sciences, Milken Institute School of Public Health, The George Washington University, 950 New Hampshire Avenue, NW, 2nd Floor, Washington, DC 20052, USA. sameera.talegawkar@alumni.tufts.edu.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

The study protocol was approved by the institutional review boards of University of California at San Francisco and Northwestern University. All participants signed informed consent prior to undergoing study procedures.

Introduction

Low-calorie sweeteners (LCS), also referred to as non-nutritive sweeteners, artificial sweeteners, high-potency sweeteners, and sugar substitutes, provide a sweet taste without the calories, and are widely used as substitutes for added sugars. LCS consumption has increased rapidly over the past several decades in the US. Currently, approximately 41% of US adults and 25% of children report daily consumption of LCS, and, of these, 44% of adults and 20% of children report the use of LCS multiple times daily (Sylvetsky et al., 2017).

While estimates of LCS use in the general US population are well described (Sylvetsky and Rother, 2016), little is known about LCS consumption among South Asians – one of the fastest-growing ethnic groups in the US (Hoeffel et al., 2012). It is important to evaluate LCS consumption in South Asians, because this minority has a disproportionately high burden of cardiometabolic disease, and the risk of diabetes and subclinical atherosclerosis among non-Hispanic whites is more than 70% lower compared to South Asians (Kanaya et al., 2010). Whether LCS are helpful or harmful to cardiometabolic health is controversial (Azad et al., 2017). LCS have been found to reduce body weight and fat mass in randomized controlled trials (Miller and Perez, 2014), and replacing sucrose with LCS during intensive weight-loss programs has been shown to result in weight loss (Rogers et al., 2015). Meanwhile, several observational studies have demonstrated a positive association between LCS use and cardiometabolic risk (Fowler, 2016). Well-controlled interventions examining the health and cardiometabolic effects of LCS in humans are limited and present with several methodological challenges, including lack of an appropriate control, failure to consider habitual LCS exposure, and selection of study participants who may not reflect the population of LCS users at large (Sylvetsky et al., 2016). In addition, most studies include individuals who self-identify as non-Hispanic white, non-Hispanic black, or Hispanic, with almost no research being conducted in South Asians.

The purpose of this study, therefore, was to assess the prevalence of LCS consumption among South Asians in the US and to investigate any differences in LCS use by socio-demographic characteristics, chronic disease status, and cardiometabolic risk factors. We hypothesized that LCS use would be associated with chronic diseases and a higher cardiometabolic risk.

Methods

A cross-sectional analysis of the baseline data from the Mediators of Atherosclerosis in South Asians Living in America (MASALA) study was carried out. Participants were recruited between 2010 and 2013 from two clinical sites in the San Francisco Bay Area and the greater Chicago area. Detailed information on the MASALA study is provided elsewhere (Kanaya et al., 2013). Among this community-based cohort of 906 South Asians, 14 participants with missing energy intake were excluded, yielding a final sample of 892 participants, among whom 403 participants were from Chicago and 489 participants were from San Francisco.

Measurements of LCS

Dietary intake in the past year was assessed using the validated Study of Health Assessment and Risk in Ethnic Groups (SHARE) semi-quantitative self-reported food frequency questionnaire (FFQ), developed for South Asians in North America (Kelemen et al., 2003). SHARE FFQ includes 163 food items, among which 61 items are specific foods for the South Asian diet. LCS consumption was based on the reported intake of diet soda and the use of LCS packets such as Equal, Splenda, or Sweet'n Low. For analyses investigating the prevalence of LCS consumption (consumer versus non-consumer) across socio-demographic factors, LCS consumers were defined as those who reported consuming greater than or equal to three servings of diet soda or LCS packets per week. Because a serving of LCS in packet form (e.g. one sweetener packet) provides a significantly smaller quantity (mg) of LCS compared to a serving of diet soda (e.g. one can), quantities reported were equalized (six packets = one can of diet soda) for analyses evaluating the cardiometabolic risk factors based on reported LCS consumption.

Measures of cardiometabolic risk factors

Anthropometric measurements included height, weight, and waist circumference, and were assessed using standard methods. Body mass index (BMI) was calculated as weight (kilograms) divided by height (meters) squared, and the World Health Organization BMI cut-offs suggested for Asian adults were used (Choo, 2002). Abdominal visceral, subcutaneous, and intermuscular fat area (cm^2) was assessed via a computed tomography (CT) scan of the abdomen. The non-contrast cardiac CT was used to measure pericardial fat volume (cm^3). Blood pressure was measured three times, and the averages of the second and third readings were used for analysis. Blood tests were conducted after a 12-hour fast. Total cholesterol, triglycerides, and high-density lipoprotein (HDL) cholesterol were measured using enzymatic methods, and low-density lipoprotein (LDL) cholesterol was calculated (Friedewald et al., 1972). Plasma glucose was assessed using the hexokinase method (Sheiko et al., 1979). Insulin resistance was assessed using homeostasis model assessment (HOMA-IR). The detailed categorization criteria for BMI, hypertension, high cholesterol, diabetes, and HOMA-IR are shown in Table 1.

Coronary artery calcium (CAC) was measured as Agatston scores calculated from cardiac CT scans, which were performed in the supine position using a gated-cardiac CT scanner. Common and internal carotid intima-media thickness (CIMT) was measured using high-resolution B-mode ultrasonography. Details regarding the various measurements are provided elsewhere (Kanaya et al., 2013).

Covariates

Information on age, sex, education, family income, insurance type, years of residence in the US, physical activity, and smoking status was obtained using structured interview questions and questionnaires (Kanaya et al., 2013). Physical activity was assessed as intentional exercise, including walking for exercise, dance, conditional activities, and sports from the Typical Week's Physical Activity Survey (Kanaya et al., 2013). Participants were classified as meeting Physical Activity Guidelines for Americans (reporting ≥75 min/week vigorous

activity or ≥150 min/week moderate activity, or combination of moderate and vigorous activity) or not (Physical Activity Guidelines Advisory Committee, 2008).

Statistical analysis

Prevalence of LCS consumption was compared across socio-demographic characteristics and cardiometabolic risk factors using chi-square or ANOVA tests. Values are reported as mean ± standard deviation (SD) or percentage (%). Multiple linear regression was used to assess the associations between continuous cardiometabolic risk factor outcomes and LCS consumption (assessed both as servings of LCS-containing sodas or packets as well as equalized for the approximate quantity of LCS consumed) and logistic models were used for categorical outcomes. Triglyceride and HOMA-IR were natural log transformed in the regression models due to skewed distribution. Covariates included age, sex, education, length of residency in the US, energy intake, BMI (where the outcome was not BMI), smoking, alcohol intake, study site, physical activity, and insurance type. All analyses were performed using Stata 13.1 (StataCorp, 2013).

Results

The mean age (SD) of the MASALA cohort was 55.3 (9.4) years, and 47% of the participants were women. Twenty-two percent of cohort participants reported the consumption of three or more servings of any LCS per week; 19% of participants consumed LCS, but less than three servings per week; and 59% of participants consumed no LCS at all. Because the prevalence of LCS packet consumption was higher than the prevalence of diet soda consumption in this cohort, only 10% of participants were classified as consuming the equivalent of three diet sodas per week, when analyses equalized packets and sodas based on the quantity of LCS contributed (three diet sodas per week equal to 18 LCS packets per week). As shown in Table 2, the prevalence of LCS use was higher among men than women ($p = 0.003$), among participants who were older ($p = 0.02$), for participants with obesity ($p = 0.001$), and for those with diabetes ($p < 0.001$), hypertension ($p < 0.001$), high cholesterol ($p = 0.004$), and higher family income ($p = 0.04$). As high cholesterol was defined as either total cholesterol ≥240 mg/dL or use of statins, LDL cholesterol was lower among LCS consumers. Prevalence of LCS consumption among participants with any measurable CAC Agatston score was 28%, which was 10% higher than those with an Agatston score of zero ($p = 0.001$). LCS consumption was more common among participants with longer residency in the US ($p = 0.05$). LCS users also had higher waist circumference ($p < 0.001$), higher pericardial fat ($p < 0.001$), and higher visceral ($p < 0.001$), subcutaneous ($p = 0.01$), and intermuscular ($p = 0.02$) fat. No differences by physical activity levels, CIMT, lipid profiles, or insulin resistance were observed based on LCS consumption. The results varied by LCS subgroups: diet soda and LCS packet use, wherein men, current smokers, and those who were obese reported a higher income, higher waist circumference, higher visceral fat, higher pericardial fat, higher triglyceride, and with any measurable CAC Agatston score, had a higher prevalence of diet soda consumption; while men, those who were older, obese, had diabetes, high total cholesterol, with government insurance, had longer residency in the US, higher waist circumference, higher visceral fat, higher subcutaneous fat, higher

intermuscular fat, higher pericardial fat, lower LDL cholesterol, and with any measurable CAC Agatston score, had a higher prevalence of LCS packet consumption (Table 2).

The adjusted associations between cardiometabolic risk factors and LCS intake, assessed both in terms of servings and packet equivalents, are shown in Table 3. When defined as three or more servings of LCS-containing diet sodas or packets per week, LCS consumption was associated with higher BMI (26.9 versus 25.7 kg/m^2, $p < 0.001$), higher waist circumference (94.0 versus 92.4 cm, $p = 0.005$), higher visceral fat (140 versus 133 cm^2, $p = 0.05$), and higher HOMA-IR (geometric means: 2.8 versus 2.5, $p = 0.02$). LCS consumers with three or more servings/week were more likely to have hypertension (odds ratio (OR) = 1.6, 95% confidence interval (CI): 1.1– 2.3, $p = 0.01$), diabetes (OR = 3.0, 95% CI: 2.1–4.3, $p < 0.001$), and high cholesterol (OR = 1.5, 95% CI: 1.0–2.1, $p = 0.03$). As shown in Table 3, findings were similar when LCS intake was assessed as packet equivalents (three or more diet sodas per week or equivalent in LCS packets (18 packets per week)); odds of cardiometabolic risk factors were of much greater magnitude when the LCS intake from diet sodas and packets was equalized, particularly for waist circumference and visceral fat.

Discussion

Nearly a quarter of middle-aged and older South Asians living in the US reported LCS consumption, and consumption was positively associated with the length of residency in the US. Consistent with prior reports (Sylvetsky et al., 2017), LCS consumption was higher among participants with obesity, hypertension, diabetes, and high cholesterol.

The associations with obesity may be explained by reverse causality, in that individuals who are already obese or who are gaining weight may consume LCS as a weight management approach (Drewnowski and Rehm, 2016). However, the role of LCS in weight management has been debated (Mattes, 2016) and various mechanisms have been proposed to explain the link between LCS and obesity (Pepino, 2015). In a recent meta-analysis of randomized controlled trials, the substitution of sucrose with aspartame, primarily in the context of intensive behavioral weight loss interventions, resulted in a modest reduction of energy intake and body weight (Rogers et al., 2015). Prospective cohort studies have indicated a higher risk of obesity and chronic diseases among LCS consumers, and LCS were shown to induce weight gain and metabolic dysregulation in rodent models (Fowler, 2016). Additionally, acute LCS exposure has been reported to increase glucose and insulin levels during oral glucose tolerance tests; however, associations between LCS consumption and weight or cardiometabolic risk have yet to be determined (Pepino et al., 2013). Based on this discrepancy between the observational and interventional studies, it is likely that reverse causality may only partially explain our findings.

LCS intakes in South Asians were lower than the general US population (Sylvetsky et al., 2017), and the majority intake of LCS was from LCS packets in this cohort, whereas LCS beverages such as diet soda have been reported as the primary source of LCS in the general US population (Sylvetsky and Rother, 2016; Sylvetsky et al., 2012). This may be attributed to the fact that soft drinks are less of a part of a traditional South Asian diet (Raj et al., 1999). Our findings also demonstrated increased LCS consumption with longer residency in

the US, suggesting that LCS intake may be associated with the transition to a Western-style diet after immigrating to America.

While most studies report higher prevalence of LCS consumption among women and more educated individuals, in the MASALA cohort, men had a higher prevalence of LCS consumption than women with no differences in LCS consumption across educational attainment. This may be because of higher prevalence of diabetes, hypertension, and high cholesterol among men in this cohort (data not shown), as those at risk for cardiometabolic complications may choose to consume diet soda as a means of lowering their sugar and/or calorie intake. It is also important to note that the majority of participants (88%) in this cohort had a bachelor's degree or higher, which may explain the lack of difference across education levels. Consistent with reports using National Health and Nutrition Examination Survey (NHANES) data (Sylvetsky et al., 2012, 2017), older age, a higher family income, higher BMI, and the presence of diabetes were associated with LCS consumption in this South Asian sample.

Our study comprises a large community-based sample of South Asians with similar socioeconomic characteristics to the South Asian population in the US. The limitations of this study include the use of a cross-sectional design, meaning that no causal relationships can be concluded. While our FFQ was developed and validated for South Asians living in North America, we were limited by the lack of detailed information on foods containing LCS on the FFQ. Only prevalence of LCS packets and diet soda consumption were evaluated, which may underestimate LCS use. Another limitation is that long-term exposure to LCS may also be associated with cardiometabolic risk, but could not be estimated in this study (Reid et al., 2016). Most participants in the MASALA cohort reported Asian Indian ethnicity, were mostly middle-aged and older, and were well-educated, with higher socioeconomic status (SES); therefore, our LCS-use findings cannot be generalized to younger South Asians and those from other diaspora countries.

LCS consumption is prevalent among South Asians and is most common among individuals with cardiometabolic diseases. Our cross-sectional findings concur with a large body of epidemiologic literature linking LCS to a variety of unfavorable cardiometabolic outcomes. Longitudinal investigations are needed to understand the determinants and health implications of LCS consumption in South Asians, as whether LCS are effective in reducing the burden of chronic disease in already metabolically vulnerable South Asian individuals is currently unknown. Additionally, interventional studies investigating the effects of repeated LCS consumption on cardiometabolic health, specifically in this high-risk South Asian population, are needed.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The MASALA study was supported by the National Institutes of Health (grant number 1R01-HL-093009) and body composition measurements were supported by grant K24HL112827. Data collection at University of California San Francisco (UCSF) was also supported by NIH/NCRR UCSF-CTSI (grant number UL1 RR024131).

References

Azad MB, Abou-Setta AM, Chauhan BF, et al. (2017) Nonnutritive sweeteners and cardiometabolic health: A systematic review and meta-analysis of randomized controlled trials and prospective cohort studies. Canadian Medical Association Journal 189(28): E929–E939. [PubMed: 28716847]

Choo V (2002) WHO Reassesses Appropriate Body-Mass Index for Asian Populations. The Lancet 360(9328): 235.

Drewnowski A and Rehm C (2016) The use of low-calorie sweeteners is associated with self-reported prior intent to lose weight in a representative sample of US adults. Nutrition & Diabetes 6(3): e202. [PubMed: 26950483]

Fowler SP (2016) Low-calorie sweetener use and energy balance: Results from experimental studies in animals, and large-scale prospective studies in humans. Physiology & Behavior 164: 517–523. [PubMed: 27129676]

Friedewald WT, Levy RI and Fredrickson DS (1972) Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clinical Chemistry 18(6): 499–502. [PubMed: 4337382]

Hoeffel EM, Rastogi S, Kim MO, et al. (2012) *The Asian population: 2010.* US Department of Commerce, Economics and Statistics Administration. Suitland, MD: US Census Bureau.

Kanaya AM, Kandula N, Herrington D, et al. (2013) Mediators of Atherosclerosis in South Asians Living in America (MASALA) study: Objectives, methods, and cohort description. Clinical Cardiology 36(12): 713–720. [PubMed: 24194499]

Kanaya AM, Wassel C, Mathur D, et al. (2010) Prevalence and correlates of diabetes in South Asian Indians in the United States: Findings from the metabolic syndrome and atherosclerosis in South Asians living in America study and the multi-ethnic study of atherosclerosis. Metabolic Syndrome and Related Disorders 8(2): 157–164. [PubMed: 19943798]

Kelemen LE, Anand SS, Vuksan V, et al. (2003) Development and evaluation of cultural food frequency questionnaires for South Asians, Chinese, and Europeans in North America. Journal of the American Dietetic Association 103(9): 1178–1184. [PubMed: 12963948]

Mattes RD (2016) Low calorie sweeteners: Science and controversy: Conference proceedings. Physiology & Behavior 164(B): 429. [PubMed: 26773467]

Miller PE and Perez V (2014) Low-calorie sweeteners and body weight and composition: A meta-analysis of randomized controlled trials and prospective cohort studies. The American Journal of Clinical Nutrition 100(3): 765–777. [PubMed: 24944060]

Pepino MY (2015) Metabolic effects of non-nutritive sweeteners. Physiology & Behavior 152: 450–455. [PubMed: 26095119]

Pepino MY, Tiemann CD, Patterson BW, et al. (2013) Sucralose affects glycemic and hormonal responses to an oral glucose load. Diabetes Care 36(9): 2530–2535. [PubMed: 23633524]

Physical Activity Guidelines Advisory Committee (2008) Physical activity guidelines for Americans. Washington, DC: US Department of Health and Human Services, pp. 15–34.

Raj S, Ganganna P and Bowering J (1999) Dietary habits of Asian Indians in relation to length of residence in the United States. Journal of the Academy of Nutrition and Dietetics 99(9): 1106.

Reid AE, Chauhan BF, Rabbani R, et al. (2016) Early exposure to nonnutritive sweeteners and long-term metabolic health: A systematic review. Pediatrics 137(3): e20153603. [PubMed: 26917671]

Rogers P, Hogenkamp P, De Graaf C, et al. (2015) Does low-energy sweetener consumption affect energy intake and body weight? A systematic review, including meta-analyses, of the evidence from human and animal studies. International Journal of Obesity 40(3): 381–394. [PubMed: 26365102]

Sheiko M, Burkhardt R and Batsakis J (1979) Glucose measurements. A 1977 CAP Survey analysis. American Journal of Clinical Pathology 72(Suppl 2): 337–340. [PubMed: 474511]

Sylvetsky AC and Rother KI (2016) Trends in the consumption of low-calorie sweeteners. Physiology & Behavior 164: 446–450. [PubMed: 27039282]

Sylvetsky AC, Blau JE and Rother KI (2016) Understanding the metabolic and health effects of low-calorie sweeteners: Methodological considerations and implications for future research. Reviews in Endocrine and Metabolic Disorders 17(2): 187–194. [PubMed: 26936185]

Sylvetsky AC, Jin Y, Clark EJ, et al. (2017) Consumption of low-calorie sweeteners among children and adults in the United States. Journal of the Academy of Nutrition and Dietetics 117(3): 441–448. [PubMed: 28087414]

Sylvetsky AC, Welsh JA, Brown RJ, et al. (2012) Low-calorie sweetener consumption is increasing in the United States. The American Journal of Clinical Nutrition 96(3): 640–646. [PubMed: 22854409]

Table 1.

Criteria of the classification for socio-demographic characteristics and cardiometabolic risk factors in the MASALA study.

Socio-demographic characteristics and cardiometabolic risk factors	Classification	Criteria
Education	Less than bachelor's	
	Bachelor's degree and above	
Family income	< US$75,000 per year	
	≥ US$75,000 per year	
Insurance types	Government	
	HMO	
	other or none	
Body mass index	Normal	<23 kg/m^2
	Overweight	23–27.4 kg/m^2
	Obese	≥27.5kg/m^2
Hypertension[a]	Yes	Systolic blood pressure ≥ 140 mm Hg and/or diastolic blood pressure≥90 mm Hg or taking blood pressure lowering medication
High cholesterol[b]	Yes	Total cholesterol values ≥240 mg/dL or use of statins
Diabetes[c]	Yes	Use of a glucose-lowering medication (assessed by medication inventory), a two-hour post-challenge glucose ≥200 mg/dL or fasting plasma glucose level ≥ 126 mg/dL
Homeostasis model assessment of insulin resistance (HOMA-IR)		Fasting insulin (μIU/mL) × Fasting glucose (mmol/L) / 22.5

HMO: health maintenance organization.

[a]Blood pressure was measured in a seated position with an automated blood pressure monitor (V100 Vital Signs Monitor, GE Healthcare, Fairfield, CT).

[b]Total cholesterol was examined with enzymatic methods (Quest, San Jose, CA).

[c]Plasma glucose was assessed using hexokinase methods.

Table 2.

Prevalence of low-calorie sweetener (LCS) consumption (≥3 servings per week) across socio-demographic subgroups and cardiometabolic risk among participants in the MASALA study.

	Any LCS consumption three or more servings/wk[a]	*p*-value[b]	Diet soda consumption three or more servings/wk[a]	*p*-value[b]	LCS packets consumption three or more servings/wk[a]	*p*-value[b]
Overall prevalence, %	22.0		5.4		19.5	
Sex, %		0.003		0.002		0.03
- Men	25.9		7.6		22.3	
- Women	17.6		2.9		16.4	
Age, %		0.02		0.99		0.001
- <50 y	17.3		5.5		13.8	
- 50–65 y	22.4		5.4		20.1	
- ≥65 y	28.7		5.2		27.6	
Education, %		0.63		0.95		0.56
- <bachelor's degree	20.2		5.5		17.4	
- ≥bachelor's degree	22.2		5.4		19.8	
Study site, %		0.47		0.32		0.28
- Chicago	23.1		6.2		21.1	
- San Francisco	21.1		4.7		18.2	
Family income (*n* = 866), %		0.04		0.04		0.19
- <US$75,000	17.0		2.6		16.6	
- ≥US$75,000	23.7		6.1		20.6	
Length of residency in the US, year (SD)	28.4 (10.9)	0.05	28.3 (10.4)	0.40	28.7 (11.0)	0.02
Insurance status (*n* = 891), %		0.07		0.40		0.05
- Government	28.6		7.7		27.5	
- HMO	22.3		5.4		19.5	
- Other or none	15.4		3.4		13.7	
Smoking status, %		0.85		0.05		0.76
- Never	21.7		4.7		19.8	
- Former	24.0		7.4		19.0	
- Current	21.4		14.3		14.3	
Physical activity, % meeting recommended guidelines	22.6	0.52	5.2	0.72	20.4	0.37

	Any LCS consumption three or more servings/wk[a]	*p*-value[b]	Diet soda consumption three or more servings/wk[a]	*p*-value[b]	LCS packets consumption three or more servings/wk[a]	*p*-value[b]
Body mass index (*n* = 890), %		0.001		0.003		0.01
- <23 kg/m^2	15.5		3.3		13.6	
- 23–27.4 kg/m^2	20.9		3.9		19.4	
- ≥27.5kg/m^2	28.8		9.3		24.4	
Waist circumference, cm (SD)	96.1 (9.9)	<0.001	99.1 (10.5)	<0.001	95.9 (9.6)	<0.001
Visceral fat area (*n* = 867), cm^2 (SD)	l50 (57)	<0.001	l64 (60)	<0.001	150 (58)	<0.001
Subcutaneous fat area (*n* = 814), cm^2 (SD)	253 (100)	0.01	254 (87)	0.23	253 (103)	0.02
Intermuscular fat area (*n* = 845), cm^2 (SD)	22.7 (9.3)	0.02	23.4 (9.4)	0.11	22.9 (9.6)	0.01
Pericardial fat volume (*n* = 88l), cm^3 (SD)	65.9 (30.4)	<0.001	68.9 (30.8)	0.01	65.8 (30.5)	<0.001
Diabetes, %		<0.001		0.54		<0.001
- No	16.5		5.1		13.8	
- Yes	37.9		6.2		36.1	
HOMA-IR (*n* = 828)	3.7 (2.8)	0.68	3.7 (2.0)	0.80	3.7 (2.9)	0.75
Hypertension, %		<0.001		0.26		<0.001
- No	17.6		4.7		15.2	
- Yes	28.5		6.4		26.0	
High total cholesterol, %		0.004		0.63		0.006
- No	19.1		5.1		16.9	
- Yes	27.5		5.9		24.5	
Triglyceride (*n* = 889), mg/dL (SD)	139 (87)	0.09	161 (141)	0.003	133 (59)	0.66
LDL cholesterol (*n* = 882), mg/dL (SD)	105 (32)	0.001	110 (27)	0.77	104 (33)	<0.001
HDL cholesterol (*n* = 889), mg/dL (SD)	48.8 (12.8)	0.11	47.3 (11.3)	0.14	48.8 (12.8)	0.16
CAC, %		0.001		0.02		<0.001
- Agatston score = 0	18.2		3.9		15.6	
- Agatston score > 0	27.6		7.5		25.2	
Common CIMT (*n* = 891), mm (SD)	0.88 (0.21)	0.57	0.86 (0.19)	0.62	0.89 (0.22)	0.35
Internal CIMT (*n* = 890), mm (SD)	1.24 (0.51)	0.25	1.17 (0.38)	0.53	1.25 (0.53)	0.14

HOMA-IR: homeostasis model assessment of insulin resistance; SD: standard deviation; LDL: low-density lipoprotein cholesterol; HDL: high-density lipoprotein cholesterol; CIMT: carotid intima-media thickness; HMO: health maintenance organization; CAC: coronaryartery calcium.

[a]Results were reported as percentage for categorical variables, mean (SD) among LCS consumers for continuous variables.

[b] Chi-square tests were used to compare categorical variables; ANOVA was used to compare continuous variables between LCS consumer and non-consumers.

Table 3.

Adjusted means and standard error or odds ratios (ORs) and 95% confidence intervals (CIs) of cardiometabolic risk factors comparing participants with low-calorie sweetener (LCS) consumption three or more versus less than three servings per week, and comparing participants with LCS consumption 18 or more versus less than 18 servings of packets (three servings of soda equivalent) per week in the MASALA study.[a]

	LCS consumption, servings/wk				LCS consumption, packets equivalents/wk			
Cardiometabolic risk factors	**3 or more**	**Less than 3**	**OR (95% CI)**	***p*-value**	**18 or more**	**less than 18**	**OR (95% CI)**	***p*-value**
Body mass index, kg/m^2	26.9 (0.3)	25.7 (0.2)		<0.001	27.1 (0.4)	25.8 (0.1)		0.005
Waist circumference, cm	94.0 (0.5)	92.4 (0.3)		0.005	94.7 (0.7)	92.6 (0.2)		0.007
Visceral fat area, cm^2	140 (3.3)	133 (1.7)		0.05	147 (4.9)	133 (1.6)		0.009
Subcutaneous fat area, cm^2	245 (5.5)	234 (2.9)		0.09	245 (8.2)	235 (2.7)		0.25
Intermuscular fat area, cm^2	21.6 (0.6)	21.4 (0.3)		0.70	21.6 (0.8)	21.4 (0.3)		0.90
Pericardial fat volume, cm^3	61.1 (1.7)	58.4 (0.9)		0.17	62.4 (2.6)	58.6 (0.8)		0.16
Triglyceride, mg/dL[b]	120 (1.0)	117 (1.0)		0.47	120 (1.0)	118 (1.0)		0.72
LDL cholesterol, mg/dL	106 (2.3)	113 (1.2)		0.008	104 (3.5)	112 (1.1)		0.03
HDL cholesterol, mg/dL	49.8 (0.8)	50.1 (0.4)		0.70	49.1 (1.2)	50.2 (0.4)		0.46
HOMA-IR[b]	2.8 (1.0)	2.5 (1.0)		0.02	2.9 (1.1)	2.5 (1.0)		0.07
Common CIMT	0.88 (0.01)	0.87 (0.01)		0.38	0.87 (0.02)	0.88 (0.01)		0.79
Internal CIMT	1.21 (0.03)	1.21 (0.01)		0.97	1.18 (0.04)	1.21 (0.01)		0.48
High cholesterol			1.5 (1.0, 2.1)	0.03			1.5 (0.9, 2.4)	0.09
Diabetes			3.0 (2.1, 4.3)	<0.001			2.2 (1.4, 3.6)	0.001
Hypertension			1.6 (1.1, 2.3)	0.01			1.5 (0.9, 2.4)	0.13
CAC Agatson score > 0			1.3 (0.9, 1.9)	0.23			1.0 (0.6, 1.8)	0.94

LDL: low-density lipoprotein cholesterol; HDL: high-density lipoprotein cholesterol; CIMT: carotid intima-media thickness; HOMA-IR: homeostasis model assessment of insulin resistance; CAC: coronary artery calcium.

[a]Multiple linear regression models were used for continuous outcomes; multiple logistic regression models were used for categorical outcomes; all regressions were adjusted for age, sex, education, length of residency in the US, energy, smoking, alcohol, study site, exercise, and insurance; body mass index was also adjusted for outcomes except itself.

[b]HOMA-IR and triglycerides were log-transformed. Values presented in the table are the geometric means.