AHA Scientific Statement

Sugar and Cardiovascular Disease

A Statement for Healthcare Professionals From the Committee on Nutrition of the Council on Nutrition, Physical Activity, and Metabolism of the American Heart Association

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The purpose of this report is to review the effects of dietary sugar on health, with an emphasis on cardiovascular disease (CVD) and its risk factors. Although there are no dietary trials linking sugar consumption and CVD, there are several reasons why sugar consumption should be limited.

Definitions

There are many, sometimes confusing, terms used in the literature. *Simple carbohydrate* (sugar) refers to mono- and disaccharides; *complex carbohydrate* refers to polysaccharides such as starch. Common disaccharides are sucrose (glucose+fructose), found in sugar cane, sugar beets, honey, and corn syrup; lactose (glucose+galactose), found in milk products; and maltose (glucose+glucose), from malt. The most common naturally occurring monosaccharide is fructose (found in fruits and vegetables). The term *dextrose* is used to refer to glucose. *Intrinsic* or *naturally occurring* sugar refers to the sugar that is an integral constituent of whole fruit, vegetable, and milk products; *extrinsic* or *added* sugar refers to sucrose or other refined sugars in soft drinks and incorporated into food, fruit drinks, and other beverages.

Sugar Consumption in the United States

Added sugar was not a significant component of the human diet until the advent of modern food-processing methods. Since then, the intake of sugar has risen steadily. The average US sugar utilization per capita on the basis of food disappearance data was 55 kg (120 lb) per year in 1970, and it reached 68 kg (150 lb) per year in 1995 (almost 0.5 lb per day).[1] Sugar (simple carbohydrate) intake averages 25% of total energy intake. Data from the 1989 to 1991 Continuing Survey of Food Intake by Individuals indicate that soft drinks and sugars added at the table (eg, sugar/syrups and jams) are 2 of the top 4 carbohydrate sources for US adults.[2]

Sugar and Coronary Heart Disease

Yudkin and colleagues in the 1960s[3] and 1970s[4] found that a higher intake of sugar was associated with increased CVD in both within-country and cross-country comparisons. A few recent studies have examined the link between sugar consumption and coronary heart disease (CHD). The Iowa Women's Health Study[5] showed no relation between the intake of sweets or desserts and risk of ischemic heart disease in 34 492 women monitored for 9 years. However, some major sources of sugar such as soft drinks were not considered. The Scottish Heart Health Study[6] of 10 359 men and women found that neither extrinsic nor intrinsic sugars were significant independent correlates of prevalent CHD after adjustment for other major risk factors, but the data were not adjusted for other dietary variables. A recent report from the Nurses' Health Study showed that women who consumed diets with a high glycemic load* (increased blood glucose excursions associated with intake of sweets or highly processed starches and sweets) had an increased CHD risk, with those in the highest quintile having a >2-fold risk during 10 years of follow-up.[7] Simple carbohydrate alone was also predictive but did not reach statistical significance. This analysis controlled for total energy intake and other major dietary and nondietary risk factors.

Dietary Sugar and Plasma Lipoproteins

A number of studies link dietary sugar with adverse changes in lipoproteins. Several studies have shown an inverse association between dietary sucrose and high-density lipoprotein (HDL) cholesterol.[8,9] Data from the Coronary Artery Risk Development In young Adults (CARDIA) study show a

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**Glycemic load* refers to a diet with many foods that have a high glycemic index. Glycemic index is a measure of the rise in glucose induced by ingestion of a carbohydrate. Foods that contain refined sugars make a major contribution to glycemic load; other contributors include refined starches, such as white bread and rice. It should be noted that glycemic index is determined by feeding individual foods.

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consistent inverse association between increased dietary sucrose intake and HDL cholesterol concentrations, in both cross-sectional and longitudinal analyses in blacks and whites, in both men and women, and after adjustment for other covariates.[10]

A diet high in sucrose (ie, >20% of energy) is associated with an elevation of plasma triglyceride concentrations.[11,12] This increase is due to both increased hepatic secretion and impaired clearance of very-low-density lipoprotein. Triglyceride response to dietary sugar may vary, however, according to the amount of sugar and the presence of other nutrients.[12]

Dietary Sugar, Insulin Resistance, and Diabetes

Few epidemiological studies have directly examined the relationship between sugar intake and diabetes incidence. In general, prospective data show no association, and in fact, several dietary studies show an inverse association between total carbohydrate intake and diabetes incidence.[13–15] This observation, however, is confounded because diets lower in carbohydrate are higher in fat (high fat intake predicts diabetes risk because of increased obesity).[16] On the other hand, two recent prospective cohort studies have reported food frequency consumption data that showed that a history of consumption of foods with a high glycemic load predicts the development of type 2 diabetes in women[17] and men.[18]

No epidemiological study has examined the effects of dietary sugar on insulin resistance. Several clinical studies have shown that altering the proportion of carbohydrates in the diet for up to 4 months in humans does not influence insulin resistance,[19] but the effects of varying sugar content per se were not examined.

It is widely believed that individuals with diabetes should avoid sugar to maintain glycemic control. However, there is considerable debate about whether high-sugar diets have adverse effects on glucose control in diabetic individuals. A number of studies that assessed the effects of single meals containing 12% to 25% of calories as sucrose found no adverse effects of sucrose on average glycemia.[20,21] Some long-term studies up to several months in duration showed that providing as much as 38% of calories as sucrose had no effect on average glucose control.[22–24] Diabetic individuals, however, may experience fluctuations in blood glucose levels with a habitual diet that is high in concentrated sweets, especially if they make errors with regard to the amount of carbohydrates they consume.

Diet and Advanced Glycation End Products

Advanced glycation end products (AGEs) form when sugar is nonenzymatically linked to proteins, inducing cross-linking of the glycated proteins. AGEs form at room temperature, but heating speeds up their formation; therefore, all cooked foods contain AGEs (formerly referred to as Maillard browning pigments). Dietary AGEs react with tissue proteins to form substances that reduce tissue elasticity and impede cellular function. AGEs have been identified as a pathogenic mechanism in diabetic nephropathy[25] and vascular complications.[26] Approximately 10% of ingested AGEs enter the circulation, but only one third are excreted within 3 days of ingestion.[25] Diabetes is associated with impairment in AGE excretion. In one study, urinary clearance of diet-derived AGE was 5% in diabetic individuals compared with 30% in the control group.[27] Thus, caution is warranted with regard to the potential effects of a high sugar intake on AGE formation and increased risk of nephropathy.[27] Additional research is needed to determine whether limiting intake of sugar in protein- and fat-containing foods reduces circulating AGE levels and risk of nephropathy.

Dietary Sugar and Overweight/Obesity

Because obesity has emerged as a major health problem in the United States[28] and as a definite cause of cardiovascular morbidity and mortality,[29] it is important to consider the potential impact of dietary sugar on weight gain. In human metabolic ward studies, the substitution of sucrose or other dietary carbohydrate for fat or protein in isocaloric diets shows no effect on weight or changes in energy expenditure.[30] Some studies show that body mass index is correlated inversely with sugar consumption[31]; however, this observation is confounded because dietary fat is correlated with obesity,[32] and high-fat diets are lower in total and simple carbohydrate. Diets low in sugar have been associated with weight loss in some ad lib dietary studies,[33] perhaps as a result of lower total calorie consumption. Another relationship between sugar and obesity comes from studies of food preferences, which report that foods high in sugar are common choices of obese individuals.[34] To lose weight, obese persons need to limit calorie intake; thus, limiting consumption of foods that are high in sugar (most of which have high energy density) can be a strategy for weight reduction.

Sugar and Other Health Problems

There have been a number of studies that link sugar consumption to hypertension in animals.[35] In humans, there is one report that high dietary sugar intake enhances the risk of CHD in diabetic individuals who use diuretics.[36]

Sugar intake can increase carbohydrate fuel reserves and physical performance.[30] However, this enhancement occurs only at exercise intensities and levels of physical activity

TABLE 1. Sugar Content of Typical Foods

Food Item	Amount	Sugar Content, g	Sugar Content, tsp
Table sugar, honey, or brown sugar	1 tsp	5	1
Jam/jelly	1 tbsp	10	2
Glazed doughnut	1 doughnut	10	2
Milkshake	10 oz	55	11
Fruit punch	12 oz	40	8
Cola	12 oz	40	8
Yogurt with fruit	1 cup	35	7
Candy bar	1	30	6
Apple pie	1 slice	15	3
Sweetened cereal	1 cup	15	3

Source: Sweetness and lite: Go easy on sugar and enjoy it. *Health Oasis, Mayo Clinic.* 1999. Available at: http://www.mayohealth.org/mayo/9606/htm/sugar.htm. Accessed June 8, 2000.

Sugar refers to both naturally occurring and added sugar.

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TABLE 2. Nutritional Content of Low- and High-Sugar Diets

	Low Sugar		High Sugar		
	Food	Portion size	Food	Portion Size	Reduced Portion Size
Breakfast	Orange juice	4 oz	Fruit juice	4 oz	4 oz
	Wheat flakes	1 cup	Sweetened children's cereal	1 cup	1 cup
	Fresh peach	1 medium			
	Skim milk	8 oz	Skim milk	8 oz	4 oz
	Whole wheat toast	2 medium slices	White toast	2 medium slices	1 medium slice
	Margarine	1 tbsp	Jelly	1 packet	1 packet
	Coffee	8 oz	Coffee	8 oz	8 oz
Lunch	Turkey sandwich on whole wheat	3 oz turkey, 2 medium slices bread	Peanut butter and jelly sandwich on white bread	2 medium slices bread, 1 packet jelly, 2 tbsp peanut butter	2 medium slices bread, 1 packet jelly, 1 tbsp peanut butter
	Cole slaw	½ cup	Doughnut	1 medium	1 medium
	Apple	1 medium			
	Diet cola	8 oz	Cola	8 oz	8 oz
Dinner	Grilled chicken breast	4 oz	Grilled chicken breast	4 oz	2 oz
	Baked potato	1 medium	Baked potato	1 medium	1 medium
	Margarine	1 tbsp			
	Green beans	½ cup	Molded gelatin salad	½ cup	½ cup
	Whole wheat roll	2 in square	Corn muffin	1 medium	
	Ice milk	½ cup	Chocolate chip cookie, 2¼ in	2 cookies	1 cookie
	Tea	8 oz	Cola	8 oz	8 oz
Snack	Mixed nuts	2 oz	Choclate/peanut candy bar	1 regular	1 regular
Nutrients					
Calories		1520		1903	1508
Fat, %		23		27	27
Carbohydrate, %		58		61	61
Sugar, g		94		167	136
Fiber, g		84		63	49
Vitamin A, RE*		24		10	7.34
Vitamin C, mg*		781		364	363
Vitamin B_6, mg*		100		13	13

*Based on whole foods only.

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associated with endurance performance of at least 30 minutes in duration. Blood glucose and liver and muscle glycogen provide the predominant fuels for muscle contraction. When these substances reach critically low amounts, fatigue may occur and consumption of sugar may rapidly return blood glucose levels to normal. For most low- to moderate-intensity activities like walking or housework, sugar consumption does not influence performance.

Another major area of interest has been the relationship between dietary sugar and behavior and cognitive function. The belief in a relationship between sugar and hyperactivity was based on two hypotheses. The first was a possible allergic response; the second was that hyperactive children might experience functional reactive hypoglycemia. Neither of these hypotheses has been proved, and a meta-analysis of 16 randomized trials in hyperactive children showed that decreasing the sugar content of the diet resulted in no improvement in degree of hyperactivity.[37]

On the other hand, sugar is a well-established risk factor for dental caries.[38–40] This observation is based on short-term cohort studies and comparisons of rates of dental caries across countries with wide variations in sugar consumption,[38] although there is a lack of research findings regarding sugar consumption and periodontal disease.[41]

High-Sugar Diets and Nutritional Adequacy

Diets high in sugar may adversely affect nutritional adequacy. Foods high in extrinsic sugar include soft drinks, candy, pastry, and cereals with high sugar content (Table 1). Fat-free manufactured foods are often high in calories because of inclusion of high amounts of sugar. American Heart Association dietary guidelines stress consumption of fruits, vegeta-

bles, grains, and complex carbohydrates so that nutritional requirements for vitamins and minerals may be met by whole foods rather than by foods that are supplemented with vitamins. High-sugar foods displace whole foods (eg, soft drinks displace milk and juice consumption in children) and contribute to nutritional deficiencies, adding empty calories that few Americans need[42] (Table 2). Some studies that have assessed the nutritional adequacy of high-sugar diets do not necessarily show differences in vitamin and mineral intake[1] because of the supplementation of these foods with vitamins and minerals instead of the preferred intake of these elements through the diet. Among children in the Bogalusa Heart Study,[43] a linear decrease in the intake of many essential nutrients was associated with increasing total sugar intake.

The Role of Dietary Fructose, Sorbitol, and Mannitol

Sugars such as fructose (monosaccharide), sorbitol, and mannitol (sugar alcohols) are used to replace sucrose in food products and may lower the postprandial rise in glucose. In the 1970s, high-fructose syrup manufactured from starch began to be used as a replacement for sucrose in beverages and baked goods.[44] Sorbitol and mannitol are used in a variety of "sugar-free" food products because they have fewer calories per gram than do either sucrose or fructose; in the liver they are readily converted to fructose.[45] Fructose bypasses the phosphofructokinase regulatory step of glycolysis, in which glucose can be converted to glycogen rather than entering the glycolytic pathway. As a result, fructose increases hepatic pyruvate and lactic acid production, activates pyruvate dehydrogenase, and shifts the balance from oxidation to esterification of fatty acids, which can increase very-low-density lipoprotein synthesis. In feeding studies, fructose has had inconsistent effects on plasma triglyceride levels, which may be related to factors such as the amount of fructose consumed; energy balance; and baseline triglyceride, insulin, and glucose levels.[46] The postprandial rise in triglyceride levels after fat intake may be augmented with the addition of fructose to a test meal.[47] However, a study in individuals with type 2 diabetes showed a lack of significant variation in glucose, lipid, and insulin responses to three 28-day isocaloric feeding periods when 20% of calories were either fructose, sucrose, or starch.[48] For most individuals, consuming fructose either free or in the form of sucrose has neither beneficial nor adverse effects.

Summary and Conclusion

As with most other dietary constituents, long-term trial data relating sugar consumption to the development of CVD events are unavailable. Longitudinal cohort studies relating sugar consumption to CVD are equivocal because of the many potential confounders that cannot be adequately controlled in the analyses. Shorter-term studies show consistent adverse effects of sugar consumption on HDL and triglyceride levels, which could accelerate atherosclerosis. High sugar consumption may worsen diabetes control, and the combination of sugar with protein and fats promotes formation of dietary AGEs, which may be especially detrimental to those with diabetes. Although increasing the amount of sugar in an isocaloric diet does not directly lead to changes in energy expenditure or weight gain in controlled feeding studies, high-sugar foods, which are sweet and calorie dense, may increase calorie consumption and lead to weight gain. Furthermore, replacement of whole foods with high-sugar foods compromises attainment of adequate dietary vitamin and mineral intake from whole food sources.

In the absence of definitive evidence, recommendations must rely on professional judgment. No data suggest that sugar intake per se is advantageous, and some data suggest it may be detrimental. The studies above, taken in total, indicate that high sugar intake should be avoided. Sugar has no nutritional value other than to provide calories. To improve the overall nutrient density of the diet and to help reduce the intake of excess calories, individuals should be sure foods high in added sugar are not displacing foods with essential nutrients or increasing calorie intake.

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