Obesity

Juice and Water Intake in Infancy and Later Beverage Intake and Adiposity: Could Juice be a Gateway Drink?

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Objectives: To examine the tracking and significance of beverage consumption in infancy and childhood.
Methods: Among 1163 children in Project Viva, we examined associations of fruit juice and water intake at 1 year (0 oz, 1-7 oz [small], 8-15 oz [medium], and ≥16 oz [large]) with juice and sugar-sweetened beverage (SSB) intake and BMI *z*-score during early (median 3.1 years) and mid-childhood (median 7.7 years).
Results: In covariate adjusted models, juice intake at 1 year was associated with greater juice and SSB intake during early and mid-childhood and also greater adiposity. Children who drank medium and large amounts of juice at 1 year had higher BMI *z*-scores during both early (medium: $\beta = 0.16$ [95% CI = 0.01-0.32]; large: $\beta = 0.28$ [95% CI = 0.01-0.56]) and mid-childhood (medium: $\beta = 0.23$ [95% CI = 0.07-0.39]; large: $\beta = 0.36$ [95% CI = 0.08-0.64]). After covariate adjustment, associations between water intake at 1 year and beverage intake and adiposity later in childhood were null.
Conclusions: Higher juice intake at 1 year was associated with higher juice intake, SSB intake, and BMI *z*-score during early and mid-childhood. Assessing juice intake during infancy could provide clinicians with important data regarding future unhealthy beverage habits and excess adiposity during childhood.

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Introduction

Sugar-sweetened beverage (SSB) consumption is associated with excess caloric intake, weight gain, and obesity (1-3), in addition to tooth decay (4) and other health problems related to the caffeine found in some soft drinks such as anxiety and poor sleep quality (5). Like SSBs, juice is a calorie-containing beverage that is often introduced during infancy (6), but patterns of intake of juice and SSBs differ throughout childhood. Caloric intake from juice among children in the United States decreases among school-aged children and then remains stable through adolescence (69 kcal/day among children ages 2-5 years, 41 kcal/day among children aged 6-11 years, 43 kcal/day among youth aged 12-19 years) (7). Conversely, SSB intake increases from early childhood through adolescence (124 kcal/day among children ages 2-5 years, 184 kcal/day among children aged 6-11 years, 301 kcal/day among youth aged 12-19 years) (7).

The relationship between SSBs or juice and weight in preschool aged children is inconsistent across studies (8-12). Although there is emerging consensus regarding the link between SSB consumption and weight gain later in childhood and adolescence (13), studies of juice intake and weight status have been null (14,15). The lack of consistent evidence linking juice intake to weight status does not preclude a role of early beverage consumption on later obesity. If juice consumption at young ages is associated with greater consumption of sweetened beverages at later ages, potentially through its impact on taste preferences (16), it could be thought of as a "gateway behavior" and, thus, a target for obesity prevention. Water may be another beverage with important applications to obesity prevention. Substituting water for juice or SSBs has been linked to lower total energy intake (1,17) developing a preference for drinking water during infancy could lead to lower SSB and juice consumption during childhood and may protect against excess weight gain.

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We identified no long-term prospective studies that have assessed whether juice or water consumption during infancy is associated with later caloric beverage intake or BMI. The aims of the present study were to examine the tracking and significance of beverage consumption in infancy and childhood. Specifically, we sought to determine the extent to which (1) juice intake at 1 year is associated with increased juice intake, SSB intake, or BMI *z*-score in early and mid-childhood, and (2) water intake at 1 year is associated with decreased juice intake, SSB intake, or BMI *z*-score in early and mid-childhood. We hypothesized that juice intake, but not water intake, at 1 year would be positively associated with juice intake, SSB intake, and BMI *z*-score in early and mid-childhood.

Methods

Study subjects were participants in Project Viva, a prospective cohort study of pre- and peri-natal factors, pregnancy outcomes, and offspring health. Details of study design and recruitment are reported elsewhere (18). Participants were recruited at their initial prenatal visit from eight urban and suburban obstetric offices of Harvard Vanguard Medical Associates in Massachusetts between 1999 and 2002. Of the 2128 mother-infant pairs who were initially enrolled, our sample includes 1163 participants who had in-person visits during early (median age 3.1 years) and mid-childhood (median age 7.7 years). The study was approved by the Institutional Review Board of Harvard Pilgrim Health Care.

At 1 year postpartum, mothers completed questionnaires that included questions about their child's beverage intake. The main exposures at 1 year of age were: (1) juice intake assessed using the question, "In the past month, how many ounces of fruit juice did your baby drink in an average day?" and (2) water intake assessed using the question, "In the past month, how many ounces of water did your baby drink in an average day?"; response options for both questions were: none, less than 8 ounces, 8-15 ounces, 16-31 ounces, and 32 ounces or more. Because intakes of juice or water above 16 ounces were uncommon, we combined the top two categories for analysis thus creating four categories of intake: 0 ounces, 1-7 ounces (small), 8-15 ounces (medium), and $\geq$16 ounces (large).

During early and mid-childhood, we conducted in-person study visits with both mothers and children. Our main outcomes were servings/day of fruit juice, servings/day of SSBs (soda and fruit drinks), and BMI *z*-scores during early and mid-childhood. We used a semi-quantitative child food frequency questionnaire previously validated among preschool-aged children at both study visits to assess soda and fruit drink intake (19). To assess juice intake, parents were asked to indicate the frequency with which their child drank orange juice and other 100% juice in two separate questions and were given the response options of: never, less than once per week, once per week, two to four times per week, nearly daily or daily, two to four times per day, and five or more times per day. To assess SSB intake, parents were asked to indicate the frequency with which their child drank soda and fruit drinks in two separate questions and were given the response options of: never, less than once per week, once per week, two to four times per week, nearly daily or daily, two to four times per day, and five or more times per day. In analyses, we assigned 0 servings per day for the "never" response, 0.5/7 servings per day for the "less than once per week" response, 1/7 servings per day for the "once per week" response, 3/7 servings per day for the "two to four times per week" response, 1 serving per day for the "nearly daily or daily" response, three servings per day for the "two to four times per day" response, and five for the "five or more times per day" response.

We measured height and weight of children at the early and mid-childhood visits using a calibrated stadiometer (Shorr Productions, Olney, MD) and scale (Seca model 881, Seca Corporation, Hanover, MD). We calculated age- and sex-specific *z*-scores using US reference growth data (20). Research assistants performing all measurements followed standardized techniques (21), and participated in in-service training to ensure measurement validity (Shorr Productions). Inter- and intra-rater measurement error were well within published reference ranges for all measurements (22).

We obtained sociodemographic data and other participant characteristics from study visit interviews, self-administered questionnaires completed at study visits, and through mailed yearly self-administered questionnaires. Mothers reported information about maternal age, height, prepregnancy weight, race/ethnicity, education (some college or less, college graduate or more), annual household income (<\$70,000, $\geq$\$70,000, missing), and duration of breastfeeding. We obtained 1-year weight and length from medical records and calculated age- and sex-specific weight-for-length (WFL) *z*-scores (20). In a previous measurement validation study among children aged 0-24 months (23), we found that clinical staff systematically overestimated children's length compared with a reference method. Thus, we used a regression correction factor to adjust for the overestimation ([clinical length in cm $\times$0.953] + 1.88 cm).

We used Poisson regression to examine the independent associations of intake of juice and water at 1 year with later juice intake and SSB intake. Model fit was assessed by estimating the quotient of the deviance to the degrees of freedom, which were near 1 for all Poisson models. We report exponentiated Poisson regression coefficients which can be interpreted as incidence rate ratios. We used linear regression to examine the independent associations of intake of juice and water at 1 year with BMI *z*-scores and report β coefficients. Fully adjusted models controlled for maternal age, education, prepregnancy BMI, household income and child age, sex, race/ethnicity and WFL *z*-score at 1 year. Although WLF *z*-score may be considered a crude proxy for caloric intake, we ran additional models additionally adjusted for calorie intake at 3 years estimated from the semi-quantitative child food frequency questionnaire (19) using the Harvard nutrient composition database used for the Nurses' Health Study and other large cohort studies. We tested the significance of juice and water intake using 3DF tests of the four-category variables.

To address missing data, we used chained equations to multiply impute values (24-26). We generated 50 imputed data sets, as is done for other Project Viva analyses using multiple imputation, and combined them in the reported results (27). We used all 2128 Project Viva subjects in the imputation process (25), but the analysis sample included only the 1163 participants with 1 year questionnaires and early or mid-childhood in-person visits. Details about variable missingness prior to imputation are included in Supporting Information Table S1. Caloric intake at 3 years was not imputed and therefore not in the imputed data set. Analyses adjusted for caloric intake include 1038 of the 1163 participants with available data for caloric intake. We conducted all of the analyses using SAS version 9.3 (SAS Institute, Cary, North Carolina).

TABLE 1 Participant characteristics, overall and by category of juice intake at 1 year

		Juice at 1 year				
	Overall $n = 1163$	None $n = 262$ (22.6%)	Small (1-7 oz/day) $n = 619$ (53.2%)	Medium (8-15 oz/day) $n = 235$ (20.2%)	Large (≥16 oz/day) $n = 47$ (4.0%)	
	Mean (SD)/%					*P*-value
Mother/family						
Prepregnancy BMI (kg/m^2)	24.5 (5.0)	23.7 (4.4)	24.3 (4.8)	25.5 (5.5)	26.7 (7.4)	<0.001
Maternal age (years)	32.4 (4.9)	33.9 (4.0)	32.6 (4.6)	30.9 (5.8)	28.5 (6.9)	<0.001
Breastfeeding duration (mos)	6.4 (4.5)	7.9 (4.4)	6.5 (4.5)	5.0 (4.3)	4.7 (4.6)	<0.001
Maternal education						<0.001
<College graduate	27.3%	11.8%	23.1%	47.1%	69.7%	
≥College graduate	72.7%	88.2%	76.9%	52.9%	30.3%	
Household income						<0.001
<$70,000/year	34.9%	19.8%	30.1%	58.5%	65.9%	
≥$70,000/year	65.1%	80.2%	69.9%	41.5%	34.1%	
Child						
Female	49.8%	53.0%	49.2%	46.5%	55.4%	0.45
Child race/ethnicity						<0.001
White	70.3%	84.3%	71.8%	59.4%	28.3%	
Black	11.7%	1.6%	9.6%	21.8%	45.1%	
Hispanic	3.7%	1.2%	3.2%	6.2%	11.1%	
Asian	3.1%	5.1%	3.0%	0.9%	4.3%	
Other	11.2%	7.8%	12.4%	11.7%	11.2%	
Weight-for-length *z*-score at 1 year	0.33 (1.06)	0.25 (1.11)	0.37 (1.07)	0.33 (1.05)	0.26 (1.16)	0.52
Water intake at 1 year						<0.001
None	6.1%	11.3%	3.9%	5.4%	8.8%	
1-7 oz/day	48.1%	46.7%	53.9%	37.3%	33.8%	
8-15 oz/day	38.1%	34.2%	36.6%	46.8%	35.5%	
≥16 oz/day	7.7%	7.8%	5.5%	10.5%	21.9%	
Early childhood						
Age (mos)	39.0 (3.8)	38.5 (3.1)	39.0 (3.8)	39.3 (4.3)	40.6 (6.8)	0.01
SSB (servings/day)	0.2 (0.6)	0.1 (0.4)	0.2 (0.5)	0.4 (0.6)	0.9 (1.3)	<0.001
Juice (servings/day)	1.8 (1.5)	1.2 (1.2)	1.9 (1.5)	2.2 (1.6)	2.4 (2.3)	<0.001
BMI (kg/m^2)	16.5 (1.5)	16.3 (1.3)	16.5 (1.4)	16.8 (1.8)	17.0 (2.2)	0.001
BMI *z*-score	0.47 (1.03)	0.34 (0.95)	0.44 (1.02)	0.61 (1.07)	0.75 (1.29)	0.01
Mid-childhood						
Age (mos)	94.7 (10.6)	94.0 (10.8)	94.5 (10.2)	95.2 (11.0)	99.0 (11.9)	0.02
SSB (servings/day)	0.3 (0.6)	0.2 (0.5)	0.3 (0.6)	0.4 (0.7)	0.9 (1.2)	<0.001
Juice (servings/day)	1.0 (1.2)	0.7 (0.9)	1.1 (1.1)	1.3 (1.4)	1.2 (1.1)	<0.001
Water (servings/day)	2.6 (1.6)	3.0 (1.6)	2.5 (1.6)	2.4 (1.7)	2.0 (1.8)	<0.001
BMI (kg/m^2)	17.1 (3.0)	16.5 (2.4)	16.9 (2.7)	17.7 (3.6)	19.1 (4.5)	<0.001
BMI *z*-score	0.36 (0.98)	0.16 (0.96)	0.34 (0.96)	0.57 (1.02)	0.82 (1.12)	<0.001

Results

Participant characteristics are found in Table 1. At 1 year of age, 22.6% drank no juice, 53.2% drank a small amount of juice, 20.2% drank a medium amount of juice, and 4.0% drank a large amount of juice. Children who drank a large amount of juice at 1 year had shorter mean [SD] breastfeeding duration than children who drank no juice (4.7 [4.6] months vs. 7.9 [4.4] months, $P < 0.001$). Mothers of children who drank a large amount of juice at 1 year had a higher mean BMI and were younger than mothers of children who drank no juice (26.7 [7.4] kg/m^2 vs. 23.7 [4.4] kg/m^2, $P < 0.001$; 28.5 [6.9] years vs. 33.9 [4.0] years, $P < 0.001$). Differences in juice intake were seen according to race/ethnicity ($P < 0.001$). Specifically, white (27.0%) and Asian (36.9%) youth were more likely to consume no juice at 1 year than black (3.1%) or Hispanic (7.2%) youth; whereas black (53.1%) and Hispanic (42.2%) youth were more likely to drink a medium or large amount of juice at 1 year when compared with white (18.6%) and Asian (11.7%) children. Differences in maternal education ($P < 0.001$) and household income ($P < 0.001$) were also seen between children according to juice intake categories. Children who were in the highest category of juice intake (≥16 ounces/large) at 1 year were the most likely to also be in the highest category of water intake (≥16 ounces/large) at 1 year, although juice intake was not associated with WFL z-score at 1 year ($P = 0.52$). On average, children who consumed large amounts of juice at 1 year consumed twice as much juice per day during early childhood (2.4 servings vs. 1.2 servings) compared to children who consumed no juice at 1 year.

Associations of beverage intake at 1 year with juice intake, SSB intake, and BMI z-score during early childhood are shown in Table 2. In the fully adjusted Poisson model, juice intake at 1 year was significantly associated ($P < 0.001$) with juice intake at early childhood, with higher juice intake observed among children consuming juice at 1 year (small: RR = 1.52 [95% CI = 1.34-1.73]; medium: RR = 1.73 [95% CI = 1.48-2.03]; large: RR = 1.92 [95% CI = 1.49-2.48]) compared to children who drank no juice at 1 year (fully adjusted model 2a). Although overall SSB intake at early childhood was low (0.2 servings/day), juice intake at 1 year was significantly associated with SSB intake at early childhood ($P < 0.001$), with a higher SSB consumption during early childhood observed among children who drank juice at 1 year (small: RR = 1.38 [95% CI = 0.91-2.10]; medium: RR = 2.01 [95% CI = 1.27-3.22]; large: RR = 3.74 [95% CI = 2.14-6.55]) when compared with children who drank no juice at 1 year (fully adjusted model 2a).

Associations of beverage intake at 1 year with juice intake, SSB intake, and BMI z-score during mid-childhood are also shown in Table 2. Juice intake at 1 year was significantly associated with both juice intake ($P = 0.0002$) and SSB intake ($P < 0.0001$) at mid-childhood, with higher juice intake (small: RR = 1.39 [95% CI = 1.16-1.65]; medium: RR = 1.58 [95% CI = 1.28-1.95]; large: RR = 1.48 [95% CI = 1.05-2.08]) and SSB intake (small: RR = 1.51 [95% CI = 1.07-2.12]; medium: RR = 1.77 [95% CI = 1.20-2.61]; large: RR = 3.29 [95% CI = 1.99-5.37]) among all three categories of juice intake at 1 year compared to children who drank no juice at 1 year (fully adjusted model 2a).

As shown in Table 2, juice intake at 1 year was significantly associated with BMI z-score at both early ($P = 0.04$) and mid-childhood ($P = 0.01$). Children who drank medium or large amounts of juice at 1 year had a higher BMI z-score during both early childhood (small: $\beta = 0.01$ [95% CI = -0.11-0.14]; medium: $\beta = 0.16$ [95% CI = 0.01-0.32]; large: $\beta = 0.28$ [95% CI = 0.01-0.56]) and mid-childhood (small: $\beta = 0.08$ [95% CI = -0.05-0.20]; medium: $\beta = 0.23$ [95% CI = 0.07-0.39]; large: $\beta = 0.36$ [95% CI = 0.08-0.64]) when compared with those who drank no juice at 1 year (fully adjusted model 2a). In stepwise models, the addition of child race/ethnicity led to the largest attenuation in the relationship between juice intake at 1 year and later SSB intake and BMI z-score.

As shown in Table 2, water intake at 1 year was not associated with intake of other beverages during early and mid-childhood. Water intake at 1 year was associated with a higher BMI z-score during early and mid-childhood in unadjusted models. After adjustment for age, education, prepregnancy BMI, household income, and child age, sex, race/ethnicity, and WFL z-score at 1 year, the association between water intake at 1 year and BMI z-score during mid-childhood remained (although was no longer statistically significant at $P = 0.05$), but there was no longer an association between water intake at 1 year and BMI z-score during mid-childhood. In stepwise models, the addition of maternal prepregnancy BMI led to the largest attenuation of the relationship between water intake at 1 year and later BMI z-scores. There was no consistent effect of covariates on the relationship between 1 year water intake and later beverage intake.

For all multivariable analyses conducted, nearly identical findings were obtained from models additionally adjusted for calorie intake (fully adjusted model 3).

Discussion

We found that higher juice intake at 1 year was associated with higher juice intake, SSB intake, and BMI z-score during early and mid-childhood. After adjustment for covariates, water intake at 1 year was not associated with beverage intake and adiposity later in childhood. While limiting or avoiding SSB consumption is a widely-accepted obesity prevention strategy, limiting juice is not as universally recommended. In fact, the American Academy of Pediatrics recommends limiting fruit juice to 4-6 ounces per day for children 1-6 years old and 8-12 ounces per day for children 7-18 years old (28). Although there is a lack of a lack of consistent empirical evidence linking fruit juice intake to excess adiposity (8-12,14,15), relatively low calorie intake from juice among children and adolescents in the US (7) may explain null results.

In contrast to studies evaluating the effect of juice intake on adiposity during childhood, we hypothesized that juice intake during infancy may establish a pattern for drinking caloric beverages such as SSBs that have been clearly linked to excess adiposity, potentially through impact on the development of taste preferences (16). By showing that juice intake at 1 year predicted both later SSB intake and higher BMI z-scores, our study shows that early juice intake could be a useful clinical marker for identifying infants at risk for unhealthy behaviors and excess adiposity during childhood. Juice intake was not associated with WFL z-score at 1 year, suggesting that the association between juice intake during infancy and later BMI z-scores does not merely reflect tracking of higher beverage calorie intake with higher adiposity. Given renewed attention to the risk of persistent obesity among children who are obese during early childhood (29,30), identifying factors during infancy that predict early childhood obesity are important for both clinicians and public health intervention. These findings add to a growing literature base documenting the potential nutritional factors during infancy and early childhood, such as intake of SSBs and fast food, underlying the development of racial/ethnic and socioeconomic disparities in obesity prevalence (31,32). Future randomized studies should explore causal mechanisms related to early beverage intake, taste preferences, and weight gain.

Our findings lends support to changes made to the Special Supplemental Program for Women, Infants, and Children (WIC) food package that eliminated support for all fruit juice for infants younger than 12 months and limited supported juice consumption to four

TABLE 2 Associations of fruit juice intake and water intake at 1 year and juice intake, SSB intake, and BMI *z*-score during early and mid-childhood

	Model 1: Unadjusted rate ratio[a] (95% CI)	Model 2a: Fully adjusted rate ratio[a,b] (95% CI)	Model 2b: Fully adjusted rate ratio[b,c] (95% CI)	Model 3: Fully adjusted + caloric intake rate ratio[c,d] (95% CI)	Model 1: Unadjusted rate ratio[a] (95% CI)	Model 2a: Fully adjusted rate ratio[a,b] (95% CI)	Model 2b: Fully adjusted rate ratio[b,c] (95% CI)	Model 3: Fully adjusted + caloric intake rate ratio[c,d] (95% CI)	Model 1: Unadjusted estimate[a] (95% CI)	Model 2a: Fully adjusted estimate[a,b] 95% CI)	Model 2b: Fully adjusted estimate[b,c] (95% CI)	Model 3: Fully adjusted + caloric intake estimate[c,d] (95% CI)
	Servings of juice during early childhood[e]				Servings of SSB during early childhood[e]				BMI *z*-score during early childhood[f]			
Fruit juice at 1 year												
None	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)
1-7 oz/day	1.54 (1.35-1.75)	1.52 (1.34-1.73)	1.52 (1.34-1.75)	1.43 (1.25-1.63)	1.68 (1.12-2.51)	1.38 (0.91-2.10)	1.28 (0.84, 1.95)	1.25 (0.81-1.90)	0.11 (−0.04-0.26)	0.01 (−0.11-0.14)	0.02 (−0.10-0.15)	0.03 (−0.10-0.15)
8-15 oz/day	1.80 (1.55-2.10)	1.73 (1.48-2.03)	1.75 (1.49-2.05)	1.65 (1.40-1.93)	3.03 (1.97-4.66)	2.01 (1.27-3.22)	1.86 (1.15, 3.00)	1.80 (1.12- 2.94)	0.24 (0.06-0.43)	0.16 (0.01-0.32)	0.17 (0.00-0.33)	0.17 (0.01-0.33)
≥16 oz/day	1.99 (1.58-2.53)	1.92 (1.49-2.48)	1.84 (1.40-2.41)	1.51 (1.15-1.99)	7.77 (4.76-12.81)	3.74 (2.14-6.55)	3.32 (1.84-5.99)	2.86 (1.55-5.26)	0.35 (0.03-0.67)	0.28 (0.01-0.56)	0.29 (−0.02-0.59)	0.30 (−0.01-0.61)
***P*-value (3 DF)**	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0002	0.002	0.03	0.04	0.07	0.07
Water at 1 year												
None	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)
1-7 oz/day	0.88 (0.73-1.07)	0.88 (0.72-1.07)	0.84 (0.69-1.04)	0.83 (0.68-1.01)	0.72 (0.45-1.14)	0.73 (0.46-1.17)	0.70 (0.43-1.13)	0.68 (0.42-1.11)	−0.02 (−0.27-0.24)	0.03 (−0.17-0.23)	0.03 (−0.18-0.25)	0.03 (−0.18-0.25)
8-15 oz/day	0.91 (0.75-1.12)	0.90 (0.74-1.11)	0.88 (0.71-1.07)	0.85 (0.70-1.04)	0.69 (0.43-1.11)	0.71 (0.44-1.15)	0.66 (0.41-1.08)	0.65 (0.39-1.06)	0.16 (−0.10-0.42)	0.06 (−0.15-0.27)	0.04 (−0.18-0.26)	0.04 (−0.18-0.26)
≥16 oz/day	0.84 (0.65-1.06)	0.84 (0.66-1.08)	0.81 (0.63-1.04)	0.85 (0.66-1.11)	0.43 (0.22-0.84)	0.43 (0.22-0.84)	0.40 (0.20-0.79)	0.43 (0.22- 0.84)	0.41 (0.09-0.73)	0.29 (0.03-0.54)	0.30 (0.03-0.56)	0.29 (0.02-0.56)
***P*-value (3 DF)**	0.43	0.49	0.34	0.34	0.10	0.11	0.07	0.10	0.001	0.05	0.05	0.06
	Servings of juice during mid-childhood[e]				Servings of SSB during mid-childhood[e]				BMI *z*-score during mid-childhood[f]			
Fruit juice at 1 year												
None	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)
1-7 oz/day	1.43 (1.21-1.70)	1.39 (1.16-1.65)	1.39 (1.16-1.68)	1.36 (1.14-1.65)	1.58 (1.14-2.23)	1.51 (1.07-2.12)	1.51 (1.07-2.14)	1.46 (1.04-2.08)	0.18 (0.04-0.33)	0.08 (−0.05-0.20)	0.06 (−0.07-0.20)	0.07 (−0.06-0.21)
8-15 oz/day	1.77 (1.45-2.14)	1.58 (1.28-1.95)	1.54 (1.22-1.93)	1.51 (1.20-1.88)	2.20 (1.52-3.22)	1.77 (1.20-2.61)	1.63 (1.07-2.48)	1.60 (1.05-2.41)	0.39 (0.21-0.57)	0.23 (0.07-0.39)	0.22 (0.04-0.39)	0.23 (0.05-0.40)
≥16 oz/day	1.68 (1.22-2.29)	1.48 (1.05-2.08)	1.62 (1.12-2.32)	1.51 (1.04-2.18)	4.66 (3.03-7.24)	3.29 (1.99-5.37)	3.19 (1.88-5.37)	2.80 (1.65-4.81)	0.62 (0.31-0.92)	0.36 (0.08-0.64)	0.24 (−0.08-0.55)	0.27 (−0.05-0.59)
***P*-value (3 DF)**	<.0001	0.0002	0.001	0.003	<.0001	<.0001	0.0004	0.003	<.0001	0.01	0.07	0.05
Water at 1 year												
None	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)	0.0 (ref)
1-7 oz/day	1.01 (0.77-1.32)	1.00 (0.76-1.31)	0.99 (0.74-1.32)	0.98 (0.73-1.31)	0.90 (0.57-1.39)	0.92 (0.59-1.46)	0.90 (0.56-1.45)	0.88 (0.55-1.40)	0.02 (−0.24-0.27)	0.05 (−0.16-0.27)	0.07 (−0.17-0.30)	0.07 (−0.16-0.31)
8-15 oz/day	0.95 (0.72-1.25)	0.94 (0.72-1.25)	0.95 (0.70-1.28)	0.93 (0.70-1.26)	0.86 (0.55-1.34)	0.87 (0.55-1.36)	0.86 (0.53-1.39)	0.84 (0.52-1.35)	0.13 (−0.13-0.38)	0.06 (−0.16-0.28)	0.06 (−0.18-0.29)	0.06 (−0.17-0.30)
≥16 oz/day	1.00 (0.71-1.40)	1.01 (0.71-1.42)	0.97 (0.67-1.40)	0.99 (0.68-1.43)	0.71 (0.39-1.27)	0.70 (0.39-1.28)	0.63 (0.33-1.17)	0.65 (0.35-1.21)	0.32 (0.01-0.63)	0.20 (−0.07-0.47)	0.25 (−0.03-0.54)	0.24 (−0.05-0.53)
***P*-value (3 DF)**	0.84	0.86	0.96	0.93	0.68	0.62	0.45	0.55	0.03	0.43	0.25	0.31

[a]Model 1 and 2a: $n = 1163$; analysis data set with imputation.
[b]Adjusted for maternal age, education, prepregnancy BMI, household income, and child age, sex, race/ethnicity, and weight-for-length z-score at 1 year. All models include both juice and water intake at 1 year.
[c]Model 2b and 3: $n = 1038$; nonimputed calories available at 3 years.
[d]Adjusted for maternal age, education, prepregnancy BMI, household income, and child age, sex, race/ethnicity, weight-for-length z-score at 1 year, and calorie intake at 3 years. All models include both juice and water intake at 1 year.
[e]Estimates are exponentiated β coefficients from Poisson regression.
[f]Estimates are β coefficients from linear regression.

ounces a day for children older than 1 year (33). The changes were made in response to an Institute of Medicine report that outlined potential improvements to the WIC package, including reducing supported juice amounts to encourage increased whole fruit and vegetable consumption among infants and young children participating in WIC (34). Analyses of the impact of the WIC package changes have found that WIC households reduced overall juice purchases (35) and that children in the program increased fruit, vegetable, and whole grain intake (36). Results from our study suggest that in addition to improving diet quality during infancy and early childhood, the reduction of juice in the WIC package has the potential to reduce subsequent SSB intake and BMI *z*-scores later in childhood. Future studies should test interventions designed as reducing juice intake in early childhood. Although one feasibility trial of an intervention to delay the introduction of juice has been conducted (37), no long-term outcome data on child weight is available on participants and, to our knowledge, no similar randomized trial has been conducted.

In contrast to our hypotheses, water intake at 1 year was not associated with either future juice and SSB intake or with BMI *z*-scores, although there was a marginally significant positive association between water intake at 1 year and BMI *z*-score at early childhood. In an analysis of three large cohort studies among adults, Pan et al. found that increasing water intake was associated with lower weight gain, but that the effect of drinking water was greatest when water was substituted for SSBs and juice (38). Given the lack of a consistent relationship between water and subsequent caloric beverage intake and BMI *z*-scores in this study, as well as the stronger findings regarding the negative effects of juice consumption, water could be promoted primarily as a substitute for juice or SSBs during infancy.

Our study has several strengths, including a relatively large sample size, use of longitudinal data, measured height and weight, and ability to adjust for a large number of covariates which could confound the relationship between early beverage intake and child adiposity. Our results should be reviewed with the caveat that our study is subject to limitations inherent to observational research. Reliance on maternally reported measures may bias our findings. In addition, we cannot rule out that the associations we observed may be explained by unmeasured confounding, incomplete adjustment, and/or residual confounding. For example, our analyses are not adjusted for paternal characteristics, sibling characteristics, childcare status, or SSB intake 1 year, all probable confounders of the relationships we examined. Further, ambiguity in our questions may have lead to considerable imprecision in our estimates of beverage intake. Specifically, our assessment of juice intake at 1 year did not specify whether the juice reported was 100% juice and our assessment of beverage intake during early and mid-childhood assessed number of servings, but did not provide details about actual serving size. Some misclassification of the 100% juice and SSB variables can be expected because mothers may not know whether beverages their children are consuming are 100% juice. Finally, the majority of the mothers in our sample are white, college-educated, and have a household income which exceeded $70,000/year in 2001. Limited racial/ethnic and socioeconomic diversity could limit the generalizability of our findings.

Our findings suggest that juice may be a "gateway behavior" to SSBs and, accordingly, early juice intake could be a target for obesity prevention. Our findings lend support for limiting or eliminating juice during infancy and recommending water as an alternative beverage to juice. O

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