Diet Soda Intake Is Associated with Long-Term Increases in Waist Circumference in a Biethnic Cohort of Older Adults: The San Antonio Longitudinal Study of Aging

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OBJECTIVES: To examine the relationship between diet soda (DS) intake (DSI) and long-term waist circumference (WC) change (ΔWC) in the biethnic San Antonio Longitudinal Study of Aging (SALSA).

DESIGN: Prospective cohort study.

SETTING: San Antonio, Texas, neighborhoods.

PARTICIPANTS: SALSA examined 749 Mexican-American and European-American individuals aged 65 and older at baseline (baseline, 1992–96); 474 (79.1%) survivors completed follow-up 1 (FU1, 2000–01), 413 (73.4%) completed FU2 (2001–03), and 375 (71.0%) completed FU3 (2003–04). Participants completed a mean of 2.64 follow-up intervals, for 9.4 total follow-up years.

MEASUREMENTS: DSI, WC, height, and weight were measured at outset and at the conclusion of each interval: baseline, FU1, FU2, and FU3.

RESULTS: Adjusted for initial WC, demographic characteristics, physical activity, diabetes mellitus, and smoking, mean interval ΔWC of DS users (2.11 cm, 95% confidence interval (CI) = 1.45–2.76 cm) was almost triple that of nonusers (0.77 cm, 95% CI = 0.29–1.23 cm) ($P < .001$). Adjusted interval ΔWCs were 0.77 cm (95% CI = 0.29–1.23 cm) for nonusers, 1.76 cm (95% CI = 0.96–2.57 cm) for occasional users, and 3.04 cm (95% CI = 1.82–4.26 cm) for daily users ($P = .002$ for trend). This translates to ΔWCs of 0.80 inches for nonusers, 1.83 inches for occasional users, and 3.16 for daily users over the total SALSA follow-up. In subanalyses stratified for selected covariates, ΔWC point estimates were consistently higher in DS users.

CONCLUSION: In a striking dose-response relationship, increasing DSI was associated with escalating abdominal obesity, a potential pathway for cardiometabolic risk in this aging population. **J Am Geriatr Soc 2015.**

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Over the past 30 years, mounting concerns over deleterious health effects of sugar consumption have led to promotion and increased intake of nonnutritive sweeteners (NNSs).[1] Nevertheless, the prevalence of obesity has increased dramatically over this time,[1] and long-term effects of NNS intake (NNSI) and diet soda (DS) intake (DSI) on health outcomes remain unclear. Although earlier studies focused on weight change, more-recent studies have examined relationships between NNSI, DSI and cardiometabolic risk. A review[2] summarized results from these studies, some of which have reported benefits or no adverse effects from NNSI and DSI, whereas others have shown greater cardiometabolic risk. High incidences of overweight and obesity,[3] hypertension,[4] metabolic syndrome,[5–7] diabetes mellitus,[8,9] kidney dysfunction,[8,10] heart attack,[11] and hemorrhagic stroke[11,12] have all recently been associated with frequent NNSI and DSI.

Although human studies have included diverse age groups, most have focused on middle-aged or younger adults rather than specifically examining the health effects of frequent DSI on individuals aged 65 and older. This gap is important, because cardiometabolic disease burden—and associated healthcare costs—is highest in this large and growing population segment. Aging-related shifts in body composition contribute to the greater morbidity and mortality that older individuals experience. Waist circumference (WC)—a measure of total and abdominal adiposity[13]—continues to rise throughout the lifespan, despite decreasing muscle mass and body weight in later years.[14] Aging-related increases in WC are particularly troubling because they reflect disproportionate increases in visceral fat,[14] which is associated with greater cardiometabolic risk.[15,16] Thus, large WC, an important component of metabolic syndrome, is associated with greater inflammation;[17] insulin resistance;[18] and incidence of type 2 diabetes mellitus,[17,19,20] cognitive impairment,[21] cardiovascular disease (CVD),[22,23] and mortality.[13,24,25]

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The relationship between initial DSI and long-term WC change (ΔWC) was therefore prospectively examined in the biethnic cohort of older Mexican-American and European-American individuals in the San Antonio Longitudinal Study of Aging (SALSA).

METHODS

SALSA participants were recruited from the San Antonio Heart Study (SAHS) cohort, a community-based prospective study of cardiovascular risk factors in Mexican Americans and European Americans conducted in San Antonio, Texas, between 1979 and 1996. SAHS design, sampling, and examination procedures have been previously documented.[26] All surviving SAHS participants aged 65 and older at the time of the SALSA baseline examination (1992–96) were invited to participate in SALSA. Of 749 individuals (70.5% of 1,062 eligible SAHS survivors) who underwent SALSA baseline examinations,[27] 474 (79.1% of 599 baseline survivors) returned for follow-up 1 (FU1, 2000–01). There was no evidence of major attrition bias between the initial SAHS survey and the SALSA baseline examination. Mean interval from baseline to FU1 was 7.0 years (range 4.4–9.7 years). Different intervals from baseline to FU1, a deliberate feature of the study design, were obtained by reexamining participants in the reverse order in which they were seen at baseline. At follow-up 2 (FU2, 2001–03), 413 participants (73.4% of 563 baseline survivors) were examined; mean interval from FU1 to FU2 was 1.5 years (range 1.3–2.2 years). At follow-up 3 (FU3, 2003–04), 375 participants (71.0% of 528 baseline survivors) returned, after a mean interval from FU2 to FU3 of 1.5 years (range 1.0–2.4 years). For FU3 participants, mean interval from baseline to F3 was 9.9 years (range 7.4–12.5 years). For all SALSA participants who returned to at least one follow-up, mean total follow-up was 9.4 years (range 4.5–12.5 years).

All examinations, described previously,[27] included measurement of fasting plasma glucose, height, weight, WC, and intake of beverages, including soft drinks. WC was measured in centimeters at the level of the umbilicus; body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Leisure-time energy expenditure was measured in kilocalories per week using the Minnesota Leisure Time Physical Activity Questionnaire.[28] Presence of diabetes mellitus was assessed using the 1998 American Diabetes Association criteria, described previously.[27] Because of the length of the baseline examination, dietary questionnaires were administered to a subset of 598 individuals (79.8% of baseline participants).

In all SALSA participants, DSI at the beginning and anthropometric data at beginning and end of each follow-up interval were available for 364 baseline to FU1, 364 FU1 to FU2, and 291 FU2 to FU3 participants. Participants with these data for one or more follow-up intervals (n = 466) were included in these analyses and contributed 3,314 person-years of follow-up by FU1, 622 additional person-years by FU2, and 543 additional person-years by FU3, for a total of 4,479 person-years of follow-up. Available WC and BMI data from earlier SAHS baseline and follow-up examinations for SALSA participants were also plotted, along with SALSA data, to display longitudinal WC and BMI trajectories. Anthropometric measurements in SAHS and SALSA followed the same protocols.

To assess DSI, participants were first asked, "How many bottles or cans of soft drinks do you drink per week?" The number of sodas consumed (per day, week, month, or year) was recorded, along with the appropriate time unit. For participants reporting no soda consumption, DSI was set to zero. Soda consumers were asked whether they usually drank sugar-free sodas, regular sodas, or similar amounts of each. For those who drank only DS, DSI was set equal to total soda intake; for those who drank similar amounts of regular and diet sodas, DSI was computed as total soda intake divided by 2; and for those who drank only regular sodas, DSI was set to zero. Mean daily DSI was then calculated for each participant. Participants with mean DSI of 0.05/d or more were categorized as DS users, and those with mean DSI of less than 0.05/d were categorized as nonusers. All participants were then categorized into one of three DSI groups: nonusers, occasional users (>0 but <1/day), and daily users (≥1/day). DSI of 1/d or more was the threshold selected for the highest consumption category because it represented chronic, ongoing DS exposure; was a meaningful behavioral cut-point; and allowed comparison of SALSA results with those recently published from other observational studies.[6,9,11,12] SALSA participant DSI was newly assessed each time they were examined, and each participant's status for each of the three follow-up intervals was reset to equal his or her status at the beginning of that interval. Thus, a participant's status as a DS user or nonuser could vary across intervals.

The endpoint—ΔWC between the beginning and end of each follow-up interval between consecutive examinations—was then compared across these three initial DSI categories.

SALSA follow-up response rates were excellent, ranging from 71.0% to 79.1% of all survivors. The main reason for nonparticipation in follow-up examinations was death; major health problems, including severe physical impairments, were the second-most-frequent impediment to participation; and the remaining causes included out-of-area moves and loss to follow-up. To assess potential response-rate biases, follow-up dropout rates were compared according to DSI category. Data were censored at the FU3 examination for participants who completed this phase and at time of last completed examination or death for all others. No significant differences in drop-out rates were detected between daily DS users or all DS users and nonusers; Cox proportional hazard ratios for drop-out before FU3, using nonusers as the reference group, were 0.92 ($P = .55$) for all DS users and 1.03 ($P = .87$) for daily users. The dropout hazard ratio for participants who did not complete the SALSA baseline dietary interview relative to those who did was 0.97 ($P = .85$).

All SALSA recruitment and study procedures were performed in accordance with the ethical standards of the institutional review board of the University of Texas Health Science Center at San Antonio, which approved the study. All participants provided written informed consent to participate in each study phase.

Analyses were performed using SAS version 9.2 (SAS Institute, Inc., Cary, NC). Repeated-measures generalized estimating equation analysis of covariance was used to compare mean ΔWC and mean change in BMI (ΔBMI) across the three DSI categories and follow-up intervals. This analytical approach accounted for the within-subject correlation across intervals while simultaneously accounting for changes in DSI that occurred over the duration of the SALSA follow-up. All interval-change analyses were adjusted for sex, ethnic group, years of education, and residential neighborhood (lower-income barrio, higher-income suburb, or middle-income transitional neighborhood) at the time of SALSA baseline, as well as the following characteristics at the beginning of each follow-up interval: age, WC (or BMI, for ΔBMI), presence of diabetes mellitus, kcal/wk of leisure-time activity, smoking status, and length of follow-up interval. Because these covariates are all known to be associated with changes in adiposity measures, potentially misleading unadjusted results were not generated. After excluding observations missing a value for any covariate, fully adjusted models were based on 1,076 observations, representing 3,706 person-years of follow-up. *P*-values are reported without Bonferroni correction. PROC MIXED was used to account for the correlation between observations from the same participant across follow-up intervals. Interaction effects between DS use (any vs none) and sex, ethnicity, BMI category, and diabetes mellitus status were also tested individually in stratified analyses.

RESULTS

Table 1 compares baseline characteristics of the 384 FU1 participants whose DSI had been ascertained at baseline. DS users did not differ significantly from nonusers with respect to age or sex but had higher education levels and were more likely to live in the suburbs and be European American and less likely to smoke or live in lower-income barrios. Users also tended to have higher leisure-time energy expenditure (kcal/wk), although this difference was not statistically significant.

Despite this general pattern of greater socioeconomic advantage and health-promotion behavior, DS users also had significantly higher baseline BMI than nonusers and tended to have larger WC, although not significantly so ($P = .06$). Baseline prevalence of overweight or obesity (BMI ≥25.0 kg/m^2) was significantly higher ($P = .04$) in occasional (80.7%) and daily (87.5%) DS users than in nonusers (71.8%). Obesity (BMI ≥30.0 kg/m^2) ($P = .07$) and diabetes mellitus ($P = .20$) prevalence were similarly highest in daily users, lowest in nonusers, and intermediate in occasional users, but neither trend was statistically significant. There were no significant differences in fasting glucose concentrations according to DSI category.

Use of regular sodas was relatively infrequent and was inversely related to DS use; regular soda intake was 0.30 cans or bottles per day in nonusers, 0.04 in occasional users, and 0.00 in daily users. Although they consumed no regular sodas, daily DS users consumed significantly more total sodas daily (1.54) than occasional DS users (0.38) or nonusers (0.34).

In the repeated-measures analyses that follow, one observation is included for each follow-up interval for which a participant had measures of DS consumption at the outset of the interval and the outcome measure of interest at the beginning and end of the interval. Overall, participants included in these analyses completed an average of 2.64 SALSA follow-up intervals, for a total mean follow-up of 9.41 years. As shown in Table 1, these parameters did not differ significantly according to DSI category.

Figure 1 depicts the divergence with aging of longitudinal trends in WC and BMI in 375 SALSA participants (146 men, 229 women) who completed their final SALSA follow-up examination (FU3). The first two data points in each panel represent mean anthropometric data (WC and BMI) from participants' earlier SAHS baseline and follow-up examinations; subsequent data points represent means from participants' SALSA examinations (baseline through FU3). For men, after age 65, BMI rose slowly, peaked by age 75, and then declined rapidly; by contrast, WC increased steadily beyond age 65 and plateaued by age 80. Divergence between BMI and WC trajectories was even more striking for women, for whom mean WC at SAHS baseline was considerably lower than for men yet increased steadily with time to approximate that of men by SALSA FU3. This divergence is consistent with previous reports of increasing visceral adiposity, with declining muscle mass, in advancing age.[14]

For all SALSA participants who returned to one or more follow-up examinations, adjusted net interval ΔBMI was minimal (Figure 2) yet varied according to DSI category. Point estimates for ΔBMI were lowest for DS nonusers (−0.41 kg/m^2, 95% CI = −0.57 to −0.25 kg/m^2), intermediate for occasional users (−0.11 kg/m^2, 95% CI = −0.38–0.16 kg/m^2), and highest for daily users (0.05 kg/m^2, 95% CI = −0.35–0.45 kg/m^2; $P = .04$ for daily vs nonusers; $P = .049$ for trend). Nonusers thus experienced minimal BMI loss, and DS users experienced no significant ΔBMI.

By contrast, WC gains occurred in all DSI categories but were dramatically higher for DS users than nonusers, despite adjustment for initial WC, age, diabetes mellitus status, leisure-time physical activity, smoking status, demographic factors, and follow-up length. Adjusted interval ΔWC was 2.11 cm (95% CI = 1.45–2.76 cm) for all DS users combined—daily and occasional—and 0.77 cm (95% CI = 0.29–1.23 cm) for nonusers ($P < .001$ for difference from users). Mean ΔWC of all users was thus almost three times that of nonusers.

When DSI was further subdivided into occasional or daily use, a striking, positive dose-response relationship ($P = .002$ for trend) emerged between DSI and WC gain (Figure 3), mean adjusted ΔWC 0.77 cm (95% CI = 0.29–1.23 cm) per interval for nonusers, 1.76 cm (95% CI = 0.96–2.57 cm) for occasional users, and 3.04 cm (95% CI = 1.82–4.26 cm) for daily users. Thus, interval ΔWC of daily users was nearly four times that of nonusers ($P = .001$). This would translate into cumulative adjusted ΔWCs of 0.80 inches for nonusers, 1.83 inches for occasional users, and 3.16 inches for daily users over the total SALSA follow-up.

By contrast, no consistent relationship was observed between regular soda use and mean ΔWC, which was highest in nonusers (1.93 cm, 95% CI = 1.44–2.42 cm), lowest in occasional users (0.37 cm, 95% CI = −0.31–1.05 cm; $P = .001$ for difference from nonusers), and intermediate

Table 1. Baseline Characteristics for San Antonio Longitudinal Study of Aging (SALSA) Participants Who Returned to the First Follow-Up Examination According to Self-Reported Diet Soda Intake Category at Baseline

	Diet Sodas Consumed per Day			
Characteristic	0, n = 255	<1, n = 89	≥1, n = 40	*P*-Value
Female, %	59.2	65.2	50.0	.26
Age, mean ± SD	69.6 ± 3.3	69.7 ± 3.7	69.0 ± 2.9	.48
Mexican American, %	54.9	32.6	35.0	<.001
Education, years, mean ± SD	11.1 ± 3.8	12.8 ± 3.6	12.3 ± 3.8	<.001
Residence, %				
Suburban	32.9	48.3	30.0	.02
Urban	27.8	13.5	15.0	<.01
Current smoker, %	14.5	3.4	12.5	.02
Sodas/d, mean ± SD				
Diet	0.00 ± 0.00	0.33 ± 0.24	1.54 ± 0.66	<.001
Regular	0.30 ± 0.58	0.04 ± 0.11	0.00 ± 0.00	<.001
Total	0.30 ± 0.60	0.38 ± 0.26	1.54 ± 0.66	<.001
Body mass index, kg/m^2, mean ± SD	28.0 ± 5.1	29.0 ± 5.3	30.0 ± 5.1	.04
Waist circumference, cm, mean ± SD	98.2 ± 13.4	101.8 ± 15.2	101.4 ± 12.2	.06
Energy expenditure, kcal/wk, mean ± SD	1,680 ± 2,108	1,846 ± 2,551	2,205 ± 2,885	.39
Overweight or obese, %	71.8	80.7	87.5	.04
Obese, %	27.8	34.1	45.0	.07
Fasting plasma glucose, mg/dL, mean ± SD	101.0 ± 36.9	98.0 ± 33.9	106.9 ± 42.6	.53
Diabetes mellitus, %	13.5%	18.2	23.7	.20
Intervals per subject, mean ± SD	2.59 ± 0.76	2.79 ± 0.55	2.63 ± 0.70	.08
Time per interval, years, mean ± SD	3.60 ± 2.81	3.47 ± 2.76	3.52 ± 2.76	.81
Total length of follow-up, years, mean ± SD	9.35 ± 1.70	9.67 ± 1.35	9.24 ± 1.74	.22

SD = standard deviation.

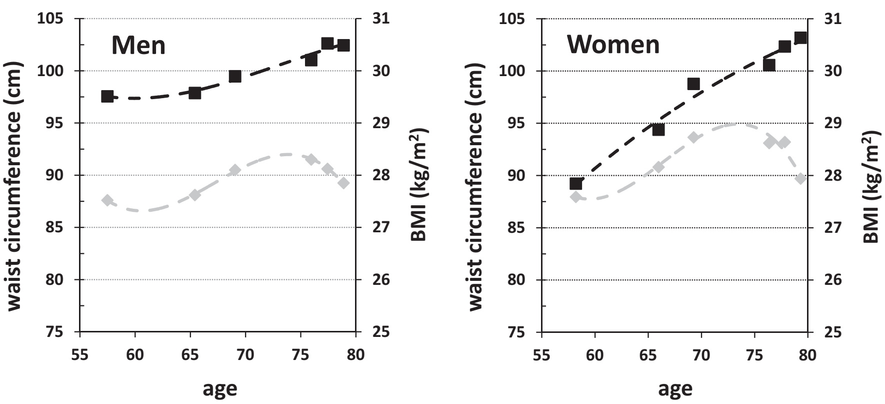

Figure 1. Longitudinal change in waist circumference (black squares) and body mass index (BMI, gray diamonds) according to sex from the San Antonio Heart Study baseline examination through the third San Antonio Longitudinal Study of Aging (SALSA) follow-up, for SALSA participants who returned to this last examination. Dashed trend lines represent third-order polynomial fits to the data points.

for daily users (1.68 cm, 95% CI = 0.36–2.99 cm) of regular soda.

Table 2 compares ΔWC for all DS users and nonusers stratified separately according to sex, ethnic group, BMI category, and diabetes mellitus status at the beginning of each follow-up interval. In these comparisons, point estimates for ΔWC were higher for DS users than for nonusers in all examined strata. Differences in ΔWC between users and nonusers were pronounced and significant for men, European Americans, participants with BMI of 30 kg/m^2 or greater and participants without diabetes mellitus; ΔWC differences were not significant for participants with diabetes mellitus (*P* = .05).

For men, mean adjusted ΔWC was dramatically greater in DS users (2.31 cm, 95% CI = 1.30–3.32 cm) than in nonusers (0.29 cm, 95% CI = −0.47–1.05 cm) (*P* = .002 for difference). For women, differences in ΔWC were less dramatic and were not statistically significant; nonetheless, for women, point estimates for mean adjusted ΔWC were 75% higher in DS users than in nonusers, and —in data not shown—point estimates for ΔWC increased monotonically in women (nonusers, 1.2 cm, 95% CI = 0.54–1.85 cm; occasional users, 2.1 cm, 95% CI = 0.92–3.24 cm; daily DS users, 2.2 cm, 95% CI = 0.21–4.18 cm). Thus, although the study was not powered to detect statistically significant differences in

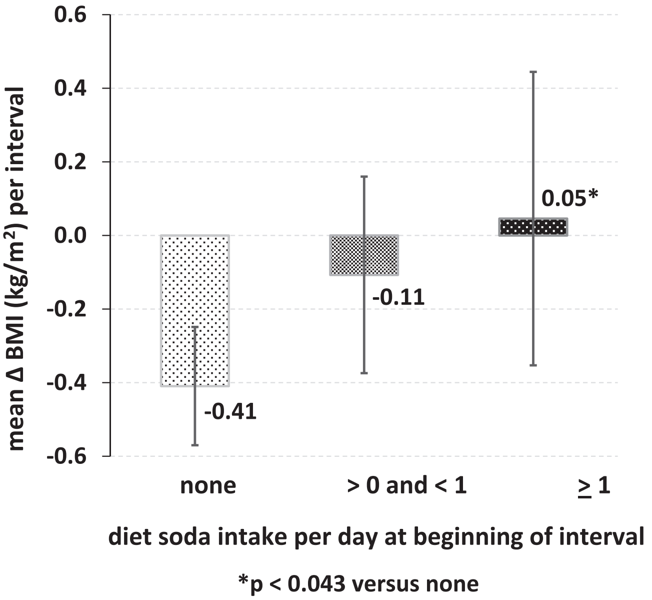

Figure 2. Mean change in body mass index (BMI, kg/m^2 (95% confidence interval)) per follow-up interval according to diet soda intake at the beginning of the interval, adjusted for sex, age, ethnicity, education, neighborhood, beginning BMI, leisure physical activity level, diabetes mellitus, smoking status, and length of interval.

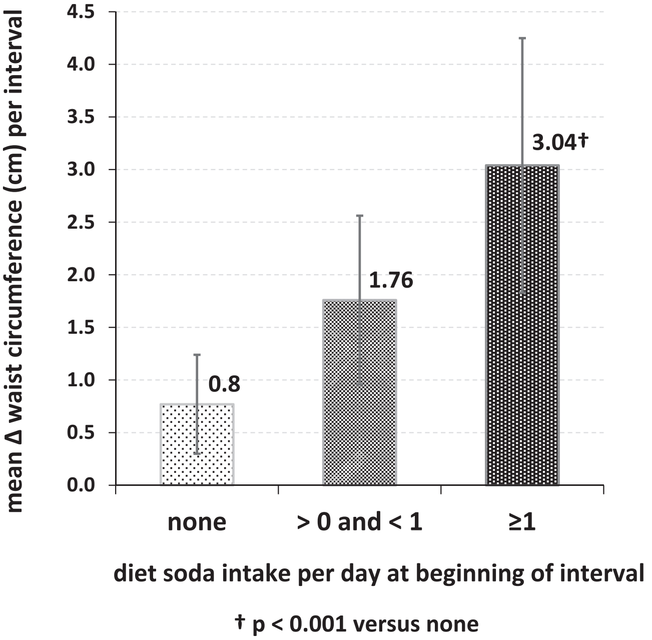

Figure 3. Mean change (Δ) in waist circumference (cm) and 95% confidence interval per follow-up interval according to diet soda consumption category at the beginning of the interval, adjusted for sex, age, ethnicity, education, neighborhood, beginning waist circumference, leisure physical activity level, diabetes mellitus, smoking status, and length of interval.

ΔWC between DS users and nonusers in all participant subgroups, the point estimate for ΔWC in women who were daily DS users was almost double that of nonusers. The ΔWC patterns observed in women were therefore congruent with those observed in men, and it was not possible to detect a statistically significant difference according to sex (P = .15) in the association between DSI and ΔWC.

BMI category had a major moderating effect on the association between DSI and ΔWC. Interval differences in ΔWC between DS users and nonusers were negligible (0.22 cm) in participants with an initial BMI less than 25.0 kg/m^2, intermediate (1.05 cm, P = .07) in participants with a BMI from 25.0 kg/m^2 to 29.0 kg/m^2, and significant (2.06 cm, P = .03) for those with a BMI of 30.0 kg/m^2 or greater.

DISCUSSION

In individuals in a biethnic cohort of Mexican Americans and European Americans aged 65 and older at baseline, a striking, positive dose-response relationship was observed between initial DSI and subsequent long-term increases in WC over a mean total follow-up of almost a decade. Over the course of this time, mean interval WC gain in all DS users—including daily and occasional users—was almost three times that of nonusers. For daily users, interval ΔWC was almost four times that of nonusers. These differences were adjusted for demographic and socioeconomic factors and initial WC, diabetes mellitus status, leisure-time physical activity, smoking status, and length of follow-up.

Table 2 displays the results of sensitivity analyses performed to compare ΔWC within ethnic, sex, BMI, and diabetes mellitus strata. In each of the nine subgroup comparisons performed, point estimates for ΔWC were higher for DS users than for nonusers and were strikingly higher for DS users in all but one stratum: those with BMI less than 25.0 kg/m^2, in whom they were only slightly higher in users. ΔWC in overweight users was double that in nonusers, and this gap was further doubled in obese individuals, who had already demonstrated heightened vulnerability to weight gain. (A similar phenomenon has been observed in female rats; greater NNS-related weight and adiposity gains occurred in those that were obesity prone.[29]) This is particularly troubling because obese individuals may be highly motivated to use DS to control weight, yet obese users had the worst outcomes in the current study.

These results are consistent with findings from other studies in humans and animals in which frequent use of DS or nonnutritively sweetened foods or beverages has been associated prospectively with greater BMI[3] and metabolic dysregulation[2] and greater incidence of overweight and obesity,[3] metabolic syndrome,[5,6] diabetes mellitus,[8,9] and cardiovascular events.[11,12] The current results suggest one potential pathway—greater abdominal adiposity—through which daily DS consumption might be linked to the greater cardiometabolic risk observed in some of these studies. Waist-gain differentials on the same scale as those observed between daily DS users (ΔWC = 3.04 cm) and nonusers (ΔWC = 0.77 cm) during a single follow-up interval have, for example, been associated with higher incidence of hyperinsulinemia, metabolic syndrome, high blood pressure, and diabetes mellitus.[30,31]

Clinical Relevance for an Aging Population

Adult WCs have increased substantially in the United States during the past quarter century.[32,33] If frequent DS

Table 2. Mean Adjusted Interval Change in Waist Circumference (WC, cm) According to Diet Soda Intake

Stratum	Diet Soda Intake: None	Diet Soda Intake: Any	Difference	*P*-Value for Difference	*P*-Value for Interaction
	WC (95% Confidence Interval) Person-Years of Follow-Up				
Overall	0.77 (0.29–1.23) 2,405	2.11 (1.45–2.76) 1,301	1.34 (0.47–2.19)	<.001	
Male	0.29 (−0.47–1.05) 955	2.31 (1.30–3.32) 526	2.02 (0.74–3.30)	.002	.15
Female	1.09 (0.47–1.71) 1,450	1.92 (1.05–2.79) 774	0.83 (−0.27–1.93)	.14	
Mexican American	0.76 (0.07–1.46) 1,299	1.71 (0.67–2.75) 517	0.95 (−0.35–2.24)	.15	.44
European American	0.80 (0.10–1.49) 1,106	2.40 (1.55–3.25) 784	1.60 (0.49–2.71)	.005	
Body mass index, kg/m^2					
<25.0	1.70 (0.68–2.72) 623	1.92 (0.10–3.74) 205	0.22 (−2.00–2.44)	.83	
25.0–29.9	1.19 (0.55–1.84) 1,076	2.24 (1.38–3.10) 575	1.05 (−0.08–2.17)	.07	<.001[1]
≥30.0	−0.53 (−1.68–0.62) 701	1.53 (0.19–2.87) 512	2.06 (0.20–3.93)	.03	<.001[2]
Diabetes mellitus	−0.93 (−2.45–0.60) 345	1.24 (−0.21–2.68) 317	2.17 (−0.01–4.33)	.05	.64
No diabetes mellitus	1.15 (0.66–1.64) 1,990	2.30 (1.55–3.05) 954	1.15 (0.20–2.09)	.02	

[1] BMI categories dichotomized as BMI <25 vs BMI ≥25.
[2] BMI categories dichotomized as BMI <30 vs BMI ≥30.

consumption is causally related to the increasing central obesity observed in daily users in the current study, the clinical relevance of this association could be substantial. Over the past 20 years, abdominal adiposity has been prospectively associated with greater risk of an array of adverse health outcomes,[15,16,34,35] including greater incidence of coronary heart disease and cardiovascular events;[36] albuminuria in women;[37] depression;[38] cognitive decline in men;[39] and mortality from cancer,[24,40] cardiovascular disease,[24] and all causes.[24,40,41] Recommendations for clinical practice have therefore included the measurement of WC, in conjunction with BMI, as part of an individual's medical evaluation.[41,42] According to these guidelines, WC measurement can be useful in identifying individuals with excess cardiometabolic risk: those with BMI from 25.0 to 34.9 kg/m^2 and normal-weight individuals, for whom large WC may offer early warning of hidden cardiometabolic risk.[42]

Dramatically greater ΔWC was observed in daily DS users, despite their stable BMI. Based on evidence from other studies, this divergence suggests that abdominal fat levels—and visceral fat, specifically—increased with frequent DSI because aging-related increases in WC reflect increasing abdominal fat—even in the absence of weight change,[42] large WC in individuals of similar BMI levels is associated with more visceral fat,[13] and aging-related increases in abdominal fat tend to reflect disproportionately greater increases in visceral fat than subcutaneous fat.[14] Thus, for these older DS users, greater abdominal girth is of particular concern because it is associated with disproportionately greater visceral fat,[14,30] which in turn is associated with greater cardiometabolic risk.[15,16] Even small increases in abdominal obesity, similar to those observed in daily DS users in SALSA, have been associated with significant increases in cardiometabolic risk factor levels.[41]

In some studies, abdominal adiposity has outperformed BMI in identifying older individuals at greater cardiometabolic risk.[15,30] Central adiposity has been associated with high glucose concentrations,[14] dyslipidemia,[14] high C-reactive protein,[43] loss of physical function in individuals with metabolic syndrome,[44] depression incidence in men,[45] and incidence of coronary heart disease[46–48] and CVD events.[48] In older individuals and individuals with coronary artery disease, central obesity has also been associated with dramatically greater risk of future CVD events[15,30] and mortality.[15,16,30]

The current results are of particular concern because approximately half of SALSA participants are Mexican American and thus members of the fastest-growing segment of the older U.S. population.[49] Along with other U.S. ethnic minorities, Mexican Americans have experienced higher levels of abdominal obesity[33] and cardiometabolic risk—including greater diabetes incidence and mortality from cardiovascular disease.[50] Health-conscious older Mexican-American adults might therefore use DS or other nonnutritively sweetened beverages in an attempt to lower their metabolic and cardiovascular risk. If this is the case, the current results suggest that such behavior might put them in double jeopardy.

For this reason, dietary counseling for older individuals would ideally include the promotion of unsweetened coffee and tea, mineral water—unsweetened or lightly sweetened with 100% fruit juice—or simply water as alternatives to highly sweetened beverages. Such alternatives would provide hydration and intake of natural antioxidants while decreasing intake of diet beverages, which are intensely sweet and—like their sugar-sweetened counterparts—have been associated with significantly greater incidence of cardiometabolic disease and other health problems.[2–12]

Strengths and Limitations

The number of SALSA participants included in these analyses is modest (n = 466), although the results are based on 3,706 person-years of follow-up. SALSA participants were aged 65 and older at baseline; the degree to which younger individuals would experience the same results is unknown. Whether DSI exacerbated the WC gains observed in SALSA participants is unclear; the analyses include adjustment for anthropometric measures and other characteristics at the outset of each follow-up interval, but other factors—including family history and perceived personal weight-gain and health-risk trajectories—that increased ΔWC but were not captured in the analyses may have influenced participant decisions to use DS. Complete dietary intake data are not available for SALSA participants; these results are thus unadjusted for caloric intake. Nonetheless, the findings of larger ΔWC are consistent with reports from other observational studies of greater cardiometabolic risk in daily DS users, even after adjustment for total caloric intake. Each participant's status as a DS user or nonuser was reset at the beginning of each follow-up interval and thus could change across intervals, but across all intervals, approximately 80% of daily DS users at the beginning of the interval remained DS users at the outset of the next follow-up period, and 82% of nonusers at the outset of each follow-up period remained nonusers at the outset of the subsequent follow-up period. SALSA, a prospective community-based study of older individuals, had several important strengths: multiple follow-up examinations over almost a decade of follow-up; high response rates in survivors within each follow-up interval; representation of individuals from a wide range of socioeconomic environments; and equal representation of European Americans and Mexican Americans, who make up a major and increasing component of U.S. individuals aged 65 and older.

CONCLUSION

A striking, positive dose-response relationship was observed between increasing DSI and escalating abdominal obesity, which represents a potential pathway for future heightened cardiometabolic risk in this vulnerable population. Together with emerging reports from other animal and human studies, these results raise concerns about the safety of chronic DSI by older individuals, especially those already at high cardiometabolic risk.

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