Drinking caloric beverages increases the risk of adverse cardiometabolic outcomes in the Coronary Artery Risk Development in Young Adults (CARDIA) Study[1–3]

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ABSTRACT

Background: Intake of caloric beverages is hypothesized to contribute to adverse health outcomes, but the beverages and populations studied vary considerably.

Objective: Our objective was to examine the relation between consumption of low- and whole-fat milk, fruit juice, and sugar-sweetened beverages (SSBs) and cardiometabolic risk factors.

Design: We used data from a prospective 20-y cohort of 2774 adults. Data are taken from CARDIA (Coronary Artery Risk Development in Young Adults) Study examination years 0 (1985–1986), 7 (1992–1993), and 20 (2005–2006). Beverage intake was averaged across years 0 and 7, and continuous and categorical (quartile) distributions were used. Incident (year 20) high waist circumference (WC), high triglycerides, high LDL cholesterol, low HDL cholesterol, hypertension, and metabolic syndrome were examined by using multivariable-adjusted Poisson regression models.

Results: Higher SSB consumption (across quartiles) was associated with higher risk of high WC [adjusted relative risk (aRR): 1.09; 95% CI: 1.04, 1.14; P for trend < 0.001]; high LDL cholesterol (aRR: 1.18; 95% CI: 1.02, 1.35; P for trend = 0.018), high triglycerides (aRR: 1.06; 95% CI: 1.01, 1.13; P for trend = 0.033), and hypertension (aRR: 1.06; 95% CI: 1.01, 1.12; P for trend = 0.023). Whole-fat milk consumption was associated with lower risk of high triglycerides (aRR: 0.91; 95% CI: 0.81, 1.00; P for trend = 0.046). With the use of continuous beverage intake, results were similar. Consumers of whole-fat milk and SSBs were more likely to be younger, black, and male and to have lower levels of physical activity and higher total energy intake in comparison with nonconsumers ($P < 0.05$).

Conclusions: Our findings suggest that higher SSB consumption is associated with cardiometabolic risk. Recommendations to limit consumption of these caloric beverages may help reduce the burden of these risk factors in US adult populations. *Am J Clin Nutr* 2010;92:954–9.

INTRODUCTION

In the past few decades in the United States, consumption of beverages with calories has increased (1, 2), accounting for 21% of daily total energy intake (2). Most of the focus has been on sugar-sweetened beverages (SSBs). Consumption of SSBs is linked with many adverse health outcomes as has been previously shown in meta-analyses (3, 4).

The role of milk and dairy consumption on changes in weight or the metabolic syndrome has been explored by using cross-sectional (5) and longitudinal (6) study designs, with conflicting results (7). Limited research has linked fruit juices with diabetes (8, 9). Although associations between SSB consumption with metabolic syndrome or type 2 diabetes were previously examined, these studies were of shorter duration, in woman only, or excluded milk and fruit juice.

Given the dramatic trends in beverage consumption over the past few decades (1), favoring energy-dense beverages with little to no nutritional value, we sought to examine associations between intake of select beverages and continuous and categorical incident cardiometabolic factors and the metabolic syndrome in a sample of black and white young adults.

SUBJECTS AND METHODS

Study sample

The Coronary Artery Risk Development in Young Adults (CARDIA) Study is a prospective study of cardiovascular risk factors in 5115 persons aged 18–30 y at baseline examination (1985–1986). Detailed description of recruitment procedures are provided elsewhere (10). We used data from exam years 0 (1985–1986, baseline), 7 (1992–1993), and 20 (2005–2006) in which

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dietary intake data were collected. We excluded women who were pregnant at the time of interview (n = 75). Analysis procedures were in accordance with the ethical standards of the University of North Carolina at Chapel Hill (UNC-CH), Gillings School of Global Public Health, with UNC-CH Institutional Review Board approval.

Exposure and outcome measures

Beverage intake

Dietary intake was assessed by using a semiquantitative, interviewer-administered, validated (11) diet history food-frequency questionnaire, which consisted of a short questionnaire on general dietary practices followed by a comprehensive food-frequency questionnaire, which asked about the previous month's consumption. We focused on low-fat (skim and $\leq$2% fat) and whole-fat ($\geq$3% fat) milk (consumed as a beverage, not used in recipes), fruit juice, and sugar-sweetened soda and fruit drinks (SSBs) as grouped by the CARDIA diet coordinating center. For each beverage, baseline intake was defined as the average intake from exam year 0 and 7 among persons with complete data. Because diet soda does not provide calories, we do not examine patterns of its consumption in this article. Furthermore, there is a strong bimodal distribution of alcohol intake, and high, long-term consumption represents a complex behavioral issue that is outside the purview of this study. We examined 3 consumption trends: energy per capita (estimates that account for persons who did not consume the beverage), percentage consuming and energy per consumer (estimates that apply only to those individuals who reported consuming the beverage).

Anthropometric measurements, blood lipids, and metabolic syndrome

Anthropometric measurements and blood lipid samples were taken at each exam year (0, 7, and 20). Waist circumference (WC) was measured as the average of 2 measures at the minimum abdominal girth (nearest 0.5 cm) from participants standing upright. High WC was defined as WC $>$88 cm (women) or $>$102 cm (men).

Seated blood pressure [millimeters of mercury (mm Hg)] was measured 3 times; we used the average of the last 2 measurements. We excluded individuals who fasted for $<$8 h Hypertension was defined as systolic blood pressure (SBP) $\geq$130 mm Hg, diastolic blood pressure (DBP) $\geq$85 mm Hg, or use of antihypertensive medication.

Fasting blood samples were collected from which assays determined lipids, glucose, and insulin according to standardized CARDIA procedures (10). Briefly, fasting insulin and glucose were obtained by venous blood draw, with glucose measured by using hexokinase coupled to glucose-6-phosphate dehydrogenase. We created the following measures (which identify adverse incident year 20 health outcomes) among persons without prevalent outcome at year 0 or 7: high fasting glucose $\geq$6.1 mmol/L or use of diabetic medication; low HDL cholesterol, defined as $<$1.3 mmol/L in women or $<$1.03 mmol/L in men or use of cholesterol-lowering medication; high LDL cholesterol, defined as $\geq$4.1 mmol/L or use of cholesterol-lowering medication; and high triglyceride concentrations, defined as $\geq$1.7 mmol/L or use of cholesterol-lowering medication. Metabolic syndrome was defined according to Adult Treatment Panel III guidelines (12) as being present if $\geq$3 of the following factors were present at year 20 among those who did not have metabolic syndrome at year 0 or 7: abdominal obesity, high fasting glucose, low HDL cholesterol, hypertension, and/or high triglycerides.

Covariates

Sociodemographic and selected health behavior covariates included the following: race and sex, smoking status (classified as never, former, or current), and highest education completed (classified as less than high school, completed high school, or more than high school). Physical activity was assessed by using the CARDIA physical activity questionnaire, a validated and reliable assessment of physical activity (13). A total score [exercise units (EU) per week] was computed by multiplying the frequency of participation by the intensity of the activity. As an example, a score of 100 EU is roughly equivalent to participation in a vigorous physical activity 2 or 3 h/wk for 6 mo of the year, calculated as [6 metabolic equivalent tasks (METs) $\times$ (3 $\times$ 6 mo of high volume activity)]. A set of food groups measuring energy per day from meats, vegetables (except fried potatoes), fruit (except fried fruit), and nonmilk dairy products was created from the CARDIA diet history. Energy from food was calculated by subtracting all beverage energy from total energy intake.

Statistical analysis

All analyses were conducted by using STATA (version 11.0; Stata Corp, College Station, TX). We examined differences in baseline sociodemographic covariates between consumers and nonconsumers of whole-fat milk and SSBs by using 2-sided t tests and chi-square tests for continuous and categorical variables, respectively. Within each of the 4 beverage groups, 2-sided t tests (per capita and per consumer) and chi-square tests (percentage consuming) were also used to determine statistical differences between years (with Bonferroni correction for multiple comparisons) for per capita/per consumer and percentage consuming estimates, respectively.

To estimate the risk of incident year 20 outcomes, we used separate multivariate Poisson regression models (n = 7 models) of incident high WC (n = 2444), high fasting glucose (n = 2160), high triglycerides (n = 2627), high LDL cholesterol (n = 2640), low HDL cholesterol (n = 1837), hypertension (n = 2639), and metabolic syndrome (n = 3596) on the 4 beverages of interest (SSBs, fruit juice, low-fat milk, and whole-fat milk). All models used beverages as continuous and divided in quartiles, which allowed for tests of trend. Categorical results are presented here, with continuous results shown under "Supplemental data" in the online issue. We used robust estimators that allow the variance of the error term to be dependent on our independent variables (energy from beverages). Year 20 incidence models (ie, incident high WC) were run by using individuals without prevalent outcome (ie, high WC) at exam year 0 or 7.

Models were adjusted for race and sex as well as year 0 age, weight, smoking status, total physical activity, calories from food, calories from the other beverages, calories from alcohol, and CARDIA exam center. Inclusion of a set of food groups (baseline servings per day of meats, vegetables, fruit, and nonmilk dairy

products) as opposed to total food calories did not affect results so we included only the latter in the interest of building the most parsimonious model possible (ie, the one with the fewest variables). Interactions with baseline overweight and race were tested in multivariable linear models but were not statistically significant (likelihood ratio test, $P > 0.05$). P value < 0.05 was set for determining statistical significance in our continuous models.

RESULTS

Baseline (year 0) demographics are presented in **Table 1**. Consumers of whole-fat milk and SSBs were significantly more likely to be younger, black, male, and current smokers and to have lower levels (EU/wk) of physical activity, higher total daily energy intake, and higher SBP compared with nonconsumers ($P < 0.05$). Consumers of SSBs were also more likely to have lower levels of HDL cholesterol and higher diastolic blood pressure compared with nonconsumers (Table 1). There were no differences in any other anthropometric or blood lipid measure between consumers and nonconsumers. Differences between low-fat milk and fruit Juice consumers and nonconsumers are available on request from the corresponding author.

Over 20 y, we observed a consistent increase in per capita calories for SSBs, adjusted for age and sex, whereas per capita intake of whole-fat and low-fat milk and fruit juice declined (**Table 2**). There was a slight (7%) increase between year 0 and year 7 followed by a considerable (14%) decrease between year 7 and year 20 in the percentage of the sample who consumed low-fat milk. The percentage of the population consuming SSBs steadily increased over the full time period, although only by a small percentage, whereas the percentage consuming fruit juice and whole-fat milk continuously declined. Energy per consumer from low- and whole-fat milk experienced consistent declines, whereas energy per consumer from SSBs increased steadily over the 20 y (Table 2).

The most consistent adverse associations between beverage intake and incident cardiometabolic outcomes were observed for SSBs, in which higher (moving from one quartile to the next) baseline consumption was associated with a significant increase in the risk of incident high WC [adjusted relative risk (aRR): 1.09; 95% CI: 1.04, 1.14; P for trend < 0.001], high triglycerides (aRR: 1.06; 95% CI: 1.01, 1.13; P for trend = 0.033), high LDL cholesterol (aRR: 1.18; 95% CI: 1.02,1.36; P for trend = 0.018), and hypertension (aRR: 1.06; 95% CI: 1.01, 1.12; P for trend = 0.023; **Table 3**). Associations for SSB intake were in the same direction (associated with higher risk) for all other outcomes, although these estimates were not statistically significant (Table 3).

Moving from one quartile to the next of whole-fat milk and fruit juice consumption was associated with lower risks of incident high triglycerides (aRR: 0.91; 95% CI: 0.81, 1.00; P for trend = 0.046) and hypertension (aRR: 0.89; 95% CI: 0.82, 0.97; P for trend= 0.007), respectively. Consumption of low-fat milk was not statistically significantly related to any incident cardiometabolic risk factor or to the metabolic syndrome (Table 3). Results using continuous beverage consumption were similar with the major difference that SSB intake was significantly associated with incident low HDL cholesterol (aRR: 1.06; 95% CI: 1.02, 1.10; $P < 0.05$) and not hypertension or incident high triglycerides, and fruit juice intake was not significantly

TABLE 1
Year 0 characteristics of study sample[1]

Variable	Year 0 (1985–1986)	Whole-fat milk		SSBs	
		Consumer	Nonconsumer	Consumer	Nonconsumer
n (%)		1865 (51.9)	1731 (48.1)	3425 (95.3)	171 (4.8)
Demographic characteristics					
Female (%)	53.5 ± 0.8	50.0 ± 1.2	57.4 ± 1.2[2]	52.9 ± 0.9	65.5 ± 3.6[2]
Black (%)	47.4 ± 0.8	65.7 ± 1.0	27.7 ± 1.1[2]	49.4 ± 0.9	7.6 ± 2.0[2]
Age (y)	25.0 ± 3.6	24.5 ± 0.09	25.5 ± 0.08[2]	24.9 ± 0.06	26.6 ± 0.22[2]
Smoking (%)					
Current	28.1 ± 0.8	32.9 ± 1.1	23.1 ± 1.0[2]	28.6 ± 0.8	18.7 ± 3.0[2]
Former	13.1 ± 0.6	10.3 ± 0.7	16.2 ± 0.9[2]	12.8 ± 0.6	19.9 ± 3.1[2]
Never	58.7 ± 0.8	56.8 ± 1.1	60.7 ± 1.2[2]	58.6 ± 0.8	61.4 ± 3.7
Physical activity (EU/wk)	429 ± 302	408.8 ± 7.1	451.2 ± 7.1[2]	426.4 ± 5.2	485.0 ± 21.5[2]
Energy from food (kcal)	2347 ± 1373	2576.6 ± 36.2	2100.5 ± 25.9[2]	2372.4 ± 23.7	1847.0 ± 70.9[2]
Anthropometric and blood chemistry measurements					
BMI (kg/m^2)	24.5 ± 5.0	24.2 ± 0.11	24.3 ± 0.11	24.3 ± 0.08	23.8 ± 0.3
Waist circumference (cm)	77.3 ± 10.9	77.2 ± 0.3	77.3 ± 0.3	77.3 ± 0.19	76.3 ± 0.8
Glucose (mg/dL)	82.2 ± 12.9	81.8 ± 0.3	82.6 ± 0.2	82.1 ± 0.22	83.7 ± 1.4
LDL cholesterol (mg/dL)	108.7 ± 30.7	108.1 ± 0.7	109.3 ± 0.7	108.8 ± 0.53	107.1 ± 2.3
HDL cholesterol (mg/dL)	53.7 ± 13.0	53.9 ± 0.3	53.6 ± 0.3	53.5 ± 0.22	57.4 ± 1.1[2]
Triglycerides (mg/dL)	70.9 ± 45.2	69.5 ± 1.0	72.4 ± 1.2	71.0 ± 0.78	69.8 ± 2.9
Blood pressure (mm Hg)					
Systolic	110.3 ± 10.9	111.0 ± 0.3	109.6 ± 0.3[2]	110.5 ± 0.2	107.6 ± 0.9[2]
Diastolic	68.6 ± 9.6	68.5 ± 0.2	68.6 ± 0.2	68.6 ± 0.2	67.3 ± 0.8[2]

[1] Values are means ± SDs or percentages ± SEs unless otherwise indicated; n = 3596 (sample used to examine incident metabolic syndrome). SSBs, sugar-sweetened beverages; EU, exercise units.

[2] Estimates within beverage group (ie, SSB or whole-fat milk consumer compared with nonconsumer) are significantly different from one another, $P < 0.05$ (chi-square test for dichotomous variables or Student's t test for continuous variables).

TABLE 2
Age- and sex-adjusted per capita energy intake, percentage consuming, and per consumer energy intake of beverages[1]

	Low-fat milk		Whole-fat milk		Fruit juice		SSBs	
	n	Values	*n*	Values	*n*	Values	*n*	Values
Per capita energy intake (kcal)								
Year 0	5034	97 ± 3	5034	100 ± 3	5034	115 ± 2	5034	167 ± 3
Year 7	3877	97 ± 5	3877	54 ± 4[2]	3877	114 ± 9[2]	3877	196 ± 8[2]
Year 20	3087	63 ± 12[3,4]	3087	33 ± 8[3,4]	3087	71 ± 11[3,4]	3087	218 ± 24[3,4]
Percentage consuming (%)								
Year 0	5034	61 ± 3	5034	47 ± 3	5034	95 ± 7	5034	89 ± 5
Year 7	3877	68 ± 8[5]	3877	33 ± 89[5]	3877	93 ± 14[5]	3877	90 ± 11[5]
Year 20	3087	54 ± 21[6,7]	3087	26 ± 28[6,7]	3087	78 ± 27[6,7]	3087	91 ± 25[6,7]
Per consumer energy intake (kcal)								
Year 0	3077	160 ± 4	2356	204 ± 6	4800	121 ± 2	4443	188 ± 3
Year 7	2760	143 ± 7[2]	1001	164 ± 13[2]	3623	122 ± 10[2]	3236	220 ± 9[2]
Year 20	1836	113 ± 19[3,4]	477	135 ± 45[3,4]	2551	87 ± 13[3,4]	2302	246 ± 30[3,4]

[1] Values are means or percentages ± SEs. Per capita energy intake estimates account for persons who did not consume the beverage. Per consumer energy intake estimates apply only to those individuals who reported consuming the beverage. Sample sizes vary as stated. SSBs, sugar-sweetened beverages.
[2,5] Significant difference between years 0 and 7, $P < 0.05$ (Bonferroni corrected): [2]Student's *t* test, [5]chi-square test.
[3,6] Significant difference between years 0 and 20, $P < 0.05$ (Bonferroni corrected): [3]Student's *t* test, [6]chi-square test.
[4,7] Significant difference between year 7 and 20, $P < 0.05$ (Bonferroni corrected): [4]Student's *t* test, [7]chi-square test.

associated with any incident cardiometabolic outcome (*see* the supplemental table under "Supplemental data" in the online issue).

DISCUSSION

In this study we observed a significant increase in the risk of incident high WC, triglycerides, LDL cholesterol, and incident hypertension associated with greater consumption of SSBs (moving across quartiles of intake). Higher baseline (average of years 0 and 7) consumption of whole-fat milk and SSBs was also associated with increased risk of several cardiometabolic risk factors. Specifically, a 100-kcal higher baseline (average of years 0 and 7) consumption of SSBs (approximately one 8-ounce can) or whole-fat milk (≈6 ounces) was associated with a higher risk of incident high WC, low HDL cholesterol (SSBs), and high LDL cholesterol (SSBs and whole-fat milk) at year 20. Generally, associations with low-fat milk consumption and the health outcomes of interest were in the same direction as SSBs but failed to reach statistical significance.

TABLE 3
Estimated risk of incident cardiometabolic risk factors associated with baseline (quartile average of years 0 and 7) beverage intake[1]

		Beverage groups							
		LFM		WFM		FJ		SSBs	
	Sample size total (outcome)	RR (95% CI)	*P* for trend	RR (95% CI)	*P* for trend	RR (95% CI)	*P* for trend	RR (95% CI)	*P* for trend
High WC[2]	2444 (637)	1.02 (0.95,1.08)	0.639	1.06 (0.98,1.13)	0.143	1.00 (0.92,1.09)	0.999	1.09 (1.04,1.15)	<0.001
High fasting glucose[3]	2160 (267)	1.01 (0.90,1.13)	0.876	0.94 (0.83,1.07)	0.328	1.00 (0.88,1.14)	0.975	1.03 (0.95,1.12)	0.460
High TG[4]	2627 (542)	1.04 (0.96,1.11)	0.352	0.91 (0.83,1.00)	0.046	0.99 (0.91,1.09)	0.912	1.06 (1.01,1.13)	0.033
High LDL[5]	2640 (94)	1.07 (0.89,1.30)	0.475	1.10 (0.89,1.37)	0.400	0.96 (0.75,1.22)	0.741	1.18 (1.02,1.36)	0.018
Low HDL[6]	1837 (252)	1.01 (0.90,1.14)	0.826	0.96 (0.83,1.10)	0.539	1.00 (0.87,1.16)	0.927	1.06 (0.97,1.16)	0.192
Hypertension[7]	2639 (609)	0.98 (0.91,1.05)	0.539	1.01 (0.93,1.09)	0.810	0.89 (0.82,0.97)	0.007	1.06 (1.01,1.12)	0.023
Metabolic syndrome[8]	3596 (459)	1.00 (0.91,1.10)	0.980	0.91 (0.81,1.02)	0.094	0.98 (0.88,1.10)	0.779	1.03 (0.96,1.11)	0.401

[1] Relative risk (RR) was estimated from multiple Poisson regression models (with robust SE estimator) of incident metabolic syndrome components and incident metabolic syndrome according to quartile of beverage consumption (average of years 0 and 7), with adjustment for race (black or white), sex, CARDIA (Coronary Artery Risk Development in Young Adults) exam center, and year 0 age, weight, smoking status [smoker, former smoker or never smoker (referent)], energy from food, total physical activity, energy from the 3 other beverages, and energy from alcohol. Individuals with the outcome [ie, those with a high waist circumference (WC)] at years 0 or 7 were excluded from analyses (ie, of incident year 20 high WC). LFM, low-fat milk; WFM, whole-fat milk; FJ, fruit juice; SSBs, sugar-sweetened beverages; TG, triglycerides.
[2] WC >102 cm [>40 inches (men)] or >88 cm [>35 inches (women)].
[3] Fasting glucose ≥100 mg/dL (≥6.1 mmol/L) or use of diabetic medication.
[4] TG ≥150 mg/dL (≥1.7 mmol/L) or use of cholesterol-lowering medication.
[5] LDL ≥130 mg/dL or use of cholesterol-lowering medication.
[6] HDL <40 mg/dL [<1.04 mmol/L (men)], <50 mg/dL [<1.3 mmol/L (women)], or use of cholesterol-lowering medication.
[7] Blood pressure ≥130 mm Hg/≥85 mm Hg or use of antihypertensive medication.
[8] Defined as having ≥3 of the following: *1*) high fasting glucose, *2*) high WC, *3*) hypertension, *4*) high TG, and *5*) low HDL cholesterol.

Our research supports previous shorter-term studies in similarly aged populations of a range of cardiometabolic measures that have linked SSBs, fructose, and fruit drink consumption to metabolic syndrome and type 2 diabetes (3, 14). It is interesting to note in our findings that SSB consumption was associated with several components of the metabolic syndrome but not with the metabolic syndrome itself. These are findings that we cannot fully explain, and except for a recent review by Malik et al (15), which reports a systematic effect of SSBs on many cardiometabolic components, the literature on overall metabolic syndrome is quite slim.

Some (5, 16–20), but not all (6), studies have shown a beneficial effect of dairy consumption on weight gain, metabolic syndrome characteristics, and diabetes; however, most of these studies examined total dairy intake and not dairy beverages explicitly. In the CARDIA study population, increased total dairy product consumption was inversely associated with a 10-y cumulative risk of obesity, abnormal glucose homeostasis, elevated blood pressure, and insulin resistance syndrome among overweight participants only (21).

In studies that examined milk specifically, results were conflicting (7). Among overweight adults, decreased consumption of whole-fat milk was associated with decreased odds of $\geq$1 kg weight gain over 8.8 y, whereas the opposite relation was observed for those who increased their low-fat milk consumption (22). By using follow-up through year 10 of the CARDIA data, Pereira et al (21) reported that weekly consumption of milk (combined low- and whole-fat) was associated with a statistically significant decrease in odds of elevated blood pressure, but was unrelated to odds of dyslipidemia (21), only among overweight (body mass index; in kg/m^2: $\geq$25) participants. Significant differences in the present study related to exposures of interest (whole- and low-fat milk beverages compared with total dairy), time duration (13-y compared with 10-y incidence), and choice of outcome (metabolic outcomes compared with insulin resistance syndrome) may partially explain the observed disparities between our study and theirs.

Several mechanisms may explain the higher risk observed among those with higher SSB (continuous and categorical results) or whole-fat milk consumption (continuous results only). Increased consumption of added sweeteners, particularly high-fructose corn syrup in SSBs, has been associated with increased insulin resistance (23), reduced HDL cholesterol (24), visceral fat (25), and increased triglyceride concentrations (26). Calcium and magnesium from dairy products can affect lipid concentrations through changing intestinal absorption of cholesterol, bile acids and fats, and milk proteins (27), and the exchange of carbohydrate for protein intake may explain effects on serum profiles, although results are conflicting (28, 29).

Compared with a nationally representative sample of US adults, a considerably greater proportion of our sample reported consuming each of the caloric beverages. For example, whereas just over 50% of adults aged $\geq$19 yr (data from National Health and Nutrition Examination Survey 2002) reported consuming SSBs (1), a full 90% of our sample consumed these beverages, a discrepancy that may be due to differences in the methods used to ascertain dietary intake (two 24-h recalls compared with a 1-mo FFQ). Also within our cohort we observed significant age-related declines in SSB intake. Our CARDIA findings are similar to national trends among older adults whereby older individuals tend to reduce their intake of SSBs and diversify their sources of liquid calories (30). Despite a greater proportion of consumers, our per consumer estimates were considerably lower than those observed in national studies (SSBs: −50 kcal; low-fat milk: −23 kcal; fruit juice: −69 kcal; whole-fat milk: −40 kcal) (1).

Given the differences in consumption, it may be the case that broad dietary patterns in individuals who maintain high intakes of caloric beverages account for some of the observed relation with obesity and metabolic syndrome. Individuals with greater intake of caloric beverages, and soda in particular, tend to have dietary patterns characterized by greater intakes of total calories and saturated and *trans* fats (31) and are at increased odds for consuming snacks or high-fat foods and fast foods compared with persons whose beverage patterns are dominated by water consumption (2). The associations observed in this study, however, remained after control for total calories from foods and inclusion of major food groups, suggesting an independent effect of the caloric beverages. This finding is supported by the literature, which has shown a lack of dietary compensation when caloric beverages are consumed (32, 33).

The major limitation of this study is that it is observational, and we cannot rule out residual confounding nor can we draw conclusive statements about the causal effect of caloric beverage consumption on cardiometabolic risk. Measurement error in dietary intake may result in nondifferential misclassification, which would bias our estimates toward the null and lead to wider CIs. Similarly, ascertainment of dietary data over the previous 30 d may not be enough to adequately capture habitual intake and, to the extent to which this happens equally across subjects, could also result in nondifferential misclassification. Finally, data on exposure were collected 14 y before the measurement of our outcome, and it is certainly possible that changes in beverage consumption over this time period may affect the associations of interest. Although our dietary intake information was self-reported, we used a validated food-frequency questionnaire (11) and averaged consumption information from 2 time points, which should provide a better estimate of habitual intake than a single estimate (34).

This study is one of the first to examine long-term intake of caloric beverages, including both whole- and low-fat milk intake. We observed consistent evidence of an association between consumption of SSBs and incident cardiometabolic risk. These results provide additional concerns about whole-fat milk intake in addition to SSBs to our public health agenda.

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