Sugar-sweetened beverage and water intake in relation to diet quality in U.S. children

S. Gemma DiMatteo, MPH
Global Food Initiative

University of California
Agriculture and Natural Resources

Background

Sugar-sweetened beverages (SSBs) are the main source of added sugar in U.S. children's diets. According to 2009-2012 data from the National Health and Nutrition Examination Survey (NHANES), 78% of U.S. children ages 2 to 18 years consume SSBs on a given day. Fluid consumption is vital for body functions, yet consuming fluid with added sugar is unnecessary and likely detrimental. Sugary drink intake has been associated with increased energy intake and obesity, metabolic syndrome, type 2 diabetes, and heart disease. Water consumption is less documented than SSBs in relation to total energy intake (TEI) and chronic disease prevention, but given that the majority of U.S. children are under-hydrated, more attention to water intake is needed. According to the 2009-2012 NHANES, more than 60% of children and adolescents drink less than 2 cups of plain water a day, and 13% drink no plain water on a given day.

Although beverages often are consumed with food, and beverage choice may be related to diet patterns, minimal literature explores the relationship between beverage choice and diet quality. While some studies have investigated beverage choice in relation to specific nutrient intakes, the association with total diet quality has not been well documented. Further, the majority of studies on beverage choice and diet quality involved only adults or small, homogenous groups of children.

Given that dietary patterns and taste preferences are formed in childhood, a better understanding of factors related to overall diet quality in children is needed. Further, understanding whether children's beverage choices are associated with dietary quality and total energy intake will help inform program and policy directions related to children's beverage intake. This study is the first to investigate water and SSB consumption in relation to total diet quality and energy intake in a representative sample of U.S. children. We hypothesized that water intake is positively correlated with diet quality and inversely correlated with energy intake, and that SSB intake is negatively correlated with diet quality and positively correlated with energy intake.

Methods

Study Population

Data are from the 2009-2012 NHANES multistage probability cross-sectional sample designed to be representative of the U.S. civilian, non-institutionalized population. Data were limited to children 2 to 18 years old who had complete dietary data and plausible energy intake.

Measures

Dietary intake data were derived from 2 days of 24-hour recall per person. This study used an average of the 2 days for all exposure and outcome variables.

SSBs (exposure variable) included soft drinks, fruit drinks with added sugar, sweetened coffee and tea drinks, sports drinks, flavored milk, and sweetened bottled water. **Plain water** (exposure variable) included all unsweetened water sources: tap water, bottled water, and unsweetened carbonated water. Diet quality was measured by the **Healthy Eating Index (HEI)-2010** (primary outcome variable). The HEI-2010 was developed by the USDA to measure compliance with the Dietary Guidelines for Americans. The total HEI-2010 has a maximum score of 100, and is comprised of 12 component scores (secondary outcome variables): total vegetables (maximum score of 5), total fruit (5), whole fruit (5), greens and beans (5), whole grains (10), dairy (10), total protein foods (5), seafood and plant proteins (5), fatty acids (10), refined grains (10), sodium (10), and empty calories (solid fats, alcohol, and added sugars) (20). For refined grains, sodium, and empty calories, a higher score indicates a lower intake.

TEI (primary outcome variable) was based on the type and amount of all caloric foods and beverages reported during the dietary recall interviews.

The following variables were used in adjusted models to control for potential confounding: sex, age, race/ethnicity, household reference education, family poverty to income ratio, household reference marriage status, and child weight status. The household reference is the first person 18 or older listed under household members who owns or rents the place of residence.

Statistical Analysis

All statistical analyses were done using Stata. NHANES survey weights and robust estimates of variance were used for all analyses. Multivariable linear regression was used to estimate mean differences in total HEI-2010 score and TEI, and generalized linear models with a gamma distribution and log-link function were used to estimate relative means of component HEI scores. A test for a dose-response relationship between both exposure variables (water and SSB intake) was conducted for both primary outcomes (HEI-2010 score and TEI) by examining the p-value on the untransformed exposure variables in models. Effect measure modification with a $p<0.05$ significance threshold by age group (2-5, 6-11, 12-18 years old) was tested with a Wald test for interaction with each exposure variable (water and SSB intake) for all models and by sex for the primary outcomes (HEI-2010 and TEI). Interaction also was tested between the exposure variables (water and SSB intake) for both primary outcomes (HEI-2010 and TEI). Missing data for household reference education (3.1%) or marital status (7.8%), and family PIR (2.3%) were handled using the missing-indicator method.

Results

Table 2. Estimated differences in total HEI and TEI (95% CI) compared to 0 servings.

	n=6092		
	n (%)	**Total HEI-2010**	**TEI (kcal/day)**
SSB			
0 servings	1404 (23)	Ref.	Ref.
0 < servings <= 1	1812 (30)	**-3.3** (-5.1, -1.4)**	59.0 (-14.3, 132.3)
1 < servings <= 2	1461 (24)	**-6.0*** (-7.7, -4.4)**	**202.2*** (126.0, 278.3)**
> 2 servings	1415 (23)	**-9.2*** (-10.9, -7.5)**	**358.1*** (294.5, 421.8)**
P-trend		< 0.001	< 0.001
Water			
0 servings	874 (14)	Ref.	Ref.
0 < servings <= 1	1332 (22)	**2.1** (0.9, 3.3)**	17.7 (-77.8, 113.2)
1 < servings <= 2	1568 (26)	**2.9*** (1.6, 4.3)**	38.5 (-43.0, 119.9)
> 2 servings	2318 (38)	**4.8*** (3.8, 5.8)**	56.5 (-39.7, 152.7)
P-trend		< 0.001	< 0.001

SSB consumption was associated with significantly lower total HEI-2010 score and higher TEI in every intake category. Each category of water intake was associated with a significant increase in total HEI-2010 score, compared to 0 servings (**Table 2)**.

The test for trend was significant ($p<0.001$) for SSB and water in every model for the primary outcomes, suggesting a dose-response relationship between beverage intake and HEI-2010 score and TEI. Effect measure modification was observed by age group in the models investigating SSB on total HEI-2010, total vegetables, greens and beans, sodium, and refined grains ($p<0.05$). Effect measure modification by sex was present in only 5 of the 16 primary outcome models ($p<0.05$), including a model for each beverage-outcome relationship and stratified by age. There was no interaction found between water and SSB intake.

SSB intake was negatively associated with the following HEI component scores: vegetables, total fruit, whole fruit, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and empty calories. SSB intake was positively associated with refined grains and sodium scores.Water intake was positively associated with the following HEI component scores: vegetables, total fruit, whole fruit, greens and beans, whole grains, seafood and plant proteins, and empty calories. Water intake was negatively associated with refined grains and sodium scores.

Discussion

We observed a dose-response relationship, suggesting that children who consume more water have a higher diet quality than those consuming less water and that children who consume more SSBs have poorer dietary quality and higher total energy intake than children who consume fewer SSBs. All of these results are adjusted for SES characteristics including child's age, sex, race, and weight status, and household reference income and education. While water intake was not found to be related to total energy intake, SSB intake was associated with substantial increased calorie intake, on average >350 additional calories for children across all age groups who reported consuming >2 servings of SSBs. Our findings are consistent with prior evidence suggesting that children and adults who drink sugar do not offset the additional calories consumed, and that SSB intake is associated with decreased diet quality and increased TEI. This study adds to the literature by showing that SSB consumption is not associated only with weight outcomes, but also with diet quality, which has independent health consequences.

The magnitude of the associations between SSB intake and TEI were relatively large, and are informative for efforts to reduce childhood obesity. *Healthy People 2020* aimed to reduce childhood obesity prevalence to 14.6% by 2020 (10% lower than the 2005-2008 level). According to Wang et al., a decrease in TEI of only 64 kcal/day for children 2-19 would meet this goal (22 kcal for 2-5 year olds, 77 kcal for 6-11 year olds, 98 kcal for 12-19 year olds). Our results suggest that limiting SSB intake would easily surpass that threshold, as our study finds that the mean SSB intake among all children was 1.3 servings/day, a consumption level that was associated with a caloric intake of approximately 200 calories more than children not consuming any SSBs. Assuming compensation does not occur through other sources of added calories, eliminating SSB intake could have a significant impact on childhood obesity.

Although the magnitude of association between beverage intake and HEI are moderate (for example, >2 servings of water was associated with an increase of 4.8 points, and >2 servings of SSBs were associated with a decrease in 9.2 points), Chiuve et al. have shown that even moderate increases in HEI score were associated with decreased risk of coronary heart disease and diabetes. Additionally, despite a relatively small magnitude of change on an individual level, over time and over an entire population, the impact of these changes is likely to be physiologically - and even economically - relevant.

Our finding that water intake is significantly associated with increased diet quality is encouraging for efforts focused on promoting drinking water. Efforts to improve children's diets should continue to consider the role of beverage choices on overall dietary quality and energy intake. These findings provide support to interventions that aim to replace SSBs with water consumption, particularly among children and adolescents, and offers additional evidence to suggest that such efforts are likely to positively impact children's health.

References

Sources of Calories from Added Sugars among the U.S. Population, 2005-06. *National Cancer Institute: Division of Cancer Control and Population Sciences*. 2017. Available at: http://riskfactor.cancer.gov/diet/foodsources/added_sugars/. Accessed February 11, 2017

Wang CY, Ludwig DS, Sonneville K, Gortmaker SL. Impact of change in sweetened caloric beverage consumption on energy intake among children and adolescents. *Archives of Pediatrics & Adolescent Medicine*. 2009;163(4):336–343. doi:10.1001/archpediatrics.2009.23. http://dx.doi.org/10.1001/archpediatrics.2009.23. Accessed February 11, 2017.

Fung TT, Malik V, Rexrode KM, Manson JE, Willett WC, Hu FB. Sweetened beverage consumption and risk of coronary heart disease in women. *American Journal of Clinical Nutrition*. 2009;89(4):1037–1042. doi:10.3945/ajcn.2008.27140.

Hu FB. Resolved: There is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. *Obesity Reviews*. 2013;14(8):606–619. doi:10.1111/obr.12040. http://dx.doi.org/10.1111/obr.12040. Accessed February 11, 2017.

Hu FB, Malik VS. Sugar-sweetened beverages and risk of obesity and type 2 diabetes: Epidemiologic evidence. *Physiology & Behavior*. 2010;100(1):47–54. doi:10.1016/j.physbeh.2010.01.036.

Roizen MF. Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: A meta-analysis. *Yearbook of Anesthesiology and Pain Management*. 2012;2012:21–22. doi:10.1016/j.yane.2012.02.008.

Kenney EL, Long MW, Cradock AL, Gortmaker SL. Prevalence of inadequate hydration among US children and disparities by gender and race/ethnicity: National health and nutrition examination survey, 2009–2012. *American Journal of Public Health*. 2015;105(8):e113–e118. doi:10.2105/ajph.2015.302572.

Marshall TA, Eichenberger Gilmore JM, Broffitt B, Stumbo PJ, Levy SM. Diet quality in young children is influenced by beverage consumption. *Journal of the American College of Nutrition*. 2005;24(1):65–75. doi:10.1080/07315724.2005.10719445.

Frary CD, Johnson RK, Wang MQ. Children and adolescents' choices of foods and beverages high in added sugars are associated with intakes of key nutrients and food groups. *Journal of Adolescent Health*. 2004;34(1):56–63. doi:10.1016/s1054-139x(03)00248-9.

Vartanian LR, Schwartz MB, Brownell KD. Effects of soft drink consumption on nutrition and health: A systematic review and Meta-Analysis. *American Journal of Public Health*. 2007;97(4):667–675. doi:10.2105/ajph.2005.083782. doi:10.3390/nu8070395.

Duffey K, Poti J. Modeling the effect of replacing sugar-sweetened beverage consumption with water on energy intake, HBI score, and obesity prevalence. *Nutrients*. 2016;8(7):395. doi:10.3390/nu8070395.

Thomson J, Tussing-Humphreys LM, Onufrak SJ, et al. Simulated reductions in consumption of sugar-sweetened beverages improves diet quality in lower Mississippi delta adults. *Food & Nutrition Research*. 2011;55(1):7304. doi:10.3402/fnr.v55i0.7304.

An R. Plain water and sugar-sweetened beverage consumption in relation to energy and nutrient intake at full-service restaurants. *Nutrients*. 2016;8(5):263. doi:10.3390/nu8050263.

An R. Beverage consumption in relation to discretionary food intake and diet quality among US adults, 2003 to 2012. *Journal of the Academy of Nutrition and Dietetics*. 2016;116(1):28–37. doi:10.1016/j.jand.2015.08.009.

An R, McCaffreyJ. Plain water consumption in relation to energy intake and diet quality among US adults, 2005-2012. *Journal of Human Nutrition and Dietetics*. 2016;29(5):624–632. doi:10.1111/jhn.12368.

Libuda L, Alexy U, Buyken AE, Sichert-Hellert W, Stehle P, Kersting M. Consumption of sugar-sweetened beverages and its association with nutrient intakes and diet quality in German children and adolescents. *British Journal of Nutrition*. 2008;101(10):1549. doi:10.1017/s0007114508094671.

Marshall TA, Eichenberger Gilmore JM, Broffitt B, Stumbo PJ, Levy SM. Diet quality in young children is influenced by beverage consumption. *Journal of the American College of Nutrition*. 2005;24(1):65–75. doi:10.1080/07315724.2005.10719445.

Healthy Eating Index. USDA Center for Nutrition Policy and Promotion. http://www.cnpp.usda.gov/healthyeatingindex. Accessed February 11, 2017.

Wang YC, Orleans CT, Gortmaker SL. Reaching the healthy people goals for reducing childhood obesity. *American Journal of Preventive Medicine*. 2012;42(5):437–444. doi:10.1016/j.amepre.2012.01.018.

Chiuve SE, Fung TT, Rimm EB, et al. Alternative Dietary Indices Both Strongly Predict Risk of Chronic Disease. *Journal of Nutrition*. 2012;142(6):1009–1018. doi:10.3945/jn.111.157222.

Acknowledgements

A huge thank you to the co-authors **Cindy Leung**, ScD at UCSF **and Lorrene Ritchie**, PhD and **Wendi Gosliner**, DrPH at The Nutrition Policy Institute for all of their help and mentorship.