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Beverage consumption patterns at age 13–17 are associated with weight, height, and BMI at age 17

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Abstract

Background—Sugar-sweetened beverages (SSBs) have been associated with obesity in children and adults; however, associations between beverage patterns and obesity are not understood.

Objective—To describe beverage patterns during adolescence, and the associations between adolescent beverage patterns and age 17 anthropometric measures.

Design—Cross-sectional analyses of longitudinally-collected data.

Participants/setting—Participants in the longitudinal Iowa Fluoride Study having at least one beverage questionnaire completed between ages 13.0 and 14.0 years, having a second questionnaire completed between 16.0 and 17.0 years and attending an age 17 clinic exam for weight and height measurements (n=369).

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Exposure—Beverages were collapsed into 4 categories {i.e., 100% juice, milk, water and other sugar-free beverages (water/SFB), and SSBs} for the purpose of clustering. Five beverage clusters were identified from standardized age 13–17 mean daily beverage intakes and named by the authors for the dominant beverage: juice, milk, water/SFB, neutral and SSB.

Outcome—Age 17 weight, height and BMI.

Statistical analyses—Ward's method for clustering of beverage variables. One-way ANOVA and chi-square tests for bivariable associations. Gamma regression for associations of weight or BMI (outcomes) with beverage clusters and demographic variables. Linear regression for associations of height (outcome) with beverage clusters and demographic variables.

Results—Participants with family incomes < \$60,000 trended shorter (1.5 ± 0.8 cm; $P=0.070$) and were heavier (2.0 ± 0.7 BMI units; $P=0.002$) than participants with family incomes $\geq 60,000$ /year. Adjusted mean weight, height and BMI estimates differed by beverage cluster membership. For example, on average, male and female members of the neutral cluster were 4.5 cm ($P=0.010$) and 4.2 ($P=0.034$) cm shorter, respectively, than members of the milk cluster. For members of the juice cluster, the mean BMI was lower than for members of the milk cluster (by 2.4 units), water/SFB cluster (3.5 units), neutral cluster (2.2 units) and SSB cluster (3.2 units) (all $P<0.05$).

Conclusions—Age 13–17 year beverage patterns were associated with age 17 anthropometric measures and BMI in this sample. Beverage patterns might be characteristic of overall food choices and dietary behaviors that influence growth.

Keywords

Beverage; sugar-sweetened beverages; milk; height; BMI

Introduction

Obesity is a disease characterized by excessive adipose tissue, and is a substantial risk factor for morbidity and premature mortality.^{1,2} Using data from the National Health and Nutritional Examination Survey, Ogden et al. reported that the prevalence of adolescent obesity increased from 10.5% (95% CI = 8.8–12.5%) in 1988–94 to 20.6% (95% CI= 16.2–25.6%) in 2013–14, with extreme obesity increasing from 2.6% (95% CI= 1.7–3.9%) to 9.1% (95% CI= 7.0–11.5%) during the same time period.³ Because obesity is difficult to treat, understanding risk factors to facilitate development of preventive strategies is necessary to reduce the disease burden.

Diet is a potentially modifiable environmental risk factor for obesity; historic dietary recommendations have targeted foods high in fats and low in nutrients. More recently, sugar-sweetened beverages (SSBs), defined as beverages containing added sugars, have been associated with obesity in children, adolescents and adults.^{4–9} The science linking SSBs with obesity is mostly observational in nature. Moreover, SSBs are consumed in the context of the whole diet — an assortment of other foods and beverages. The relationships among foods and beverages within the diet might exacerbate or minimize the impact of a particular food or beverage item. In addition the physical state (i.e., solid vs. liquid) of food and beverage items is thought to influence satiety with implications for obesity.^{10,11}

Beverages (i.e., 100% juice, water, milk, SSBs) differ in both energy and nutrient density. The choice of beverage to consume in a given situation is likely influenced by flavor, perceived nutrient quality and/or perceived health benefits. As a result, most individuals consume multiple beverages throughout the day. Individual associations between SSBs, milk and 100% juice and obesity have been investigated; the majority of studies, particularly those of high quality, suggest a positive association between SSBs and weight gain, overweight or obesity.^{4-9,12-15} However, few investigations of beverage patterns and obesity in children or adolescents have been reported.¹⁶ LaRowe et al. reported that the BMIs of children ages 6–11 years were higher ($P<0.05$) in children with water (adjusted mean BMI=19.9), sweetened beverages (18.7) or soda (18.7) beverage patterns compared to mix/light (18.2) and high-fat milk (17.8) beverage patterns.¹⁶ To our knowledge, the relationships among beverage patterns and growth measures during adolescence have not been reported. Therefore, the objective of this manuscript is to describe beverage patterns during adolescence and the associations between the adolescent beverage patterns and anthropometric measures at age 17 years.

Methods

Study Design

Secondary analyses of data collected as part of the longitudinal Iowa Fluoride Study (IFS) and Iowa Bone Development Study (IBDS), which investigated relationships among dietary exposures, fluoride exposures, oral health and bone health, were conducted.^{6,17-20} Food and beverage intakes, oral health behaviors and systemic health information have been collected by questionnaire at approximately 6 month intervals since the children's birth. Dental exams and/or dual-energy x-ray absorptiometry exams were conducted during clinic visits when the children were approximately 5, 9, 13 and 17 years of age for assessment of oral and bone health. All components of the IFS and IBDS were approved by the Institutional Review Board at the University of Iowa. Written informed consent was obtained from mothers at recruitment and from parents at clinic visits, while written assent was obtained from children beginning at 13 years of age.

Subjects

Mothers of newborn infants were recruited at the time of their child's birth between 1992 and 1995 for their child's participation in the IFS. A total of 1,382 mothers/newborns originally were in the study after recruitment and returned at least 1 questionnaire at 6 weeks, 3 months, or 6 months of age. Attrition averaged about 7% per year thereafter through the age 17 dental examinations. Children who participated in the age 17 clinic exam ($n=428$), and returned at least one questionnaire completed between ages 13.0 and 14.0 years and a second questionnaire between ages 16.0 and 17.0 years were included in the current analyses ($n=369$). Of children who met the study's inclusion criteria, 97% ($n=359$) had data for mother's education, while 95% ($n=352$) had data for family income. Neither gender ($P=0.45$), mother's education ($P=0.58$), nor income ($P=0.74$) differed between subjects meeting inclusion criteria and those excluded due to missing beverage data.

Parents whose children attended the age 5 clinic visit were invited to participate in the IBDS; parental weight and height were measured and bone mineral density and content were assessed at that time. Of children who met the study's inclusion criteria, weight data were available for 64% (n=237) of mothers, height data for 64% (n=238) and both weight and height for 64% (n=236).

Data collection

IFS questionnaires queried information regarding family demographics, oral health behaviors, systemic health and food and beverage intakes. Beverage frequency questionnaires, previously validated using 3 day diaries for reference in 9 year old children, queried whether the beverage was consumed during the previous week, and, if consumed, the frequency and quantity of consumption.¹⁸ Individual beverage types (i.e., 100% juice, milk, water, soda-pop, sports drinks, ready-to-drink beverages, reconstituted beverages, etc.) were queried. If a beverage was consumed, then the participant was asked to provide detailed product information including the brand, type and flavor. Beverages were collapsed into four categories: 100% juice, milk, water and other sugar-free beverages (SFB) and sugar-sweetened beverages (SSBs). Mean daily beverage intakes were averaged from all available age 13.0–17.0 surveys. The averages of the four beverage categories were used for clustering.

Weight and height were measured at the age 17 clinic visit with participants wearing lightweight clothing and without shoes. Weight was measured using a standard physician's scale; height was measured using a stadiometer. Body mass index (kg/m^2) was calculated from weight and height measures. Participants were categorized as normal weight (BMI <24.9), overweight (BMI = 25.0–29.9) or obese (BMI > 30) using United States Centers for Disease Control and Prevention adult guidelines.²¹ Adult guidelines were used because the 85th and 95th percentiles used to define 'at risk for overweight' and 'overweight' for children overlap adult standards beginning at age 17 years.²¹

Statistical analyses

Cross-sectional analyses of longitudinal beverage exposures and age 17 anthropometric measures were conducted using SAS.²² Participant demographic characteristics, beverage intakes and anthropometric measures are presented as percentages or means $\pm$ standard deviations (SD).

Prior to clustering, the variables for the four beverage categories were individually standardized (mean 0, standard deviation 1) using their respective summary statistics to minimize the impact of different distributions within beverage categories. Standardized beverages were clustered using Ward's hierarchical clustering from the "stats" package in R to create cluster groups.^{23,24} Clustering is a descriptive technique that maximizes the variability between clusters and minimizes the variability within a cluster. A clustering algorithm results in the delineation of groups that have different overall beverage intake patterns.

Demographic variables (e.g., age, sex) were compared among the beverage clusters using one-way ANOVAs for continuous demographic variables and chi-square tests of association for categorical demographic variables.

Sex-specific associations between beverage cluster membership and age 17 distributions of weight, height and BMI were investigated. Due to the skewness of weight and BMI variables, gamma regression was used to assess the associations of these outcome variables with the beverage clusters, while traditional linear regression (i.e., normal regression) was used for the outcome of height. For the gamma regressions, inverse, log, and identity link functions were considered. The identity link function produced a better penalized fit for both weight and BMI according to the Akaike information criterion, and this link was therefore used for all gamma regression analyses (data not shown). Covariates in all models included beverage cluster for males, beverage cluster for females, mother's education and income.

Results

Mean $\pm$ SD age of all participants at the age 17 clinic visit was 17.7 ± 0.7 years; males were 17.8 ± 0.7 years and females were 17.7 ± 0.7 years. Forty-eight percent of participants were male; 50% had mothers with a 4 year college degree or higher; and 68% were raised in households with an income of $\leq \$60,000$. Participants were primarily non-Hispanic white (95%).

Researchers determined that five distinct clusters captured clinically meaningful beverage patterns better than any other number (i.e., 2–7) of clusters considered. The distinct beverage clusters were named by the authors for their dominant beverage (i.e., 100% juice, milk, water/SFB, and SSBs) or 'neutral' indicating a relatively neutral beverage distribution. Mean daily age 13–17 year intakes of beverages within each beverage cluster are presented in Table 1. Intakes of juice and water/SFB were similar between sexes; males reported higher milk and SSB intakes. Water alone constituted 86% of the water/SFB category, and soda pop alone constituted 43% of the SSB category.

Participant age at the 13 and 17 year dental exams did not differ among beverage clusters for all subjects, males or females (data not shown; $P > 0.19$), suggesting that age is not a confounder for beverage cluster-anthropometric analyses. The distribution of beverage cluster membership differed by sex (data not shown; $P < 0.001$) with a lower proportion of males in the juice and neutral clusters and a higher proportion of males in the milk and SSB clusters. The distribution of dietary clusters also differed by mother's education; participants with mothers having less than a 4 year degree were less likely to be in the juice cluster and more likely to be in the SSB cluster than participants whose mothers had a 4 year degree or more (data not shown; $P < 0.001$). Cluster membership did not differ by income.

Age 17 anthropometric measures according to beverage cluster membership are presented in Table 2. Mother's education was not associated with either weight or height; however, participants whose mothers had less than a 4 year degree had higher BMIs than children whose mothers had a 4 year degree or more (data not shown; $P = 0.040$). Participants with family incomes $< \$60,000$ trended heavier (data not shown; $P = 0.060$), were shorter (data not

shown; $P=0.023$) and had higher BMIs (data not shown; $P<0.001$) than participants with family incomes \$60,000 and above.

The multivariable regression models used to predict anthropometric measurements for all subjects from sex-specific beverage cluster, mother's education and income are presented in Table 3. Adjusted pairwise differences in anthropometric measures between beverage clusters are presented in Table 4, with comparisons for weight and height stratified by sex.

Income and female-specific beverage cluster were significant predictors of weight (Table 3). Those whose parents made < \$60,000 weighed on average 5.2 kg more than those whose parents made \$60,000 or more. The mean differences between clusters in Table 4 are interpreted as how much the mean for the cluster in the first column changes from the clusters in the next columns within the same row. Both males and females in the juice cluster trended toward lower weights than males and females in the milk cluster, and weighed significantly less than males and females in the water and SSB clusters. Females in the neutral cluster weighed less than females in the water and SSB clusters.

Income, male-specific beverage cluster and female-specific beverage cluster trended as predictors of height (Table 3). Those whose parents made < \$60,000 trended 1.5 cm shorter than those whose parents made \$60,000 or more. Males in the milk category trended taller (4.2 cm; $P=0.052$; Table 4) than males in the juice cluster, while males in the neutral cluster were shorter than males in the milk and water clusters and trended shorter than those in the SSB cluster. Females in the neutral cluster trended shorter than females in the juice cluster, and were shorter than females in the milk and SSB clusters.

Income and female-specific beverage cluster were significant predictors of BMI (Table 3). Mean BMIs of participants whose parents made < \$60,000 were 2.0 units higher than mean BMIs of those whose parents made \$60,000 or more. Mean BMIs of participants in the milk, water, neutral and SSB clusters were 2.4, 3.5, 2.2 and 3.1 units higher (all $P<0.05$) than mean BMIs of participants in the juice cluster (Table 4). Beverage clusters were also predictive of BMIs categorized as underweight/normal, overweight or obese (data not shown; $P=0.014$). Participants in the juice cluster were more likely to be categorized as underweight/normal (83%) than participants in the milk (73%), water (51%), neutral (67%) and SSB (67%) clusters.

Associations between children's beverage cluster membership and their mother's anthropometric measures from the age 5 dental exam were investigated (data not shown). Beverage clusters were not associated with either weights or heights, but were associated with mother's BMI ($P=0.039$). Mothers of juice cluster members had higher mean BMIs than mothers of members of the milk (3.1 units; $P=0.033$), water (3.8 units; $P=0.022$), and SSB (4.1 units, $P=0.010$) clusters.

Discussion

Five beverage clusters consistent with either higher 100% juice, water/SFB, milk, or SSB intakes or a neutral intake pattern were identified from age 13–17 beverage intakes of IFS participants. Mean weights and heights for both male and female IFS participants were

within normal limits, while the mean BMIs were high. Weight, height and BMI measurements differed among beverage clusters; beverage cluster differences were not consistent between sexes. Beverage cluster membership and anthropometric measures also differed by socioeconomic status.

Dietary energy and nutrient intakes are impacted by beverage choices. Energy dense beverages displace nutrient dense foods; milk is the primary source of dietary calcium and vitamin D; and 100% juice is an important source of vitamin C.^{17,25–27} Energy and nutrient intakes of IFS participants from beverages are expected to differ according to beverage cluster membership. Estimated mean daily energy intake from beverages was higher for 100% juice (415 kcal), milk (560 kcal) and SSB (470 kcal) cluster members than for water (315 kcal) and neutral (250 kcal) cluster members. Only members of the milk cluster's mean milk consumption met the recommended 3 cups of milk/day,²⁸ and the mean intake of all participants was approximately half this recommendation. While food sources high in calcium and/or vitamin D could replace dietary milk, it is likely that many participants had inadequate calcium and vitamin D intakes. SSBs contain added sugar and few, if any, other nutrients; intakes of SSB exceeded sugared beverage intake recommendations, particularly for members of the SSB cluster.²⁸ Of interest, members of the neutral cluster consumed less, while members of the water/SFB cluster consumed more, total fluid than other groups.

Point-in-time weight measurements in and of themselves are not particularly useful measures as weight is expected to vary by height. Regardless, the magnitude of the weight differences observed among beverage clusters was surprising. Both male and female 100% juice clusters had clinically meaningful lower weights than the water and SSB clusters and they trended lower than the milk cluster. While SSBs are associated with obesity,^{4–9,12–16} neither male nor female SSB cluster weights differed significantly from milk or water cluster weights. Differences in estimated energy intakes from beverages suggest that beverage intakes are not solely responsible for the observed weight differences among beverage clusters. Beverage cluster membership might reflect differences in food choices and meal pattern behaviors that could impact weight; however, we did not investigate food intakes or behaviors.

The differences in height observed by income and beverage cluster membership were completely unexpected. Overall, participant heights are normal according to United States (U.S.) standards;²¹ and we were unable to locate contemporary studies in adolescents reporting associations between food or beverage intakes and height for comparison. The population has a relatively high income by U.S. standards and both grocery stores and supermarkets are abundant in eastern Iowa; thus, access to adequate food supplies has not previously been considered a concern by investigators for the study sample. While clinically meaningful differences in heights were noted among clusters, the cluster differences were not consistent by sex. Males in the neutral clusters were shorter than those in the milk and water clusters. Energy, calcium and vitamin D intakes from beverages of male neutral cluster members were lower than intakes of milk cluster members. Females in the neutral cluster were shorter than those in the milk and SSB clusters; female neutral cluster members had lower beverage energy intakes than milk and SSB cluster members and lower beverage calcium and vitamin D intakes than milk cluster members. Of interest, members of the

neutral cluster had meaningfully lower total beverage intakes than all other groups, although the relevance of the limited intake is unknown. Black et al reported that 3–11 year old New Zealand children who avoided cows' milk were shorter than their peers,²⁹ and Okada reported that 9 year old Japanese children with low milk intakes had lower height velocities than their peers in subsequent years.³⁰ Our neutral cluster had lower milk intakes than the milk cluster; however, the neutral cluster's milk intake did not differ from other clusters suggesting that milk intakes are not solely responsible for observed height differences. The clinical relevance of being shorter is not clear; however, linear growth failure is associated with cognitive impairments, increased susceptibility to infection and increased risk of chronic disease.³¹

Differences observed in BMI by income and beverage cluster membership are consistent with previous reports in the literature.^{5,16,31} Multiple investigators have reported that individuals with lower incomes have difficulty accessing adequate and appropriate food stuff leading to greater consumption of highly processed energy dense foods.^{33,34} Both male and female 100% juice clusters had mean BMIs within the normal adult range (19–25), while BMIs of other clusters bordered the upper limit of normal.²¹ Members of the water/SFB cluster were more likely to be overweight or obese than other participants; however, they also consumed less energy from beverages. These results suggest that water/SFB members might select water/SFB in response to weight concerns and/or consume more energy dense foods. Our results are consistent with LaRowe et al's observations in 6–11 year old children; a higher percentage of children in their water (42.6%), soda (35.5%) and sweetened drinks (35.4%) clusters were heavier than those in the light drinker (28.0%) and high fat milk (22.1%) clusters.¹⁶

Both genetics and environment are associated with achieving one's growth potential as well as development of obesity. Mothers' weights and heights did not differ according to their children's beverage clusters suggesting that the observed differences in weights and heights among clusters was not due to genetic factors. Mothers of juice cluster members had higher BMIs than mothers of all other clusters; this finding is not consistent with a strong genetic influence, but rather suggests that environmental measures are primarily at play.

The associations among beverage clusters and anthropometric measures reported herein are clinically meaningful, yet perplexing. While energy and nutrient intakes can be estimated for beverage clusters, beverages are the liquid component of the diet — foods are expected to contribute the majority of energy and nutrient intakes. Beverage choices might be characteristic of overall dietary behaviors; if the overall dietary behaviors result in different energy and nutrient profiles, they could be responsible for differences in growth measures and obesity outcomes. Our data — particularly the differences in heights observed between beverage clusters — begs the question, “are there subpopulations in the U.S. who do not receive adequate nutrition to achieve their expected growth potential?” In underdeveloped countries, stunting with subsequent obesity has been reported in children who lack access to healthy food.³⁵ Our population is relatively well educated and reasonably wealthy; thus, one might speculate that nutrition literacy — that is, an awareness of proper food and nutrition — could be responsible for differences in height and subsequent obesity rather than limited access to healthy food.

Several limitations must be considered when interpreting our results. The analyses were cross-sectional; associations observed between beverage clusters and anthropometric measures should not be considered causal. Anthropometric measures were reported for one point in time; we do not know if the observed height reductions reflect an insult during early childhood or chronic insults throughout life. Furthermore, to the best of our knowledge, associations between height and diet have not been reported recently for healthy adolescents in the U.S. Thus, the height results should be interpreted with caution until reproduced in other U.S. populations. While the height results should be interpreted with caution, they must not be ignored — a subgroup of U.S. adolescents stunted because of poor dietary behaviors would present a public health nutrition issue that must be addressed. We reported BMIs; high BMIs are consistent with high percent body fats, but BMI does not measure body composition or body fat percentage. Beverage intakes were self-reported and might not reflect actual intakes. The sample size is small and the sample is self-selected. The IFS population is mostly from rural or smaller cities, white, reasonably well-educated and reasonably wealthy, and is not representative of other U.S. or international adolescent populations. In addition to the limitations, the IFS has several strengths. The cohort is loyal, having participated in the study for approximately 20 years. Beverage intakes were queried at multiple time points during adolescence, which provides a better estimate of actual intake than a single measure.

Conclusions

The results suggest that patterns of beverage intakes are associated with anthropometric measures and BMI in adolescents. While energy and nutrient intakes from the beverages might impact anthropometric measures and/or BMI directly, it is more reasonable that the beverage patterns characterize overall dietary behaviors that influence growth. Of concern, clinically meaningful differences in heights were associated with beverage patterns; other investigators are encouraged to evaluate and report height and weight measures in addition to BMI when investigating diet and/or nutrition in children and adolescents. Additional research to understand relationships among beverage patterns and overall dietary quality, associations among growth potential and diet quality in U.S. children, and the growth trajectories of children in contemporary society is warranted.

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References

1. Jovic D, Marinkovic J, Vukovic D. Association between body mass index and prevalence of multimorbidity: a cross-sectional study. *Public Health*. 2016; doi: 10.1016/j.puhe.2016.04.014

2. Han TS, Lean ME. A clinical perspective of obesity, metabolic syndrome and cardiovascular disease. *JRSM Cardiovasc Dis.* 2015; 5:1–5.
3. Ogden CL, Carroll MD, Lawman HG, Fryar CD, Kruzon-Moran D, Kit BK, Flegal KM. Trends in obesity prevalence among children and adolescents in the United States, 1988–1994 through 2013–14. *JAMA.* 2016; 315(21):2292–2299. [PubMed: 27272581]
4. Torre SBD, Keller A, Depeyre JL, Kruseman M. Sugar-sweetened beverages and obesity risk in children and adolescents: a systematic analyses on how methodological quality may influence results. *J Acad Nutr Diet.* 2016; 116:638–659. [PubMed: 26194333]
5. Scharf RJ, DeBoer MD. Sugar-sweetened beverages and children's health. *Annu Rev Public Health.* 2016; 37:273–293. [PubMed: 26989829]
6. Marshall TA, Eichenberger-Gilmore JM, Broffitt BA, Warren JJ, Levy SM. Dental caries and childhood obesity: roles of diet and socioeconomic status. *Community Dent Oral Epidemiol.* 2007; 35:449–458. [PubMed: 18039286]
7. Leermakers ETM, Felix JF, Erler NS, et al. Sugar-containing beverage intake in toddlers and body composition up to age 6 years: the Generation R Study. *Eur J Clin Nutr.* 2015; 69:314–321. [PubMed: 25649238]
8. Pan L, Li R, Park S, Galuska DA, Sherry B, Freedman DS. A longitudinal analyses of sugar-sweetened beverage intake in infancy and obesity at 6 years. *Pediatrics.* 2014; 134:S29–S35. [PubMed: 25183752]
9. Ebbeling CB, Feldman HA, Chomitz VR, Antonelli TA, Gortmaker SL, Osganian SK, Ludwig DS. A Randomized trial of sugar-sweetened beverages and adolescent body weight. *N Engl J Med.* 2012; 367:1407–1416. [PubMed: 22998339]
10. Cassady BA, Considine RV, Mattes RD. Beverage consumption, appetite, and energy intake: what did you expect? *Am J Clin Nutr.* 2012; 95(3):587–593. [PubMed: 22258267]
11. McCrickerd K, Chambers L, Yeomans MR. Fluid of fuel? The context of consuming a beverage is important for satiety. *PLoS One.* 2014 Jun 19;9(6):e.100406. doi: 10.1371.
12. Deboer MS, Scharf RJ, Demmer RT. Sugar-sweetened beverages and weight gain in 2-to5-year-old children. *Pediatrics.* 2013; 132(3):413–420. [PubMed: 23918897]
13. Vanselow MS, Pereira MA, Newmark-Sztainer DN, Raatz SK. Adolescent beverage habits and changes in weight over time: findings from Project EAT. *Am J Clin Nutr.* 2009; 90:1489–1495. [PubMed: 19864412]
14. Dennison BA, Rockwell HL, Nichols MJ, Jenkins P. Children's growth parameters vary by type of fruit juice consumed. *J Am Coll Nutr.* 1999; 4:346–352.
15. Keller A, Torre SBD. Sugar-sweetened beverages and obesity among children and adolescents: a review of systematic literature reviews. *Child Obes.* 2015; 11:338–346. [PubMed: 26258560]
16. LaRowe TL, Moeller SM, Adams AK. Beverage patterns, diet quality and body mass index of US preschool and school-aged children. *J Am Diet Assoc.* 207(107):1124–1133.
17. Marshall TA, Eichenberger Gilmore JM, Broffitt B, Stumbo PJ, Levy SM. Diet quality in young children is influenced by beverage consumption. *J Am Coll Nutr.* 2005; 24:65–75. [PubMed: 15670987]
18. Marshall TA, Eichenberger Gilmore JM, Broffitt B, Stumbo PH, Levy SM. Relative validity of the Iowa Fluoride Study targeted nutrient semi-quantitative questionnaire and the Block Kids' Food Questionnaire for estimating beverage, calcium and vitamin D intakes by children. *J Am Diet Assoc.* 2008; 108(3):465–472. [PubMed: 18313429]
19. Warren JJ, Levy SA, Kanellis MJ. Dental caries in the primary dentition: Assessing prevalence of cavitated and noncavitated lesions. *J Public Health Dent.* 2002; 62(2):109–114. [PubMed: 11989205]
20. Janz KF, Gilmore JM, Burns TL, Levy SM, Torner JC, Willing MC, Marshall TA. Physical activity augments bone mineral accrual in young children: The Iowa Bone Development study. *J Pediatr.* 2006; 148(6):793–799. [PubMed: 16769389]
21. Centers for Disease Control and Prevention Overweight and Obesity. US Department of Health and Human Services. Available at: <http://www.cdc.gov/obesity/index.html>. Accessed 8/19/16
22. SAS [statistical analyses software]. Version 9.4. SAS Institute Inc; Cary NC: 2013.

23. Ward J. Hierarchical grouping to optimize an objective function. *J Amer Statist Assoc.* 1963; 58(301):236–244.
24. R: A Language and Environment for Statistical Computing. Version R-3.0.2. R Foundation for Statistical Computing; Vienna Austria: 2013.
25. Ballew C, Kuester S, Gillespie C. Beverage choices affect adequacy of children's nutrient intakes. *Arch Pediatr Adolesc Med.* 2000; 154:1148–1152. [PubMed: 11074858]
26. Kranz S, Smiciklas-Wright H, Siega-Riz AM, Mitchell D. Adverse effect of high added sugar consumption on dietary intake in American preschoolers. *J Pediatr.* 2005; 146:105–111. [PubMed: 15644832]
27. Fulgoni IIVL, Quann EE. National trends in beverage consumption in children from birth to 5 years: analyses of NHANES across three decades. *Nutr J.* 2012; 11:92.doi: 10.1186/1475-2891-11-92 [PubMed: 23113956]
28. MyPlate. United States Department of Agriculture. <http://www.choosemyplate.gov/>. Accessed 6/1/16
29. Black RE, Williams SM, Jones IE, Goulding A. Children who avoid drinking cow milk have low dietary calcium intakes and poor bone health. *Am J Clin Nutr.* 2002; 76:675–680. [PubMed: 12198017]
30. Okada T. Effect of cow milk consumption on longitudinal height gain in children. *Am J Clin Nutr.* 2004; 80:1088–90. [PubMed: 15447933]
31. De Onis M, Branca F. Childhood stunting: a global perspective. *Matern Child Nutr.* 2016; 12(S1): 12–26. [PubMed: 27187907]
32. Ludwig DS, Peterson KE, Gortmaker SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analyses. *Lancet.* 2001; 357:505–508. [PubMed: 11229668]
33. Dhurandhar EJ. The food-insecurity obesity paradox: A resource scarcity hypothesis. *Physiol Behav.* 2016; 162:88–92. [PubMed: 27126969]
34. Spears KE, Fiese BH, STRONG Kids Research Team. The relationship between food insecurity and BMI for preschool children. *Matern Child Health J.* 2016; 20(4):925–933. [PubMed: 26662281]
35. Lobstein T, Jackson-Leach R, Moodie ML, et al. Child and adolescent obesity: part of a bigger picture. *Lancet.* 2014; 385:2510–2520.

Practice Implications

1. Physicians and dentists should monitor their pediatric patients' weight and height throughout childhood. Patients whose growth deviates from CDC growth charts should be referred to registered dietitians for dietary assessment.
2. Physicians and dentists should monitor their patients' beverage intakes and recommend reduction of high energy, low nutrient beverages. Inclusion of a registered dietitian as part of the health care team is encouraged to improve patient's overall diet quality.
3. Nutrition health literacy of allied health clinicians, school personnel and adolescents is encouraged to promote healthy nutrition and impact long term health.

Table 1

Distribution of age 13–17 daily beverage intakes^a by beverage cluster membership for 2 Iowa Fluoride Study participants.

Cluster	n	Beverage Intakes (oz)			
		100% Juice	Water & Sugar-free Beverages	Milk	All beverages
	All participants				
Juice	42	6.7 ± 2.3	18.3 ± 8.7	14.7 ± 5.1	6.8 ± 3.9
Milk	51	1.5 ± 1.9	17.2 ± 10.4	25.3 ± 8.3	12.3 ± 5.3
Water & Sugar-free Beverages	70	1.3 ± 1.1	37.5 ± 12.6	11.6 ± 7.4	9.6 ± 5.4
Neutral	101	1.3±1.1	13.9 ± 5.1	9.3 ± 5.4	6.9 ± 3.3
Sugar-Sweetened Beverages	105	2.4±2.6	18.5 ± 10.5	10.0 ± 7.7	22.3 ± 8.3
All subjects	369	2.2 ± 2.5	20.6 ± 12.7	12.8 ± 8.7	12.5 ± 8.7
	Males				
Juice	15	7.6 ± 2.1	13.7 ± 7.0	16.2 ± 5.6	7.4 ± 2.9
Milk	35	1.4 ± 1.7	18.1 ± 11.3	25.5 ± 8.8	12.5 ± 5.6
Water & Sugar-free Beverages	33	1.0 ± 1.1	37.3 ± 13.7	13.7 ± 7.7	10.9 ± 5.4
Neutral	30	1.3 ± 1.2	14.4 ± 4.7	11.5 ± 5.4	7.3 ± 3.1
Sugar-Sweetened Beverages	63	2.6 ± 2.6	19.5 ± 11.6	11.1 ± 8.6	23.8 ± 8.4
All subjects	176	2.3 ± 2.6	21.2 ± 13.4	14.9 ± 9.5	14.9 ± 9.3
	Females				
Juice	27	6.1 ± 2.3	20.8 ± 8.7	13.8 ± 8.6	6.5 ± 4.4
Milk	16	1.6 ± 2.3	15.3 ± 8.1	25.1 ± 7.3	11.8 ± 4.9
Water & Sugar-free Beverages	37	1.4 ± 1.1	37.6 ± 11.7	9.8 ± 6.7	8.3 ± 5.2
Neutral	71	1.3 ± 1.1	13.6 ± 5.3	8.4 ± 5.1	6.7 ± 3.4
Sugar-Sweetened Beverages	42	2.0 ± 2.5	17.0 ± 8.6	8.4 ± 5.7	20.0 ± 7.7
All subjects	193	2.2 ± 2.4	20.1 ± 12.1	10.8 ± 7.3	10.3 ± 7.4

^aOunces; mean ± standard deviation

Age 17 anthropometric measures^a by age 13–17 beverage cluster membership for Iowa Fluoride Study participants.**Table 2**

Cluster	Weight (kg)			Height (cm)			BMI		
	All Subjects (n = 369)	Males (n = 176)	Females (n = 193)	All Subjects (n = 369)	Males (n = 176)	Females (n = 193)	All Subjects (n = 369)	Males (n = 176)	Females (n = 193)
Juice	64.6 ± 12.5	70.5 ± 15.1	61.3 ± 9.6	171.2 ± 8.7	177.9 ± 8.0	167.5 ± 6.7	21.9 ± 2.9	22.1 ± 3.3	21.8 ± 2.8
Milk	77.7 ± 22.1	80.5 ± 19.5	71.4 ± 26.5	177.6 ± 9.6	181.8 ± 7.7	168.4 ± 6.6	24.5 ± 6.3	24.2 ± 5.0	25.1 ± 8.7
Water & Sugar-free Beverages	77.8 ± 19.3	83.7 ± 17.4	72.5 ± 19.5	172.6 ± 10.3	180.3 ± 8.2	165.8 ± 6.6	26.0 ± 5.6	26.0 ± 4.4	26.3 ± 6.5
Neutral	68.1 ± 18.7	79.1 ± 17.7	63.6 ± 17.3	167.8 ± 8.5	177.0 ± 7.1	164.0 ± 5.8	24.1 ± 6.2	25.2 ± 5.0	23.7 ± 6.6
Sugar-Sweetened Beverages	76.9 ± 19.6	80.7 ± 20.0	71.3 ± 17.8	174.4 ± 9.5	179.3 ± 7.0	167.2 ± 8.0	25.2 ± 5.9	25.0 ± 5.8	25.5 ± 6.1
All subjects	73.4 ± 19.6	80.1 ± 18.8	66.3 ± 18.3	172.4 ± 9.8	179.5 ± 7.6	165.9 ± 6.8	24.6 ± 5.8	24.8 ± 5.1	24.4 ± 6.4

^aMean + standard deviation

Table 3

Models predicting age 17 anthropometric measures from age 13–17 beverage clusters for Iowa Fluoride Study participants.

Variable	Category	Weight (kg) ^a		Height (cm) ^b		BMI ^d	
		$\hat{\beta}(SD)^c$	P-value	$\hat{\beta}(SD)^c$	P-value	$\hat{\beta}(SD)^c$	P-value
Beverage Cluster Males	Juice	-10.2±4.9		-2.6±2.0		-2.6±1.4	
	Milk	-1.1±4.0		1.6±1.5		-0.8±1.1	
	Water/SFB ^d	2.6±4.2	0.250	0.8±1.5	0.060	0.4±1.2	0.331
	Neutral SSBs ^e (Reference)	-2.1±4.2		-2.9±1.6		0.2±1.2	
Beverage Cluster Females	Juice	-9.7±4.0		0.2±0.8		-3.5±1.3	
	Milk	-0.4±5.0		1.2±2.1		-0.5±1.6	
	Water/SFB ^d	0.3±3.9	0.011	-1.5±1.6	0.081	0.5±1.3	0.016
	Neutral SSBs ^e (Reference)	-7.7±3.3		-2.9±1.4		-1.8±1.1	
Mother's Education	< 4 Year Degree						
	4 Year Degree or More (Reference)	-0.2±1.9	0.912	-1.1±0.8	0.162	0.3±0.6	0.632
Income	<\$60k per year						
	\$60k or more per year (Reference)	5.2±2.1	0.013	-1.5±0.8	0.070	2.0±0.7	0.002

^aGamma multivariable regression was used.

^bNormal multivariable regression was used.

^cThe parameter values in each cell can be interpreted as the mean change in weight, height, or BMI when the explanatory variable changes from its reference value to the level of interest, assuming the values of all other variables are held constant.

^dWater & Sugar-free Beverages

^eSugar Sweetened Beverages

Age 17 adjusted pairwise mean comparisons^{a,b} between age 13–17 dietary clusters for weight, height and BMI for Iowa Fluoride Study participants.

	Weight (kg) ^c									
	Males					Females				
Cluster	Juice	Milk	Water/SFB ^d	Neutral	SSBs ^e	Juice	Milk	Water/SFB	Neutral	SSBs
Juice	---	-9.1 0.086	-12.8 0.019	-8.0 0.139	-10.2 0.038	---	-9.4 0.065	-10.0 0.011	-2.0 0.546	-9.7 0.014
Milk		---	-3.7 0.428	1.1 0.821	-1.1 0.789		---	-0.7 0.894	7.4 0.108	-0.4 0.942
Water/SFB			---	4.8 0.328	2.6 0.533			---	8.0 0.015	0.3 0.936
Neutral				---	-2.1 0.616				---	-7.7 0.018
SSBs					---					---
	Height (cm) ^f									
	Males					Females				
Cluster	Juice	Milk	Water/SFB	Neutral	SSBs	Juice	Milk	Water/SFB	Neutral	SSBs
Juice	---	-4.2 0.052	-3.4 0.118	0.4 0.873	-2.6 0.201	---	-1.1 0.629	1.6 0.363	3.1 0.053	0.2 0.929
Milk		---	0.8 0.652	4.5 0.010	1.6 0.288		---	2.7 0.201	4.2 0.034	1.2 0.556
Water/SFB			---	3.7 0.035	0.8 0.590			---	1.5 0.300	-1.5 0.362
Neutral				---	-2.9 0.065				---	-2.9 0.036
SSBs					---					---
	BMI ^b									
	All Subjects									
Cluster	Juice	Milk	Water/SFB	Neutral	SSBs					
Juice	---	-2.4 0.034	-3.5 <0.001	-2.2 0.021	-3.1 0.002					
Milk		---	-1.2 0.260	0.1 0.885	-0.7 0.482					
Water			---	1.3 0.136	0.5 0.579					
Neutral				---	-0.8 0.308					
SSBs					---					

In each cell, the mean difference between clusters is reported in addition to the P -value. The differences are interpreted as how much the mean for the cluster in the column differs from the cluster in the row. For example, in the male's weight portion, the average difference between the Juice cluster and Milk cluster is -9.1 kg, which means that members of the Juice cluster on average weigh 9.1 kg less than members of the Milk cluster; the difference is not statistically significant ($p=0.086$).

^b P -values were not adjusted for multiple comparisons.

^c Gamma multivariable regression was used.

^d Water & Sugar-free beverages

^e Sugar Sweetened Beverages

^f Normal multivariable regression was used.