Excess Fruit Juice Consumption by Preschool-aged Children Is Associated With Short Stature and Obesity

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ABSTRACT. ***Background.*** **In a referral population of young children, excessive fruit juice consumption has been reported to be a contributing factor in nonorganic failure to thrive.**

Objective. **To evaluate, in a population-based sample of healthy children, fruit juice consumption and its effects on growth parameters during early childhood.**

Design. **Cross-sectional study.**

Setting. **General primary care health center in upstate New York.**

Participants. **One hundred sixteen 2-year-old children and one hundred seven 5-year-old children, who were scheduled for a nonacute visit, and their primary care taker/parent were recruited over a 2-year period.**

Measurements. **For 168 children (ninety-four 2-year-old children and seventy-four 5-year-old children), mean dietary intake was calculated from 7 days of written dietary records, entered, and analyzed using the Minnesota Nutrition Data System. Height was measured using a Harpenden Stadiometer. Weight was measured using a standard balance beam scale.**

Results. **The 2-year-old and 5-year-old children consumed, on average, 5.9 and 5.0 fl oz/day of fruit juice and 9.8 and 11.0 fl oz/day of milk, respectively. Nineteen children (11%) consumed 12 fl oz/day of juice. Forty-two percent of children consuming 12 fl oz/day of juice had short stature (height less than 20th sex-specific percentile for age) vs 14% of children drinking less than 12 fl oz/day of juice. Obesity was more common among children drinking 12 fl oz/day of juice compared with those drinking less juice: 53% vs 32% had a body mass index 75th age- and sex-specific percentile; 32% vs 9% had a body mass index 90th age- and sex-specific percentile; and 32% vs 5% had a ponderal index 90th age-specific percentile. After adjustment for maternal height, child age, child sex, and child age-sex interaction, children consuming 12 fl oz/day of juice, compared with those drinking less than 12 fl oz/day of juice, were shorter (86.5 vs 89.3 cm and 106.5 vs 111.2 cm for the 2-year-old and 5-year-old children, respectively) and more overweight (body mass index = 17.2 vs 16.3 kg/m^2 and ponderal index = 18.4 vs 16.8 kg/m^3).**

Conclusions. **Consumption of 12 fl oz/day of fruit juice by young children was associated with short stature and with obesity. Parents and care takers should limit young children's consumption of fruit juice to less than 12 fl oz/day.** ***Pediatrics*** **1997;99:15–22;** ***child nutrition, obesity, body height, fruit juice, beverages, diet, nutrition policy, growth disorders.***

ABBREVIATIONS. AAP, American Academy of Pediatrics; SAS, Statistical Analysis System; BMI, body mass index; NHANES, National Health and Nutrition Examination Survey.

Fruit juice consumption by infants and young children has increased during the past 30 to 40 years for a number of reasons, including an increase in the varieties of fruit juice produced and an increase in availability. Fruit juice is a convenient snack food for children and adults, is favorably priced compared with milk or soda pop, and is perceived as a healthy drink. National public health programs[1,2] and manufacturers' marketing efforts designed to promote increased consumption of fruits and vegetables also may have contributed to recent increases in fruit juice consumption.

Preference for sweetened beverages is present even in neonates.[3] Preschool-aged children's food preferences are best explained by sweet taste and exposure,[4,5] so it is not surprising that most young children drink naturally sweet fruit juice (90% by the age of 1 year).[6] Concerns about excessive fruit juice consumption have been raised by a number of professional groups since at least 1978. The American Academy of Pediatrics (AAP) and the American Academy of Pedodontics have twice issued a joint statement that "the use of juices from a bottle should be discouraged."[7] They and the AAP Committee on Nutrition expressed concern about fruit juice in infant bottles leading to the development of nursing-bottle caries.[7,8] Despite these statements, $164 million was reportedly spent in 1992 on bottled infant juice.[9]

In 1991, the AAP Committee on Nutrition issued a statement concerning sorbitol, a naturally occurring but nonabsorbable sugar alcohol present primarily in pear juice and apple juice.[10] The committee cautioned that the "excessive use of fruit juice" may result in gastrointestinal symptoms, such as chronic diarrhea, abdominal pain, or bloating. The role of juice carbohydrate malabsorption in chronic nonspecific diarrhea in children has been recognized for some time.[11,12] Fructose malabsorption is relatively common[13] and increases at higher concentrations and at higher doses of fructose.[14] In the presence of sorbitol, fructose malabsorption is further increased.[15] However, when combined with glucose, fructose malab-

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sorption decreases, and at equal concentrations of fructose and glucose, fructose is rarely malabsorbed.[14] Fruits and their corresponding juices differ by nutrient density, carbohydrate composition and concentration, and the amounts of sorbitol, pectin, and fiber present. These differences affect gastric emptying time and result in varying degrees of carbohydrate malabsorption and gastrointestinal symptoms. Using hydrogen breath testing, a noninvasive method to measure bacterial fermentation of malabsorbed carbohydrate and other fermentable substances reaching the colon,[16] a recent article reported that more infants and children had evidence of malabsorption (hydrogen breath test more than 20 ppm) after ingestion of apple juice compared with white grape juice (54% vs 19%).[6]

Among children referred for evaluation of failure to thrive, excessive fruit juice consumption (12 to 30 fl oz/day) was reported as a contributing factor in nonorganic failure to thrive in eight children, aged 14 to 27 months.[17] Marked reduction in the amount of juice consumed, with an increase in the total calories consumed, and adoption of a more balanced diet resulted in resolution of the growth failure.

The purpose of this study was to evaluate, in a population-based sample of healthy children, fruit juice consumption and its effects on growth parameters during early childhood.

METHODS

Study Population

A total of 225 children, 2 or 5 years old, who were scheduled for a nonacute visit, and their parent or primary care taker were recruited from a general primary care practice located in Schoharie county, a rural community in upstate New York. The study population is 97% white and low to middle class. Children with significant medical conditions that affect growth and/or dietary intake were excluded (one with diabetes mellitus and one with chronic renal failure). Our data were collected during 1992 to 1993 as part of a larger study to evaluate different methods of assessing dietary fat intake in young children. Written informed consent was obtained from the child's parent or legal guardian. This study was approved by the institutional review board of the Mary Imogene Bassett Hospital.

Dietary Intake Assessment

The child's parent(s) or primary care taker was given detailed instructions by a research nutritionist in how to complete a written, consecutive, 7-day dietary record for their child. Dietary records included brand names of foods, preparation techniques, and a detailed description of the foods consumed. Parents were given measuring cups, measuring spoons, rulers, and a "Kids Food Portion Booklet" to improve estimation of portion size. They were given a postage-paid, preaddressed envelope to return the questionnaire and were called twice to remind them to mail in the dietary record. Dietary data were reviewed by a registered dietitian and entered by a trained research nutritionist. Nutrient calculation was performed using the Minnesota Nutrition Data System software (Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN, program version 2.3; food database version 5A; nutrient database version 20). The child's daily consumption of beverages—milk (all types), fruit juice (100% juice, all varieties), soda pop, and other drinks (including fruit drinks, fruit punches, Kool-aid, etc, but excluding water)—was determined.

Children's Anthropometric Measurements

The children's height, in stocking feet, was measured to the nearest 0.1 cm using a Harpenden Stadiometer (Cambridge, MD). The child, lightly clad and in stocking feet, was measured to the nearest 0.25 pounds using a standard balance beam scale.

Questionnaire Data

Demographic data, self-reported height and weight, and reported child activity level (5-point Lickert scale) were collected from the parent or primary care taker by a trained interviewer. All questionnaire data were dual-entered and verified before being entered into a Statistical Analysis System (SAS Institute, Cary, NC) database.

Statistical Analysis

After the dietary data were entered and analyzed using the Nutrition Data System computer software system, the total daily intake of each nutrient was calculated and transferred to an ASCII file, which was used to create an SAS database. The 7-day mean intakes of each nutrient and each beverage consumed were determined and used in all analyses.

The distribution of fruit juice consumption is skewed to the right (Fig 1). We defined excess fruit juice consumption, based on a 7-day mean, as ≥12 fl oz/day for several reasons. This amount of juice is approximately twice the mean daily juice intake (5.5 fl oz/day) and about three times the median daily juice intake (4.7 fl oz/day) of children in this population-based study. This amount was also the lower range of excessive juice intakes (12 to 30 fl oz/day) previously reported as contributing to nonorganic failure to thrive in a group of young children,[17] and coincides with the maximum amount recommended for young children by several experts.[9,10] For the purposes of analysis, we defined low milk consumption, based on a 7-day mean, as less than 16 fl oz/day, which is the lower amount recommended for preschool-aged children (2 to 3 cups per day) by the AAP Committee on Nutrition.[18] Furthermore, 2 cups of milk provides about 75% of the recommended dietary allowance for calcium (800 mg/day) for children in this age group[19,20] and dairy products provide 75% of calcium in the United States food supply.[21]

Sex-specific height-for-age percentiles were determined using the National Center for Health Statistics growth charts.[22] Decreased height or short stature is a relative index and may be defined several ways. For the purpose of these analyses, we defined short stature as height less than 20th sex-specific percentile for age.

Obesity is a relative index and may be defined by a number of measures. Although the body mass index (BMI) is generally accepted as the standard measure of adiposity in adults, some have argued that the ponderal index, which shows a lower direct correlation with height than BMI, is a better measure of excess weight in growing children.[23] Therefore, we used both BMI and the ponderal index as measures of adiposity. BMI was calculated as BMI = weight (kg)/[height (m)]^2 The ponderal index was calculated as ponderal index = weight (kg)/[height (m)]^3 We used the age- and sex-specific BMI cutpoints from Hammer et al[24] to define obese as a BMI ≥ 75th age- and sex-specific percentile and very obese as BMI ≥ 90th age- and sex-specific percentile. Additionally, we also defined children with a ponderal index ≥90th age-specific percentile (our distribution: ie, ponderal index ≥22 for 2-year-old children and ponderal index ≥16 for 5-year-old children) as very

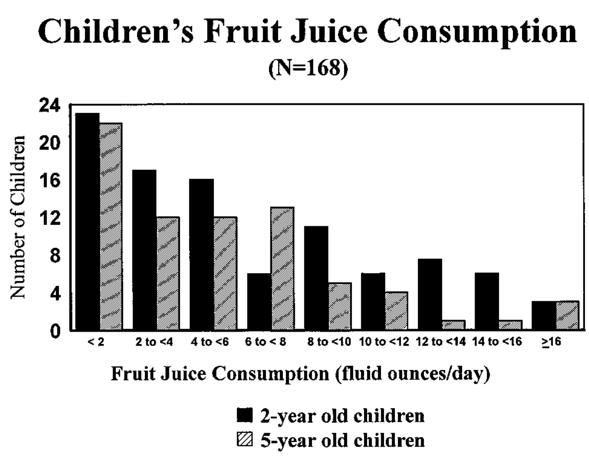

Fig 1. Distribution of children's fruit juice consumption (7-day mean) shown separately for 2- and 5-year-old children.

obese. In cases where the primary care taker completing the questionnaire was the child's natural mother, maternal BMI was also calculated as above.

χ^2 tests or Fisher's exact tests were used to compare dichotomous variables. Nonparametric tests (Wilcoxon) were used to compare ordered data. Student's t tests were used to compare continuous variables. General Linear Models (SAS: PROC GLM) were used to compare continuous variables by primary care taker education (high school degree or less, some college, college degree, or higher). The Cochran-Mantel-Haenszel test was used to evaluate the association between short stature and obesity after controlling for juice consumption. Statistical adjustments to address genetic contributions to short stature and obesity were conducted using General Linear Models. Child height, child BMI, and child ponderal index were tested for differences between the two juice consumption groups (≥12 fl oz/day and less than 12 fl oz/day) while statistically adjusting for maternal height, child age, child sex, and child age-sex interaction. Similar models were developed, which included maternal BMI, in addition to maternal height, child age, child sex, and child age-sex interaction. Unless otherwise indicated, all statistical tests were two-sided. All statistical analyses were conducted using the SAS software package (version 6.08) on a VAX computing system.

RESULTS

Study Participant Characteristics

Table 1 illustrates the healthy volunteer effect and reflects the difficulty of collecting multiple days of dietary records from parents of healthy children. Of the 223 children and parents/primary care takers recruited into the study, 43 (19%) did not return any written dietary records. For 3 children, only 6 days of written records were returned; for 1 child, 5 days of records were returned; and for 1 child, the 7 days of returned records were not consecutive days. Seven parents dropped out of the study because they decided they did not wish to have their child's blood drawn (part of the larger study).

No differences were found in the age or the percent of primary care takers who worked outside the home between those who finished the study compared with those who did not. Ninety-six percent of the primary care takers participating in the study were the child's natural mother. The primary care takers who finished the study were less likely to smoke cigarettes, were less likely to receive food assistance (ie, participate in the Special Supplemental Food Program for Women, Infants, and Children and/or receive food stamps), and were better educated; 27% had a 4-year college degree compared with 5% of those who did not finish the study. There were no measured differences in the children who finished the study compared with those who did not. The children were equally divided by sex, and those finishing had the same height, weight, and relative adiposity (BMI and ponderal index) as the children who did not finish the study.

Children's Dietary Intake

In Table 2 the children's dietary intake is contrasted to that reported in the latest National Health and Nutrition Examination Survey (NHANES).[25] Although the age range for the NHANES III grouped data is wider than our study and the years of collection for NHANES III were 1988 to 1991 compared with 1992 to 1993 for our data, the children's dietary intakes are strikingly similar for energy and the macronutrients shown.

The two age groups of children consumed a similar amount of milk (9.8 and 11.0 fl oz/day for the 2- and 5-year-old children, respectively) and fruit juice (5.9 and 5.0 fl oz/day for the 2- and 5-year-old children, respectively) (Table 3). The older children consumed more soda pop (2.1 vs 1.2 fl oz/day; $P < .001$) and other beverages (3.1 vs 1.9 fl oz/day; $P < .01$) than the younger children, although the younger children consumed a higher volume of beverages per unit body weight than the older children (43.2 vs 32.6 mL/kg/day; $P < .0001$). In this study, 39% of the fruit juice consumed was mixed fruit juice, 30% was apple juice, 23% was orange juice, 7% was grape juice, and 1% was pear or pear-apple juice.

TABLE 1. Participants Who Finished the Study Compared to Those Who Did Not Finish the Study

	2-Year-Old Children		5-Year-Old Children	
	Finished (N = 94)	Did Not Finish (N = 22)	Finished (N = 74)	Did Not Finish (N = 33)
Parent/primary caretaker				
Age (yr)	29.9 ± 5.0*	27.7 ± 8.6	33.7 ± 5.0	31.8 ± 6.0
Mother of child (%)	97	95	95	97
Works outside home (%)†	51	59	48	61
Smokes cigarettes regularly (%)‡‖	27	50§	22	33
Receives food assistance (%)‖	34	59§	24	45§
Education completed (%)‖				
High school or less	42	50	42	55
Some college	31	45	32	39
College degree	28	5	26	6
Child				
Sex (% male)	53	55	53	47
Weight (kg)‡	13.3 ± 1.6	13.4 ± 1.6	19.8 ± 2.7	19.7 ± 2.6
Height (cm)†	89.0 ± 4.6	89.4 ± 4.7	111.0 ± 5.6	110.1 ± 5.6
Body mass index (kg/m²)†	16.8 ± 1.4	16.8 ± 1.3	16.1 ± 1.5	16.2 ± 1.4
Ponderal index (kg/m³)†	18.9 ± 2.1	18.8 ± 1.9	14.5 ± 1.5	14.8 ± 1.4

* Mean ± SD, unless otherwise stated.
† Data are missing for three children.
‡ Data are missing for one child.
‖ χ^2 test, $P < .05$, age groups combined.
§ χ^2 test, $P < .05$, age groups separately.

TABLE 2. Children's Energy and Macronutrient Intake

Dietary Variable	Our Study	NHANES III*	Our Study	NHANES III*
	2.0–2.9 yr (N = 94)	1.0–2.9 yr (N = 424)	5.0–5.9 yr (N = 74)	3.0–5.0 yr (N = 425)
Energy (kcal)	1245 ± 30†	1286 ± 22	1549 ± 34	1573 ± 28
Protein (g)	43 ± 1.3	47 ± 0.9	53 ± 1.6	55 ± 1.2
(% kcal)	14.0 ± 0.2	14.7 ± 0.2	13.7 ± 0.2	14.1 ± 0.2
Carbohydrate (g)	169 ± 4.6	171 ± 3.3	211 ± 5.1	215 ± 4.0
(% kcal)	54.4 ± 0.6	53.9 ± 0.6	54.7 ± 0.6	55.3 ± 0.5
Total fat (g)	46 ± 1.3	49 ± 1.1	57 ± 1.6	58 ± 1.4
(% kcal)	33.2 ± 0.5	33.5 ± 0.4	33.0 ± 0.5	32.7 ± 0.4
Saturated fat (g)	19 ± 0.6	20 ± 0.5	23 ± 0.7	22 ± 0.6
(% kcal)	13.7 ± 0.3	13.8 ± 0.2	13.2 ± 0.3	12.5 ± 0.2
Cholesterol (mg)	155 ± 6.7	168 ± 7.0	173 ± 7.2	175 ± 7.2
(mg/1000 kcal)	126 ± 5.1	131‡	111 ± 4.1	111‡

* Non-Hispanic White.[25]
† Mean ± SEM.
‡ Calculated from NHANES III data; no SD or SEM available.

TABLE 3. Children's Beverage Consumption*

	2-Year-Old Children	5-Year-Old Children	*P* value <†
	(N = 94)	(N = 74)	
Milk (oz/day) (all varieties)	9.8 ± 6.1 (0.6 to 31.8)	11.0 ± 6.9 (1.1 to 38.2)	NS
Fruit juice (oz/day) (100% juice)	5.9 ± 4.7 (0 to 17.8)	5.0 ± 4.4 (0 to 22.3)	NS
Soda pop (oz/day)	1.2 ± 1.5 (0 to 8.9)	2.1 ± 1.9 (0 to 8.5)	.001
Other drinks (oz/day) (excluding water)	1.9 ± 2.8 (0 to 12.6)	3.1 ± 3.4 (0 to 13.6)	.01
Total beverages (oz/day)	18.7 ± 8.4 (3.6 to 43.8)	21.2 ± 8.2 (6.3 to 46.3)	NS
Total beverages (mL/kg/day)	43.2 ± 20.9 (6.9 to 102.9)	32.6 ± 13.3 (9.6 to 76.4)	.0001

* All data shown are the mean of 7 days of dietary data ± SD (range).
† Student's *t* test, 2-year-old children versus 5-year-old children; NS = not significant ($P > .05$).

The children's consumption of milk and juice did not differ by primary care taker education or income status (as reflected by participation in the food stamp and/or Special Supplemental Food Program for Women, Infants, and Children programs). However, consumption of soda pop was higher in 2-year-old children whose parents received food assistance compared with those who did not (1.7 vs .9 fl oz/day; $P < .05$) and was inversely related to primary care taker education; mean soda pop consumed was 0.6, 1.0, and 1.6 fl oz/day by the children whose primary care taker had completed college, had attended college, or had a high school education or less, respectively ($P < .05$).

Excess Fruit Juice Consumption

Nineteen children (11%) consumed ≥12 fl oz/day of fruit juice and 4 children (2%) consumed ≥16 fl oz/day of fruit juice (Fig 1). The children drinking excess fruit juice did not have a statistically higher total energy intake than the children drinking less juice (both $P = .06$) (Table 4). However, for the 2-year-old children, energy intake, standardized by either weight or height, was higher for those who consumed ≥12 fl oz/day of fruit juice compared with those consuming less than 12 fl oz/day (47.1 vs 41.9 kcal/kg and 1528 vs 1371 kcal/m, respectively; both $P < .05$). The number of 5-year-old children who consumed ≥12 fl oz/day of fruit juice was small (N = 4). Nonetheless, energy intake, standardized by height, was higher (borderline significant) among children consuming ≥12 fl oz/day of fruit juice compared with those drinking less than 12 fl oz/day (1665 vs 1399 kcal/m, respectively; $P = .06$).

Although the absolute intake (grams) of total fat and saturated fat did not differ between children in the two juice groups, the 2- and 5-year-old children drinking ≥12 fl oz/day of fruit juice consumed a significantly lower percentage of total calories from total fat (29.1% vs 34.0% [$P < .0005$] and 28.0% vs 33.2% [$P < .05$]) and saturated fat (12.3% vs 13.9% and 11.1% vs 12.3% [both $P < .05$]), respectively, than children drinking less juice. Children drinking ≥12 fl oz/day of fruit juice consumed a much higher percentage of total calories as simple carbohydrates than children drinking less juice (36.5% vs 28.7% [$P < .0001$] and 34.2% vs 28.4% [$P < .05$] for the 2- and 5-year-old children, respectively). The major naturally occurring sugars present in fruit juices are fructose and glucose. Thus, it is not surprising that fructose intake was twice as high and glucose intake was 80% higher among the children drinking excess fruit juice compared with those drinking less juice (all $P < .0001$).

Short Stature and Fruit Juice Consumption

The prevalence of short children was higher among the children who consumed excess fruit juice (Fig 2). Forty-two percent (8/19) of children consuming ≥12 fl oz/day of fruit juice were short (height less than 20th sex-specific percentile for age) compared with 14% (21/149) of children drinking less than 12 fl oz/day of juice ($P < .01$). Among the 2-year-old children, those who consumed excess fruit juice were three times as likely to be short as were children who consumed less fruit juice (47% vs 14%, $P < .01$). There was no evidence that children drinking excess fruit juice were substituting fruit juice for milk; children drinking ≥12 fl oz/day of fruit juice compared with children drinking less juice consumed 11.1 vs 10.2 fl oz/day of milk, respectively ($P > .05$). No association was observed between short stature and milk consumption; 18% of children drinking less than 16 fl oz/day of milk were short compared with 16% of children drinking ≥16 fl oz/day of milk ($P > .05$).

A comparison of the 7-day mean dietary intakes of the short children to the intakes of children who were not short, separately for the two age groups, yielded no significant differences in total calories, total fat, saturated fat, protein, or cholesterol consumed. However, among the 2-year-old children, the short children consumed a higher percent of total calories as sugar (33.5% vs 29.1%; $P < .005$) and a lower percentage of calories as complex carbohydrates (22.3% vs 24.9%; $P < .01$) than children who were not short.

TABLE 4. Dietary Intake Based on Total Fruit Juice Consumption by Age Group*

Dietary Variable	2-Year-Old Children			5-Year-Old Children		
	<12 Oz Juice/Day (N = 79)	≥12 Oz Juice/Day (N = 15)	*P* Value <†	<12 Oz Juice/Day (N = 70)	≥12 Oz Juice/Day (N = 4)	*P* Value <†
Energy (kcal)	1220 ± 277	1376 ± 342	NS (0.06)	1534 ± 296	1827 ± 131	NS (0.06)
(kcal/kg)	41.9 ± 8.0	47.1 ± 9.4	.05	36.2 ± 8.2	40.9 ± 9.6	NS
(kcal/m)	1371 ± 267	1528 ± 323	.05	1399 ± 273	1665 ± 212	NS (0.06)
Protein (g)	43.0 ± 10.0	45.3 ± 18.4	NS	53.0 ± 13.3	60.6 ± 13.1	NS
(% kcal)	14.2 ± 2.1	12.8 ± 2.1	.05	13.8 ± 1.7	13.3 + 2.4	NS
Total carbohydrate (g)	162.1 ± 42.2	203.3 ± 43.2	.001	207.1 ± 41.8	274.3 ± 24.3	.005
(% kcal)	53.3 ± 5.5	59.9 ± 4.8	.0001	54.4 ± 5.3	60.4 ± 5.6	.05
Complex carbohydrate (g)	74.7 ± 22.3	80.4 ± 30.1	NS	98.7 ± 23.4	118.5 ± 22.4	NS
(% kcal)	24.6 ± 4.1	23.4 ± 4.1	NS	26.1 ± 4.1	26.1 ± 4.5	NS
Simple carbohydrate (g)	87.4 ± 26.9	122.8 ± 18.6	.0001	108.4 ± 26.3	155.9 ± 21.2	.001
(% kcal)	28.7 ± 5.5	36.5 ± 4.6	.0001	28.4 ± 4.9	34.2 ± 4.9	.05
Fructose (g)	18.7 ± 8.3	39.2 ± 7.8	.0001	21.3 ± 8.6	47.7 ± 13.5	.0001
(% kcal)	6.2 ± 2.5	11.8 ± 2.8	.0001	5.6 ± 2.2	10.4 ± 2.6	.0001
Galactose (g)	0.2 + 0.2	0.2 + 0.2	NS	0.2 ± 0.3	0.5 ± 0.4	.05
(% kcal)	0.05 + 0.07	0.06 + 0.06	NS	0.05 + 0.08	0.11 + 0.08	NS
Glucose (g)	16.9 ± 6.9	32.0 ± 8.6	.0001	20.6 ± 7.5	43.3 ± 10.0	.0001
(% kcal)	5.6 ± 1.9	9.5 ± 2.6	.0001	5.4 ± 1.9	9.5 ± 2.3	.0001
Lactose (g)	18.4 ± 9.2	19.9 ± 7.9	NS	21.8 ± 9.9	22.7 ± 12.4	NS
(% kcal)	6.1 ± 3.0	5.9 ± 2.0	NS	5.7 ± 2.3	4.9 ± 2.6	NS
Sucrose (g)	33.3 ± 15.9	31.5 ± 10.3	NS	44.5 ± 13.7	41.6 ± 20.6	NS
(% kcal)	10.8 ± 3.9	9.3 ± 3.0	NS	11.6 ± 2.9	9.3 ± 5.0	NS
Pectin (g)	1.0 + 0.5	1.6 + 0.8	.05	1.0 + 0.5	1.8 + 0.6	.01
Total fat (g)	46.4 ± 12.3	45.3 ± 13.3	NS	57.2 ± 13.8	57.4 ± 10.1	NS
(% kcal)	34.0 ± 4.4	29.1 ± 4.0	.0005	33.2 ± 4.4	28.0 ± 3.7	.05
Saturated fat (g)	18.9 ± 5.3	19.1 ± 5.7	NS	22.8 ± 5.8	22.7 ± 6.5	NS
(% kcal)	13.9 ± 2.6	12.3 ± 1.8	.05	13.3 ± 2.1	11.1 ± 2.8	.05
Cholesterol (mg)	157 ± 65	144 ± 66	NS	174 ± 63	144 ± 31	NS
(mg/1000 kcal)	130 ± 50	103 ± 37	NS	113 ± 35	78 ± 13	NS

* All data shown are the mean of 7 days of dietary data ± SD.
† Student's *t* test, <12 oz juice/day vs ≥12 oz juice/day, separately by age; NS = not significant ($P > .05$).

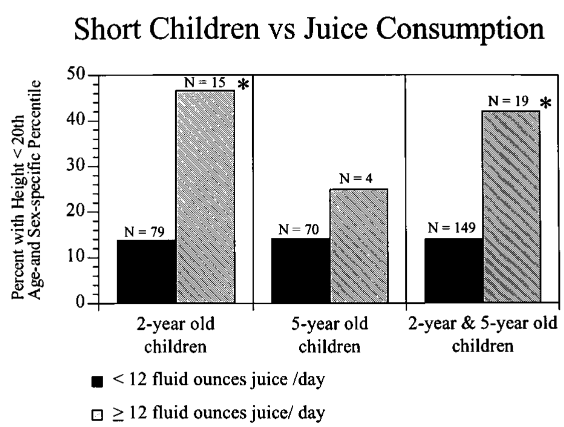

Fig 2. The prevalence of children with decreased stature (height less than 20th age- and sex-specific percentile) is compared between children drinking less than 12 fl oz/day of fruit juice and children drinking ≥12 fl oz/day of fruit juice. Fisher's exact test: *$P < .01$.

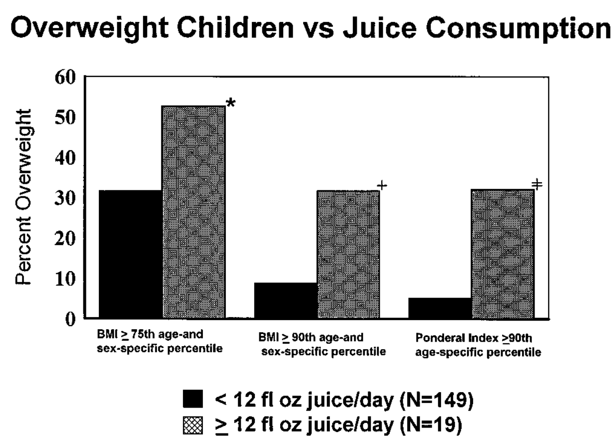

Fig 3. The prevalence of overweight children is compared between children consuming less than 12 fl oz/day of fruit juice and children drinking ≥12 fl oz/day of fruit juice. Fisher's exact test: *$P = .06$ (1-sided); †$P < .01$; and ‡$P < .005$.

Obesity and Fruit Juice Consumption

The prevalence of overweight children was higher among the children consuming ≥12 fl oz/day of juice (Fig 3). Fifty-three percent (10/19) of children drinking ≥12 fl oz/day of juice had a BMI ≥75th age- and sex-specific percentile compared with 32% (47/149) of those drinking less than 12 fl oz/day of juice ($P = .06$; 1-sided test). Thirty-two percent (6/19) of children drinking ≥12 fl oz/day of juice had a BMI ≥90th age- and sex-specific percentile compared with 9% (13/149) of those drinking less than 12 fl oz/day of juice ($P < .01$). Thirty-two percent (6/19) of children drinking ≥12 fl oz/day of juice had a ponderal index ≥90th age-specific percentile compared with 5% (8/149) of those drinking less juice ($P < .005$). No association was observed between obesity and milk consumption. Prevalence of obesity was not increased among children drinking ≥16 fl oz/day of milk compared with those drinking less than 16 fl oz/day of milk: 6% vs 12% had a BMI ≥90th age- and sex-specific percentile; 32% vs 34% had a BMI ≥75th age- and sex-specific percentile;

TABLE 5. Adjusted Child Height, Body Mass Index, and Ponderal Index Versus Juice Consumption*

	2-Year-Old Children (N = 90)			5-Year-Old Children (N = 70)			2- and 5-Year-Old Children (N = 160)		
	<12 Oz Juice/Day	≥12 Oz Juice/Day	*P* Value	<12 Oz Juice/Day	≥12 Oz Juice/Day	*P* Value	<12 Oz Juice/Day	≥12 Oz Juice/Day	*P* Value
Child height (cm)	89.3† (0.4)	86.5 (0.9)	0.003	111.2 (0.5)	106.5 (2.3)	.05	98.9 (0.3)	95.6 (0.9)	.001
Child body mass index (kg/m^2)	16.7 (0.1)	17.1 (0.3)	NS	15.9 (0.2)	18.0 (0.7)	.002	16.3 (0.1)	17.2 (0.3)	.005
Child ponderal index (kg/m^3)	18.7 (0.2)	19.9 (0.5)	0.02	14.3 (0.2)	17.1 (0.7)	.0001	16.8 (0.1)	18.4 (0.4)	.0001

* Statistical adjustment was conducted using General Linear Models (SAS: PROC GLM). All three models included maternal height, child age, child sex, and child age-sex interaction term; NS = not significant ($P > .05$).
† Least squares mean (SEM).

and 3% vs 9% had a ponderal index ≥90th age-specific percentile (all $P > .05$).

A comparison of the 7-day mean dietary intakes of the overweight children (based on each of the three obesity definitions) to the dietary intakes of the children who were not overweight, separately for the two age groups, revealed no significant differences in total calories, total fat, saturated fat, protein, or carbohydrates (total, simple, or complex) consumed. However, among the 2-year-old children, those with a BMI ≥90th age- and sex-specific percentile consumed more cholesterol than children with a lower BMI (155 vs 122 mg/1000 kcal; $P < .05$). For the 2-year-old children, energy intake standardized by height or weight did not differ between the overweight and nonoverweight children. Energy intake standardized by height did not differ between the overweight and nonoverweight 5-year-old children. Among the 5-year-old children, however, those who were overweight had a lower weight-adjusted mean energy intake than the nonoverweight children (33.1 vs 38.6 kcal/kg for those with BMI ≥75th vs less than 75th percentile, respectively [$P < .005$] and 30.8 vs 37.2 kcal/kg for those with a BMI ≥90th vs less than 90th percentile, respectively, [$P < .03$]. A comparison of the reported physical activity levels of the overweight children to the nonoverweight children, revealed a significant difference for the 5-year-old children; those with a BMI ≥75th percentile were reported by their parent/primary care taker to be less active than those with a BMI less than 75th percentile (Wilcoxon test; $P < .02$).

The distribution of short/not short and obese/not obese children was compared among the children, grouped by fruit juice consumption, using the Cochran-Mantel-Haenszel test. This test demonstrated no association between short stature and any of the three measures of obesity, after controlling for juice consumption (Cochran-Mantel-Haenszel summary statistics; all $P > .05$).

Statistical Adjustment—Child Height, Child BMI, and Child Ponderal Index

For 159 children (95%), where the primary care taker who completed the questionnaire was the child's natural mother, we had self-reported maternal height, and for 152 children (90%) we had self-reported maternal weight. The mothers (N = 7) who refused to give their weight, however, appeared to the interviewers, as a group, more likely to be markedly overweight than those responding, raising the possibility of nonrandom missing data. Mean maternal height and BMI were the same for children consuming less than 12 fl oz/day of juice and for children consuming ≥12 fl oz/day of juice (164 vs 163 cm, and 25.7 vs 23.4 kg/m,[2] respectively; both $P > .05$).

General Linear Models were used to examine the relationship between juice consumption and three dependent variables: child height, child BMI, and child ponderal index, while adjusting for maternal height, child age, child sex, and child age-sex interaction (Table 4). With these statistical adjustments, children consuming ≥12 fl oz/day of fruit juice were found to be significantly shorter than children consuming less juice; the adjusted child heights were 86.5 vs 89.3 cm ($P < .005$) and 106.5 vs 111.2 cm ($P < .05$) for the 2-year-old and 5-year-old children, respectively. Children consuming ≥12 fl oz/day of fruit juice were also more overweight than those consuming less juice, with adjusted BMIs of 17.2 vs 16.3 kg/m^2 ($P < .005$) and ponderal indexes of 18.4 vs 16.8 kg/m^3 ($P < .0001$). General Linear Models were also developed to examine the relationship of child height, child BMI, and child ponderal index with juice consumption, while adjusting for maternal BMI in addition to maternal height, child age, child sex, and child age-sex interaction. Maternal BMI was not statistically significant in any of the models. Despite a small reduction in sample size because of missing maternal weight (N = 7) and concerns about nonrandom missing data biasing the findings toward the null hypothesis, inclusion of maternal BMI in the models did not materially change any of the findings reported in the models that did not include maternal BMI.

DISCUSSION

The children's dietary intakes in this study were strikingly similar to those reported in NHANES III for a nationally representative sample of Caucasian children,[25] supporting the external validity of our findings. The 2- and 5-year-old children in this study had a mean fruit juice intake of 5.9 and 5.0 fl oz/day, respectively, which is similar to the 6.0 fl oz/day reported recently for low-income 4- and 5-year old

Latino children.[26] These preschool-aged children consumed more juice than the 9 gallon/year or 3.2 fl oz/day reported for children younger than 5 by the juice manufacturers.[6] They also consumed more than the 4.0 fl oz/day reported for children 2 through 18 in the United States Department of Agriculture's 1989 to 1991 Continuing Survey of Food Intakes by Individuals.[27] These recent studies suggest an increase in fruit juice consumption among preschool-aged children over the past 5 years. Concomitant with an increase in fruit juice consumption has been a decrease in milk consumption.[21] The children in this study had a mean milk intake of 10.4 fl oz/day, which is considerably less than the reported 16.7 fl oz/day (500 mL/day) per capita consumption of milk by children and adults in the United States reported a few years ago.[28] Considering that this study was conducted in rural upstate New York, where dairy farming is highly prevalent and visible, one would expect the children in this study to drink more milk than the national average.

In this cross-sectional sample of healthy young children, excess fruit juice consumption was associated with short stature and with obesity. The distribution of short stature and obesity did not differ between the two juice consumption groups, indicating that the findings observed were not due, for example, to an increase in short obese children among those drinking excess fruit juice. After statistical adjustment for maternal height, child age, child sex, and child age-sex interaction, the association between juice consumption and short stature was strengthened. This finding is consistent with that observed by Smith and Lifshitz,[17] who found that excess juice consumption was associated with nonorganic failure to thrive in some children. Children drinking excess fruit juice consumed a greater proportion of total calories from simple sugars (twice as much fructose and 80% more glucose) than children drinking less juice. For the most part, simple sugars are empty calories. Some of the children drinking excess juice might be substituting the extra juice for more nutritious foods, although other children might be malabsorbing some of the sugars (especially fructose and/or sorbitol) found in the fruit juice. Both of these factors could adversely affect growth, contributing to the development of decreased height and/or weight. We collected no information regarding gastrointestinal symptoms that might accompany malabsorption. In recent studies, however, only a small proportion of children (1/10) with evidence of malabsorption (hydrogen breath test more than 20 ppm) had gastrointestinal symptoms,[6] and many parents did not recognize gastrointestinal symptoms accompanying carbohydrate malabsorption in young children.[29]

In other children, excessive fruit juice consumption was associated with obesity. After statistical adjustment for maternal height, child age, child sex, and child age-sex interaction, the associations between juice consumption and obesity (measured by BMI and ponderal index) were strengthened. Studies in newborn infants have demonstrated a preference for, and increased consumption of, sweetened water compared with plain water.[3] Moreover, the consumption of sweetened beverages by infants increases proportionate to the concentration and to the sweetness (ie, more of the sweeter sucrose-water was consumed than the less sweet glucose-water).[30] Rats offered sugar-sweetened water in addition to rat food consumed more calories and gained more body weight than rats fed just rat food and plain water.[31] The rats decreased their food intake, but not enough to offset for the calories provided by the sugar solution. Analogous to animal studies, it is possible that some children, when offered sweetened beverages in addition to food, will consume extra calories and gain excess weight. The higher energy intake, standardized by either weight or height, of 2-year-old children consuming excessive fruit juice supports this theory. In other words, excessive consumption of fruit juice may contribute to excessive caloric consumption that results in extra weight gain.

In this study, as in many cross-sectional studies, we did not find a significantly higher total caloric intake in the overweight children compared with the nonoverweight children. This could be because there were no differences in total caloric intake between the overweight and nonoverweight children, because there is differential underreporting by parents of overweight and nonoverweight children, or because the variance in the methods used to ascertain dietary intake exceeds the variance between groups, obscuring any small differences in energy intake between obese and nonobese children.[32] For example, an extra 3% increase in energy intake by a 2-year-old child would result in an extra 4-lb weight gain above and beyond that expected due to normal growth.[33] Most current dietary assessment methods are not able to detect differences this small, which may explain why the significant increases in body weight observed in several population-based surveys cannot be explained by any detectable changes in caloric intake.[33,34]

The finding that the reported mean energy intake, standardized by weight, for the 5-year-old children, was lower for the overweight children than for the nonoverweight children is intriguing. This difference could be real or could reflect differential underreporting by overweight and nonoverweight children and their parents, that is perhaps more apparent in the older children. This lower weight-adjusted caloric intake, however, is consistent with the lower levels of physical activity reported in the overweight 5-year-old children (BMI ≥75th percentile) compared with the nonoverweight children.

CONCLUSIONS

Young children depend on parents or care takers to provide food and beverages. Some parents might offer children fruit juice instead of water when they are thirsty, or could give the children too much juice to drink for any number of reasons, including convenience, ready availability, favorable cost, perceived health benefits, and the child's preference for fruit juice. Because this is an observational study, we cannot determine why individual children drank more or less juice, nor can we infer causality. A multitude of factors influence eating behaviors in children, including the influences of parents and care takers, social and environmental influences (such as the use of foods as rewards and the withholding of food as punishment), and media influences.[35,36] The development of obesity is also multifactorial, with genetic, social, and environmental determinants. Our findings linking excess fruit juice consumption in young children to short stature and obesity need to be replicated in additional populations of children. Longitudinal studies are needed to evaluate causality. As with most things in life, however, moderation is probably best. Until other studies prove otherwise, it seems prudent for parents and care takers to limit young children's consumption of fruit juice to less than 12 fl oz/day.

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Excess Fruit Juice Consumption by Preschool-aged Children Is Associated With Short Stature and Obesity

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