ORIGINAL ARTICLE

# A Trial of Sugar-free or Sugar-Sweetened Beverages and Body Weight in Children

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## ABSTRACT

### BACKGROUND

The consumption of beverages that contain sugar is associated with overweight, possibly because liquid sugars do not lead to a sense of satiety, so the consumption of other foods is not reduced. However, data are lacking to show that the replacement of sugar-containing beverages with noncaloric beverages diminishes weight gain.

### METHODS

We conducted an 18-month trial involving 641 primarily normal-weight children from 4 years 10 months to 11 years 11 months of age. Participants were randomly assigned to receive 250 ml (8 oz) per day of a sugar-free, artificially sweetened beverage (sugar-free group) or a similar sugar-containing beverage that provided 104 kcal (sugar group). Beverages were distributed through schools. At 18 months, 26% of the children had stopped consuming the beverages; the data from children who did not complete the study were imputed.

### RESULTS

The z score for the body-mass index (BMI, the weight in kilograms divided by the square of the height in meters) increased on average by 0.02 SD units in the sugar-free group and by 0.15 SD units in the sugar group; the 95% confidence interval (CI) of the difference was −0.21 to −0.05. Weight increased by 6.35 kg in the sugar-free group as compared with 7.37 kg in the sugar group (95% CI for the difference, −1.54 to −0.48). The skinfold-thickness measurements, waist-to-height ratio, and fat mass also increased significantly less in the sugar-free group. Adverse events were minor. When we combined measurements at 18 months in 136 children who had discontinued the study with those in 477 children who completed the study, the BMI z score increased by 0.06 SD units in the sugar-free group and by 0.12 SD units in the sugar group (P=0.06).

### CONCLUSIONS

Masked replacement of sugar-containing beverages with noncaloric beverages reduced weight gain and fat accumulation in normal-weight children. (Funded by the Netherlands Organization for Health Research and Development and others; DRINK ClinicalTrials.gov number, NCT00893529.)

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THE INCREASED PREVALENCE OF OBESITY in children, a major health problem,[1,2] has coincided with a large increase in the consumption of sugar-sweetened beverages.[3] These beverages are considered to be more fattening than solid foods because they do not lead to a sense of satiety.[4] Thus, children who increase their consumption of sugar-sweetened beverages may not reduce their intake of calories from other foods and beverages, with a resultant increase in total energy intake and weight gain.

Consumption of sugar-sweetened beverages has been associated with weight gain in most observational studies,[5-8] though not all such studies.[9,10] However, children who drink more sugar-sweetened beverages also tend to eat more fast food and to watch more television.[11] Most studies adjust statistically for such confounders, but residual and unmeasured confounding cannot be ruled out.[12,13]

Results of available trials are inconclusive,[14-19] possibly owing to small samples, a lack of adequate placebos, a short duration of the study, lack of individual randomization, or a combination of these factors. In addition, effectively blinded trials are important, because when investigators and participants know which treatment should cause weight loss, results may be biased.[20]

We conducted the Double-blind, Randomized Intervention Study in Kids (DRINK)[20] to examine the effect on weight gain of masked replacement of sugar-sweetened beverages with noncaloric, artificially sweetened beverages. The double-blind design permitted the study of physiological mechanisms that were independent of behavioral cues and voluntary changes in consumption.

## METHODS

### DESIGN AND STUDY POPULATION

The study was an 18-month, double-blind, randomized, controlled trial involving schoolchildren living in the community who were 4 years 10 months to 11 years 11 months of age. The design of the study has been described previously.[20] The study started on November 14, 2009, and ended on July 22, 2011. We recruited children at eight elementary schools in an urban area near Amsterdam. Baseline characteristics, including usual beverage consumption, were determined with the use of a questionnaire. Children were eligible only if they commonly drank sugar-sweetened beverages, because we considered it unethical to provide sugary beverages to children who did not habitually consume such beverages. We excluded children with various medical conditions (see Table S1 in the Supplementary Appendix, available with the full text of this article at NEJM.org). We enrolled and individually randomly assigned 641 children, stratified according to school, sex, age, and initial body-mass index (BMI, the weight in kilograms divided by the square of the height in meters) (Fig. 1).[20] Children in the same household received the same type of beverage, but they were unaware of this assignment.

For each child enrolled in the study, written informed consent was provided by a parent or guardian who had obtained assent from the child. The study protocol was approved by the medical ethics committee of VU University Medical Center Amsterdam and is available at NEJM.org. Refresco Benelux, the manufacturer of the beverages, had no role in the design of the study, the accrual or analysis of the data, or the preparation of the manuscript. All authors vouch for the accuracy of the data and the fidelity of the study to the protocol.

### INTERVENTION

We provided children with 1 can per day of a noncaloric, artificially sweetened, noncarbonated beverage or a sugar-containing noncarbonated beverage. We developed custom drinks for this study to ensure that the sugar-free and sugar-containing drinks tasted and looked essentially the same.[20] We hired Refresco Benelux to produce these beverages. The identical-looking 250-ml (8-oz) cans provided either 0 or 26 g of sucrose (0 or 104 kcal per day). The sugar-free beverages contained 34 mg of sucralose and 12 mg of acesulfame potassium per can.[21]

Participating children received a box at school each week labeled with their name and containing 8 cans, 1 for each day of the week plus 1 extra to be used as a spare in case a can was misplaced. The teachers checked to see whether the children consumed their beverage during the morning break in class and reminded them to take cans home for the weekend and any holidays.

We measured body weight, height, skinfold thickness (of the biceps, triceps, and subscapular and suprailiac regions), waist circumference, and arm-to-leg electrical impedance, and we collected urine samples at 0, 6, 12, and 18 months.[20] For children who stopped drinking the beverages before the study was completed, measurements were obtained if the parent or guardian consent-
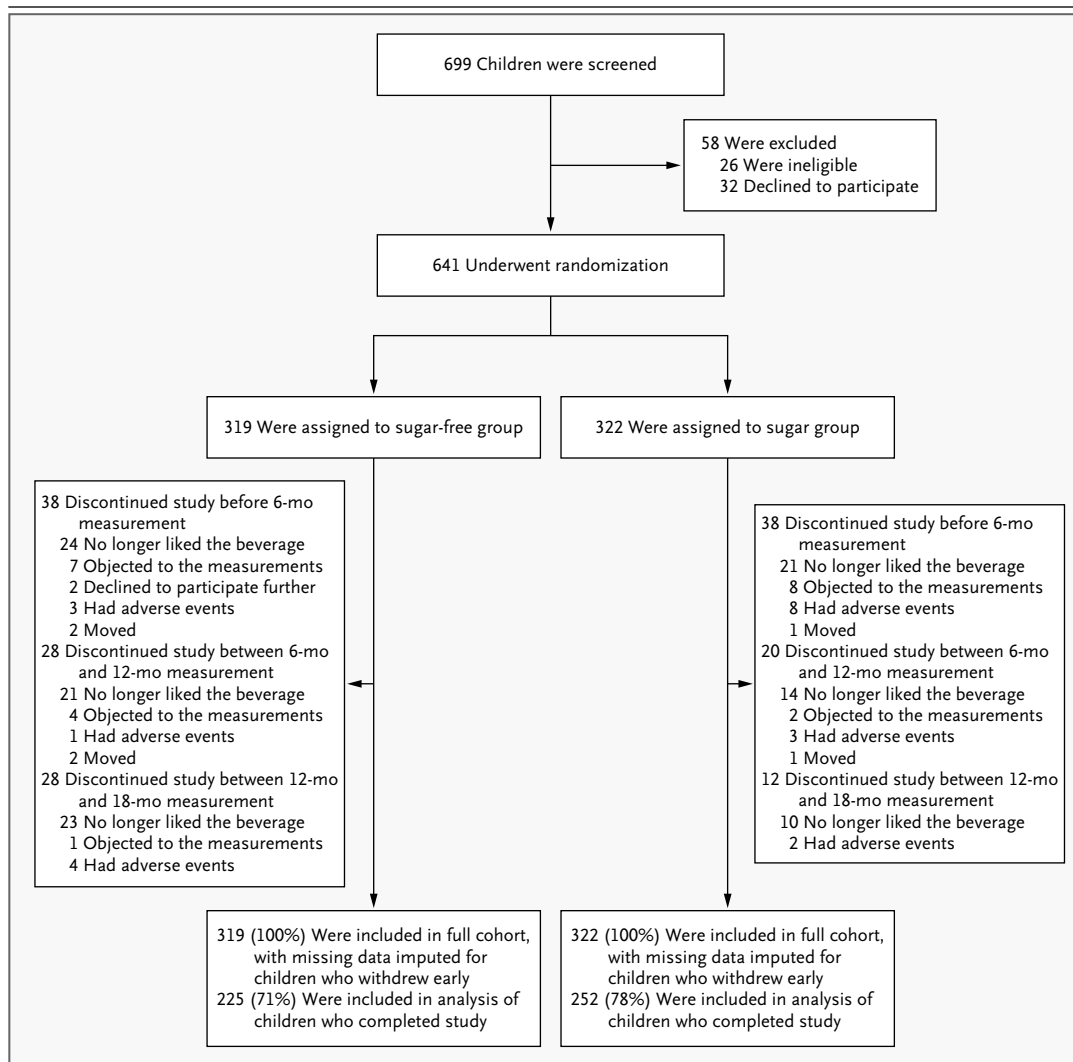
**Figure 1. Screening, Randomization, and Follow-up of the Study Participants.**

A total of 164 children stopped consuming the study beverages. Measurements in 136 of these children (79 children in the sugar-free group and 57 in the sugar group) were available at 18 months. Thus, measurements in 28 children who did not complete the study (15 children in the sugar-free group and 13 in the sugar group) were not available at 18 months. We randomly assigned 641 children, not 642, as previously reported,[20] since after unblinding, one child whom we believed to have undergone randomization[20] had not undergone randomization.

ed and the child assented. Data were available at 18 months for 136 children who did not complete the study and for 477 children who did complete the study. Each child was evaluated by the same investigator throughout the study. Two specially trained researchers measured the waist circumference and the thickness of four skinfolds.

**ADHERENCE**

We provided frequent incentives for schools, teachers, parents, and children, including tournaments, newsletters, birthday cards, and small gifts to en-

courage adherence. We requested that parents report adverse events by contacting us through the e-mail address or telephone number printed on each beverage can.[20] We visited the schools at least once a month to ensure that the study beverages were delivered correctly to the classrooms. We calculated the adherence rate per child during school days from the number of cans returned empty, half-filled, or full during one randomly selected week each month (Table S2 in the Supplementary Appendix). We measured the sucralose concentration in urine as an additional compliance marker.[22]

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## STATISTICAL ANALYSIS

Our predefined primary analysis involved the 477 children who completed the study (i.e., the children who consumed the study beverages throughout the study).[20] We also used multiple imputation to impute the outcome values for the 164 children who did not complete the study at 18 months. We created 30 multiple imputed-data sets with five iterations, using the multivariate imputation by chained-equations algorithm in R software, version 2.13. Variables included in the imputation model were age at baseline, race or ethnic group, parents' level of education, sex, compliance, study group, and baseline and 18-month measurements — when available — of the outcome being predicted.

The primary outcome[20] was the BMI z score (expressed as the number of standard deviations by which the BMI differed from the mean for a child's age and sex in the Netherlands).[23] Prespecified secondary outcomes were the waist-to-height ratio, the sum of the four skinfold-thickness measurements, and fat mass determined by means of electrical impedance.[20] Additional outcomes were weight, height, z score for height,[23] waist circumference, and weight change adjusted for height change. Responses of the two study groups to the beverages were compared with two-sided t-tests. We performed adjusted analyses with linear regression, using SPSS software. Prespecified adjustments for interdependency of outcomes in siblings, degree of adherence, and baseline values[20] had negligible effects on outcomes (Tables S3, S4, and S5 in the Supplementary Appendix).

## RESULTS

### PARTICIPANTS

Baseline characteristics were similar in the two study groups, except for a difference in the parents' level of education (Table 1). The mean BMI z score was 0.03, which corresponded with the 51st percentile of Dutch children.[23] The SD of 1.02 confirmed that our sample was representative of Dutch children, for whom the SD equals 1.00 by definition. At baseline, the participants consumed a mean (±SD) of 1.02±0.20 sugar-sweetened beverages in the classroom during the 10 a.m. break, Monday through Friday, and 1.50±1.40 sugar-sweetened beverages per day during weekends.

The net duration of the study was a mean of 541±8 days.[20] The percentage of participants who consumed the study beverages decreased from 100% at the beginning of the study to 88% at 6 months, 81% at 12 months, and 74% at 18 months (Fig. 1). The major reasons for discontinuing the study were dislike of the beverage (accounting for 69% of the children who discontinued the study) and minor adverse events (13%); weight gain accounted for 4% of children who discontinued the study (four in the sugar group and two in the sugar-free group) (Fig. 1, and Table S6 in the Supplementary Appendix).

### ADHERENCE AND BLINDING

A total of 26% of the participants stopped consuming the beverages. These children had a slightly higher BMI at baseline, and their parents had completed fewer years of school (Table S7 in the Supplementary Appendix). This difference in educational levels theoretically might have influenced the effect of the beverages on weight loss. During the first 6 months of the study, however, weight loss was the same among children who ultimately completed the study as among children who discontinued the study after 6 months or more (Fig. S1E in the Supplementary Appendix). The proportion of children who were aware of the type of beverage they were consuming was similar among children who did and those who did not complete the study (Table S8 in the Supplementary Appendix). Also, most children who did not complete the study were lean, and few children dropped out because of concern about weight (Tables S6 and S7 in the Supplementary Appendix). Most children who stopped drinking the study beverages did so because they no longer liked the beverages. Analyses in which missing values were imputed (Table 2) also suggested that results for the full cohort would have been similar to those for the children who completed the study.

The 477 children who completed the study consumed 5.8 cans, or 83% of the assigned 7 cans per week, with no difference according to the type of beverage consumed and no changes over time (Table S2 in the Supplementary Appendix). The mean level of urinary sucralose was 6.7±4.7 mg per liter in the sugar-free group and 0.1±0.3 mg per liter in the sugar group (Fig. 2), indicating adherence in the group of children who drank the artificially sweetened beverages.

At 18 months, 609 children were asked which type of beverage they thought they had received (Table S8 in the Supplementary Appendix). Among 474 children who completed the study, 48% in

**Table 1. Baseline Characteristics of the Study Participants.***

| Characteristic | Sugar-free Group (N=319) | Sugar Group (N=322) |
|---|---|---|
| Female sex (%) | 46 | 47 |
| Age (yr) | 8.2±1.8 | 8.2±1.8 |
| Ancestry (%)† | | |
|     Dutch | 80 | 76 |
|     Non-Western | 19 | 22 |
| Highest level of education attained by parent or guardian (%)‡ | | |
|     Elementary, vocational, or technical school | 17 | 10 |
|     High-school diploma | 33 | 28 |
|     College or university degree | 49 | 61 |
| Weight (kg) | 30.04±8.93 | 30.33±8.82 |
| Height | | |
|     Measured (cm) | 132.1±12.5 | 133.0±12.7 |
|     z score (SD units above or below mean in the Netherlands)§ | −0.09±1.00 | 0.03±0.99 |
| BMI | | |
|     Calculated BMI | 16.9±2.6 | 16.8±2.6 |
|     BMI z score (SD units above or below mean in the Netherlands)§ | 0.06±1.00 | 0.01±1.04 |
|     Low (%)¶ | 1 | 1 |
|     Normal (%) | 80 | 81 |
|     Overweight (%) | 16 | 15 |
|     Obese (%) | 3 | 3 |
| Sum of thicknesses of four skinfolds (mm)‖ | 36.4±17.7 | 35.6±17.9 |
| Waist-to-height ratio (%) | 44.6±4.0 | 44.2±4.0 |
| Fat mass on electrical impedance | | |
|     Measured (kg)** | 5.8±3.8 | 5.7±3.7 |
|     As % of body weight | 18 | 18 |

* Plus–minus values are means ±SD. There were no significant between-group differences at baseline except for the educational level of the parent or guardian (P=0.02). P values were based on chi-square tests and t-tests.
† Data were available for 633 children; eight households did not provide this information. A child was classified as Dutch if both parents were born in the Netherlands and as non-Western if one or both parents were born in Suriname, Dutch Antilles, Turkey, Morocco, Russia, Egypt, or Vietnam.
‡ Data were available for 632 children; nine households did not provide this information. We based the educational level on that of the parent or guardian who had the higher level of education.
§ The z scores for BMI and height were calculated with the use of the data described by Schönbeck et al.[23]
¶ We used international cutoff points for low and normal BMI[24] and for overweight and obesity.[25]
‖ Data were available for 640 children; 1 child declined to be measured.
** Data were available for 637 children; 4 children declined to be measured.

the sugar-free group and 50% in the sugar group answered that they did not know, 36% in the sugar-free group and 27% in the sugar group answered "artificially sweetened," and the remainder said "sugar-sweetened." The proportion of participants who correctly responded "artificially sweetened" was 21% (95% confidence interval [CI], 12 to 30) higher (47 more children) than expected by chance, as estimated with the "blinding index" described by Bang et al.[27] In the sugar group, the proportion of children who were aware of the type of beverage they had consumed was 3% (95% CI, −12 to 6) lower (7 fewer children) than expected. Among 135 children who did not complete the study, the beverage was correctly identified by 12% more, or 9 more children, than expected, in the sugar-free group, and by 1 less child than expected in the sugar group.

**Table 2. Primary and Secondary Outcomes in the Full Cohort, with Imputed Data for Children Who Did Not Complete the Study, and in the Cohort of Children Who Completed the Study.***

| Outcome | Sugar-free Group (N=319) | | | Sugar Group (N=322) | | | Difference in Change from Baseline (95% CI) | P Value for Difference† |
|---|---|---|---|---|---|---|---|---|
| | 0 Mo | 18 Mo | Change | 0 Mo | 18 Mo | Change | | |
| **Full cohort, with imputed data** | | | | | | | | |
| Primary end point: BMI z score‡ | 0.06±1.00 | 0.08±0.99 | 0.02±0.41 | 0.01±1.04 | 0.15±1.06 | 0.15±0.42 | −0.13 (−0.21 to −0.05) | 0.001 |
| Secondary end points | | | | | | | | |
| Sum of thicknesses of four skinfolds (mm) | 36.4±17.7 | 39.6±20.4 | 3.2±8.8 | 35.6±17.9 | 41.1±21.1 | 5.5±10.2 | −2.2 (−4.0 to −0.4) | 0.02 |
| Waist-to-height ratio (%) | 44.6±4.0 | 43.7±4.0 | −0.9±2.0 | 44.2±4.0 | 43.7±4.0 | −0.5±2.0 | −0.4 (−1.0 to −0.0) | 0.05 |
| Fat mass on electrical impedance (kg)§ | 5.76±3.85 | 6.77±4.71 | 1.01±2.62 | 5.70±3.68 | 7.28±4.89 | 1.58±2.47 | −0.57 (−1.02 to −0.12) | 0.02 |
| Fat mass on electrical impedance (% of body weight)§ | 17.91±7.01 | 17.22±8.44 | −0.70±5.31 | 17.67±6.92 | 18.05±8.25 | 0.38±4.86 | −1.07 (−1.99 to −0.15) | 0.02 |
| Other end points | | | | | | | | |
| Weight (kg) | 30.04±8.93 | 36.39±10.41 | 6.35±3.07 | 30.33±8.82 | 37.69±11.05 | 7.37±3.35 | −1.01 (−1.54 to −0.48) | <0.001 |
| Height (cm) | 132.06±12.55 | 142.34±12.48 | 10.28±1.91 | 133.02±12.71 | 143.67±13.05 | 10.65±1.97 | −0.37 (−0.72 to −0.02) | 0.04 |
| Height z score‡ | −0.09±1.00 | −0.07±0.99 | 0.03±0.27 | 0.03±0.99 | 0.09±0.99 | 0.06±0.27 | −0.04 (−0.10 to 0.02) | 0.17 |
| Waist circumference (cm) | 58.85±7.44 | 62.22±7.97 | 3.37±2.97 | 58.69±7.05 | 62.72±7.92 | 4.03±3.12 | −0.66 (−1.23 to −0.09) | 0.02 |
| **Children who completed study¶** | | | | | | | | |
| Primary end point: BMI z score‡ | 0.05±0.99 | 0.07±0.98 | 0.02±0.40 | −0.02±1.00 | 0.14±1.06 | 0.15±0.42 | −0.13 (−0.20 to −0.06) | 0.001 |
| Secondary end points | | | | | | | | |
| Sum of thicknesses of four skinfolds (mm) | 36.0±16.9 | 39.1±20.2 | 3.2±8.1 | 34.4±15.8 | 40.1±20.4 | 5.7±10.0 | −2.5 (−4.2 to −0.8) | 0.003 |
| Waist-to-height ratio (%) | 44.6±3.7 | 43.7±3.8 | −0.9±1.9 | 44.1±3.7 | 43.7±4.1 | −0.5±2.1 | −0.4 (−0.8 to −0.1) | 0.02 |
| Fat mass on electrical impedance (kg)§ | 5.61±3.44 | 6.65±4.29 | 1.02±1.68 | 5.45±3.21 | 7.02±4.40 | 1.57±2.05 | −0.55 (−0.89 to −0.21) | 0.001 |
| Fat mass on electrical impedance (% of body weight)§ | 17.69±6.63 | 17.11±7.22 | −0.61±3.71 | 17.35±6.39 | 17.85±7.36 | 0.45±3.81 | −1.05 (−1.73 to −0.37) | 0.003 |
| Other end points | | | | | | | | |
| Weight (kg) | 29.76±8.44 | 36.09±10.19 | 6.33±2.71 | 29.75±8.20 | 37.06±10.66 | 7.30±3.39 | −0.97 (−1.52 to −0.42) | 0.001 |
| Height (cm) | 131.72±12.44 | 141.92±12.23 | 10.21±1.85 | 132.40±12.57 | 142.98±12.89 | 10.57±1.93 | −0.36 (−0.71 to −0.02) | 0.04 |
| Height z score‡ | −0.12±0.92 | −0.12±0.95 | −0.001±0.38 | −0.002±1.01 | 0.06±0.99 | 0.06±0.44 | −0.07 (−0.14 to 0.01) | 0.08 |
| Waist circumference (cm) | 58.63±6.90 | 61.99±7.79 | 3.36±2.69 | 58.30±6.43 | 62.35±7.55 | 4.05±3.10 | −0.69 (−1.22 to −0.17) | 0.01 |

* Values are means (±SD) or means with 95% confidence intervals. Children were considered to have completed the study if they consumed the beverages for the full 18 months. Mean changes for the children who completed the study may differ slightly from the difference between means at 18 and 0 months because measurements were not available from a few participants who discontinued the study and SPSS software, version 17.0, for all other analyses.

† Differences in changes from baseline between the sugar-free group and the sugar group were analyzed with the use of an independent-sample t-test; P≤0.05 was considered to indicate significance.

‡ The z scores for body-mass index and height were calculated with the use of the data described by Schönbeck et al.[23]

§ Impedance measurements were calculated with the use of the method described by Rush et al.[26]

¶ A total of 225 children in the sugar-free group and 252 children in the sugar group completed the study.

## BMI Z SCORE AND OTHER END POINTS

In the full cohort of 641 children, the mean BMI z score increased by 0.02±0.41 SD units in the sugar-free group and by 0.15±0.42 SD units in the sugar group (Table 2) when missing values were imputed. The mean difference of 0.13 SD units was significant. The sugar-free group gained significantly less body fat, as evidenced by skinfold thickness, waist-to-height ratio, and electrical impedance. The mean weight increased by 6.35±3.07 kg in the sugar-free group and by 7.37±3.35 kg in the sugar group. The mean difference of 1.01 kg (2.2 lb) was significant. The mean difference in weight gain decreased to 0.82 kg (P=0.002) when adjusted for height change. The BMI adjusted for age[28] increased 0.36 less in the sugar-free group than in the sugar group (P=0.001). An alternative method for handling missing data — namely, complete case analysis with covariate adjustment[29] — yielded very similar results and levels of significance (Table S9 in the Supplementary Appendix).

Similar results were also seen in the 477 children who consumed the study beverages for the full 18 months (74% of the children enrolled) (Table 2 and Fig. 3). Children in the sugar-free group who completed the study gained 35% less body fat than those in the sugar group, according to impedance measurements,[26] and 19% less when fat mass was calculated from the sum of the thicknesses of four skinfolds. According to the changes in skinfold thickness, the sugar-free group gained 1.47 kg of body fat and the sugar group gained 1.82 kg.[30] Most of the effect on BMI z score and weight was achieved in the first 6 months (Fig. 3B, and Fig. S2B in the Supplementary Appendix). The mean height increased by 10.21±1.85 cm in the sugar-free group and by 10.57±1.93 cm in the sugar group. The mean difference of 0.36 cm (0.14 in) was significant (P=0.04), but the difference in z score for height was not significant (Table 2).

We obtained measurements at 18 months in 136 of the 164 children who did not complete the study. When we combined their measurements with those in the 477 children who completed the study, the mean BMI z score increased by 0.06±0.44 SD units in the sugar-free group and by 0.12±0.44 SD units in the sugar group. The mean difference of 0.07 SD units was not significant (95% CI, −0.134 to 0.002; P=0.06).
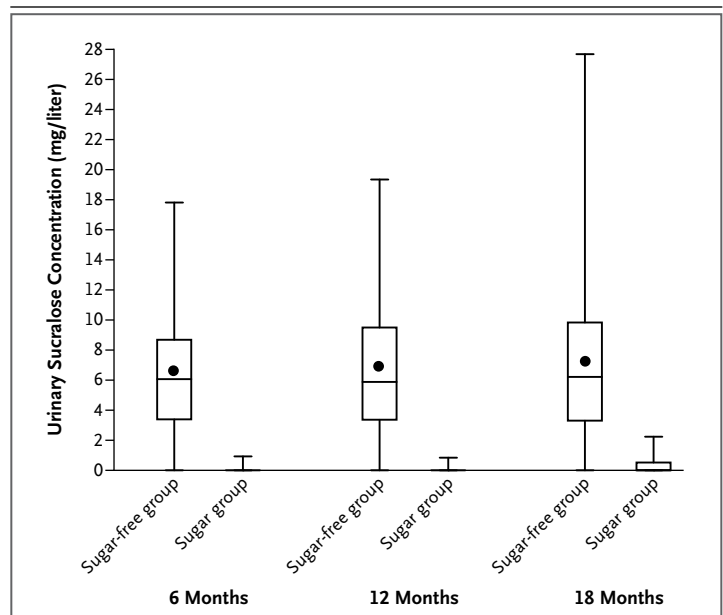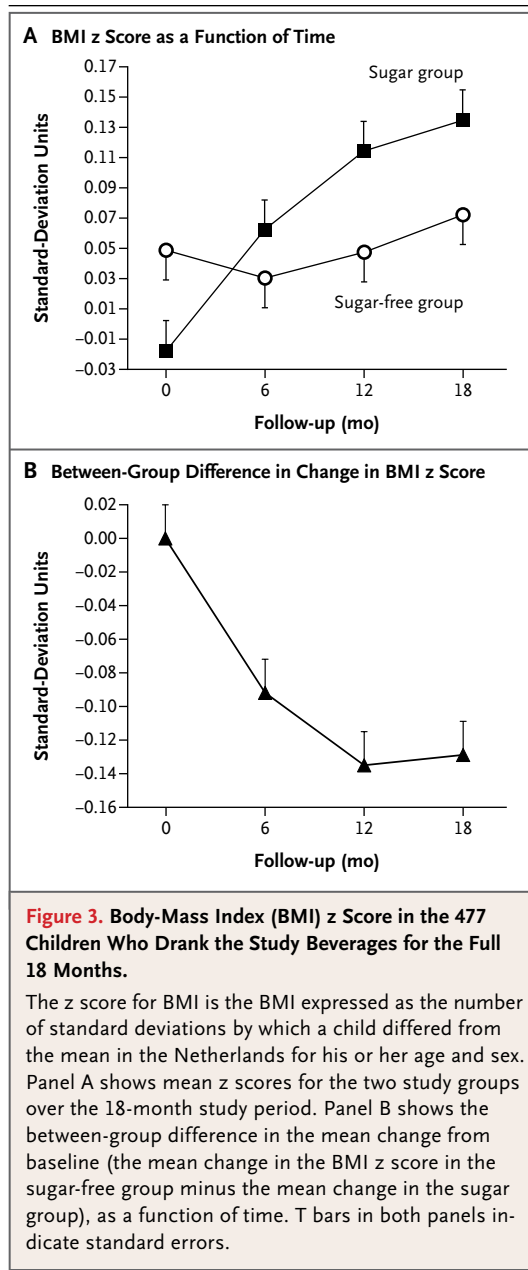


**Figure 2. Urinary Sucralose Concentrations.**

The sucralose concentration was determined in spot urine samples by means of liquid chromatography with mass spectrometry.[21] Samples were obtained from randomly selected children who completed the study. We assigned a value of 0.01 to samples below the detection limit of 0.02 mg per liter. The upper and lower ends of the boxes indicate the 25th and 75th quartiles, the black dots means, the horizontal lines within the boxes medians, the upper whisker the maximum value, and the lower whisker the minimum value. Values for the sugar-free group are based on samples obtained from 116 children at 6 months and from 117 children at 12 and 18 months. Mean (±SD) urinary sucralose concentrations were 6.3±3.7 mg per liter at 6 months, 6.6±4.5 mg per liter at 12 months, and 7.0±5.6 mg per liter at 18 months; sucralose was undetectable in 3% of samples at 6 months, 8% of samples at 12 months, and 10% of samples at 18 months. Values for the sugar group are based on samples obtained from 54 children at 6 months and 36 children at 12 and 18 months. Mean values were 0.04±0.13 mg per liter at 6 months, 0.03±0.14 mg per liter at 12 months, and 0.31±0.56 mg per liter at 18 months; sucralose was undetectable in 93% of samples at 6 months, 97% of samples at 12 months, and 67% of samples at 18 months. We also pooled 543 samples from participants at baseline to produce 20 pools. The mean sucralose concentration in these samples was 0.06±0.07 mg per liter.

## DISCUSSION

We found that masked replacement of a sugar-containing beverage with a sugar-free beverage significantly reduced weight gain and body fat gain in healthy children. Our study had several strengths. The double-blind design eliminated the effects of psychological cues and socially desirable behavior and allowed testing of biologic mechanisms alone. Although blinding was im-

## A  BMI z Score as a Function of Time



## B  Between-Group Difference in Change in BMI z Score



**Figure 3. Body-Mass Index (BMI) z Score in the 477 Children Who Drank the Study Beverages for the Full 18 Months.**

The z score for BMI is the BMI expressed as the number of standard deviations by which a child differed from the mean in the Netherlands for his or her age and sex. Panel A shows mean z scores for the two study groups over the 18-month study period. Panel B shows the between-group difference in the mean change from baseline (the mean change in the BMI z score in the sugar-free group minus the mean change in the sugar group), as a function of time. T bars in both panels indicate standard errors.

other factors that affect weight were also similar between the groups. Thus, the observed differences in body fat and BMI z score can be ascribed primarily to the assigned beverage.

Our study had certain limitations. A total of 26% of the participants did not complete the study. However, as long as they were participating in the study, their changes in weight and body fat paralleled those in children who ultimately completed the study. We therefore suggest that the study beverage was not inherently inefficacious in these children. Data on weight and height at the end of the study were available for most of the children. When we pooled those measurements with the measurements for the children who completed the study, the effect of the study beverage became smaller and nonsignificant. This finding was expected; the children who did not complete the study probably went back to drinking sugary beverages, which attenuated the effect of any sugar-free beverages that they consumed before discontinuation.

Approximately 0.5 kg of the difference in weight gain between the two study groups was due to fat mass. We speculate that another 0.3 kg may have been due to the changes in lean mass that accompany changes in body fat.[33-35] Thus, about 0.8 kg of the difference in weight gain was probably due to body fat and associated muscle and other tissues.[33] Another 0.2 kg can be ascribed to the difference in height gain.[23] Therefore, the increases in body weight as predicted from increases in fat mass and height differed by about 1 kg between the study groups. This estimate is consistent with the actual measured difference in body-weight change.

Although the difference in height gain was minute, it warrants scrutiny. Some studies suggest that obese prepubertal children are indeed taller than normal-weight children.[36] However, obesity is associated with an earlier onset of puberty,[37-39] which predicts shorter stature in adults.[40] The increase in BMI in Dutch children in the past decades has not led to an increase in final height.[23] We speculate that a modest reduction of liquid calories in children will have little effect on adult height.

A plausible explanation for the observed reduction in body fat is that the removal of liquid sugar was not sensed by satiating mechanisms and was incompletely compensated for by the increased consumption of other foods.[41] We speculate that reduced ingestion of liquid sugars might also

perfect, it was more successful than in most randomized, double-blind trials.[31,32] Measurements of urinary sucralose levels suggested a high rate of adherence. Previous trials may have yielded inconsistent results because of small samples, short duration, poor adherence, or lack of individual randomization.[14-19] Our sample size was adequate to allow precise outcomes, and the 18-month study duration ensured that the observed effect was not transient. The large sample and stratified randomization produced well-balanced study groups at baseline. We assume that the mean changes in

reduce the insulin spike and thus diminish hunger.[42] We find it less likely that our results were caused by the artificial sweeteners in the sugar-free beverages, because sweeteners do not suppress caloric intake.[43,44] Therefore, we assume that water or other noncaloric beverages would be as effective.

In observational studies, the consumption of artificially sweetened beverages is associated with weight gain rather than weight loss.[45,46] This finding has led to the hypothesis that artificial sweeteners induce weight gain (e.g., by activating sweet-taste receptors in the gut).[47] Our findings do not support this hypothesis. Alternatively, people who are at risk for gaining weight may turn to artificial sweeteners in an attempt to reduce caloric intake.[45,46] Consumers may also believe that the use of such sweeteners permits them to eat more of other foods, but this may lead to a net increase in total caloric intake.[46] Whatever the explanation, the epidemiologic association of the use of artificial sweeteners with obesity does show that switching to artificially sweetened beverages by itself is insufficient to combat weight gain.

The participants in our study were healthy Dutch children, most of whom were white and of normal weight. Thus, we do not know whether the results would be similar in other ethnic groups, obese children, or adults, though we speculate that the same biologic mechanisms are operative. The findings of Ebbeling et al.,[48] reported elsewhere in this issue of the *Journal*, would support such speculation. The findings of Qi et al.,[49] reported elsewhere in this issue of the *Journal*, suggest that persons with a genetic predisposition to obesity are especially susceptible to the effects of sugar-sweetened beverages on BMI.

Children in the United States consume on average almost three times as many calories from sugar-sweetened beverages as the amount provided in our trial.[50] We speculate that decreased consumption of such beverages might reduce the high prevalence of overweight in these children.

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# Supplementary Appendix

This appendix has been provided by the authors to give readers additional information about their work.

# Supplementary Appendix

Supplement to: De Ruyter JC, Olthof MO, Seidell JC, Katan MB. Randomized Trial of Sugar-free versus Sugar-containing Beverages and Body Weight in Children

**Figure S1. Comparison of Outcomes after 6 Months in Completers and Future Noncompleters**.

Diamonds indicate differences in response between treatment groups among the 88 children who still consumed their drinks at 6 months but became noncompleters later; each point represents the mean of 56 children in the sugar-free group minus the mean of 32 in the sugar-containing group. Triangles indicate differences in response between treatment groups among the completers, i.e. the 477 children who drank the beverages for the full 18 months; each point represents the mean of 225 children in the sugar-free group minus the mean of 252 in the sugar-containing group. Bars indicate one standard error.
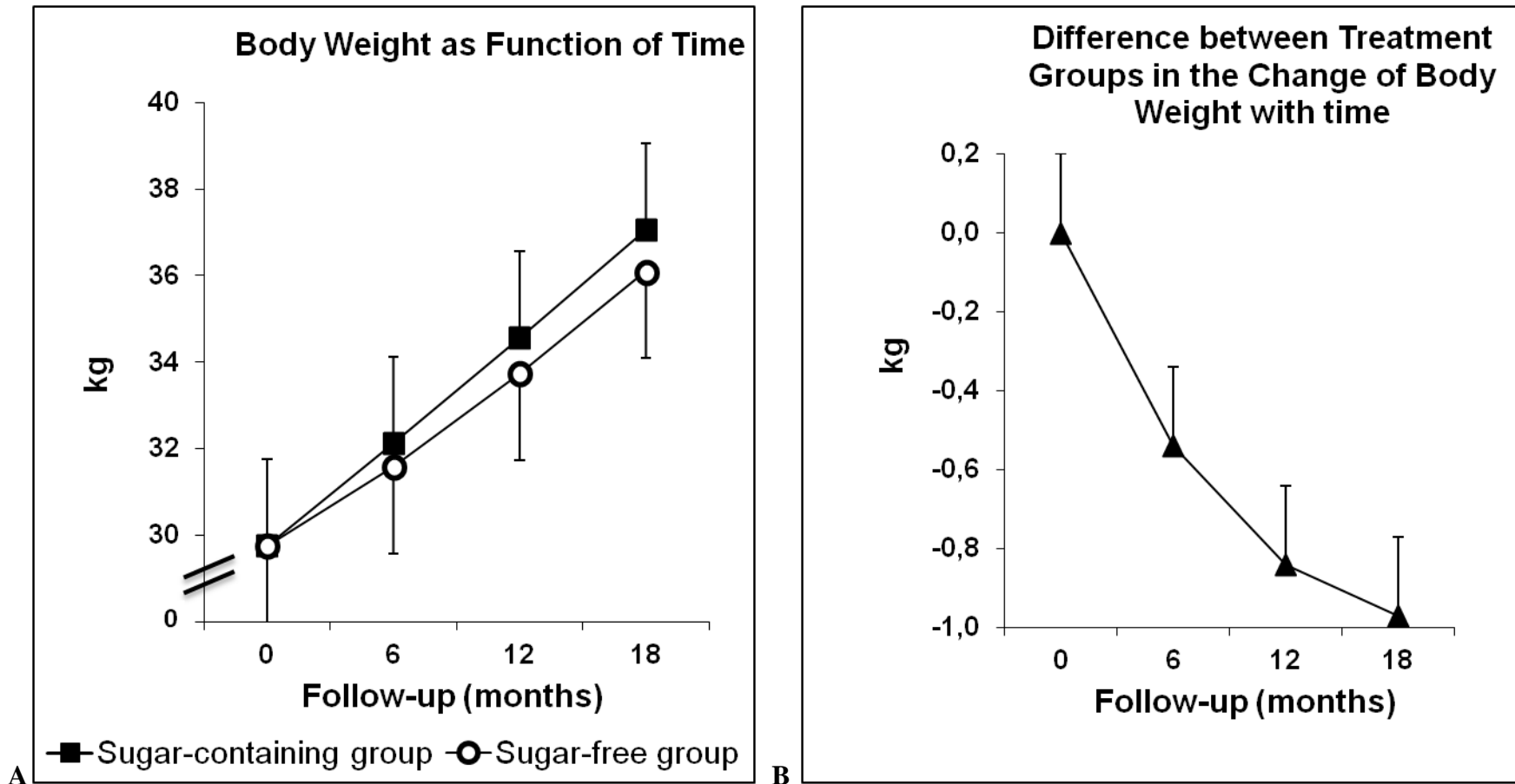
**Figure S2. Time Course of Body Weight in the 477 Completers.**
**Panel A** shows the mean body weight for the sugar-free and the sugar-containing group over the course of the trial. **Panel B** shows the mean body weight gain in the sugar-free group minus that in the sugar-containing group. Bars indicate one standard error.
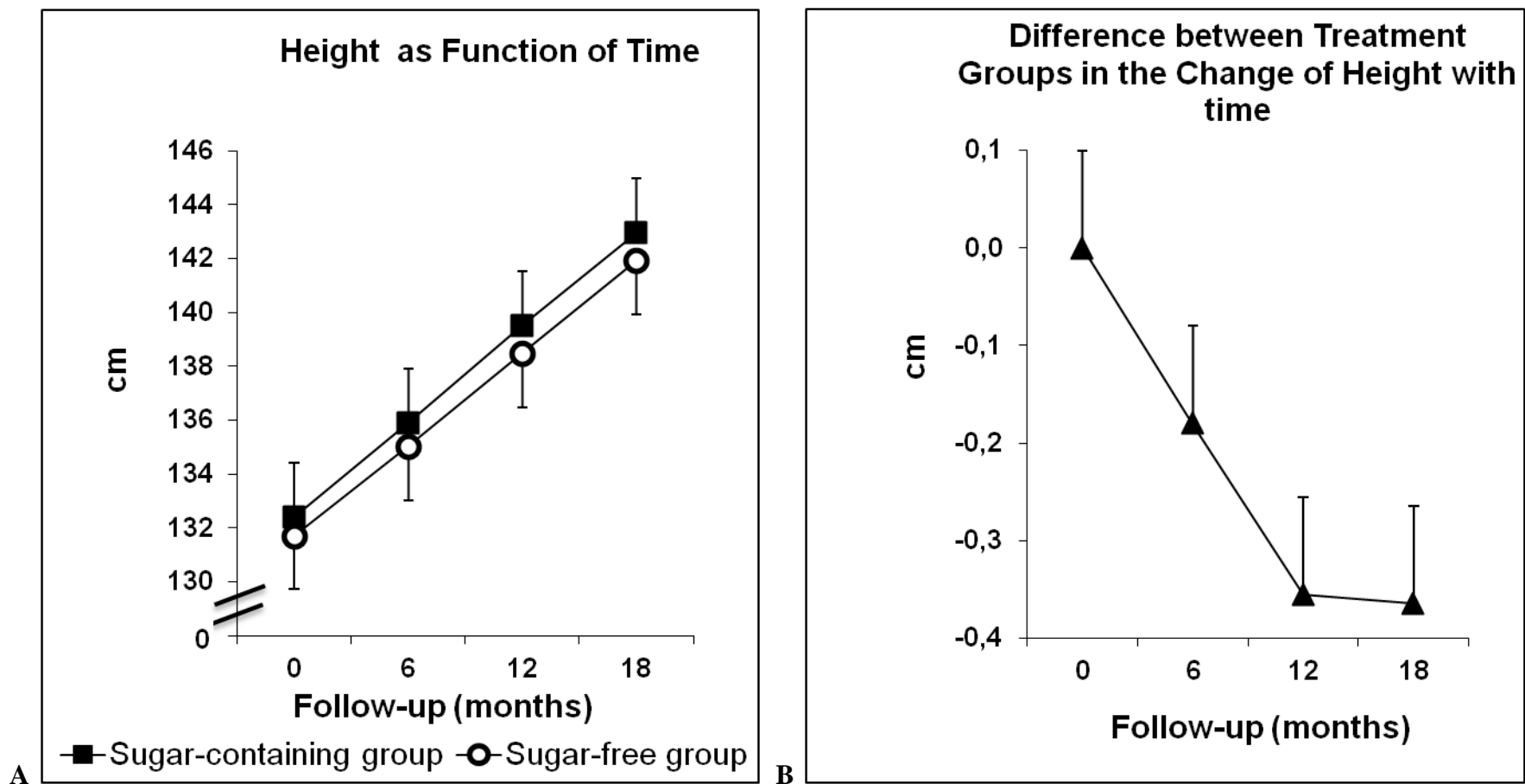
**Figure S3. Time Course of Height in the 477 Completers**
**Panel A** shows mean heights for the sugar-free and the sugar-containing group over the course of the study. **Panel B** shows the height gain in the sugar-free group minus the height gain in the sugar-containing group. Bars indicate one standard error.

**Table S1. Inclusion and Exclusion Criteria for Participation [1]**

**Inclusion criteria:**
- Habitual consumption of 250 mL or more per day of sugar-containing beverages on at least three out of five school days [a]
- Minimum age of 5 years at the start of the trial
- Young enough to be still in elementary school at the end of the trial
- Written informed consent by a parent or guardian

**Exclusion criteria:**
- Medication or medical treatment for obesity
- Diabetes, growth disorders, celiac disease, or serious gastro-enterologic diseases (for example inflammatory bowel disease).
- Medical history or surgery known to interfere with the study
- Participation in another intervention study up to 3 months before and during the trial if the intervention interfered with our study
- Physical disabilities that hamper the measurements
- Intention to change location of residence and elementary school during the trial

[a] At baseline the participants actually consumed 1.02±0.2 (mean±SD) sugar-sweetened beverages in the classroom during the 10 am morning break, Monday through Friday, and 1.5±1.4 (mean±SD) sugar-sweetened beverages per day on Saturday and Sunday.

| Table S2. Adherence as Estimated from Can Counts | | | |
|---|---|---|---|
| Treatment | Number of can counts during trial (weeks) | Number of completers available per can count, mean ±SD | % of assigned cans returned empty, mean ±SD |
| **Completers** | | | |
| Sugar-free group | 17 | 205 ±16 | 84.7 ±24.4 |
| Sugar-containing group | 17 | 228 ±18 | 85.2 ±24.3 |

We measured compliance by counting returned school day cans. Children were instructed to drink one can per day at school Monday to Friday, and to place both empty and full cans back into their kid boxes to be collected by us. We counted returned cans of one week each month. Empty cans counted as 100% adherence, half-filled cans as 50% and full cans as 0%. Lowest adherence was 74% in April 2010, 5 months into the study, and highest adherence was 92%, in September 2010.

Cans emptied during weekends and holidays were not returned, but cans for weekends and holidays that had been left uncollected at school were returned. In order to estimate adherence during weekends, we checked how many cans the children took home. We provided 2 cans for each weekend plus one spare can. Completers returned a mean±SD of 1.18±1.10 full cans per week. Thus they took on average 1.82 full cans home per weekend, or 0.91 per weekend day. We assume that 15% of this was wasted and 85% consumed. Total consumption per week would then be 85% of 1.82 cans per weekend plus 85% of 5 cans per school week, for a total of 5.8 cans. That equals 83% of the planned 7 cans.

**Table S3. Results when Data of Siblings were collapsed into a Single Experimental Unit**

| | 0 month | 18 months | **Change** | 0 month | 18 months | **Change** | **Difference in changes (95% CI)** | **P for difference** |
|---|---|---|---|---|---|---|---|---|
| | | **Sugar-containing group** | | | **Sugar-free group** | | | |
| *Completers only* [b] | | N=176 | | | N=199 | | | |
| Primary endpoint | | | | | | | | |
| BMI z score [c] | 0.07±0.92 | 0.09±0.92 | 0.02±0.40 | −0.002±0.92 | 0.14±0.98 | 0.15±0.39 | −0.13 (−0.21 to −0.05) | 0.002 |
| Secondary endpoints | | | | | | | | |
| Sum of skinfolds (mm) | 36.5±16.0 | 39.6±19.2 | 3.1±8.2 | 34.5±14.2 | 40.2±18.8 | 5.7±9.3 | −2.7 (−4.5 to −0.9) | 0.004 |
| Waist-to-height ratio (%) | 44.6±3.5 | 43.7±3.7 | −0.9±1.8 | 44.1±3.4 | 43.6±3.9 | −0.46±2.01 | −0.4 (−0.8 to −0.04) | 0.03 |
| Electrical-impedance fat mass (kg) | 5.66±3.22 | 6.71±3.99 | 1.03±1.61 | 5.53±2.97 | 7.15±4.03 | 1.63±1.87 | −0.60 (−0.95 to −0.24) | 0.001 |
| Electrical-impedance fat mass (% of body weight) | 17.97±6.41 | 17.43±6.82 | −0.58±3.51 | 17.63±6.18 | 18.21±6.88 | 0.58±3.57 | −1.16 (−1.89 to −0.44) | 0.002 |
| Other endpoints | | | | | | | | |
| Weight (kg) | 29.83±7.84 | 36.19±9.53 | 6.36±2.62 | 30.02±7.53 | 37.35±9.74 | 7.33±3.13 | −0.97 (−1.56 to −0.38) | 0.001 |
| Height (cm) | 131.76±11.49 | 141.98±11.38 | 10.22±1.74 | 132.94±11.47 | 143.49±11.70 | 10.55±1.83 | −0.33 (−0.69 to 0.04) | 0.08 |
| Height z score [c] | −0.13±0.90 | −0.13±0.92 | 0.02±0.37 | 0.02±0.98 | 0.09±0.95 | 0.07±0.44 | −0.05 (−1.14 to 0.03) | 0.21 |
| Waist circumference (cm) | 58.73±6.53 | 62.09±7.43 | 3.36±2.60 | 58.50±5.93 | 62.52±6.97 | 4.02±3.00 | −0.67 (−1.24 to −0.09) | 0.02 |

[a] This was a prespecified analysis.[1] Values are means±SD, or means with 95% confidence intervals in parentheses. N is the number of independent households. 119 household provided more than one participant, and values of siblings were averaged to provide a single experimental unit. We used the Statistical Package for the Social Sciences (SPSS) version 17.0 to perform the analyses. Differences in change between the sugar-free group en sugar-containing group were analysed with an independent sample *t*-test: we considered $P \leq 0.05$ significant.
[b] Completers were participants who consumed the drinks for the full 18 months. Mean changes may differ slightly from the difference between means at 18 and 0 months because a few participants lacked measurements at either timepoint.
[c] We calculated z scores of body-mass index and height from the Dutch 2009 reference data.[2]

| Table S4. Results in the 80% Most Compliant Participants.[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 months | 18 months | **Change** | 0 months | 18 months | **Change** | **Difference in changes (95% CI)** | **P for difference** |
| | **Sugar-free group** **N=174** | | | **Sugar-containing group** **N=209** | | | | |
| *Completers only [b]* | | | | | | | | |
| <u>Primary endpoint</u> | | | | | | | | |
| BMI z score [c] | 0.04±0.97 | 0.06±0.96 | 0.02±0.41 | 0.01±1.01 | 0.17±1.05 | 0.16±0.40 | −0.14 (−0.23 to −0.06) | 0.001 |
| <u>Secondary endpoints</u> | | | | | | | | |
| Sum of skinfolds (mm) | 35.3±16.9 | 38.2±19.9 | 2.9±8.2 | 34.1±15.7 | 39.7±20.0 | 5.7±10.2 | −2.7 (−4.6 to −0.8) | 0.005 |
| Waist-to-height ratio (%) | 44.6±3.7 | 43.6±3.8 | −1.0±1.9 | 44.2±3.6 | 43.8±4.0 | −0.4±2.1 | −0.5 (−0.9 to −0.1) | 0.01 |
| Electrical-impedance fat mass (kg) | 5.49±3.44 | 6.44±4.17 | 0.95±1.60 | 5.35±3.09 | 6.88±4.20 | 1.53±1.98 | −0.59 (−0.95 to −0.22) | 0.002 |
| Electrical-impedance fat mass (% of body weight) | 17.39±6.60 | 16.70±7.00 | −0.68±3.76 | 17.22±6.22 | 17.78±7.27 | 0.50±3.82 | −1.18 (−1.95 to −0.41 | 0.003 |
| <u>Other endpoints</u> | | | | | | | | |
| Weight (kg) | 29.59±8.47 | 35.84±10.08 | 6.25±2.63 | 29.49±8.17 | 36.64±10.38 | 7.14±3.18 | −0.89 (−1.47 to −0.30) | 0.003 |
| Height (cm) | 131.54±12.20 | 141.84±12.00 | 10.30±1.91 | 131.83±12.27 | 142.32±12.56 | 10.48±1.92 | −0.18 (−0.57 to 0.20) | 0.35 |
| Height z score [c] | −0.06±0.91 | −0.06±0.95 | −0.005±0.42 | 0.05±1.00 | 0.09±0.98 | 0.05±0.46 | −0.05 (−0.14 to 0.04) | 0.26 |
| Waist circumference (cm) | 58.57±7.01 | 61.86±7.67 | 3.29±2.62 | 58.15±6.42 | 62.20±7.32 | 4.05±3.08 | −0.76 (−1.34 to −0.18) | 0.01 |

[a] This was a prespecified analysis.[1] Values are means±SD, or means with 95% confidence intervals in parentheses. We excluded children with an adherence of 77.3% or less. We used the Statistical Package for the Social Sciences (SPSS) version 17.0 to perform the analyses. Differences in change between the sugar-free group en sugar-containing group were analyzed with an independent sample *t*-test: we considered P ≤ 0.05 significant.

[b] Completers were participants who consumed the drinks for the full 18 months. Mean changes may differ slightly from the difference between means at 18 and 0 months because a few participants lacked measurements at either timepoint.

[c] We calculated z scores of body-mass index and height from the Dutch 2009 reference data.[2]

**Table S5. Linear Regression Analyses with Correction for Baseline Differences.**[a]

| | 0 months | 18 months | **Change** | 0 months | 18 months | **Change** | **Difference in changes (95% CI)** | **P for difference** |
|---|---|---|---|---|---|---|---|---|
| | | **Sugar-free group**<br>**N=319** | | | **Sugar-containing group**<br>**N=322** | | | |
| ***Full cohort, noncompleters imputed*** [b] | | | | | | | | |
| <u>Primary endpoint</u> | | | | | | | | |
| BMI z score [d] | 0.06±1.00 | 0.08±0.99 | 0.02±0.41 | 0.01±1.04 | 0.15±1.06 | 0.15±0.42 | −0.12 (−0.20 to −0.04) | 0.001 |
| <u>Secondary endpoints</u> | | | | | | | | |
| Sum of four skinfolds (mm) | 36.4±17.7 | 39.6±20.4 | 3.2±8.8 | 35.6±17.9 | 41.1±21.1 | 5.5±10.2 | −2.3 (−4.1 to −0.5) | 0.01 |
| Waist-to-height ratio (%) | 44.6±4.0 | 43.7±4.0 | −0.9±2.0 | 44.2±4.0 | 43.7±4.0 | −0.5±2.0 | −0.004 (−0.01 to −0.0) | 0.08 |
| Electrical-impedance fat mass (kg) | 5.76±3.85 | 6.77±4.71 | 1.01±2.62 | 5.70±3.68 | 7.28±4.89 | 1.58±2.47 | −0.57 (−1.02 to −0.12) | 0.01 |
| Electrical-impedance fat mass (% of body weight) | 17.91±7.01 | 17.22±8.44 | −0.70±5.31 | 17.67±6.92 | 18.05±8.25 | 0.38±4.86 | −1.06 (−1.98 to −0.14) | 0.02 |
| <u>Other endpoints</u> | | | | | | | | |
| Weight (kg) | 30.04±8.93 | 36.39±10.41 | 6.35±3.07 | 30.33±8.82 | 37.69±11.05 | 7.37±3.35 | −0.97 (−1.46 to −0.48) | < 0.001 |
| Height (cm) | 132.06±12.55 | 142.34±12.48 | 10.28±1.91 | 133.02±12.71 | 143.67±13.05 | 10.65±1.97 | −0.37 (−0.72 to −0.02) | 0.05 |
| Height z score [d] | −0.09±1.00 | −0.07±0.99 | 0.03±0.27 | 0.03±0.99 | 0.09±0.99 | 0.06±0.27 | −0.04(−0.10 to 0.02) | 0.12 |
| Waist circumference (cm) | 58.85±7.44 | 62.22±7.97 | 3.37±2.97 | 58.69±7.05 | 62.72±7.92 | 4.03±3.12 | −0.66 (−1.23 to −0.09) | 0.02 |
| ***Completers only*** [c] | | **N=225** | | | **N=252** | | | |
| <u>Primary endpoint</u> | | | | | | | | |
| BMI z score [d] | 0.05±0.99 | 0.07 ±0.98 | 0.02 ±0.40 | −0.02 ±1.00 | 0.14 ±1.06 | 0.15 ±0.42 | −0.13 (−0.20. to −0.05) | 0.001 |
| <u>Secondary endpoints</u> | | | | | | | | |
| Sum of four skinfolds (mm) | 36.0 ±16.9 | 39.1 ±20.2 | 3.2 ±8.1 | 34.4 ±15.8 | 40.1±20.4 | 5.7 ±10.0 | −2.7 (−4.3 to −1.05) | 0.001 |
| Waist-to-height ratio (%) | 44.6 ±3.7 | 43.7 ±3.8 | −0.9 ±1.9 | 44.1 ±3.7 | 43.7 ±4.1 | −0.5 ±2.1 | −0.4 (−0.8 to −0.1) | 0.03 |
| Electrical-impedance fat mass (kg) | 5.61 ±3.44 | 6.65 ±4.29 | 1.02 ±1.68 | 5.45 ±3.21 | 7.02 ±4.40 | 1.57±2.05 | −0.58 (−0.90 to −0.26) | < 0.001 |
| Electrical-impedance fat mass (% of body weight) | 17.69±6.63 | 17.11±7.22 | −0.61±3.71 | 17.35±6.39 | 17.85±7.36 | 0.45±3.81 | −1.04 (−1.72 to −0.36) | 0.003 |
| <u>Other endpoints</u> | | | | | | | | |
| Weight (kg) | 29.76±8.44 | 36.09±10.19 | 6.33±2.71 | 29.75±8.20 | 37.06±10.66 | 7.30±3.39 | −0.97 (−1.42 to −0.52) | < 0.001 |
| Height (cm) | 131.72±12.44 | 141.92±12.23 | 10.21±1.85 | 132.40±12.57 | 142.98±12.89 | 10.57±1.93 | −0.37 (−0.71 to −0.03) | 0.04 |
| Height z score [d] | −0.12±0.92 | −0.12±0.95 | −0.001±0.38 | −0.002±1.01 | 0.06±0.99 | 0.06±0.44 | −0.08 (−0.15 to −0.003) | 0.04 |
| Waist circumference (cm) | 58.63±6.90 | 61.99±7.79 | 3.36±2.69 | 58.30±6.43 | 62.35±7.55 | 4.05±3.10 | −0.70 (−1.24 to −0.20) | 0.007 |

[a] This was a prespecified analysis where we used the difference in change between the sugar-containing and sugar-free group as dependent variable, treatment as independent variable, and the

baseline value of each endpoint as covariate.[1] Values are means±SD, or means with 95% confidence intervals in parentheses.  We used R software version 2.1 to impute endpoints of 164 participants who discontinued treatment, and the Statistical Package for the Social Sciences (SPSS) version 17.0 for all other analyses. The difference in changes between the sugar-free group and sugar-containing group were analyzed with linear regression: we considered $P \leq 0.05$ significant.

[b] Endpoints of 164 participants who withdrew from treatment were imputed, see Methods.

[c] Completers were participants who consumed the drinks for the full 18 months. Mean changes may differ slightly from difference between means at 18 and 0 months because a few participants lacked measurements at either timepoint.

[d] We calculated z scores of body-mass index and height from the Dutch 2009 reference data.[2]

**Table S6. Adverse Events.** [a]

| Adverse Events | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | | **Sugar-free group** | | | **Sugar-containing group** | |
| | **Completers** | **Noncompleters** | **Total** | **Completers** | **Noncompleters** | **Total** |
| Headache | 0 | 0 | 0 | 1 | 1 | 2 |
| Allergy | 0 | 2 | 2 | 0 | 3 | 3 |
| Weight increase | 0 | 2 | 2 | 2 | 4 | 6 |
| Weight decrease | 1 | 0 | 1 | 0 | 0 | 0 |
| Behavioral problems | 0 | 2 | 2 | 1 | 0 | 1 |
| Abdominal discomfort | 0 | 2 | 2 | 2 | 5 | 7 |
| Total | 1 | 8 | **9** | 6 | 13 | **19** |

[a] We urged parents to report adverse events at the email address or cell phone number printed on all beverage cans and gave all parents the telephone number of an independent physician to report and discuss adverse events. None of the parents approached this physician. Adverse events were reported by 21 noncompleters as a reason to stop drinking the beverages and by 7 children who completed the study.

**Table S7. Baseline Characteristics of Completers versus Noncompleters.** [a]

| Characteristic | Completers (n = 477) | Noncompleters (n = 164) [b] |
|---|---|---|
| Girls | 43% | 57% |
| Age (years) | 8.13±1.84 | 8.38±1.88 |
| Dutch ancestry [c] | 87% | 79% |
| Non-western ancestry | 12% | 20% |
| Parent education lower to intermediate [d] | 11% | 20% |
| Parent education highschool | 31% | 29% |
| Parent education college or university | 57 % | 49% |
| Weight (kg) | 29.76±8.30 | 31.43±10.27 |
| Height (cm) | 132.1±12.5 | 133.9±12.9 |
| Height z score (SD units above Dutch mean) [f] | −0.06±0.97 | 0.04±1.05 |
| Body-mass index [e] | 16.73±2.29 | 17.15±3.23 |
| Body-mass index z score (SD units above Dutch mean) [f] | 0.01±0.99 | 0.08±1.09 |
| Low body-mass index [g] | 1% | 1% |
| Healthy body-mass index | 80% | 81% |
| Overweight | 17% | 12% |
| Obese | 2% | 7% |
| Sum of four skinfolds (mm) [h] | 35.12±16.36 | 38.68±21.17 |
| Waist-to-height ratio (%) | 44.33±3.67 | 44.60±4.89 |
| Electrical-impedance fat mass (kg) [i] | 5.53±3.32 | 6.41±4.75 |
| Electrical-impedance fat mass (% of body weight) | 18% | 19% |

[a] Differences between completers and noncompleters at baseline were significant for Sex, Ancestry, Weight status and Electrical-impedance fat mass, based on Chi-square and *t*-tests. Plus-minus values are mean±SD.
[b] 94 children dropped-out in the sugar-free and 70 in the sugar group (P=0.03 for difference between groups). For reasons to discontinue treatment, see Figure 1 of main paper and Table S6 of the Supplementary Appendix.
[c] N = 633; 8 households did not fill out this form. A child is designated *Dutch* if both parents were born in the Netherlands, and *Non-western* if one or both parents were born in Suriname, Dutch Antilles, Turkey, Morocco, Russia, Egypt or Vietnam.
[d] N = 632; 9 households did not fill out this form. *Lower to intermediate education* is Elementary school, Lower vocational secondary education, Technical secondary education, Intermediate secondary education or Intermediate vocational education. We based educational level on whichever of the parents had the highest education.
[e] Body-mass index is the weight in kilograms divided by the square of the height in meters.
[f] We calculated z scores of body-mass index and height from the Dutch 2009 reference data.[2]
[g] We used international cut-offs for low and healthy body-mass index [4] and for overweight and obesity.[5]
[h] N = 640; 1 child refused the measurements.
[i] N = 637; 4 children refused the measurements

**Table S8. Responses of Participants to the Question which Type of Beverage they Thought they had Consumed.**[a]

| Treatment | Response | | | |
|---|---|---|---|---|
| | 'Sweetened with artificial sweeteners' | 'Sweetened with sugar' | 'I don't know' or equivalent | Subtotals |
| **Completers** | | | | |
| Sugar-free group | 81 (36%) | 34 (15%) | 107 (48%) | 222 |
| Sugar-containing group | 67 (27%) | 60 (24%) | 125 (50%) | 252 |
| Total | 148 | 94 | 232 | **474** |
| | | | | |
| **Noncompleters** | | | | |
| Sugar-free group | 21 (27%) | 12 (15%) | 45 (58%) | 78 |
| Sugar-containing group | 12 (21%) | 11 (19%) | 34 (60%) | 57 |
| Total | 33 | 23 | 79 | **135** |
| | | | | |
| Total | | | | **609** |

[a] Values are numbers of children, with percentage of subtotal in parentheses. At the final visit at 18 months we asked available children (*in Dutch*): 'Alle kinderen hebben dezelfde smaken limonade gedronken: perzik, framboos, mango en citroen. De limonades die door de kinderen werden gedronken waren allemaal zoet. Sommige kinderen hebben altijd limonade gedronken dat zoet was gemaakt met suiker. Andere kinderen hebben altijd limonade gedronken dat zoet was gemaakt met kunstmatige zoetstoffen. Welke limonade heb jij gedronken: limonade met suiker of limonade met kunstmatige zoetstof?' *English translation*: 'All children have consumed nonfizzy softdrinks with the same tastes: peach, raspberry, mango and lemon. All the drinks that the children drank were sweet. Some children always drank drinks that had been sweetened with sugar. Other children always drank drinks that had been sweetened with artificial sweeteners. Which drink did you consume: drinks sweetened with sugar or drinks with artificial sweetener?'

**Table S9. Comparison of Outcomes According to the Independent Sample *t*-Test, Ancova-Complete Case Analysis with Covariate Adjustment,[3] and the Independent Sample *t*-Test with Values of Noncompleters Imputed.** [a]

| | Independent sample *t*-test | | Ancova-complete case analysis with covariate adjustment | | Independent sample *t*-test after multiple imputation of missing values | |
|---|---|---|---|---|---|---|
| | Difference in changes (95% CI) | P for difference | Difference in changes (95% CI) | P for difference | Difference in changes (95% CI) | P for difference |
| Primary endpoint | | | | | | |
| BMI z score | −0.13 (−0.20 to −0.06) | 0.001 | −0.13 (−0.20 to −0.05) | 0.001 | −0.13 (−0.21 to −0.05) | 0.001 |
| Secondary endpoints | | | | | | |
| Sum of four skinfolds (mm) | −2.5 (−4.2 to −0.8) | 0.003 | −2.8 (−4.45 to −1.13) | 0.001 | −2.2 (−4.0 to −0.4) | 0.02 |
| Waist-to-height ratio (%) | −0.4 (−0.8 to −0.1) | 0.02 | −0.4 (−0.76 to −0.03) | 0.03 | −0.4 (−1.0 to −0.0) | 0.05 |
| Electrical-impedance fat mass (kg) | −0.55 (−0.89 to −0.21) | 0.001 | −0.60 (−0.92 to −0.27) | < 0.001 | −0.57 (−1.02 to −0.12) | 0.02 |
| Electrical-impedance fat mass (% of body weight) | −1.05 (−1.73 to −0.37) | 0.003 | −0.47 (−1.08 to 0.13) | 0.12 | −1.07 (−1.99 to −0.15) | 0.02 |
| Other endpoints | | | | | | |
| Weight (kg) | −0.97 (−1.52 to −0.42) | 0.001 | −1.02 (−1.47 to −0.56) | < 0.001 | −1.01 (−1.54 to −0.48) | < 0.001 |
| Height (cm) | −0.36 (−0.71 to −0.02) | 0.04 | −0.36 (−0.69 to −0.02) | 0.04 | −0.37 (−0.72 to −0.02) | 0.04 |
| Height z score | −0.07 (−0.14 to 0.01) | 0.08 | −0.08 (−0.15 to −0.00) | 0.05 | −0.04 (−0.10 to 0.02) | 0.17 |
| Waist circumference (cm) | −0.69 (−1.22 to −0.17) | 0.01 | −0.71 (−1.24 to −0.17) | 0.01 | −0.66 (−1.23 to −0.09 | 0.02 |

[a] Outcomes of the independent sample *t*-test and the independent sample *t*-test after multiple imputation are copied from Table 2 of the main paper, and are given here for comparison only. We included age at baseline, sex, ethnicity, and parental education as covariates in the Ancova-complete case analysis with covariate adjustment.

# References for the Supplementary Appendix

1.      de Ruyter JC, Olthof MR, Kuijper LD, Katan MB. Effect of sugar-sweetened beverages on body weight in children: design and baseline characteristics of the Double-blind, Randomized INtervention study in Kids. Contemp Clin Trials 2012;33:247-57.
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