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SOFT DRINKS AND OBESITY: THE EVIDENCE

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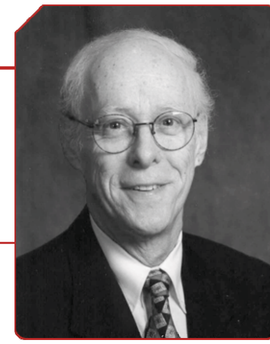

Key Points

- Intake of sugar-sweetened beverages has continued to rise, and the fructose they contain, either from sugar (sucrose) or high-fructose corn syrup has been associated with higher energy intake, an increase in body weight, a risk of developing metabolic syndrome and gout in men.
- Fructose in single doses increases thermogenesis, blood pressure and triglycerides, particularly in men.
- Sugar-sweetened beverages or fructose itself increase blood pressure and hepatic lipid production in healthy individuals over a 10-week period.
- Mechanisms for these effects of sugar-sweetened beverages may reflect reduced caloric compensation of “liquid calories” and increased production of uric acid during hepatic metabolism of fructose.

Introduction

Obesity has become an epidemic problem. It affects both children and adults. Recent data from the National Health and Nutrition Examination Survey [1] showed that the prevalence of obesity in children has continued to rise and is now 18%. This extra fat requires the intake of more food energy over time than is needed by the body. Thus, any form of energy that we ingest may play a role in the development of obesity. These extra calories are of particular concern for the childhood obesity epidemic, because children have limited responsibility for their caloric intake. With this focus on children, I have reviewed the data on the effects of fructose on acute and intermediate metabolic responses and on the effects of beverage intake on energy intake and weight gain. The possibility that “calorie-containing beverages” might have a strong relationship in the development of obesity was highlighted in a paper which showed that the growing use of high-fructose corn syrup between 1970 and 1990 paralleled the rising prevalence of obesity in the period between 1970 and 2000 [2-4].

Acute Studies

Several studies have examined the effects of single doses of fructose vs. glucose on energy expenditure, serum lipids and blood pressure. From these studies it is clear that fructose increases thermogenesis more than glucose, that it increases triglycerides and increases blood pressure. A 75 g oral load of glucose or fructose was given to 17 volunteers and metabolic changes followed for 4 hours. Fructose stimulated oxygen consumption more than glucose but produced a much smaller stimulation of insulin [5]. Fructose increased the respiratory quotient more than glucose, a finding that may imply increase de novo lipogenesis. Blockade of the sympathetic nervous system with propanolol, a beta-adrenergic blocking drug, reduced oxidation of both fructose and glucose by about 40%. Of interest, both obese and diabetic patients had a similar stimulation of oxygen uptake after infusion of glucose which was smaller than the response to fructose [6]. To evaluate the effect of fructose on lipids, 17 obese men (n=9) and women (n=8) with a body mass index (BMI) >30 kg/m^2 were admitted to the Clinical and Translational Research Center for a cross-over study lasting 24 hours in where mixed meals and beverages with 30% fructose or 30% glucose were given to healthy volunteers and blood samples drawn periodically. The area under the curve of insulin, leptin, and triglycerides were measured. The rise in plasma glucose was smaller after fructose, but the rise in triglycerides and lactate larger. Insulin and leptin both showed a lower response to fructose than to glucose. These responses in lipids are seen primarily in men with no response or only small responses in women [7]. The response of blood pressure to fructose was examined in 15 healthy men who drank 500 ml volumes of water (placebo) or 60 g of fructose or glucose on 3 occasions. Blood pressure, metabolic rate and autonomic nervous system activity were measured for 2 hours. Administration of fructose was associated with an increase in both systolic and diastolic blood pressure. Blood pressure did not rise after either glucose or water [8].

Intermediate Length Studies

A number of studies comparing sucrose, artificially-sweetened beverages, fructose or glucose have been reported. In one 10-week study, 41 overweight men and women entered a 10-week parallel arm study. One group of 21 adults received 3.4 MJ (813 kcal) of sugar-containing beverages and were compared with 20 others who received beverages sweetened with aspartame, containing about 1 MJ (240 kcal) and no sugar. For their other foods, the subjects could select freely from foods at a kiosk run by the study group. After 10 weeks, energy intake had increased by 1.6 MJ/day and sucrose to 28% of intake in the group receiving the sugar-containing beverages. Protein and fat intake declined. Body weight and fat mass increased by 1.6 and 1.3 kg respectively in the sugar group and decreased by -1.0 and -0.3 kg in the aspartame-sweetened group. Blood pressure increased by 3.8/4.1 mmHg in the sugar-consuming group but did not change in the other group. Concentrations of several inflammatory markers were also changed. In the group consuming sucrose, haptoglobin increased by 13%, transferrin by 5% and C-reactive protein by 6%. In the group receiving the aspartame-sweetened beverages, haptoglobin decreased by 16%, C-reactive protein decreased by 26% and transferrin was basically unchanged with a small 2% fall [9, 10].

In a study of similar length, fructose and glucose were compared when added to the diet as 25% of calories for 10 weeks, 8 weeks as out-patients and 2 weeks as in-patients at the end of the study. Thirty two men and women had a diet with 15% protein, 30% fat and 55% carbohydrate. Fifteen received 25% of calories in glucose beverages and 17 in fructose beverages. Intra-abdominal (visceral) fat increased by 14% in the fructose-consuming group compared to about 5% in the control group with no significant change in body weight or subcutaneous fat. De novo lipogenesis increased and postprandial triglycerides increased, particularly at night [11].

Meta-Analyses of Beverage Consumption

Several meta-analyses on the effect of soft-drink consumption on changes in energy intake or changes in body weight have been published. In the study by Vartanian et al. [12] the magnitude of the relationship between the beverage intake and body weight was expressed as the effect size or "r value", which represents the magnitude of the relationship between the beverage intake and body weight. An effect size of 0.1 is small, of 0.25 is moderate and a value of 0.4 is large. They examined the effect size between soft drink consumption and BMI in 11 cross-sectional studies and found a significant positive relationship in 2, but not in 9 others, and there were no studies where drinking beverages was associated with a significant reduction in BMI. Among longitudinal studies that have examined the association between soft drink consumption and change in body weight or BMI, one was positive, 2 were mixed and 4 showed no association. Of 7 experimental studies, 5 reported a positive association with weight. Overall, the effect size for body weight was smaller than for energy intake since soft drinks are only one source of calories. In cross-sectional studies the effect size was only 0.06, in longitudinal studies it was 0.03 and in short-experimental studies it was 0.24. Calcium intake inversely related to soft drink consumption. One study showed that a 1 oz decrease in soft drink intake increased milk intake by 0.25 oz.

A second meta-analysis reported by Olsen and Heitmann [13] included some additional studies. A total of 14 prospective and 5 experimental studies were identified. The majority of the prospective studies found positive associations between intake of calorically-sweetened beverages and obesity. Three experimental studies found positive effects of calorically-sweetened beverages on body fat, but 2 did not find any effects.

The third meta-analysis examined the relation of beverage intake in children and adolescents [14]. This meta-analysis included 2 randomized clinical trials and 8 longitudinal studies. In an erratum to their original paper, the predicted change in BMI for each serving per day change in sugar-sweetened beverage consumption was 0.02 BMI units/day (95% CI: 0.01-0.04). The overall estimate of the association was 0.004 change in BMI during the time defined by the study for each serving per day change in sugar-sweetened beverage consumption. Since the BMI unit change/day is a very small unit, it was converted to a yearly change which is 1.46 BMI units – enough to explain much of the current epidemic of obesity.

Association of Fructose Intake with Disease Risk

As the quantity of fructose and sucrose/high-fructose corn syrup in the diet has increased, the number of health related issues has increased. There is a report that consumption of soft drinks is associated with the metabolic syndrome [15] and gout in men [16]. There is also a suggestion that it is associated with the development of diabetes [17].

Potential Mechanisms for the Potential Detrimental Effects of Fructose

Three main mechanisms have been suggested for the effects of fructose from either high-fructose corn syrup or sucrose. The inadequate reduction in caloric intake when calorie-sweetened beverages are ingested has been proposed as part of the mechanism for increased energy intake and obesity [4, 18].

In acute feeding studies, sugar-sweetened beverages fail to reduce energy intake, in contrast to water [19]. The metabolic pathway for fructose, in contrast to glucose, may account for the increased de novo lipogenesis and higher triglycerides [20]. Fructose is metabolized primarily in the liver where it is converted to fructose-1-phosphate from which it can readily become a substrate for the backbone of the triglyceride molecule. Third, the metabolism of fructose in the liver generates adenosine 5'phosphate that is a substrate for conversion to uric acid through a process which alters nitric oxide generation. The enhanced production of uric acid by the liver may contribute to the relation of uric acid to cardiovascular disease [21].

The rising consumption of calorie-sweetened beverages provides an increasing amount of dietary fructose. Based on this review of the literature, I conclude that in the amounts now ingested, fructose is hazardous to the health of some people.

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