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Review

Substituting sugar-sweetened beverages with water or milk is inversely associated with body fatness development from childhood to adolescence

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ABSTRACT

Objective: The aim of this study was to examine the association between different types of beverage intake and substitution of sugar-sweetened beverages (SSBs) by water, milk, or 100% fruit juice in relation to 6-y change in body fatness.

Methods: A cohort of 9-y-old children ($N = 358$) who participated in the Danish part of the European Youth Heart Study was followed for development of body fatness over 6 y. Multivariate linear regression was used to examine the associations between beverage intake at baseline and change in body fatness (body mass index *z* score [BMIz]), waist circumference (WC), and sum of four skinfolds (Σ4SF) over 6 y with adjustment for potential confounders. Substitution models were used to evaluate various beverages as alternatives to SSBs.

Results: SSB intake at age 9 y, but not intake of other beverages, was directly associated with subsequent 6-y changes in BMIz ($\beta = 0.05$; $P = 0.02$) and Σ4SF ($\beta = 0.86$; $P = 0.02$). Daily substitution of 100 g water for 100 g SSB was inversely associated with changes in BMIz ($\beta = -0.04$; $P = 0.02$), WC ($\beta = -0.29$; $P = 0.04$), and Σ4SF ($\beta = -0.91$; $P = 0.02$) over 6 y. Daily substitution of 100 g milk for 100 g SSB was also inversely associated with changes in BMIz ($\beta = -0.05$; $P = 0.02$), WC ($\beta = -0.33$; $P = 0.046$), and Σ4SF ($\beta = -0.79$; $P = 0.06$). No effect was observed for substitution of SSB by 100% fruit juice.

Conclusion: Our results suggest that SSB intake is associated with long-term changes in body fatness in children, and replacing SSBs with water or milk, but not 100% fruit juice, is inversely associated with body fatness development.

Introduction

Increased consumption of beverages, particularly sugar-sweetened beverages (SSBs), is thought to play a role in the etiology of obesity [1,2]. It is assumed that energy consumed in a liquid form is less satiating than energy consumed in a solid form and may lead to an incomplete compensatory reduction in energy from other sources, resulting in excess energy intake and

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subsequent weight gain [3]. Moreover, shifts in beverage consumption patterns, that is, increases in SSB consumption and decreases in milk consumption particularly in children and adolescents, and the interrelation of beverage consumption with other unhealthy eating patterns also may contribute to weight gain and obesity [4]. The glycemic and metabolic effects of beverages containing rapidly absorbable carbohydrates also are likely to increase body weight and fat gain [4] with regular soft drinks and fruit drinks containing carbohydrate in the form of added sugars (~10% sucrose or high fructose corn syrup). Conversely, milk contains 4% to 5% lactose as well as protein, fat, and other food components that slow the rate of carbohydrate absorption.

Childhood obesity has become a major public health concern worldwide. Limiting SSB consumption has been acknowledged as one of the primary preventive strategies for combating the childhood obesity epidemic [5,6]. The replacement of SSBs with low-energy alternatives such as water and diet beverages is likely to benefit weight control [7,8]. Previous studies, mostly short-term feeding trials and weight loss intervention studies, have documented that the replacement of SSBs with water [9–11] and diet beverages [12] may promote weight loss and reduce fat accumulation and obesity risk. Energy-containing nutritious beverages such as milk and 100% fruit juice, when consumed in recommended amounts, may be better alternatives than SSBs. Indeed, previous intervention trials have revealed a beneficial effect on lean body mass and growth in children when habitual SSB consumption is replaced with regular milk [13]. However, the effects of replacing SSBs with other beverages revealed by these short-term experimental studies might not extrapolate to the long term. Only a limited number of studies have examined the long-term effects on obesity development of replacing SSBs with other beverages [14,15].

Considering the elevated public health concern on the influence of SSB consumption in childhood obesity and the emerging debate on the effectiveness of limiting SSB consumption in childhood obesity prevention, we aimed to prospectively examine the association between the intake of different beverage types and subsequent 6-y changes in body fatness as well as the relationship of replacing SSB with water, coffee/tea, milk, or 100% fruit juice to subsequent 6-y changes in body fatness.

Materials and methods

Study population

The European Youth Heart Study (EYHS) is an international multicenter study designed to address environmental, personal, lifestyle, and physiological factors that may influence the development of cardiovascular risk factors in children. All study protocols complied with the Declaration of Helsinki and were approved by the scientific ethics committee of the local counties of Vejle and Funen, Denmark (VF 20030067). Written explanations of the study aims and possible hazards, discomfort, and inconvenience of test procedures were provided to both parents and children. Data collection was conducted throughout the school year to minimize seasonal effects. Most of the study protocols used in the EYHS were standard procedures that are well validated in children of similar age, otherwise additional validation studies were undertaken [16]. Detailed study design and procedures have been described previously [17].

Our current study used data from the 9-y-old (third-grade) children who participated in the Danish part of EYHS in 1997 with a 6-y follow-up in 2003. In 1997, 71% of invited children (n = 590) participated in the baseline interview. The dropout rate from baseline to first follow-up interview in 2003 was 34.9% (n = 384). The attrition analysis for participants and nonparticipants were similar regarding anthropometrics, dietary intake, socioeconomic status (SES), physical activity, and pubertal status [18]. Twenty-five children who had incomplete dietary information at baseline or incomplete anthropometric data at either time point were excluded from the analysis. Underreporting of energy intake was assessed by the Goldberg cutoff method by calculating the ratio of reported energy intake (EI) to basal metabolic rate (BMR) [19]. BMR was calculated using the Schofield equation [20]. The lower 95th percentile cutoff value of 0.9 was applied to individuals. One female underreporter was identified and excluded from the analysis resulting in a final sample size of 358 children (201 girls and 157 boys).

Beverage intakes

Dietary intake was assessed by one 24-h recall face-to-face interview supplemented with a parent-assisted food record. Different sizes of drinking glasses, plates, and spoons together with food pictures of the most commonly consumed foods and beverages in various portion sizes were used to facilitate the estimation of quantities during the interview. Food records were entered into the software program Dankost 3000 (Danish Catering Centre, Copenhagen, Denmark) for nutrient analysis using the Danish Food Composition Tables 2006 [21]. Information on seven types of beverages including plain water (tap or bottled), milk (regular, low-fat, skim, plain, or flavored), SSBs (regular soft drinks, lemonade, or fruit-flavored drinks), 100% pure fruit juice (apple juice, orange juice- or other juice), coffee/tea (plain or sweetened), diet soft drinks, and alcoholic drinks were obtained. Diet soft drinks and alcoholic drinks were excluded from the analysis due to the small number of participants who consumed these beverages (<5%). Daily per capita consumption of each beverage type and total beverages in absolute amount in g were calculated.

Assessment of anthropometry

According to the standardized procedures for anthropometric measurements, height was measured in bare feet to the nearest 5 mm by a stadiometer and body weight was measured in light clothing to the nearest 0.1 kg by a beam balance scale. Body mass index (BMI) was calculated as body weight in kg divided by meter^2 of height. Age- and sex-specific BMI z score (BMIz) was generated using the least mean squares method [22].Waist circumference (WC) was measured twice with a metal anthropometric tape placed midway between the lower rib margin and the iliac crest, at the end of gentle expiration. The mean value of the two measurements was used for analysis. Skinfold thickness was measured with Harpenden fat calipers with two measurements taken at each site. The sum of four skinfolds (Σ4SF) was obtained by adding the average skinfolds of the biceps, triceps, subscapular, and suprailiac [16]. BMIz, WC, and Σ4SF were used as indicators for total body fatness, visceral fat, and subcutaneous fat, respectively.

Assessment of covariates

Physical activity level was measured by both a validated accelerometer (Actigraph model 7164, Manufacturing Technology Inc, Fort Walton Beach, FL, USA) [23] and a computer-based questionnaire. Because a large number of participants failed to complete the accelerometer measurements, the questionnaire measurement was chosen to represent the physical activity of the study population to maximize sample size. Participants were classified as either physically inactive (reported no exercise or infrequent exercise) or physically active (reported regular exercise). The accelerometer measurements were used in a sensitivity analysis that found good agreement with the questionnaire method [24]. To obtain demographic and socioeconomic data, we asked parents to complete a computer-based questionnaire. Maternal education, shown to be the best indicator of SES for children, was used to represent the SES of the current study population [25]. SES was categorized as low (elementary, high school, and vocational education) or high (short-, medium-, or long-term tertiary education). Trained personnel assessed pubertal status according to Tanner's stages using a 5-point scale of pictures [26].

Statistical analysis

Descriptive analysis was performed for all variables at baseline and follow-up. Sample mean ± SD was calculated for continuous variables and percentage of participants was calculated for categorical variables. Paired t test was used to examine the differences between anthropometric data at baseline and at follow-up. Multivariate linear regression analysis was used to test the associations between baseline beverage intake and subsequent changes in body fatness. Pearson correlation was conducted to assess multicollinearity among individual beverage intake before regression analysis. Because correlation coefficients were small ($r <$ 0.2), individual beverage intakes (per 100 g) were included in the same model to account for mutual confounding. Thus, the independent effect of each beverage type on changes in body fatness could be examined. Changes in BMIz, WC, and Σ4SF calculated by subtracting baseline data from follow-up data, were evaluated separately in three multivariate models. Potential confounders were identified as variables that associated with outcome variables at a P-value <0.25 and those that are predictors of obesity and may be related to beverage consumption [27]. All models were controlled for the following potential confounders: age, sex, baseline BMIz/WC/Σ4SF, physical activity, SES, and pubertal status. Interaction terms were used to test the potential effect modification by sex in these models.