Consumption of Beverages Containing Low-Calorie Sweeteners, Diet, and Cardiometabolic Health in Youth With Type 2 Diabetes

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ABSTRACT

Background Low-calorie sweetened beverages (LCSBs) are commonly used as a lower-calorie alternative to sugar-sweetened beverages (SSBs) by individuals with type 2 diabetes. However, little is known about how intake of LCSBs is related to dietary intake and cardiometabolic health, particularly among youth.

Objective To test the hypothesis that having higher baseline LCSB intake and increasing LCSB intake over 2 years of follow-up are associated with poorer dietary intake and higher cardiometabolic risk factors among youth enrolled in the Treatment Option for Type 2 Diabetes in Adolescents and Youth (TODAY) study.

Design Secondary, exploratory, analysis of baseline and longitudinal data from the TODAY study, which was a randomized, multisite trial conducted from 2004 to 2012, to compare effects of 3 interventions (metformin alone, metformin + rosiglitazone, and metformin + intensive lifestyle intervention) on glycemic control in youth with type 2 diabetes.

Participants/setting The study included 476 children and adolescents (10-17 years, mean body mass index 34.9 ± 7.8 kg/m^2), who were participants in the multicenter (n = 15) TODAY study.

Main outcome measures Diet was assessed using a food frequency questionnaire. Differences in energy intake, macronutrients, food group intakes, and cardiometabolic biomarkers were evaluated in 3 groups of LCSB consumers at baseline (low [1-4 servings/wk], medium [5-11 servings/wk], and high [≥12 servings/wk]), each compared with nonconsumers, and between 4 groups of change in LCSB intake (nonconsumption at start of study and nonconsumption after 2 years, increase in consumption after 2 years, decrease in consumption after 2 years, and high consumption at start of study and high consumption after 2 years).

Statistical analyses performed Multivariable linear regression was performed at baseline and longitudinally over 2 years of follow-up.

Results Energy (kilocalories), fiber, carbohydrate, total fat, saturated fat, and protein intake (grams) were higher among high LCSB consumers compared with nonconsumers at baseline. No associations were observed between LCSB consumption and cardiometabolic risk factors at baseline. Change in LCSB intake between baseline and follow-up was not associated with change in energy intake or cardiometabolic risk factors. Participants who decreased LCSB consumption reported greater increases in sugar intake (18.4 ± 4.8 g) compared with those who increased LCSB consumption (5.7 ± 4.9 g) or remained high LCSB consumers (5.9 ± 7.4 g), but this trend was not statistically significant after a correction for multiple testing.

Conclusions LCSB consumption was associated with higher energy intake in youth with type 2 diabetes, with the highest energy intakes reported in high LCSB consumers. Those who reduced LCSB consumption tended to report greater increases in sugar intake during follow-up, but further studies are needed to better understand this trend.
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CONSUMPTION OF LOW-CALORIE SWEETENED BEVERAGES (LCSBs) has increased in children and adolescents in the United States, with 19% of US youth reporting consumption of LCSBs on a given day in 2009 to 2012, compared with approximately 6% a decade earlier.[1,2] Although LCSBs offer a lower-calorie alternative to sugar-sweetened beverages (SSBs), their effectiveness in improving the overall diet, encouraging weight management, and promoting cardiometabolic health has been challenged.[3,4] Given the scarcity of evidence and resulting uncertainty regarding the role of LCSBs in child health, the American Heart Association recently published a science advisory, which advised against prolonged consumption of LCSBs by children.[5] However, the advisory also stated that although water is optimal, children with diabetes mellitus "who consume a balanced diet and closely monitor their blood glucose may be able to prevent excessive glucose excursions by substituting LCSBs for sugar-sweetened beverages when needed."[5]

In observational studies, positive associations between LCSB intake and weight,[6,7] type 2 diabetes,[8] and metabolic syndrome[9,10] are reported in adults. In children and adolescents, LCSB intake is also positively associated with body weight,[11] with little available data on other cardiometabolic outcomes. In contrast to the observational literature, the majority of randomized controlled trials demonstrate that replacement of added sugars with low-calorie sweeteners (LCSs) lowers total energy intake and reduces body weight.[4,12-14] However, only a few randomized controlled trials[15,16] have examined LCSB effects on cardiometabolic outcomes other than body weight.

The effects of LCSBs on the overall diet are also not well understood, and no studies have examined the impact of LCSB consumption (the main contributor to total LCS intake among children[1]) on dietary intake in children, nor in individuals with type 2 diabetes. In observational studies, mixed findings regarding LCSB consumption and dietary intake are reported in adults,[17-19] with a dearth of available evidence in children. Some cross-sectional analyses demonstrate that adult LCSB consumers report higher discretionary calorie intake,[19] more snack foods purchases,[20] and higher total energy intake[20] compared with SSB consumers. A separate analysis also reported that adults with overweight or obesity who consume LCSBs have higher daily energy intake compared with similar-weight individuals who consume SSBs.[17] On the other hand, other cross-sectional analyses in adults have reported improvements in diet quality[18] and lower energy, carbohydrate, and sugar intake among LCS consumers.[21,22] Reduced intake of saturated fats and greater attention to nutrition labels have also been reported among adults who consume LCSBs,[23] as well as micronutrient intakes consistent with higher dietary quality.[24] Only 1 randomized controlled trial to date, which was a weight loss trial, has assessed changes in dietary outcomes other than energy intake (eg, food groups).[12] In this trial, lower dessert intake was reported among individuals randomized to LCSBs compared with individuals randomized to water.[25]

The objective of this study was to determine the relationship between LCSB consumption, dietary intake, and cardiometabolic risk factors among already metabolically at-risk youth with type 2 diabetes, enrolled in the Treatment Option for Type 2 Diabetes in Adolescents and Youth (TODAY) study. We hypothesized that LCSB intake would be associated with poorer diet and increased presence of cardiometabolic risk factors at baseline. A further hypothesis was that increasing LCSB intake over the course of the 2-year follow-up would unfavorably impact dietary intake and exacerbate cardiometabolic risk factors.

The Continuing Professional Education (CPE) quiz for this article is available for free to Academy members through the MyCDRGo app (available for iOS and Android devices) and through www.jandonline.org (click on "CPE" in the menu and then "Academy Journal CPE Articles"). Log in with your Academy of Nutrition and Dietetics or Commission on Dietetic Registration username and password, click "Journal Article Quiz" on the next page, then click the "Additional Journal CPE quizzes" button to view a list of available quizzes. Non-members may take CPE quizzes by sending a request to journal@eatright.org. There is a fee of $45 per quiz (includes quiz and copy of article) for non-member Journal CPE. CPE quizzes are valid for 1 year after the issue date in which the articles are published.

RESEARCH SNAPSHOT

Research Question: Is consumption of beverages containing low-calorie sweeteners (LCSBs) associated with poorer diet and increased cardiometabolic risk factors in youth with type 2 diabetes?

Key Findings: Energy (kilocalories), fiber, carbohydrate, total fat, saturated fat, and protein intake (grams) were higher among high LCSB consumers compared with nonconsumers at baseline. No association between change in LCSB and change in energy intake between baseline and follow-up were observed; however, participants who decreased LCSB consumption tended to report greater increases in sugar intake. Associations were attenuated after adjustment for energy intake and correction for multiple testing.

MATERIALS AND METHODS

Study Population

Data for the present exploratory analyses were collected during the first 2 years of the TODAY study. The TODAY study was a National Institute of Diabetes and Digestive and Kidney Diseases–sponsored, multicenter (n = 15 sites, all within the United States), randomized clinical trial, conducted from 2004 to 2012. The TODAY study was designed to compare the efficacy of 3 treatment interventions (metformin alone, metformin plus rosiglitazone, and metformin plus intensive lifestyle intervention) to achieve glycemic control in participants with youth-onset type 2 diabetes (ClinicalTrials.gov, NCT# 00081328). The primary objective of the TODAY study was to compare time to treatment failure, defined as loss of glycemic control (sustained hemoglobin A_{1c} [HbA_{1c}] $\geq$ 8%), across 3 treatment interventions. The details of the intensive lifestyle intervention have previously been described.[26] Briefly, the goal of the lifestyle program was to achieve sustained weight losses ($\geq$7% of initial percent overweight) by changing dietary intake and physical activity. In this approach, foods were divided into the colors of the traffic light. With respect to beverages, participants were encouraged to "rethink their drink" with the following classification: (1) beverages high in sugar or fat content (eg, sodas, fruit punch) were considered red drinks and strongly discouraged, (2) beverages with moderate amounts of sugar or with artificial sweeteners (eg, diet soda, 100% fruit juice, low-calorie sports drink) were considered yellow drinks and encouraged to be taken in moderation, and (3) beverages with no added sugars and no artificial sweeteners (eg, water, 1% lowfat milk beverages) were classified as green beverages and strongly encouraged as the healthiest choice. Kriska et al[27] reported no effect of randomized treatment group on change in dietary intake in the first 2 years of the TODAY

Table 2. Baseline demographic characteristics of TODAY[a] study participants (n = 476) by LCSB[b] consumption status[c]

Demographic characteristics	All participants (n = 476)	LCSB nonconsumer (n = 87; 18.3%)	LCSB low consumer (n = 129; 27.1%)	LCSB medium consumer (n = 96; 20.2%)	LCSB high consumer (n = 164; 34.4%)
	←mean ± standard deviation→				
Age (y)	13.8 ± 2.0	13.7 ± 2.1	13.6 ± 1.9	13.8 ± 1.9	14.1 ± 2.0
	←%→				
Female	67.2	78.2	75.2	70.8	53.0***
Race or ethnicity					
Non-Hispanic black	31.3	29.9	27.9	34.4	32.9
Hispanic	40.8	44.8	51.2	36.5	32.9
Non-Hispanic white	21.6	16.1	13.9	22.9	29.9
Other	6.3	9.2	7.0	6.2	4.3
	←mean ± standard deviation→				
BMI[d] (kg/m^2)	34.9 ± 7.8	34.9 ± 7.3	33.6 ± 7.5	34.4 ± 7.7	36.2 ± 8.2
Household highest level of education	←%→				
12th grade or less	26.7	35.6	32.0	28.7	16.7***
High school graduate/GED[e]	25.5	21.8	25.0	19.1	31.5
Some college	30.4	34.5	27.3	29.8	30.9
Bachelors degree or higher	17.4	8.0	15.6	22.3	21.0

[a]TODAY = Treatment Options for type 2 Diabetes in Adolescents and Youth.
[b]LCSB = low-calorie sweetened beverage.
[c]*P* values were calculated from *F* tests for continuous variables and from χ^2 tests for the demographic variables. Unadjusted *P* values are given for the demographic variables. Each LCSB consumption group (low, medium, and high LCSB consumers) is compared with LCSB nonconsumers.
[d]BMI = body mass index.
[e]GED = General Educational Development.
***$P < .001$ for difference compared with the LCSB nonconsumer group.

study, and other TODAY publications have reported the effects of the lifestyle intervention on cardiometabolic risk.[28]

Following institutional review board approval, participants 10 to 17 years of age, less than 2 years from their type 2 diabetes diagnosis, and with a body mass index (BMI) ≥ 85th percentile were recruited from 15 clinical centers. Only youth with complete dietary data at baseline and 24 months (476 [68% of the total TODAY cohort] were included in the present secondary analysis. A comparison of the 476 participants included in the analysis with the 223 participants excluded showed no differences in baseline age, sex, race or ethnicity, household income, household education, BMI, or HbA_{1c} (Table 1, available at www.jandonline.org). A detailed description of the TODAY study procedures is published elsewhere.[29] All participants and their parent(s) provided written informed consent or assent, in accordance with the policies at each site. The study protocol (available at: https://today.bsc.gwu.edu/) was approved by the institutional review board of each participating institution.

Assessment of Dietary Intake

Dietary intake was assessed using a food frequency questionnaire (FFQ), which was a modified version of the SEARCH for Diabetes in Youth FFQ,[30] derived from the Block Kids' Food Questionnaire,[31] and was not designed specifically for use in adolescents with T2D. Although the instrument has been previously tested in an ethnically diverse sample of 10- to 17-year-old youth,[32] data on the validity and reproducibility of the FFQ specifically in this study population are not available. Modifications made in the development of the FFQ have been detailed previously.[33] The FFQ consists of approximately 100 items and the same questionnaire was used at baseline and follow-up. For each food and beverage item, participants were asked if they had consumed the item in the past week (yes or no), and if so, on how many days (1 day, 2 days, 3-4 days, 5-6 days, every day) and how much per day (1 serving, 2 servings, 3-4 servings, or 5+ servings). Portion size was ascertained using pictures of food in bowls or plates (as appropriate), which were provided along with the FFQ form. The Nutrient Data System for Research (University of Minnesota)[34] and industry data were used to calculate nutrient information.

Six food groups were determined based on the 1992 US Department of Agriculture Food Pyramid (grains; vegetables; fruits and fruit juice; dairy; meats; and fats, oils, and sweets).[35] The fats, oils, and sweets food group was further subcategorized into 2 food-groups by the TODAY Diet Analysis Center at the University of South Carolina (sweets and

Table 3. Baseline energy and macronutrient intake of TODAY[a] study participants (n = 476) by LCSB[b] consumption[c]

Daily energy or macronutrient intake[d]	LCSB nonconsumer (n = 87; 18.3%)	LCSB low consumer (n = 129; 27.1%)	LCSB medium consumer (n = 96; 20.2%)	LCSB high consumer (n = 164; 34.4%)
	←————	*mean ± standard deviation*		————→
Energy intake (kcal)	1,086 ± 418	1,173 ± 531	1,282 ± 534*	1,381 ± 545***
Sugar, total (g)	57.7 ± 34.8	57.9 ± 35.9	63.4 ± 36.7	65.8 ± 40.7
Fiber (g)	7.8 ± 3.8	9.0 ± 4.5	9.7 ± 4.6*	10.0 ± 4.9***
Carbohydrates (g)	121.3 ± 51.2	130.2 ± 61.8	142.8 ± 64.1	150.4 ± 66.5**
% kcal from carbohydrates	44.9 ± 9.4	44.7 ± 7.9	44.7 ± 8.5	43.7 ± 9.1
Total fat (g)	46.5 ± 21.9	49.5 ± 24.1	55.3 ± 26.0*	60.1 ± 27.4**
% kcal from fat	38.1 ± 7.3	37.8 ± 5.7	38.5 ± 6.1	39.1 ± 6.9
Saturated fat (g)	16.1 ± 8.1	17.1 ± 8.2	18.9 ± 9.2	20.5 ± 8.8**
% kcal from saturated fat	13.2 ± 3.2	13.1 ± 2.5	13.2 ± 2.6	13.4 ± 2.9
Protein (g)	48.1 ± 20.9	54.1 ± 30.2	56.5 ± 25.7	62.9 ± 28.2***
% kcal from protein	17.8 ± 3.7	18.4 ± 3.9	17.7 ± 3.5	18.2 ± 3.2

[a]TODAY = Treatment Options for type 2 Diabetes in Adolescents and Youth.
[b]LCSB = low-calorie sweetened beverage.
[c]*P* values were calculated from *F* tests for continuous variables. Adjusted *P* values for the energy or macronutrient intake variables are calculated from models adjusted for baseline age, sex, race or ethnicity, highest household level of education, and body mass index. Variables were log transformed prior to testing due to departures from normality. Each LCSB consumption group (low, medium, and high LCSB consumers) is compared with LCSB nonconsumers.
[d]Dietary intake was assessed using a food frequency questionnaire, which was a modified version of the SEARCH for Diabetes in Youth Food Frequency Questionnaire,[31] derived from the Block Kids' Food Questionnaire.[32]
*$P < .05$ for difference compared with the LCSB nonconsumer group.
**$P < .01$ for difference compared with the LCSB nonconsumer group.
***$P < .001$ for difference compared with the LCSB nonconsumer group.

desserts; fats and oils). Intakes of each food group or food item were assessed as servings per day. Intake of macronutrients (eg, carbohydrates, fats, and protein) was analyzed in grams and as a percentage of total daily calories (% kcal).

LCSB consumption was assessed using the FFQ item, "Last week, did you drink diet soda, sugar-free Kool-Aid [Kraft-Heinz], or unsweetened mineral water?" LCSB consumption (as opposed to mineral water) was verified using reported intake of aspartame (milligrams), the only LCS available in the database. Although some LCSBs contain LCSs other than aspartame (eg, sucralose), the majority of diet sodas available during the study period (2001-2012) contained aspartame.[36] For example, it was not until 2015 that PepsiCo removed aspartame from Diet Pepsi in the United States and replaced it with sucralose and acesulfame-potassium, although Diet Pepsi with aspartame was later reintroduced due to consumer demand.[37] Sugar-free Kool-Aid, the other LCSBs explicitly mentioned in the above FFQ item, is also aspartame-sweetened (as per current publicly available online nutritional information). SSB consumption included intake of canned or bottled sodas (not counting diet soda), fruit drinks, sports drinks, any other similar drink, or intake of sweetened tea or coffee containing sugar. Fruit juice consumption included intake of "real orange juice" or "real fruit juice" (100% apple juice or grape juice). Any participant reporting LCSBs, SSBs, or fruit juice use, regardless of their intake of other beverages, was categorized as a LCSB, SSB, or fruit juice consumer, respectively. The frequency of each beverage item reported was then multiplied by the serving size to obtain the total amount of beverage consumed as serving per week. For the calculations, the midpoint value was used for items consumed 3 to 4 or 5 to 6 days per week (ie, amount was multiplied by 3.5 or 5.5). Similarly, a serving size of 6 was used if the participants reported consuming 5+ servings per day. TODAY participants were then classified as non-LCSB consumers (0 servings/wk), low LCSB consumers (1-4 servings/wk), medium LCSB consumers (5-11 servings/wk), and high LCSB consumers (≥12 servings/wk). Beverage categories approximated those used in a prior longitudinal study of LCSBs and body weight in adults,[6] while accounting for the distribution of LCSB consumption in the TODAY participants. Changes in LCSB consumption between baseline and follow-up were categorized as (a) nonconsumption at both time points; (b) decrease in consumption (high to medium, high to low, medium to low, etc); (c) increase in consumption (low to high, medium to high, etc); or (d) high consumption at both time points. Low consumption at both time points and medium consumption at both time points were also evaluated, but are not shown in the tables.

Assessment of Demographic and Cardiometabolic Biomarkers

Weight, height, calculated BMI, systolic blood pressure, diastolic blood pressure, and laboratory tests were measured at both baseline and month 24, as previously described.[29] Fasting blood samples were obtained at each time point

Table 4. Baseline associations between LCSB[a] consumption, beverage consumption, and food group intake among 476 children and adolescents in the TODAY[b] study[c]

Beverage intake[d]	LCSB nonconsumer (n = 87; 18.3%)	LCSB low consumer (n = 129; 27.1%)	LCSB medium consumer (n = 96; 20.2%)	LCSB high consumer (n = 164; 34.4%)
	←median (25th-75th percentile)→			
LCSB intake (servings/wk)	—	2 (1-3.5)	7 (7-7)	20 (14-24)
	←%→			
SSB[e] consumer	56.3	51.9	53.1	44.5
	←median (25th-75th percentile)→			
SSB intake (servings/wk)	1.8 (1-2.7)	1.5 (1-2)	1.7 (1-3.5)	2 (1-3.4)
	←%→			
Fruit juice consumer	34.5	41.9	41.7	39.6
	←median (25th-75th percentile)→			
Fruit juice intake (servings/wk)	2 (1-3.5)	2 (1-2)	2 (1-3.5)	2 (1-5.5)
Food group (servings/d)[df]	←mean ± standard deviation→			
Bread, cereal, rice, pasta	9.0 ± 6.3	9.1 ± 5.3	9.7 ± 6.2	10.2 ± 6.3
Vegetables	0.8 ± 0.8	1.1 ± 0.7	1.1 ± 0.9	1.2 ± 1.1
Fruit (including fruit juice)	0.8 ± 0.7	1.0 ± 0.8	0.9 ± 0.8	1.2 ± 1.1
Milk, yogurt, cheese	4.8 ± 4.6	5.3 ± 4.3	4.3 ± 3.5	4.7 ± 4.5
Meat, poultry, eggs, fish	2.2 ± 1.4	2.4 ± 1.5	2.7 ± 1.5	3.1 ± 1.7**
Sweets and desserts	2.3 ± 3.3	1.8 ± 2.5	1.7 ± 2.2	1.7 ± 2.5
Fats and oils	1.8 ± 2.3	2.5 ± 2.5	2.6 ± 2.5	3.0 ± 3.5

[a]LCSB = low-calorie sweetened beverage.
[b]TODAY = Treatment Options for type 2 Diabetes in Adolescents and Youth.
[c]LCSB, sugar-sweetened beverage, and fruit juice intake (servings/wk) are calculated among participants that reported consuming that beverage. *P* values were calculated from multivariate linear regression models, testing for beverage (servings/wk) and food group (servings/d) differences comparing each LCSB consumption group (low, medium, and high LCSB consumers) to LCSB nonconsumers, after adjustments for baseline age, sex, race or ethnicity, highest household level of education, and body mass index.
[d]Dietary intake was assessed using a food frequency questionnaire, which was a modified version of the SEARCH for Diabetes in Youth Food Frequency Questionnaire, derived from the Block Kids' Food Questionnaire.
[e]SSB = sugar-sweetened beverage.
[f]Other food groups were available in the data set provided by the TODAY Diet Analysis Center at the University of South Carolina; however, analyses for these food groups (eg, eggs, beans, yellow and green vegetables) are not presented due to relatively low consumption among TODAY participants.
**$P < .01$ (reference group = nonconsumer).

for assessment of blood glucose, HbA_{1c}, total cholesterol, low-density lipoprotein, high-density lipoprotein, and triglycerides. Samples were processed using standard procedures and shipped on dry ice to the Central Biochemistry Laboratory for the TODAY study, which was at the University of Washington (Seattle). Biochemical assays were conducted at the Northwest Lipid Research Laboratory and details are available at www.todaystudy.org. Time (hours per day) spent in moderate to vigorous physical activity was assessed via the validated self-report 3-day physical activity recall questionnaire,[38] which captures physical activity for the previous 3 days.

Statistical Analyses

Participants in 3 treatment groups (metformin alone, metformin plus rosiglitazone, and metformin plus intensive lifestyle intervention) were analyzed as a combined cohort. Analyses were performed using SAS (version 9.4 for Windows; SAS Institute, Cary, North Carolina)[39] and all analyses were considered exploratory. To account for multiple testing (3 main comparisons of interest in the baseline analyses and 4 main comparisons of interest for the change from baseline analyses), a conservative significance value of $P < .01$ was used. Results that were significant at the $P < .05$ level but were not significant after correction were identified as trends that may merit further exploration in future studies. Variables with a skewed distribution were log transformed as appropriate. Analysis of variance and χ^2 were used to compare the demographic variables by LCSB consumption status (all comparisons versus nonconsumers) at baseline. Nonparametric tests were used for SSB and fruit juice intake (servings per week) due to skewed distribution. Multivariable general linear regression models were used to determine baseline associations between LCSB consumption, energy or macronutrient, and food group intake, while adjusting for baseline age, sex, race or ethnicity, highest household level of education, and BMI. Separate regression models considered total daily energy intake and SSB consumption as additional covariates. The regression modeling was performed with and without adjustment for physical activity. In all baseline analyses, individuals in the 3 LCSB consumption groups were compared with nonconsumers.

Similar multivariate linear regression models were used to determine associations between 2-year changes in energy, macronutrient, food group intake, and cardiometabolic risk factors, as a function of change in LCSB consumption. In the 2-year analyses, the 4 main comparisons of interest for the LCSB groups of change consisted of (1) increase in consumption over the 2 years vs nonconsumption at start of study and nonconsumption after 2 years, (2) increase vs decrease in consumption after 2 years, (3) high consumption at start of study and high consumption after 2 years vs nonconsumption at start of study and nonconsumption after 2 years, and (4) high consumption at start of study and high consumption after 2 years vs decrease in consumption after 2 years. These subsequent models adjusted for baseline age, sex, race or ethnicity, highest household level of education, BMI at follow-up (month 24), randomized treatment group, the baseline value of the outcome, and baseline LCSB consumption. Frequencies of participant LCSB consumption at follow-up, and daily energy and macronutrient intake by categories of LCSB consumption at baseline and over time, were also evaluated separately by randomized treatment group.

RESULTS

Demographic characteristics of LCSB nonconsumers and low, medium, and high LCSB consumers are presented in Table 2. High LCSB consumption was associated with higher household educational attainment ($P = .0007$) and comprised a greater proportion of male participants ($P = 0.0001$) compared with non-LCSB consumers.

Baseline Associations Between LCSB, Dietary Intake, and Cardiometabolic Risk Factors

After adjusting for BMI and other relevant covariates, high LCSB consumption (≥12 servings/wk) was associated with higher energy, fiber, carbohydrate, total fat, saturated fat, and protein intake at baseline compared with nonconsumers (Table 3). Medium LCSB consumption (5-11 servings/wk) showed similar trends for energy, fiber, and total fat intake, compared with nonconsumers. Total sugar intakes were similar across the 4 groups. Although absolute intakes of carbohydrate (150.4 ± 66.5 vs 121.3 ± 51.2 g, $P = .0056$), total fat (60.1 ± 27.4 vs 46.5 ± 21.9 g; $P = .0012$), saturated fat (20.5 ± 8.8 vs 16.1 ± 8.1 g, $P = .0027$), and protein (62.9 ± 28.2 vs 48.1 ± 20.9; $P = .0005$) were greater

Table 5. Baseline associations between LCSB[a] consumption and cardiometabolic risk factors among 476 children and adolescents enrolled in the TODAY[b] study[c]

Cardiometabolic risk factors	LCSB nonconsumer (n = 87; 18.3%)	LCSB low consumer (n = 129; 27.1%)	LCSB medium consumer (n = 96; 20.2%)	LCSB high consumer (n = 164; 34.4%)
	←———	*mean ± standard deviation*		———→
BMI[d] (kg/m^2)	34.9 ± 7.3	33.6 ± 7.6	34.4 ± 7.7	36.2 ± 8.2
Systolic blood pressure (mm Hg)[e]	112.9 ± 11.1	110.4 ± 9.8	112.8 ± 11.8	113.9 ± 11.3
Diastolic blood pressure (mm Hg)[e]	66.3 ± 8.2	65.6 ± 7.8	66.6 ± 8.6	66.7 ± 8.8
HbA_{1c}[f] (%)	6.0 ± 0.7	5.9 ± 0.8	6.2 ± 0.8	6.0 ± 0.7
Fasting glucose (mg/dL)[g]	105.7 ± 20.6	109.0 ± 23.9	113.7 ± 28.2	109.3 ± 24.8
Total cholesterol (mg/dL)[h]	148.9 ± 32.7	143.2 ± 28.6	145.4 ± 32.7	144.6 ± 30.0
LDL[i] cholesterol (mg/dL)[h]	86.8 ± 29.4	82.1 ± 22.3	84.4 ± 26.4	84.7 ± 25.0
HDL[j] cholesterol (mg/dL)[h]	39.7 ± 8.3	38.9 ± 9.3	38.8 ± 8.5	38.3 ± 8.2
Triglycerides (mg/dL)[k]	114.0 ± 69.2	113.3 ± 85.3	113.2 ± 89.5	111.2 ± 75.4

[a]LCSB = low-calorie sweetened beverage.
[b]TODAY = Treatment Options for type 2 Diabetes in Adolescents and Youth.
[c]Each LCSB consumption group (low, medium, and high LCSB consumers) is compared with LCSB nonconsumers. No significant difference by LCSB group found when compared with nonconsumers for any of the cardiometabolic risk factors (all $P > .05$), in models adjusted for baseline age, sex, race or ethnicity, highest household level of education, and BMI (except for BMI model).
[d]BMI = body mass index.
[e]For conversion to SI units, values are multiplied by 133.32.
[f]HbA_{1c} = hemoglobin A_{1c}.
[g]For conversion to SI units, values are multiplied by 0.0555.
[h]For conversion to SI units, values are multiplied by 0.02586.
[i]LDL = low-density lipoprotein.
[j]HDL = high-density lipoprotein.
[k]For conversion to SI units, values are multiplied by 0.01129.

among high LCSB consumers compared with nonconsumers, respectively, no significant differences in these macronutrient intakes were observed when they were expressed as a percentage of total daily energy intake. All associations were attenuated after adjustment for energy intake.

Intake of SSBs and fruit juice consumption was similar across the LCSB groups and nonconsumers (Table 4). Table 4 displays reported food group intake according to LCSB consumption. High LCSB consumers reported higher meat, poultry, eggs, and fish intake compared with nonconsumers (3.1 ± 1.7 vs 2.2 ± 1.4 servings per day; $P = .0011$), but this association was attenuated after adjustment for energy intake. No associations between LCSB consumption and any cardiometabolic risk factor (glucose, HbA_{1c}, blood lipids, or blood pressure) were observed (Table 5).

Two-Year Changes in LCSB Intake, Dietary Intake, and Cardiometabolic Risk Factors

Of the 87 TODAY participants who did not report LCSB consumption at baseline (nonconsumers), 48% (n = 42) remained nonconsumers at follow-up (Figure, available at www.jandonline.org). Of 164 youth who reported high LCSB consumption at baseline, 48% (n = 79) also reported high consumption after 2 years (Figure, available at www.jandonline.org). Although some participants were consistently low (n = 47) or medium (n = 26) consumers at both baseline and 2 years, the majority of participants either increased (n = 119, 25%) or decreased (n = 163, 34%) their LCSB intake between baseline and follow-up. Changes in LCSB consumption from baseline to follow-up, overall and by treatment group, are shown in the Figure (available at www.jandonline.org).

Changes in LCSB intake were not associated with changes in energy intake (Table 6) between baseline and follow-up. Participants who decreased LCSB consumption tended to report greater increases in sugar intake (18.4 ± 4.8 g) compared with those who increased LCSB intake (5.7 ± 4.9, $P = .0134$) or remained high LCSB consumers (5.9 ± 7.4, $P = .0155$). However, this result was not statistically significant after accounting for multiple tests. Sugar intake (and specifically, SSB intake) was higher at follow-up (compared with baseline) across all 4 groups, irrespective of changes in LCSB consumption. Lower increases in the percentage of total calories from carbohydrate and smaller decreases in percentage of total calories from fat and saturated fat were observed in participants who remained high LCSB consumers, compared with those who decreased LCSB intake or remained non-LCSB consumers (all $P < .01$). Associations between changes in macronutrient and LCSB intakes were attenuated after adjustment for change in SSB intake. No

Table 6. Two-year changes in LCSB[a] consumption, energy (kcal), and macronutrient intake (g)[b] among children and adolescents enrolled in the TODAY[c] study[d]

Daily energy or macronutrient intake change from baseline	Non−non[e] LCSB consumption (n = 42; 8.8%)	Decrease in LCSB consumption (n = 163; 34.2%)	Increase in LCSB consumption (n = 119; 25.0%)	High−high[f] LCSB consumption (n = 79; 16.6%)
	←———— *mean ± standard error* ————→			
Energy intake (kcal)	55 ± 79	72 ± 47	100 ± 62	4 ± 87
Sugar, total (g)[g]	10.5 ± 9.6	18.4 ± 4.8	5.7 ± 4.9	5.9 ± 7.4
Fiber (g)	−0.0 ± 0.6	0.1 ± 0.4	0.2 ± 0.5	−0.8 ± 0.8
Carbohydrates (g)	17.2 ± 11.7	18.1 ± 6.7	13.3 ± 7.4	3.9 ± 11.1
% kcal from carbohydrates[h]	3.1 ± 1.9	3.0 ± 0.9	0.5 ± 1.1	−0.1 ± 1.1
Total fat (g)	−1.4 ± 3.8	0.4 ± 2.2	3.9 ± 3.1	−0.8 ± 4.1
% kcal from fat[h]	−2.2 ± 1.4	−1.9 ± 0.7	−0.3 ± 0.8	0.1 ± 0.8
Saturated fat (g)	−0.3 ± 1.5	−0.3 ± 0.8	1.7 ± 1.1	0.3 ± 1.3
% kcal from saturated fat[h]	−0.6 ± 0.7	−0.9 ± 0.3	0.1 ± 0.3	0.1 ± 0.4
Protein (g)	−0.6 ± 4.2	−0.7 ± 2.3	2.6 ± 3.5	−1.4 ± 4.2
% kcal from protein	−1.1 ± 0.8	−1.1 ± 0.4	−0.4 ± 0.5	−0.2 ± 0.4

[a]LCSB = low-calorie sweetened beverage.

[b]Dietary intake was assessed using a food frequency questionnaire, which was a modified version of the SEARCH for Diabetes in Youth Food Frequency Questionnaire, derived from the Block Kids' Food Questionnaire.

[c]TODAY = Treatment Options for type 2 Diabetes in Adolescents and Youth.

[d]*P* values were calculated from multivariate linear regression models. Adjusted *P* values are calculated from models adjusted for baseline age, sex, race or ethnicity, highest household level of education, month 24 body mass index, randomized treatment group, the baseline value of the outcome, and baseline LCSB consumption (servings/wk). Variables were log-transformed prior to testing due to departures from normality. The following comparisons between the LCSB groups of change were made: (1) increase vs non−non, (2) increase vs decrease, (3) high−high vs non−non, and (4) high−high vs decrease. Significant comparisons are described in the footnotes below.

[e]Non−non = nonconsumption at start of study and nonconsumption after 2 years.

[f]High−high = high consumption at start of study and high consumption after 2 years.

[g]Change in sugar intake was different between the decrease vs increase ($P < .05$) and high−high ($P < .05$) LCSB consumption group.

[h]Change in % kcal from carbohydrates, % kcal from fat, and % kcal from saturated fat were different between high−high vs increase ($P < .01$), decrease ($P < .001$), and non−non ($P < .01$).

Table 9. Two-year changes in LCSB[a] consumption and cardiometabolic risk factors among children and adolescents enrolled in the TODAY[b] study[c]

Cardiometabolic risk factors change from baseline	Non–non[d] LCSB consumption (n = 42; 8.8%)	Decrease in LCSB consumption (n = 163; 34.2%)	Increase in LCSB consumption (n = 119; 25.0%)	High–high[e] LCSB consumption (n = 79; 16.6%)
	←———— *mean ± standard error* ————→			
BMI[f] (kg/m^2)	1.7 ± 0.5	1.3 ± 0.2	1.2 ± 0.3	1.6 ± 0.3
Systolic blood pressure (mm Hg)	−0.3 ± 1.5	2.6 ± 0.8	2.4 ± 0.9	2.0 ± 1.2
Diastolic blood pressure (mm Hg)	1.0 ± 1.3	2.6 ± 0.7	2.6 ± 0.9	1.2 ± 1.1
HbA_{1c} (%)	1.3 ± 0.3	1.2 ± 0.2	1.3 ± 0.2	1.0 ± 0.2
Fasting glucose (mg/dL)[g]	48.7 ± 10.7	36.0 ± 4.4	39.8 ± 5.7	33.1 ± 6.4
Total cholesterol (mg/dL)[h]	14.6 ± 4.2	14.0 ± 2.3	9.6 ± 2.4	11.5 ± 3.1
LDL[i] cholesterol (mg/dL)[h]	8.5 ± 3.1	7.0 ± 1.6	5.8 ± 1.9	5.2 ± 2.2
HDL[j] cholesterol (mg/dL)[h]	3.0 ± 0.9	3.6 ± 0.6	3.2 ± 0.7	1.3 ± 0.8
Triglycerides (mg/dL)[k]	9.5 ± 7.9	20.9 ± 11.5	3.4 ± 6.4	24.2 ± 9.5

[a]LCSB = low-calorie sweetened beverage.
[b]TODAY = Treatment Options for type 2 Diabetes in Adolescents and Youth.
[c]No significant association found between change from baseline in LCSB consumption group with change from baseline in cardiometabolic risk factors (all $P > .05$), in models adjusted for baseline age, sex, race or ethnicity, highest household level of education, month 24 BMI, randomized treatment group, the baseline value of the outcome, and the baseline status of LCSB consumption. The following comparisons between the LCSB groups of change were made: (1) increase vs non–non, (2) increase vs decrease, (3) high–high vs non–non, and (4) high–high vs decrease. None of the comparisons were statistically significant.
[d]Non–non = nonconsumption at start of study and nonconsumption after 2 years.
[e]High–high = high consumption at start of study and high consumption after 2 years.
[f]BMI = body mass index.
[g]For conversion to SI units, values are multiplied by 0.0555.
[h]For conversion to SI units, values are multiplied by 0.02586.
[i]LDL = low-density lipoprotein.
[j]HDL = high-density lipoprotein.
[k]For conversion to SI units, values are multiplied by 0.01129.

statistically significant interactions between treatment group and LCSB intake (Tables 7 and 8, both available at www.jandonline.org) were observed, and results were unaffected when physical activity was included or removed from the model.

Change in LCSB intake was not associated with changes in food group intake (data not shown). Change in LCSB intake also did not affect changes in any cardiometabolic risk factors between baseline and follow-up (Table 9).

DISCUSSION

To our knowledge, this study is the first to examine associations between LCSB, diet, and cardiometabolic risk factors in youth with type 2 diabetes. The present study investigated both cross-sectional (baseline) and longitudinal (over 2 years of follow-up) associations in a diverse cohort of youth with type 2 diabetes, who report a high prevalence of LCSB use. Consistent with findings reported in studies of youth without diabetes,[40] we observed that LCSB intake is associated with higher energy intake in youth with type 2 diabetes. Notably, the highest energy intakes were reported among participants with the highest reported LCSB consumption.

In the longitudinal analyses, there was a trend (did not reach statistical significance after accounting for multiple testing) toward greater increases in sugar intake among TODAY participants who reduced their LCSB consumption between baseline and the 2-year follow-up. Notably, reported energy and sugar intake increased over 2 years across all groups, regardless of changes in LCSB. These results suggest that although LCSB may successfully suppress SSB consumption in youth with type 2 diabetes, this replacement may not benefit the overall diet. These findings support guidance put forth in a recent American Academy of Pediatrics Position Statement,[41] which states that “when substituted for caloric sweetened foods or beverages, NNSs [synonymous with LCS] can reduce weight gain or promote small amounts of weight loss (∼1 kg) in children (and adults); however, data are limited, and use of NNSs in isolation is unlikely to lead to substantial weight loss.”

Positive associations between LCSB consumption and energy intake may be explained by several potential factors. One suggested physiologic mechanism is that LCS ingestion may enhance circulating levels of insulin,[42,43] an anabolic hormone known to promote food intake. Another potential mechanism, which has received considerable support in rodent models, is that LCS exposure may disturb the predictability of sweetness as a signal for calories, leading to dysregulated energy homeostasis and higher calorie intake.[44]

Some short-term, preload studies testing LCS effects on food intake demonstrate that children eat more solid food calories at meals following ingestion of LCSB compared with SSB (and thus completely compensate for the diluted energy content of LCSB). Nonetheless, findings are inconsistent across studies and some report lower total energy intake after LCSB using a similar preload design.[11,45] Behavioral mechanisms, including motivation for LCSB use and the possibility that perceived calorie savings from consuming LCSB may justify subsequent consumption of highly caloric foods and beverages,[46] may also contribute and are likely not mutually exclusive. Rather, physiologic and behavioral mechanisms may together contribute to greater energy intake observed among high LCSB consumers in the present analysis. It is also possible that those with the highest energy intakes may have previously been counseled to consume more LCSB, and thus, findings may be in part explained by reverse causality.

Despite the observed positive associations between LCSB consumption and energy intake at baseline, the lack of an association between baseline LCSB consumption and sugar intake is noteworthy and is in contrast with findings of a similar cross-sectional analyses in children without diabetes.[40] Furthermore, the lack of an association between LCSB consumption and sugar intake challenges the hypothesis that LCSBs uniquely stimulate overconsumption of sweet-tasting, and often sugar-rich, foods and beverages.[47,48] This null finding is consistent with a recent meta-analysis, which reported equivocal evidence for an association between dietary sweetness exposure and preferences for or consumption of other sweetened foods or beverages.[49]

Null findings with regard to LCSB consumption and the presence of cardiometabolic risk factors also contrasts with the preponderance of existing observational evidence in adults.[3] This may be explained by the relatively small sample size of youth with type 2 diabetes included in the present analysis, as well as the fact that the majority of adult studies included healthy individuals, free of preexisting diabetes. Importantly, youth with type 2 diabetes enrolled in the TODAY study were already metabolically at risk, minimizing the likelihood that differences in cardiometabolic risk factors would be observed based on LCSB consumption.

Key strengths of the present study were the high prevalence and wide-ranging quantities of LCSB intake, which allowed for comparisons of outcomes in relation to the dosages of LCSB consumed. However, widespread LCSB consumption in the TODAY cohort at baseline may also be viewed as a limitation because the relatively small percentage of individuals not reporting any LCS consumption limited the ability to compare diet and metabolic risk factors between LCSB consumers and nonconsumers. The present study is further strengthened by the ability to investigate both cross-sectional and longitudinal associations between LCSB, diet, and cardiometabolic risk factors.

A key limitation is that the post hoc secondary analyses performed for this study were exploratory and may have been underpowered. Results are subject to several other limitations, particularly the flaws inherent in self-reported dietary data collected using an FFQ, and the wording of the questionnaire item, which included mineral water along with LCSB. As with any self-report dietary assessment method, FFQ data are subject to recall bias, social desirability bias, and measurement error, and thus, some dietary estimates may be inaccurate. Furthermore, although the FFQ used in TODAY was designed to measure habitual dietary intake over time, the FFQ used has not been validated specifically in adolescents with T2D. And the ability of the instrument to accurately estimate energy intake is limited,[50] which may explain the relatively low reported energy intakes across LCSB consumption groups.[33] Another limitation was that computation of an overall diet index, such as the Healthy Eating Index, was not possible due to lack of available data for key Healthy Eating Index subcomponents, such as added sugar intake. However, given that no differences in individual diet components were observed, it is unlikely that a composite score would have provided additional meaningful information. Finally, the investigators did not control for medication use in the analysis, yet given that there was no treatment effect nor were differences observed in any of the cardiometabolic risk factors, it is unlikely that medication use played a significant role. It is also plausible that the cardiometabolic outcomes examined in this study were not sufficiently responsive to dietary changes in this sample of adolescents with type 2 diabetes, as limited changes in dietary intake were reported and may reflect a regression to the mean phenomenon.

CONCLUSIONS

The need to elucidate the impact of LCSB consumption on overall dietary intake is particularly critical in youth with type 2 diabetes, who frequently receive guidance to consume LCSB to lower carbohydrate intake, support weight management, and improve glycemic control. However, the higher energy intake observed among high LCSB consumers in the TODAY cohort at baseline, and the fact that increasing LCSB intake over 2 years did not result in lower energy intake at follow-up, challenges the benefits of LCSB consumption in this patient population. The present findings further justify the importance of investigating effects of LCSB on diet and cardiometabolic health in youth with type 2 diabetes in future well-designed and sufficiently powered, randomized controlled trials.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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AUTHOR CONTRIBUTIONS

A. C. Sylvetsky, J. A. Welsh, and S. A. Talegawkar designed the study. L. El ghormli and A. Chandran conducted the statistical analyses. A. C. Sylvetsky wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approve of the final version submitted to the Journal of the Academy of Nutrition and Dietetics.

Table 1. Baseline demographic characteristics[a] of included and excluded TODAY[b] study participants

Demographic characteristics	Included (n = 476)	Excluded[c] (n = 223)
	←mean (standard deviation)→	
Age (y)	13.8 ± 2.0	14.2 ± 2.0
	←%→	
Female	67.2	60.1
Race or ethnicity		
Non-Hispanic black	31.3	35.0
Hispanic	40.8	37.7
Non-Hispanic white	21.6	17.9
Other	6.3	9.4
	←mean (standard deviation)→	
BMI[d] (kg/m^2)	34.9 ± 7.8	35.0 ± 7.3
HbA_{1c}[e]	6.0 ± 0.7	6.1 ± 0.8
Household highest level of education	←%→	
12th grade or less	26.7	26.0
High school graduate or GED[f]	25.5	24.2
Some college	30.4	34.9
Bachelors degree or higher	17.4	14.9
Household highest level of income ($)		
<25,000	40.2	44.4
25,000-49,999	36.7	27.0
≥50,000	23.1	28.6

[a]All *P* values > .05 from χ^2 or *t* tests for comparison of characteristics between those participants included in the sample vs those excluded.
[b]TODAY = Treatment Options for type 2 Diabetes in Adolescents and Youth.
[c]Excluded due to lack of complete dietary data at baseline and 24 months.
[d]BMI = body mass index.
[e]HbA_{1c} = hemoglobin A_{1c}.
[f]GED = General Educational Development.

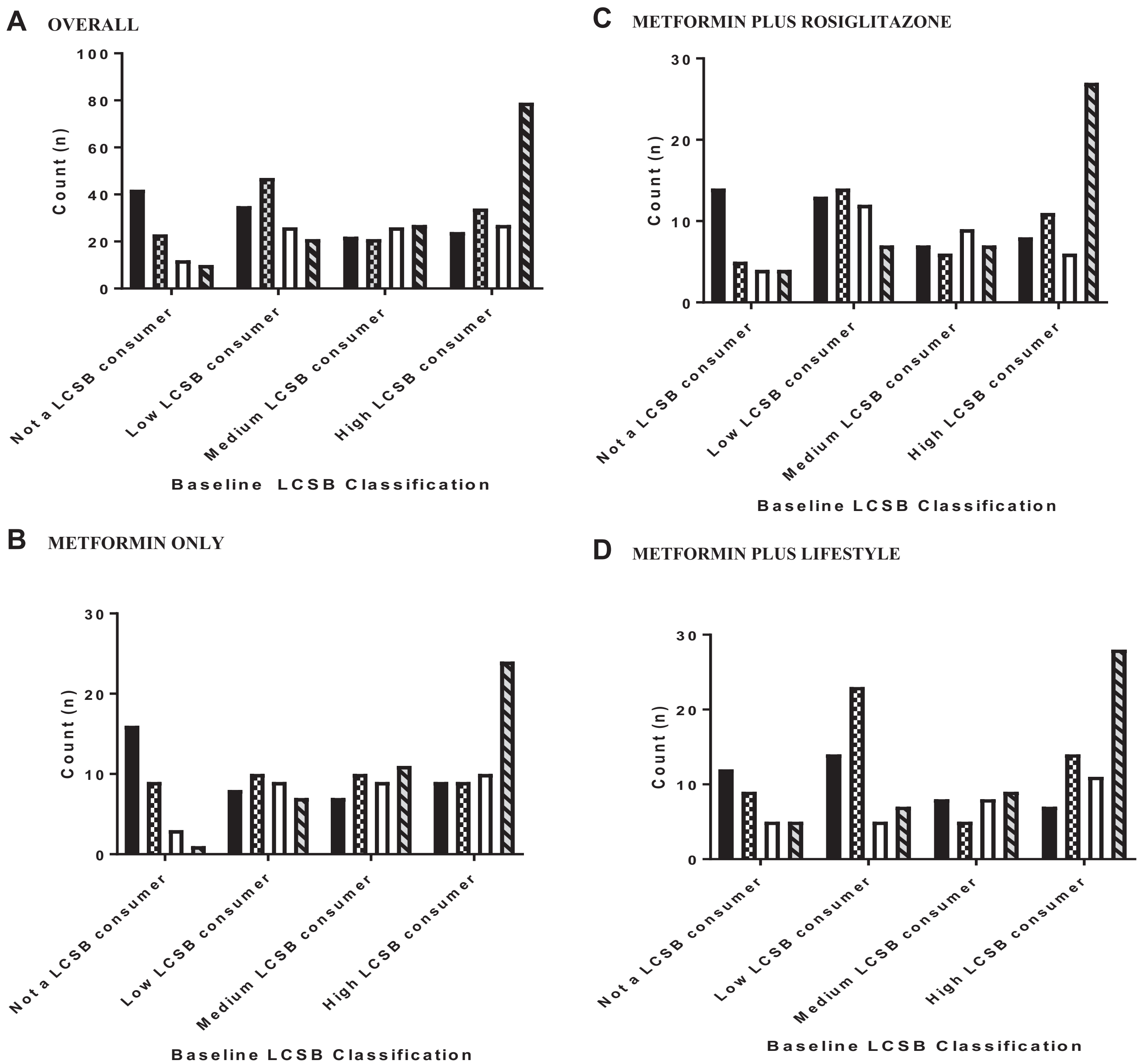

Figure. Changes in low-calorie sweetened beverage (LCSB) consumption between baseline and follow-up are shown overall (A) and separately by each of the 3 treatment groups: metformin only (B), metformin plus rosiglitazone (C), and metformin plus lifestyle (D). Participants classified as nonconsumers, low consumers, medium consumers, and high consumers at follow-up are shown in solid black, checkered, solid white, and striped bars, respectively.

Table 7. Baseline associations between LCSB[a] consumption and energy and macronutrient intake among 476 children and adolescents enrolled in the TODAY[b] study, stratified by treatment group

Daily energy or macronutrient intake[c]	LCSB nonconsumer	LCSB low consumer	LCSB medium consumer	LCSB high consumer
	←n→			
Metformin alone	29	34	37	52
	←*mean ± standard deviation*→			
Energy intake (kcal)	1,086 ± 455	1,257 ± 503	1,268 ± 506	1,422 ± 635
Sugar, total (g)	59.1 ± 37.0	58.3 ± 26.0	61.4 ± 39.1	62.3 ± 32.7
Fiber (g)	123.6 ± 50.6	134.5 ± 42.5	140.5 ± 65.3	144.7 ± 57.6
Carbohydrates (g)	7.7 ± 4.1	8.9 ± 2.9	9.5 ± 4.9	10.7 ± 5.9
% kcal from carbohydrates	46.4 ± 10.3	44.0 ± 6.9	44.3 ± 7.8	41.9 ± 9.5
Total fat (g)	45.4 ± 23.8	54.7 ± 24.7	54.2 ± 21.6	64.8 ± 35.7
% kcal from fat	36.7 ± 7.3	38.8 ± 4.3	38.5 ± 5.8	40.2 ± 6.9
Saturated fat (g)	16.0 ± 9.6	18.9 ± 7.2	19.1 ± 8.0	22.2 ± 10.4
% kcal from saturated fat	12.9 ± 3.8	13.6 ± 2.0	13.5 ± 2.6	14.0 ± 2.9
Protein (g)	48.2 ± 24.4	59.0 ± 41.4	56.9 ± 24.8	68.2 ± 36.9
% kcal from protein	17.7 ± 4.0	18.1 ± 4.2	18.0 ± 3.6	18.8 ± 3.5
	←n→			
Metformin plus rosiglitazone	27	46	29	52
	←*mean ± standard deviation*→			
Energy intake (kcal)	1,062 ± 460	1,117 ± 456	1,252 ± 524	1,372 ± 506
Sugar, total (g)	54.9 ± 38.9	57.9 ± 32.4	62.4 ± 39.3	64.5 ± 47.6
Fiber (g)	112.4 ± 55.1	130.7 ± 61.5	142.4 ± 70.7	152.8 ± 71.6
Carbohydrates (g)	7.3 ± 2.9	9.0 ± 4.1	9.7 ± 4.7	10.4 ± 4.3
% kcal from carbohydrates	42.3 ± 7.6	46.7 ± 8.4	44.8 ± 9.7	44.4 ± 9.5
Total fat (g)	46.7 ± 22.3	45.2 ± 18.7	53.5 ± 24.3	59.0 ± 23.2
% kcal from fat	39.8 ± 6.3	36.5 ± 6.5	38.8 ± 7.1	38.7 ± 7.1
Saturated fat (g)	16.1 ± 7.9	15.5 ± 6.5	17.9 ± 8.6	19.1 ± 6.9
% kcal from saturated fat	13.7 ± 2.4	12.5 ± 3.0	13.0 ± 2.8	12.7 ± 2.3
Protein (g)	50.4 ± 24.2	49.4 ± 20.5	53.9 ± 22.5	61.5 ± 24.4
% kcal from protein	18.8 ± 3.6	17.8 ± 3.7	17.6 ± 3.7	18.0 ± 3.0

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Table 7. Baseline associations between LCSB[a] consumption and energy and macronutrient intake among 476 children and adolescents enrolled in the TODAY[b] study, stratified by treatment group (*continued*)

Daily energy or macronutrient intake[c]	LCSB nonconsumer	LCSB low consumer	LCSB medium consumer	LCSB high consumer
	←*n*→			
Metformin plus intensive lifestyle intervention	31	49	30	60
	←*mean ± standard deviation*→			
Energy intake (kcal)	1,107 ± 349	1,167 ± 613	1,330 ± 591	1,352 ± 499
Sugar, total (g)	58.9 ± 29.6	57.6 ± 44.5	66.8 ± 31.9	70.0 ± 40.9
Fiber (g)	126.9 ± 48.8	126.8 ± 73.2	146.0 ± 57.4	153.4 ± 69.9
Carbohydrates (g)	8.4 ± 4.2	9.1 ± 5.2	9.5 ± 4.3	10.0 ± 4.7
% kcal from carbohydrates	45.9 ± 9.8	43.4 ± 7.9	45.3 ± 8.5	44.7 ± 8.5
Total fat (g)	47.5 ± 20.5	49.9 ± 27.7	58.3 ± 32.4	57.1 ± 22.1
% kcal from fat	38.1 ± 8.1	38.4 ± 5.6	38.4 ± 5.8	38.4 ± 6.6
Saturated fat (g)	16.3 ± 6.8	17.3 ± 9.9	19.6 ± 11.1	20.4 ± 8.6
% kcal from saturated fat	13.2 ± 3.3	13.3 ± 2.3	12.9 ± 2.4	13.6 ± 3.2
Protein (g)	46.2 ± 13.6	55.3 ± 28.7	58.4 ± 30.2	59.4 ± 21.7
% kcal from protein	17.1 ± 3.5	19.1 ± 3.8	17.3 ± 3.4	17.9 ± 3.2

[a]LCSB = low-calorie sweetened beverage.
[b]TODAY = Treatment Options for type 2 Diabetes in Adolescents and Youth.
[c]Dietary intake was assessed using a food frequency questionnaire, which was a modified version of the SEARCH for Diabetes in Youth Food Frequency Questionnaire,[31] derived from the Block Kids' Food Questionnaire.[32]

Table 8. Two-year changes in LCSB[a] consumption, energy (kcal), and macronutrient intake (g) among children and adolescents enrolled in the TODAY[b] study, stratified by treatment group

Daily energy or macronutrient intake[c]	Non–non[d] LCSB consumption	Decrease in LCSB consumption	Increase in LCSB consumption	High–high[e] LCSB consumption
	←n→			
Metformin alone	16	53	40	24
	←*mean ± standard error*→			
Energy intake (kcal)	139 ± 164	110 ± 93	22 ± 83	−21 ± 192
Sugar, total (g)	25.0 ± 22.7	21.9 ± 10.9	9.8 ± 8.1	12.0 ± 13.3
Fiber (g)	0.4 ± 1.2	0.4 ± 0.6	−0.3 ± 0.6	−1.7 ± 2.0
Carbohydrates (g)	35.1 ± 24.3	24.0 ± 14.4	8.9 ± 11.1	17.1 ± 22.9
% kcal from carbohydrates	4.7 ± 3.5	2.0 ± 1.9	1.1 ± 1.8	2.9 ± 1.6
Total fat (g)	−0.9 ± 7.3	1.7 ± 4.0	−0.2 ± 3.8	−8.1 ± 9.3
% kcal from fat	−3.4 ± 2.5	−1.3 ± 1.3	−0.8 ± 1.2	−2.6 ± 1.4
Saturated fat (g)	−0.2 ± 3.1	0.0 ± 1.6	0.1 ± 1.2	−2.0 ± 2.6
% kcal from saturated fat	−1.1 ± 1.3	−1.0 ± 0.5	−0.4 ± 0.6	−1.0 ± 0.6
Protein (g)	1.9 ± 8.0	0.8 ± 4.8	−3.4 ± 6.3	−5.9 ± 8.1
% kcal from protein	−1.3 ± 1.1	−0.6 ± 0.7	−0.5 ± 0.9	−0.5 ± 0.6
	←n→			
Metformin plus rosiglitazone	14	51	39	27
	←*mean ± standard error*→			
Energy intake (kcal)	48 ± 84	91 ± 76	109 ± 105	−71 ± 154
Sugar, total (g)	5.2 ± 6.0	23.6 ± 6.3	−6.8 ± 8.1	−7.1 ± 14.2
Fiber (g)	0.6 ± 0.7	−0.2 ± 0.7	0.1 ± 0.8	−1.5 ± 1.1
Carbohydrates (g)	16.1 ± 11.3	21.2 ± 9.5	4.3 ± 13.7	−22.0 ± 19.3
% kcal from carbohydrates	3.2 ± 3.0	4.5 ± 1.6	−0.9 ± 2.3	−3.9 ± 1.8
Total fat (g)	−1.1 ± 5.5	0.5 ± 4.0	7.6 ± 5.2	1.8 ± 6.8
% kcal from fat	−2.4 ± 2.1	−3.1 ± 1.1	1.0 ± 1.5	2.8 ± 1.3
Saturated fat (g)	0.1 ± 2.1	0.6 ± 1.3	2.9 ± 1.9	2.2 ± 2.3
% kcal from saturated fat	−0.5 ± 1.0	−0.8 ± 0.4	0.6 ± 0.6	1.9 ±0.6
Protein (g)	−1.9 ± 7.3	0.4 ± 4.1	5.3 ± 5.5	−0.9 ± 7.7
% kcal from protein	−1.0 ± 2.0	−1.5 ± 0.6	−0.3 ± 0.9	0.7 ± 0.7

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Table 8. Two-year changes in LCSB[a] consumption, energy (kcal), and macronutrient intake (g) among children and adolescents enrolled in the TODAY[b] study, stratified by treatment group (*continued*)

Daily energy or macronutrient intake[c]	Non—non[d] LCSB consumption	Decrease in LCSB consumption	Increase in LCSB consumption	High—high[e] LCSB consumption
	←——— *n* ———→			
Metformin plus intensive lifestyle intervention	12	59	40	28
	←——— *mean ± standard error* ———→			
Energy intake (kcal)	−48 ± 149	22 ± 75	168 ± 132	99 ± 111
Sugar, total (g)	−2.8 ± 13.3	10.7 ± 7.3	13.9 ± 8.9	13.3 ± 10.7
Fiber (g)	−1.2 ± 1.1	0.0 ± 0.7	0.7 ± 0.9	0.6 ± 1.1
Carbohydrates (g)	−5.3 ± 21.0	10.3 ± 10.8	26.3 ± 13.8	17.4 ± 15.6
% kcal from carbohydrates	1.0 ± 3.5	2.5 ± 1.4	1.2 ± 1.7	1.1 ± 2.1
Total fat (g)	−2.3 ± 6.9	−0.8 ± 3.6	4.4 ± 6.7	3.0 ± 5.3
% kcal from fat	−0.3 ± 2.4	−1.4 ± 1.1	−1.1 ± 1.3	−0.1 ± 1.5
Saturated fat (g)	−1.0 ± 2.1	−1.3 ± 1.3	2.3 ± 2.3	0.4 ± 1.9
% kcal from saturated fat	−0.2 ± 1.4	−0.8 ± 0.5	0.2 ± 0.5	−0.5 ± 0.6
Protein (g)	−2.4 ± 6.3	−3.0 ± 3.1	6.1 ± 6.5	1.8 ± 6.3
% kcal from protein	−0.8 ± 1.2	−1.1 ± 0.5	−0.2 ± 0.8	−0.8 ± 0.7

[a]LCSB = low-calorie sweetened beverage.
[b]TODAY = Treatment Options for type 2 Diabetes in Adolescents and Youth.
[c]Dietary intake was assessed using a food frequency questionnaire, which was a modified version of the SEARCH for Diabetes in Youth Food Frequency Questionnaire,[31] derived from the Block Kids' Food Questionnaire.[32]
[d]Non—non = nonconsumption at start of study and nonconsumption after 2 years.
[e]High—high = high consumption at start of study and high consumption after 2 years.