HHS Public Access

Author manuscript

Acta Diabetol. Author manuscript; available in PMC 2015 December 03.

Published in final edited form as:

Acta Diabetol. 2011 December ; 48(4): 275–282. doi:10.1007/s00592-010-0246-9.

Sugar-sweetened and diet beverage consumption is associated with cardiovascular risk factor profile in youth with type 1 diabetes

Andrey V. Bortsov,
Department of Epidemiology and Biostatistics, Arnold School of Public Health, University of South Carolina, 800 Sumter Street, Columbia, SC 29208, USA

Angela D. Liese,
Department of Epidemiology and Biostatistics, Arnold School of Public Health, University of South Carolina, 800 Sumter Street, Columbia, SC 29208, USA; Center for Research in Nutrition and Health Disparities, Arnold School of Public Health, University of South Carolina, Columbia, SC 29208, USA

Ronny A. Bell,
Department of Epidemiology and Prevention, Wake Forest University School of Medicine, Winston-Salem, NC 27157, USA

Dana Dabelea,
University of Colorado Health Sciences Center, Denver, CO 80262, USA

Ralph B. D'Agostino Jr,
Department of Biostatistical Sciences, Wake Forest University School of Medicine, Winston-Salem, NC 27157, USA

Richard F. Hamman,
University of Colorado Health Sciences Center, Denver, CO 80262, USA

Georgeanna J. Klingensmith,
University of Colorado Health Sciences Center, Denver, CO 80262, USA; University of Colorado Barbara Davis Center, Denver, CO 80262, USA

Jean M. Lawrence,
Department of Research and Evaluation, Kaiser Permanente Southern California, Pasadena, CA 91101, USA

David M. Maahs,
University of Colorado Health Sciences Center, Denver, CO 80262, USA; University of Colorado Barbara Davis Center, Denver, CO 80262, USA

Robert McKeown,
Department of Epidemiology and Biostatistics, Arnold School of Public Health, University of South Carolina, 800 Sumter Street, Columbia, SC 29208, USA

Correspondence to: Angela D. Liese, liese@sc.edu.

Santica M. Marcovina,
Northwest Lipid Research Laboratories, Department of Medicine, University of Washington, Seattle, WA 98109, USA

Joan Thomas,
Department of Nutrition, University of North Carolina, Chapel Hill, NC 27599, USA

Desmond E. Williams, and
Division of Diabetes Translation, Centers for Disease Control and Prevention/NCCDPHP, Atlanta, GA 30341, USA

Elizabeth J. Mayer-Davis
Department of Epidemiology and Biostatistics, Arnold School of Public Health, University of South Carolina, 800 Sumter Street, Columbia, SC 29208, USA; Department of Nutrition, University of North Carolina, Chapel Hill, NC 27599, USA

Angela D. Liese: liese@sc.edu

Abstract

The prevalence of cardiovascular disease (CVD) risk factors among youth with type 1 diabetes is high and associated with age, gender, and race/ethnicity. It has also been shown that youth with type 1 diabetes often do not follow dietary recommendations. The objective of this cross-sectional observational study was to explore the association of sugar-sweetened and diet beverage intake with A1c, plasma lipids, adiponectin, leptin, systolic, and diastolic blood pressure in youth with type 1 diabetes. We examined data from 1,806 youth age 10–22 years with type 1 diabetes, of which 22% were minority (10% Hispanic, 8% African Americans, 4% other races) and 48% were female. Sugar-sweetened beverage, diet beverage, and mineral water intake was assessed with a food frequency questionnaire. After adjustment for socio-demographic and clinical covariates, physical activity and total energy intake, high sugar-sweetened beverage intake (at least one serving per day vs. none), was associated with higher levels of total cholesterol, LDL cholesterol, and plasma triglycerides, but not with A1c. High diet beverage intake was associated with higher A1c, total cholesterol, LDL cholesterol, and triglycerides. These associations were partially confounded by body mass index, saturated fat and total fiber intake. High sugar-sweetened beverage intake may have an adverse effect on CVD risk in youth with type 1 diabetes. Diet beverage intake may be a marker of unhealthy lifestyle which, in turn, is associated with worse metabolic control and CVD risk profile in these youth. Youth with diabetes should be encouraged to minimize sugar-sweetened beverage intake.

Keywords

Diabetes mellitus; Child; Adolescent; Beverages; Lipids

Introduction

In a recent Consensus Statement from the American Heart Association endorsed by the American Academy of Pediatrics recommends reduced intake of sugar-sweetened beverages and foods by children and adolescents [1]. Sweetened carbonated beverage intake has been associated with increased risk of overweight and obesity in adolescents [2–4] and with increased risk of developing metabolic syndrome, obesity, higher blood pressure, hypertriglyceridemia, and lower HDL cholesterol in adults [5–7]. In the SEARCH cohort, we have previously shown that the prevalence of cardiovascular risk factors, such as increased blood pressure and triglycerides levels, decreased high-density lipoprotein (HDL) cholesterol levels among youth with diabetes, was high and associated with age, gender, and race/ethnicity [8]. Older adolescents with T1DM also had an increased prevalence of vascular changes such as coronary artery calcification [9]. A recent analysis of dietary intake showed that sweetened soda intake was twice as high for older (>15 years) youth with type 2 diabetes (T2DM) than youth with type 1 diabetes (T1DM) of all ages as well as higher than among younger T2DM youth [10]. This may suggest that the poorer metabolic profile observed in older adolescents may be partially explained by increased soda intake in this age group. Few studies have assessed the relationship between sugar-sweetened beverages and CVD risk factors in youth with type 1 diabetes [11].

In this study, we explore the association of sugar-sweetened and diet beverage intake with CVD risk factors and metabolic control in youth with type 1 diabetes. Specifically, we hypothesized that consumption of sugar-sweetened beverages may be associated with an adverse CVD risk profile, including poorer metabolic control, in youth with diabetes.

Methods

The SEARCH study is an ongoing multi-center study that began ascertainment of cases of physician-diagnosed diabetes mellitus in youth younger than age 20 years in 2001. SEARCH has six centers, located in Ohio, Colorado, Washington, South Carolina, Hawaii, and California. A detailed description of the SEARCH study was published elsewhere [12]. The study was reviewed and approved by the local institutional review boards at each center. Parents of participants under age 18 years at the time of data collection provided written informed consent and the participant assented; all participants aged 18 years or older provided written informed consent.

Study participants

This analysis included youth whose diabetes was prevalent in 2001 or incident in 2002–2005 who participated in the SEARCH examination. Of the 8,031 registered, valid subjects age 10 years and older, 3,354 youth (42%) attended the SEARCH clinic visit; 3,074 youth completed dietary assessment. Among these youth, we excluded those with provider-defined diabetes other than type 1 (type 2, other types including mature onset of diabetes of youth, hybrid, and secondary, unknown type and missing type, $n = 494$); diabetes duration less than 6 months ($n = 369$); race/ethnicity other than non-Hispanic white, African American, Hispanic, Asian/Pacific Islander, or Native American ($n = 12$); those who reported eating much more or much less in the week of the diet assessment than in a typical week ($n = 154$), and those who did not fast for at least 8 h prior to the blood collection ($n = 480$). A total of 1,268 observations were excluded from the analysis due to one or more criteria listed above; data from 1,806 youth were included in these analyses.

Beverage intake

Sugar-sweetened and diet beverage intake in the previous week was assessed with a food frequency questionnaire. The SEARCH food frequency questionnaire (FFQ) has been described in detail previously [10]. The FFQ consisted of 85 food lines for which the participant indicated whether the item(s) was/were consumed in the past week (“yes/no”) and if yes, how many days, and the average portion size. Sugar-sweetened beverage intake was assessed by combining the answers to the following questions in the FFQ: (1) “last week, did you drink any sodas like Coke, Sprite, etc.? (don't count diet soda)”; (2) “did you drink any Kool-Aid or Gatorade?”; (3)”did you drink any Sunny Delight, Hi-C, Hawaiian Punch, or Ocean Spray?” Diet beverage and mineral water intake (further referred to as “diet beverage intake”) was assessed with a question “Did you drink diet soda or unsweetened mineral water?” Frequency of intake in the previous week was categorized as follows: “1 day”, “2 days”, “3–4 days”, “5–6 days”, and “every day”. Usual amount was assessed with a question “How many glasses in 1 day”, with possible answers from 1 to 4 glasses. The average amount of these beverages consumed per day was calculated based on these answers.

The FFQ was self-administered by study participants of age 10 years or older after careful instruction by study staff. About 7% of the FFQs were interviewer-administered because of participant difficulties in form completion. The nutrient and portion size databases for this instrument were modified from the respective Diabetes Prevention Program databases, using the Nutrition Data System for Research (database 3 version 4.05/33, 2002, Nutrition Coordinating Center, University of Minnesota, Minneapolis) and industry sources.

For the purposes of the analysis, the sugar-sweetened beverage intake was categorized into three groups: no intake in the previous week (“no-intake group”), more than zero servings but less than one per day (“moderate-intake group”), one serving per day or more (“high-intake group”). Diet beverage intake was categorized into three groups using the same cut-points.

Covariates

Race and ethnicity were obtained through self-report using the standard census questions [13] and categorized into five groups. First, youth of Hispanic ethnicity were categorized as Hispanic. Then, youth who reported one race, which included non-Hispanic white, African American, Asian/Pacific Islander, or American Indian, were assigned to one of these categories. Finally, youth that reported multiple races were categorized into one of the four race groups using the race-bridging methods developed by the NCHS [14]. Highest parental education level was based on the parent with the highest education as reported on a questionnaire.

Other covariates were selected based on their association with the exposure and outcomes of interest. Diabetes duration and frequency of missing insulin were included in the analysis as confounders. Physical activity was assessed by questions developed for the Youth Risk Behavior Surveillance System (YRBSS) [15]. Sedentary behavior was assessed by a slightly modified YRBSS question “On each weekday, about how much time do you usually spend watching TV?" [16]. Height and weight were measured to the nearest 0.5 cm and 0.1 kg. Body mass index (BMI) was calculated as (weight (kg)/(height*height(m)) and converted to BMI-z-score using standard CDC approach [17].

Outcome measures

Blood pressure was measured using a portable mercury manometer, and cuffs of five different sizes were available for use, depending on the size of the arm of the participants. The blood pressure measurement was conducted after the patient had been sitting for at least 5 min. Blood pressure was measured three times, with 30-s rest between assessments. Second and third assessments were used to calculate the mean blood pressure. Blood was drawn after fasting for at least 8 h for measurement of A1c and lipids (total cholesterol, low-density lipoprotein (LDL) cholesterol, HDL cholesterol, and triglycerides). Laboratory samples were obtained only if there was no episode of diabetic ketoacidosis within the prior month. Specimens were processed at the site and shipped within 24 h to the Northwest Lipid Metabolism and Diabetes Research Laboratories in Seattle, Washington. Levels of plasma cholesterol, triglyceride, and HDL cholesterol were observed on a Hitachi 917 autoanalyzer (Boehringer Mannheim Diagnostics, Indianapolis, IN). LDL cholesterol was calculated by the Friedewald equation for individuals with triglyceride concentration <400 mg/dL (4.52 mM/L) and by the BetaQuantification procedure for those with triglyceride ≥400 mg/dL [18]. A1c was measured by a dedicated ion exchange high-performance liquid chromatography instrument (TOSOH, Bioscience, Inc., San Francisco, CA). An assessment of lipoprotein cholesterol distribution was performed after density gradient ultra-centrifugation and calculation of the LDL relative flotation rate (Rf). Adiponectin and leptin were measured using a commercial RIA procedure [19].

Statistical analyses were conducted using SAS (version 9.1, 2003, SAS Institute Inc, Cary, NC). Analysis of covariance (ANCOVA) was used to fit statistical models. Outcome variables with skewed distribution (plasma triglycerides, adiponectin and leptin concentration) were log-transformed before fitting the models. Post hoc pairwise comparisons between beverage intake groups were performed with the Tukey adjustment method [20]. An alpha of <0.05 was considered significant.

Results

Study participants included 1,806 youth aged 10–22 years with physician-diagnosed T1DM of which 22% were minority (10% Hispanic, 8% African Americans, 4% other races), and 48% were female. Of these youth, 50% reported no sugar-sweetened beverage intake in the previous week ("no-intake group"); 33% reported an average of less than one serving per day ("moderate-intake group"); and 17% reported one or more servings/day of sugar-sweetened beverages in the previous week ("high-intake group"). Average sugar-sweetened beverage intake was 0.46 ± 0.88 servings/day. On the other hand, only 11% of youth with T1DM reported no diet beverage intake in the previous week, while 34% reported an average of less than one serving per day ("moderate-intake group") and 55% of youth reported one or more servings per day of diet beverages in the previous week ("high-intake group”). Average diet beverage intake was 1.34 ± 1.18 servings/day. Fourteen participants had missing data on diet beverages intake.

As shown in Table 1, higher sugar-sweetened beverage intake was associated with older age, male gender, African American race, longer diabetes duration, longer time watching television on weekdays, and skipping insulin ($P < 0.05$). In girls, moderate sugar-sweetened beverage intake was positively associated with participating in team sports ($P = 0.01$); in boys, no significant association with involvement in team sports was present. Diet beverage intake was similarly associated with the same set of correlates except race/ethnicity (Table 1). Correlations between foods and nutrients were explored. Saturated fat and dietary fiber intake were found to explain a substantial proportion of variability in diet, including beverage intake (data not shown) and were used in multivariate analyses.

Sugar-sweetened beverage

After adjustment for age, gender, race/ethnicity, parental education, diabetes duration, skipping insulin, time watching television, involvement in team sports, and total energy intake, high sugar-sweetened beverage intake (i.e. one or more servings per day), but not moderate intake, was associated with higher levels of total cholesterol, LDL cholesterol, and plasma triglycerides when compared to no beverage intake (Table 2, Model 1). There was no significant difference in CVD risk factor profile between the moderate- and no-intake groups. After additional adjustment for BMI-z-score, the associations were slightly attenuated but remained significant (Table 2, Model 2). Additional adjustment for saturated fat and total fiber intake resulted in loss of association with total cholesterol, LDL cholesterol, and plasma triglycerides (Table 2, Model 3). A1c, LDL particle size, adiponectin, leptin, HDL cholesterol, LDL/HDL cholesterol ratio, systolic, and diastolic blood pressure were not associated with sugar-sweetened beverage intake in youth with T1DM.

Diet beverage

After adjustment for potential confounders, diet beverage intake was associated with higher A1c, total cholesterol, LDL cholesterol, and plasma triglycerides (Table 3, Model 1). After additional adjustment for BMI-z-score, the associations of diet beverage intake with LDL cholesterol became non-significant (Table 3, Model 2). Further adjustment for saturated fat and total fiber intake did not affect the associations of diet beverage intake with CVD risk factors profile (Table 3, Model 3). HDL cholesterol, LDL particle size, adiponectin, leptin, systolic, and diastolic blood pressure were not associated with diet beverage intake in youth with T1DM. LDL/HDL cholesterol ratio did not differ between diet beverage intake groups after total adjustment (Model 3, $P = 0.47$).

Discussion

In this study, high *sugar-sweetened beverage* intake as contrasted to no intake was associated with increased levels of total cholesterol, LDL cholesterol, and triglycerides in youth with T1DM. Several explanations of this association can be made. First, high beverage intake may be directly related to CVD risk factor profile. Sweetened soda belongs to the medium glycemic index category based on its sucrose sweetener content [21]. Moreover, sucrose was shown to have higher glycemic and peak incremental indices than honey in adolescents with T1DM [22]. The association of sugar-rich diets with impaired lipid profile was observed both in animal [23] and in human studies. After a 6-week eucaloric dietary intervention with a high-sucrose diet, Black et al. [24] observed an increase in total and LDL cholesterol in healthy subjects when compared to those consuming a low-sucrose diet. HDL cholesterol and fasting triglycerides were similar on the two diets. Erkkila et al. [25] found that high intake of sucrose was associated with high serum triglycerides only in patients with E2 allele of APOE, irrespective of diabetes. Interestingly, in this study, sugar-sweetened beverage intake was not associated with A1c levels in youth with T1DM. Potential explanations are that glucose management may adequately balance the amount of sugar-sweetened beverage consumed or that the amount of extra carbohydrate uncovered by insulin is not sufficient to substantially increase A1c levels.

On the other hand, sweetened beverage intake may be an indicator of an adverse dietary pattern or lifestyle. In adults with T1DM, low educational level was found to be associated with increased smoking and alcohol consumption, as well as worse cardiometabolic risk profile [26]. In our analyses, several socio-demographic, diabetes-related, and lifestyle factors were used for adjustment, such as age, sex, race/ethnicity, parental education, diabetes duration, skipping insulin, time watching TV, and involvement in team sports. However, none of them was found to be strong confounders of the associations between sweetened beverage intake and plasma lipids. These associations were at least partially confounded by saturated fat and total fiber intake. Therefore, it may be suggested that dietary pattern characterized by increased sweetened beverage intake may be a factor associated with higher CVD risk in youth with diabetes.

In this study, involvement in team sports was associated with a higher proportion of moderate sugar-sweetened beverage intake in girls. We suspect that this increased intake represents drinking Gatorade and similar beverages with exercise to prevent hypoglycemia which is commonly recommended. This consumption pattern may be quite different than “unhealthy” drinking of sweetened sodas while playing video games or watching TV. However, there was no way to differentiate these two consumption patterns in this study.

In this study, high *diet beverage* intake was associated with higher total, LDL cholesterol, and plasma triglycerides compared to no diet beverage intake. Moreover, diet beverage intake was associated with worse metabolic control in youth with diabetes, as reflected by significantly higher levels of A1c. These results agree with those obtained previously [5] for middle-aged adults. Dhingra et al. [5] showed that diet soda intake was associated with increased (1.8-fold) prevalence of metabolic syndrome. Interestingly, in this study, the association of diet beverage intake with A1c, total cholesterol, and triglycerides was not confounded by saturated fat and total fiber intake, implying that other unmeasured factors may be involved in this association. Moreover, due to cross-sectional design of our study, the observed relationship between diet beverage intake and CVD risk factors may occur due to reverse causation. That is, children with high CVD risk may be more strongly encouraged to drink diet soda instead of regular sweetened beverages.

In this study, BMI was inversely associated with sugar-sweetened beverage intake. This association was statistically non-significant. Youth with increased BMI are more likely to be advised to restrict sweetened beverage intake. We adjusted for BMI in an attempt to control for this “behavioral” confounding effect of BMI. Association of BMI with diet beverages was in the opposite direction, though also non-significant. Youth with high diet beverage consumption tended to have higher BMI, and be less active (less likely to participate in team sports and more likely to watch TV > 2 h/day). Therefore, diet beverage intake may be a marker of adverse lifestyle resulting in poor cardiovascular risk factor profile. The strengths of the SEARCH study include a large sample size and diverse populations, as well as a variety of outcome and exposure measures obtained from the study sample. Of course, this study also has some potential limitations. First, lack of precision in diet measurement may have an impact on the results of the study. Food frequency questionnaires usually tend to underestimate the actual intake [27]. Beverage intake history only for the previous week may not accurately reflect usual long-term consumption of carbonated beverages. Second, misclassification of the exposure groups is probably due to the structure of the FFQ questions. “Sugar-sweetened beverage” category as assigned in this study may include some artificially sweetened variants of the beverages listed in the FFQ questions. The category “diet beverage” in this study combines the intake of artificially sweetened soda and mineral (unsweetened) water. Artificially sweetened soda and mineral water are likely to differ on their association with the outcomes. However, available FFQ data did not allow distinguishing between these two effects. In our opinion, this combined group association is more driven by diet soda intake and to a much lesser extent by mineral water since mineral water less popular among youth.

It may be concluded that high sugar-sweetened and diet beverage intake as contrasted to no and moderate intake is associated with higher levels of CVD risk factors in youth with diabetes. These findings, together with the fact that diabetes by itself is a major risk factor for CVD and other pathological disorders [28], support the statement that youth with diabetes should be encouraged to lower sugar-sweetened beverage intake. Somewhat unexpected strong positive association of diet beverage intake with plasma lipids and metabolic control rather suggests that artificially sweetened beverage such as diet soda may be a marker of unhealthy lifestyle which, in turn, is associated with worse metabolic control and CVD risk profile in these youth. Further exploration of the association of artificially sweetened beverage intake with CVD risk factors is needed.

Acknowledgments

Grant Support: SEARCH for Diabetes in Youth is funded by the Centers for Disease Control and Prevention (PA number 00097 and DP-05-069) and supported by the National Institute of Diabetes and Digestive and Kidney Diseases. Site Contract Numbers: Kaiser Permanente Southern California (U01 DP000246), University of Colorado Health Sciences Center (U01 DP000247), Pacific Health Research Institute (U01 DP000245), Children's Hospital Medical Center (Cincinnati) (U01 DP000248), University of North Carolina at Chapel Hill (U01 DP000254), University of Washington School of Medicine (U01 DP000244), Wake Forest University School of Medicine (U01 DP000250). The contents of this paper are solely the responsibility of the authors and do not necessarily represent the official views of the Centers for Disease Control and Prevention and the National Institute of Diabetes and Digestive and Kidney Diseases. The SEARCH for Diabetes in Youth Study is indebted to the many youth and their families, and their health care providers, whose participation made this study possible. The authors wish to acknowledge the involvement of General Clinical Research Centers (GCRC) at the following institutions in the SEARCH for Diabetes in Youth Study: Medical University of South Carolina (Grant number M01 RR01070); Cincinnati Children's Hospital (Grant number M01 RR08084); Children's Hospital and Regional Medical Center and the University of Washington School of Medicine (Grant numbers M01RR00037 and M01RR001271); Colorado Pediatric General Clinical Research Center (Grant number M01 RR00069).

References

1. Gidding SS, Dennison BA, Birch LL, Daniels SR, Gilman MW, Lichtenstein AH, Rattay KT, Steinberger J, Stettler N, Van HL. Dietary recommendations for children and adolescents: a guide for practitioners: consensus statement from the American Heart Association. Circulation. 2005; 112(13):2061–2075. [PubMed: 16186441]
2. Berkey CS, Rockett HR, Field AE, Gillman MW, Colditz GA. Sugar-added beverages and adolescent weight change. Obes Res. 2004; 12(5):778–788. [PubMed: 15166298]
3. Phillips SM, Bandini LG, Naumova EN, Cyr H, Colclough S, Dietz WH, Must A. Energy-dense snack food intake in adolescence: longitudinal relationship to weight and fatness. Obes Res. 2004; 12(3):461–472. [PubMed: 15044663]
4. Ludwig DS, Peterson KE, Gortmaker SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. Lancet. 2001; 357(9255):505–508. [PubMed: 11229668]
5. Dhingra R, Sullivan L, Jacques PF, Wang TJ, Fox CS, Meigs JB, D'Agostino RB, Gaziano JM, Vasan RS. Soft drink consumption and risk of developing cardiometabolic risk factors and the metabolic syndrome in middle-aged adults in the community. Circulation. 2007; 116(5):480–488. doi:CIRCULATIONAHA.107.689935. [PubMed: 17646581]
6. Lutsey PL, Steffen LM, Stevens J. Dietary intake and the development of the metabolic syndrome: the atherosclerosis risk in communities study. Circulation. 2008; 117(6):754–761. doi:CIRCULATIONAHA.107.716159. [PubMed: 18212291]
7. Swarbrick MM, Stanhope KL, Elliott SS, Graham JL, Krauss RM, Christiansen MP, Griffen SC, Keim NL, Havel PJ. Consumption of fructose-sweetened beverages for 10 weeks increases postprandial triacylglycerol and apolipoprotein-B concentrations in overweight and obese women. Br J Nutr. 2008; 100(5):947–952. doi:S0007114508968252. [PubMed: 18384705]
8. Rodriguez BL. Dietary studies in the multi-Ethnic Hawaiian population. J Am Diet Assoc. 2006; 106(2):209–210. [PubMed: 16442867]
9. Salem M, Moneir I, Adly AM, Esmat K. Study of coronary artery calcification risk in Egyptian adolescents with type-1 diabetes. Acta Diabetologica. 201010.1007/s00592-010-0214-4
10. Mayer-Davis EJ, Nichols M, Liese AD, Bell RA, Dabelea DM, Johansen JM, Pihoker C, Rodriguez BL, Thomas J, Williams D. Dietary intake among youth with diabetes: the SEARCH for Diabetes in Youth Study. J Am Diet Assoc. 2006; 106(5):689–697. [PubMed: 16647326]
11. Overby NC, Margeirsdottir HD, Brunborg C, Andersen LF, Dahl-Jorgensen K. The influence of dietary intake and meal pattern on blood glucose control in children and adolescents using intensive insulin treatment. Diabetologia. 2007; 50(10):2044–2051.10.1007/s00125-007-0775-0 [PubMed: 17687538]
12. Group SS. SEARCH for diabetes in youth: a multicenter study of the prevalence, incidence and classification of diabetes mellitus in youth. Control Clin Trials. 2004; 25(5):458–471. [PubMed: 15465616]
13. Grieco, EM.; Cassidy, RC. Overview of race and hispanic origin: census 2000 Brief. US Census Bureau; Washington, DC: 2001.
14. Ingram DD, Parker JD, Schenker N, Weed JA, Hamilton B, Arias E, Madans JH. United States Census 2000 population with bridged race categories. Vital Health Stat. 2003; 2135:1–55.
15. Krowchuk DP, Kreiter SR, Woods CR, Sinal SH, DuRant RH. Problem dieting behaviors among young adolescents. Arch Pediatr Adolesc Med. 1998; 152(9):884–888. [PubMed: 9743034]
16. Eisenmann JC, Bartee RT, Wang MQ. Physical activity, TV viewing, and weight in US youth: 1999 youth risk behavior survey. Obesity. 2002; 10(5):379–385.
17. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, Wei R, Curtin LR, Roche AF, Johnson CL. 2000 CDC growth charts for the United States: methods and development. Vital Health Stat. 2002; 11246:1–190.

18. Hainline A Jr, Miller DT, Mather A. The coronary drug project. Role and methods of the Central Laboratory. Control Clin Trials. 1983; 4(4):377. [PubMed: 6327187]

19. Diez JJ, Iglesias P, Fernandez-Reyes MJ, Aguilera A, Bajo MA, varez-Fidalgo P, Codoceo R, Selgas R. Serum concentrations of leptin, adiponectin and resistin, and their relationship with cardiovascular disease in patients with end-stage renal disease. Clin Endocrinol. 2005; 62(2):242–249.

20. Kleinbaum, DG.; Kupper, LL.; Muller, KE. Applied regression analysis and other multivariable methods. PWS Publishing Co; USA: 1988.

21. Malik VS, Schulze MB, Hu FB. Intake of sugar-sweetened beverages and weight gain: a systematic review. Am J Clin Nutr. 2006; 84(2):274–288. doi:84/2/274. [PubMed: 16895873]

22. Abdulrhman M, El-Hefnawy M, Hussein R, El-Goud AA. The glycemic and peak incremental indices of honey, sucrose and glucose in patients with type 1 diabetes mellitus: effects on C-peptide level-a pilot study. Acta Diabetologica. 200910.1007/s00592-009-0167-7

23. Lombardo YB, Drago S, Chicco A, Fainstein-Day P, Gutman R, Gagliardino JJ, Gomez Dumm CL. Long-term administration of a sucrose-rich diet to normal rats: relationship between metabolic and hormonal profiles and morphological changes in the endocrine pancreas. Metabolism. 1996; 45(12):1527–1532. [PubMed: 8969287]

24. Appel LJ, Brands MW, Daniels SR, Karanja N, Elmer PJ, Sacks FM. Dietary approaches to prevent and treat hypertension: a scientific statement from the American Heart Association. Hypertension. 2006; 47(2):296–308. [PubMed: 16434724]

25. Erkkila AT, Sarkkinen ES, Lindi V, Lehto S, Laakso M, Uusitupa MI. APOE polymorphism and the hypertriglyceridemic effect of dietary sucrose. Am J Clin Nutr. 2001; 73(4):746–752. [PubMed: 11273849]

26. Nadas J, Putz Z, Fovenyi J, Gaal Z, Gyimesi A, Hidvegi T, Hosszufalusi N, Neuwirth G, Oroszlan T, Panczel P, Vandorfi G, Winkler G, Wittmann I, Jermendy G. Cardiometabolic risk and educational level in adult patients with type 1 diabetes. Acta Diabetol. 2009; 46(2):159–162. [PubMed: 18843447]

27. Willett, WC. Nutritional Epidemiology. 2nd. Oxford University Press; Oxford: 1998.

28. Tarquini R, Lazzeri C, Pala L, Rotella CM, Gensini GF. The diabetic cardiomyopathy. Acta Diabetologica. 201010.1007/s00592-010-0180-x

Table 1

Baseline characteristics of youth with T1DM by beverage intake groups

	Sweetened beverage				Diet beverage			
	None (n = 902)	<1 Glass/day (n = 600)	1 Glass/day or more (n = 304)	P-value	None (n = 192)	<1 Glass/day (n = 614)	1 Glass/day or more (n = 986)	P-value
Age, years	14.6 ± 3.1	14.8 ± 3.0	15.6 ± 3.1	<0.01	15.1 ± 3.2	14.1 ± 3.0	15.3 ± 3.0	<0.01
Gender								
Females	482 (55)	287 (32)	113 (13)	<0.01	101 (12)	324 (37)	450 (51)	0.01
Males	420 (45)	313 (34)	191 (21)		91 (10)	290 (32)	536 (58)	
Race/ethnicity								
Asian/Pacific islanders	33 (54)	20 (33)	8 (13)	<0.01[a]	6 (10)	24 (39)	31 (51)	0.88[a]
African American	47 (34)	47 (34)	43 (32)		17 (12)	40 (30)	78 (58)	
Hispanic	97 (52)	58 (31)	31 (17)		21 (12)	63 (34)	99 (54)	
Native American	4 (31)	6 (46)	3 (23)		0 (0)	4 (31)	9 (69)	
Non-Hispanic white	721 (51)	469 (33)	219 (16)		148 (11)	483 (34)	769 (55)	
Parent education								
More than high school	863 (50)	579 (33)	292 (17)	0.71	182 (11)	595 (34)	948 (55)	0.27
High school graduate or less	36 (54)	19 (29)	11 (17)		10 (16)	17 (28)	34 (56)	
Diabetes duration								
12 + months	748 (48)	519 (34)	282 (18)	<0.01	160 (10)	509 (33)	867 (57)	0.01
6–11 months	154 (60)	81 (31)	22 (9)		32 (13)	105 (41)	119 (46)	
Watching TV								
<2 h per day	420 (52)	280 (35)	109 (13)	<0.01	98 (12)	333 (41)	375 (47)	<0.01
2 + h per day	476 (48)	314 (32)	193 (20)		91 (9)	277 (29)	604 (62)	
Team sports								
Boys 0–1 team	306 (47)	211 (33)	129 (20)		68 (11)	187 (29)	385 (60)	0.05
2 + teams	114 (41)	102 (37)	62 (22)	0.20	23 (8)	103 (37)	151 (55)	
Girls 0–1 teams	359 (57)	186 (30)	83 (13)		76 (12)	207 (33)	341 (55)	<0.01
2 + teams	123 (48)	101 (40)	30 (12)	0.01	25 (10)	117 (47)	109 (43)	
Skipping insulin								
1 per week or more	89 (43)	71 (34)	49 (23)		27 (13)	54 (26)	128 (61)	0.03

	Sweetened beverage				Diet beverage			
	None (*n* = 902)	**<1 Glass/day (*n* = 600)**	**1 Glass/day or more (*n* = 304)**	***P*-value**	**None (*n* = 192)**	**<1 Glass/day (*n* = 614)**	**1 Glass/day or more (*n* = 986)**	***P*-value**
1–3 per month	182 (48)	131 (34)	67 (18)		43 (11)	119 (32)	215 (57)	
Never	622 (52)	388 (32)	186 (16)	0.03	117 (10)	433 (36)	636 (54)	
Treatment								
Pump	185 (47)	133 (34)	77 (19)		43 (11)	148 (38)	202 (51)	0.22
Insulin injections	709 (51)	460 (33)	225 (16)	0.21	147 (11)	460 (33)	776 (56)	
BMI z-score	0.64 ± 0.90	0.60 ± 0.83	0.58 ± 0.94	0.51	0.56 ± 0.81	0.56 ± 0.85	0.66 ± 0.91	0.08
Total energy intake, kcal/day[b]								
Males	1,934 ± 751	2,139 ± 846	2,710 ± 1,324	<0.01	2,249 ± 1,196	1,974 ± 736	2,254 ± 1,031	<0.01
Females	1,564 ± 664	1,759 ± 676	2,231 ± 1,038	<0.01	1,677 ± 664	1,626 ± 725	1,778 ± 793	0.02

Mean ± standard deviation, number of observations (row percent)

[a] Chi-square test was performed after combining Asian/Pacific islanders and Native Americans due to low cell frequencies in these groups

[b] Estimated with a food frequency questionnaire

Table 2

Metabolic characteristics and CVD risk factors in T1DM youth by sugar-sweetened beverage intake groups

	Sweetened beverage intake in the previous week					
	None	<1 Glass/day	1 Glass/day or more	*P*-value of overall difference between means		
	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)	Model 1	Model 2	Model 3
HbA1c (%)	9.1 (8.8–9.4)	9.1 (8.8–9.4)	9.1 (8.7–9.4)	0.99	0.98	0.95
Total cholesterol (mg/dl)	172 (165–178)	173 (166–179)	179 (172–186)[b]	0.010	0.026	0.075
LDL cholesterol (mg/dl)	101 (95–106)	102 (97–107)	106 (100–112)[b]	0.022	0.033	0.18
Triglycerides (mg/dl)[a]	76 (69–84)	76 (69–84)	86 (78–96)[b]	<0.001	0.007	0.061
HDL cholesterol (mg/dl)	53 (51–55)	53 (51–55)	52 (50–55)	0.83	0.80	0.86
LDL-Rf	0.27 (0.27–0.28)	0.27 (0.27–0.28)	0.27 (0.27–0.28)	0.62	0.60	0.91
Adiponectin (μg/ml)[a]	16.0 (14.6–17.4)	15.6 (14.3–17.1)	15.4 (14.0–16.9)	0.39	0.34	0.49
Leptin (ng/ml)[a]	4.7 (3.9–5.7)	4.6 (3.8–5.6)	4.6 (3.7–5.7)	0.90	0.32	0.37
Systolic blood pressure (mm Hg)	107 (105–109)	107 (105–108)	105 (103–108)	0.17	0.23	0.34
Diastolic blood pressure (mm Hg)	68 (66–69)	68 (66–70)	67 (65–69)	0.87	0.70	0.58

Means and confidence intervals (CI) adjusted for age, sex, race/ethnicity, parental education, diabetes duration, skipping insulin, time watching TV, involvement in team sports, and total energy intake

Model 1 adjusted for age, sex, race/ethnicity, parental education, diabetes duration, skipping insulin, time watching TV, involvement in team sports, and total energy intake

Model 2 Model 1 + adjusted for BMI-z-score

Model 3 Model 1 + adjusted for saturated fat intake, total fiber intake, and BMI-z-score

[a]Back-transformed from log-values to original units

[b]Differed significantly ($P < 0.05$) from no-beverage level

Table 3

Metabolic characteristics and CVD risk factors in T1DM youth by diet beverage intake groups

	Unsweetened beverage intake in the previous week					
	None	<1 Glass/day	1 Glass/day or more	*P*-value of overall difference between means		
	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)	Model 1	Model 2	Model 3
HbA1c (%)	8.7 (8.4–9.1)	8.9 (8.6–9.2)	9.3 (9.0–9.6)[b]	<0.001	<0.001	<0.001
Total cholesterol (mg/dl)	166 (159–174)	172 (166–179)	176 (170–183)[b]	<0.001	0.006	0.008
LDL cholesterol (mg/dl)	98 (92–104)	101 (96–107)	104 (99–109)[b]	0.013	0.092	0.12
Triglycerides (mg/dl)[a]	73 (65–82)	76 (68–84)	82 (74–90)[b]	0.002	0.009	0.008
HDL cholesterol (mg/dl)	51 (49–54)	53 (50–55)	52 (50–55)	0.42	0.53	0.59
LDL-Rf	0.27 (0.27–0.28)	0.27 (0.27–0.28)	0.27 (0.27–0.28)	0.80	0.84	0.79
Adiponectin (μg/ml)[a]	15.3 (13.8–17.0)	15.5 (14.2–16.9)	15.8 (14.5–17.3)	0.45	0.16	0.16
Leptin (ng/ml)[a]	4.2 (3.3–5.2)	4.7 (3.9–5.7)	4.6 (3.8–5.6)	0.31	0.11	0.13
Systolic blood pressure (mm Hg)	106 (104–108)	106 (104–108)	106 (105–108)	0.70	0.65	0.68
Diastolic blood pressure (mm Hg)	67 (65–69)	68 (66–69)	68 (66–70)	0.46	0.49	0.50

Means and confidence intervals (CI) adjusted for age, sex, race/ethnicity, parental education, diabetes duration, skipping insulin, time watching TV, involvement in team sports, and total energy intake

Model 1 adjusted for age, sex, race/ethnicity, parental education, diabetes duration, skipping insulin, time watching TV, involvement in team sports, and total energy intake

Model 2 Model 1 + adjusted for BMI-z-score

Model 3 Model 1 + adjusted for saturated fat intake, total fiber intake, and BMI-z-score

[a]Back-transformed from log-values to original units

[b]Differed significantly ($P < 0.05$) from no-beverage level