AHA SCIENTIFIC STATEMENT

Added Sugars and Cardiovascular Disease Risk in Children

A Scientific Statement From the American Heart Association

BACKGROUND: Poor lifestyle behaviors are leading causes of preventable diseases globally. Added sugars contribute to a diet that is energy dense but nutrient poor and increase risk of developing obesity, cardiovascular disease, hypertension, obesity-related cancers, and dental caries.

METHODS AND RESULTS: For this American Heart Association scientific statement, the writing group reviewed and graded the current scientific evidence for studies examining the cardiovascular health effects of added sugars on children. The available literature was subdivided into 5 broad subareas: effects on blood pressure, lipids, insulin resistance and diabetes mellitus, nonalcoholic fatty liver disease, and obesity.

CONCLUSIONS: Associations between added sugars and increased cardiovascular disease risk factors among US children are present at levels far below current consumption levels. Strong evidence supports the association of added sugars with increased cardiovascular disease risk in children through increased energy intake, increased adiposity, and dyslipidemia. The committee found that it is reasonable to recommend that children consume ≤25 g (100 cal or ≈6 teaspoons) of added sugars per day and to avoid added sugars for children <2 years of age. Although added sugars most likely can be safely consumed in low amounts as part of a healthy diet, few children achieve such levels, making this an important public health target.

Miriam B. Vos, MD, MSPH, FAHA, Chair
Jill L. Kaar, PhD
Jean A. Welsh, PhD, MPH, RN
Linda V. Van Horn, PhD, RD, FAHA
Daniel I. Feig, MD, PhD
Cheryl A.M. Anderson, PhD, MPH, MS, FAHA
Mahesh J. Patel, MD
Jessica Cruz Munos, MD
Nancy F. Krebs, MD, MS
Stavra A. Xanthakos, MD, MS
Rachel K. Johnson, PhD, MPH, RD, FAHA
On behalf of the American Heart Association Nutrition Committee of the Council on Lifestyle and Cardiometabolic Health; Council on Clinical Cardiology; Council on Cardiovascular Disease in the Young; Council on Cardiovascular and Stroke Nursing; Council on Epidemiology and Prevention; Council on Functional Genomics and Translational Biology; and Council on Hypertension

Key Words: AHA Scientific Statements ■ child ■ diet ■ nutritional status ■ obesity ■ sugar ■ sweetening agents

CLINICAL STATEMENTS AND GUIDELINES

Atherosclerotic cardiovascular disease (CVD) is the leading cause of death in North Americans and generates tremendous personal and economic burden globally. Efforts to reduce the prevalence of CVD and its associated conditions (obesity, hypertension, type II diabetes mellitus, and nonalcoholic fatty liver disease [NAFLD]) have focused attention on the role of diet and the growing evidence that atherosclerosis starts in childhood.[1–3] Accumulating evidence implicates dietary sugars, particularly those added to processed foods or used in the preparation of foods and beverages. In part because of the lack of clarity and consensus on how much sugar is considered safe for children, sugars remain a commonly added ingredient in foods and drinks, and overall consumption by children and adults remains high. Although intake of added sugars has decreased slightly in recent years,[4] they still contribute nearly 16% of the calories consumed by US children daily (Table 1).

The purposes of this statement are to review the available evidence on added sugars intake and CVD risk in children and adolescents, to identify research gaps, and to make recommendations on the consumption of added sugars intake to reduce CVD risk.

APPROACH

The writing group members conducted literature searches for each section using relevant search terms, including *sugar*, *fructose*, *added sugars*, *dietary*, *sugar-sweetened beverages*, *sweeteners*, *children*, *noncaloric sweeteners*, *artificial sweeteners*, *nonnutritive sweeteners*, *diabetes mellitus*, *insulin resistance*, *triglycerides*, *lipids*, *cardiovascular disease*, *cardiovascular risk*, *uric acid*, *hypertension*, *blood pressure*, *allopurinol*, *liver*, *steatohepatitis*, *nonalcoholic fatty liver disease*, and *inflammation*. The PubMed searches were limited to original research, studies conducted in humans, and systematic reviews through November 2015. The reference lists of relevant articles were reviewed for additional articles. The articles were summarized, and the summaries were discussed during conference calls among the topic area experts who were part of the writing group. Group consensus was used to develop recommendations (Table 2).

To provide the most up-to-date estimates of added sugar consumption in the United States, dietary data from the NHANES (National Health and Nutrition Examination Survey) 2009 to 2012 were analyzed. NHANES data are collected and made publically available by the National Center for Health Statistics. The analytical methods used replicate[5] those used by Welsh et al in their analysis of NHANES data from 1999 through 2008.[4]

TERMINOLOGY AND DEFINITIONS

There are several different forms of dietary sugars, and the terminology used to describe them can be a source of confusion for researchers, policy makers, and consumers. Commonly used terms are described below.

Sugar

Although commonly used more broadly, the US Federal Drug Administration defines the term *sugar* as a sweet, crystalline substance, $C_{12}H_{22}O_{11}$, obtained chiefly from the juice of the sugarcane and the sugar beet.[6]

Total Sugars

The term *total sugars* is used conventionally to describe the monosaccharides glucose, galactose, and fructose, as well as the disaccharides sucrose, lactose, maltose, and trehalose.[7] Total sugars include all sugars in a food or beverage from any source, including those naturally occurring (such as fructose in fruit and lactose in milk) and those added to foods.[6]

Added Sugars

Added sugars, as defined by the US Department of Agriculture, include all sugars used as ingredients in processed and prepared foods and sugars eaten separately or added to foods at the table.[8] The term was first used in the 2000 US Dietary Guidelines for Americans to highlight foods and beverages that were higher in calories but lacked other important nutrients.[9] Because fructose is the sweetest of the commonly consumed sugars, it (or sugars that contain it) is frequently added to foods and beverages to increase their palatability. As a result, sucrose and high-fructose corn syrup, both of which are made up of glucose and fructose in approximately equal amounts, are the most commonly added sugars in the US food supply.

Naturally Occurring Sugars

Naturally occurring sugars include those that are an innate component of foods (eg, fructose in fruits and vegetables and lactose in milk and other dairy products).[6]

Extrinsic and Intrinsic Sugars

The terms *extrinsic* and *intrinsic sugars* originated from the UK Department of Health. Intrinsic sugars are defined as sugars that are present within the cell walls of plants (eg, naturally occurring sugars) and are always accompanied by other nutrients. Extrinsic sugars are those not located within the cellular structure of a food and are found in fruit juice, honey, and syrups and added to processed foods. The term *nonmilk extrinsic sugars* is used to differentiate lactose-containing extrinsic sugars from all others because

Circulation. 2017;135:e1017–e1034. DOI: 10.1161/CIR.0000000000000439

Table 1. Added Sugars Intake by Food and Beverages Sources Among US Children and Adolescents, NHANES 2009 to 2012

	Age, y							
	All (n=6412)		2–5 (n=1695)		6–11 (n=2300)		12–19 (n=2417)	
	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
Total added sugars intake								
Added sugars, % energy	16.1	15.6–16.6	13.5	13.1–13.8	16.4	15.9–16.8	17.2	16.3–18.1
Added sugars, g	80.0	77.2–82.7	53.3	51.2–55.3	78.7	76.6–80.8	93.9	89.1–98.8
Added sugars, teaspoon	19.0	18.4–19.7	12.7	12.2–13.2	18.7	18.2–19.2	22.4	21.2–23.5
SSBs, % energy	7.9	7.6–8.3	5.2	4.7–5.6	7.3	6.9–7.6	9.8	9.1–10.5
Added sugars by food source, g								
Sweets	43.0	40.5–45.5	21.2	19.2–23.2	37.0	34.9–39.1	58.1	53.5–62.7
Sodas, regular	17.0	15.3–18.8	4.1	3.4–4.8	12.1	10.6–13.7	26.9	23.7–30.2
Fruit-flavored and sports drinks	12.9	12.1–14.6	10.0	8.5–11.4	12.7	11.5–13.9	14.4	12.3–16.5
Other beverages	0.3	0.2–0.4	0.1	0.0–0.2	0.3	0.1–0.6	0.3	0.2–0.5
Sugars and syrups	3.3	2.6–4.0	2.6	1.5–3.6	3.4	2.8–4.0	3.6	2.3–4.9
Candy and gum	5.0	4.2–5.7	3.6	3.1–4.1	5.7	4.6–6.7	5.1	3.9–6.4
Coffee and tea	4.0	3.1–4.9	0.9	0.6–1.1	2.8	1.8–3.9	6.4	4.6–8.2
Alcohol-containing drinks	<0.1	<0.1–<0.1	0.0	0.0–0.0	0.0	0.0–0.0	0.1	0.0–0.2
Energy drinks	0.5	0.1–1.0	0.0	0.0–0.0	<0.1	<0.1–<0.1	1.2	0.2–2.2
Grains	20.0	19.2–20.7	15.8	14.9–16.7	22.4	20.9–23.9	20.2	18.7–21.7
Cakes and cookies	10.1	9.6–10.7	8.0	7.3–8.6	11.5	10.4–12.7	10.2	9.1–11.2
RTE cereals	4.4	4.0–4.8	3.7	3.2–4.2	4.8	4.2–5.5	4.4	3.6–5.1
Breads and muffins	3.2	2.9–3.5	2.3	1.8–2.9	3.4	2.9–3.9	3.4	3.0–3.9
Other grains	2.3	2.0–2.5	1.7	1.4–2.1	2.6	2.3–3.0	2.2	1.9–2.6
Dairy products	10.2	9.3–11.0	10.5	9.7–11.4	12.3	10.9–13.7	8.5	7.3–9.6
Dairy desserts	4.0	3.3–4.6	2.7	2.0–3.5	4.8	3.6–6.1	4.0	3.3–4.7
Sweetened milk	4.3	3.7–4.8	4.6	3.6–5.5	5.4	4.7–6.1	3.3	2.3–4.2
Yogurt	1.3	1.1–1.6	2.5	1.9–3.1	1.5	1.1–1.9	0.7	0.3–1.0
Other dairy	0.6	0.4–0.7	0.8	0.5–1.0	0.5	0.3–0.7	0.5	0.3–0.7
Fruits and vegetables	1.9	1.7–2.1	1.8	1.5–2.1	2.3	1.9–2.7	1.7	1.4–2.1
100% Fruit juices	0.0	0.0–0.0	0.0	0.0–0.0	0.0	0.0–0.0	0.0	0.0–0.0
Other fruits and vegetables	1.9	1.7–2.1	1.8	1.5–2.1	2.3	1.9–2.7	1.7	1.4–2.1
Meats, beans, eggs	1.9	1.7–2.2	1.3	1.0–1.7	1.7	1.4–1.9	2.4	2.0–2.9
Oil	<0.1	<0.1–<0.1	<0.1	<0.1–<0.1	<0.1	<0.1–<0.1	<0.1	<0.1–<0.1

CI indicates confidence interval; NHANES, National Health and Nutrition Examination Survey; % energy, % total energy intake; RTE, ready to eat; and SSB, sugar-sweetened beverage.

the metabolic response for the 2 types of sugars differs substantially.[10]

Free Sugars

Free sugars is a term used by the World Health Organization that refers to all monosaccharides and disaccharides added to foods by the manufacturer, cook, and consumer (eg, added sugars) plus sugars naturally present in honey, syrups, and fruit juices[11] (eg, nonmilk extrinsic sugars).

CHALLENGES WITH STUDYING SUGARS IN THE DIET

Nutrition studies are inherently challenging because humans have complex activities, diets, and metabolism. In

Table 2. Applying Classification of Recommendations and Level of Evidence

ESTIMATE OF CERTAINTY (PRECISION) OF TREATMENT EFFECT	SIZE OF TREATMENT EFFECT: CLASS I *Benefit >>> Risk* Procedure/Treatment **SHOULD** be performed/ administered	CLASS IIa *Benefit >> Risk* *Additional studies with focused objectives needed* **IT IS REASONABLE** to perform procedure/administer treatment	CLASS IIb *Benefit ≥ Risk* *Additional studies with broad objectives needed; additional registry data would be helpful* Procedure/Treatment **MAY BE CONSIDERED**	CLASS III *No Benefit* or CLASS III *Harm* Procedure/Test / Treatment COR III: No benefit — Not Helpful / No Proven Benefit COR III: Harm — Excess Cost w/o Benefit or Harmful / Harmful to Patients
LEVEL A Multiple populations evaluated* Data derived from multiple randomized clinical trials or meta-analyses	■ Recommendation that procedure or treatment is useful/effective ■ Sufficient evidence from multiple randomized trials or meta-analyses	■ Recommendation in favor of treatment or procedure being useful/effective ■ Some conflicting evidence from multiple randomized trials or meta-analyses	■ Recommendation's usefulness/efficacy less well established ■ Greater conflicting evidence from multiple randomized trials or meta-analyses	■ Recommendation that procedure or treatment is not useful/effective and may be harmful ■ Sufficient evidence from multiple randomized trials or meta-analyses
LEVEL B Limited populations evaluated* Data derived from a single randomized trial or nonrandomized studies	■ Recommendation that procedure or treatment is useful/effective ■ Evidence from single randomized trial or nonrandomized studies	■ Recommendation in favor of treatment or procedure being useful/effective ■ Some conflicting evidence from single randomized trial or nonrandomized studies	■ Recommendation's usefulness/efficacy less well established ■ Greater conflicting evidence from single randomized trial or nonrandomized studies	■ Recommendation that procedure or treatment is not useful/effective and may be harmful ■ Evidence from single randomized trial or nonrandomized studies
LEVEL C Very limited populations evaluated* Only consensus opinion of experts, case studies, or standard of care	■ Recommendation that procedure or treatment is useful/effective ■ Only expert opinion, case studies, or standard of care	■ Recommendation in favor of treatment or procedure being useful/effective ■ Only diverging expert opinion, case studies, or standard of care	■ Recommendation's usefulness/efficacy less well established ■ Only diverging expert opinion, case studies, or standard of care	■ Recommendation that procedure or treatment is not useful/effective and may be harmful ■ Only expert opinion, case studies, or standard of care
Suggested phrases for writing recommendations	should is recommended is indicated is useful/effective/beneficial	is reasonable can be useful/effective/beneficial is probably recommended or indicated	may/might be considered may/might be reasonable usefulness/effectiveness is unknown/unclear/uncertain or not well established	COR III: No Benefit: is not recommended; is not indicated; should not be performed/ administered/ other; is not useful/ beneficial/ effective COR III: Harm: potentially harmful; causes harm; associated with excess morbidity/mortality; should not be performed/ administered/ other
Comparative effectiveness phrases†	treatment/strategy A is recommended/indicated in preference to treatment B treatment A should be chosen over treatment B	treatment/strategy A is probably recommended/indicated in preference to treatment B it is reasonable to choose treatment A over treatment B		

A recommendation with Level of Evidence B or C does not imply that the recommendation is weak. Many important clinical questions addressed in the guidelines do not lend themselves to clinical trials. Although randomized trials are unavailable, there may be a very clear clinical consensus that a particular test or therapy is useful or effective.

*Data available from clinical trials or registries about the usefulness/efficacy in different subpopulations, such as sex, age, history of diabetes, history of prior myocardial infarction, history of heart failure, and prior aspirin use.

†For comparative effectiveness recommendations (Class I and IIa; Level of Evidence A and B only), studies that support the use of comparator verbs should involve direct comparisons of the treatments or strategies being evaluated.

attempts to study a single nutrient such as sugar, it is impossible to isolate its effects completely, especially with the known limitations in self-reported diet data from children/parents and the short duration feasible with feeding studies. For example, adding sugars to a diet may result in the intake of excess calories. Some have proposed that studies should be adjusted for these effects. However, adjustment does not mirror free-living people who do not typically adjust their diet or activity level to keep total calories at a set level. In fact, the most telling studies of the health effect of sugars are probably those in the real world. In our approach, we attempted to synthesize the body of literature under each topic, including articles that reflect real-world effects of sugar and those that attempt to discern biological effects of isolated added sugars administration while focusing on the goal of making high-quality recommendations for practice and policy.

CURRENT INTAKE GUIDELINES

In 2005, sample diets for children from the Food Guide Pyramid, which translated the Dietary Guidelines for

Circulation. 2017;135:e1017–e1034. DOI: 10.1161/CIR.0000000000000439

Americans recommendations into food group–based advice for a healthy diet, suggested a limit ranging from 6% to 10% of total calorie intake as discretionary calories depending on a child's age, sex, and level of physical activity. Discretionary calories are those available for consumption as added sugars and solid fats once a child's daily nutrient requirements are met. In the same year, this recommendation was supported by the American Heart Association (AHA) in collaboration with the American Academy of Pediatrics, which also specified that "sweetened beverages and naturally sweet beverages, such as fruit juice, should be limited to 4 to 6 ounces per day for children 1 to 6 years old and to 8 to 12 ounces per day for children 7 to 18 years old."[12]

According to the 2010 Dietary Guidelines for Americans, reducing the consumption of added sugars would lower the energy content of the diet without compromising its nutrient adequacy.[13] The guidelines suggested that this strategy could play an important role in reducing the high prevalence of obesity in the United States. The guidelines advised that sweetened foods and beverages be replaced with those that have no added sugars or are low in added sugars. For example, the guidelines advise consumers to "drink water instead of sugary drinks." Also in 2010, the AHA advised that, to achieve and maintain healthy weights and to decrease cardiovascular risk while meeting essential nutritional needs, adults reduce their intake of added sugars.[14] The AHA recommended an upper limit of intake of added sugars at 100 cal/d or 6 teaspoons for most American women and 150 cal/d or 9 teaspoons for most American men. The AHA recommendation focused on all added sugars without singling out any particular types such as high-fructose corn syrup.[14]

The 2015 Dietary Guidelines Advisory Committee released a scientific report in early 2015 recommending that added sugars be limited.[15] The report pointed out that in a healthy meal pattern, after food group and nutrient recommendations are met, only a limited number of calories are available to be consumed as added sugars. Specifically, only 3% to 9% of calories would be available from added sugars for all patterns, and within the most appropriate patterns (1600–2400 cal), the range is 4% to 6% of calories from added sugars (or 4.5–9.4 teaspoons). The expert committee concluded that strong and consistent evidence shows that intake of added sugars is associated with excess body weight compatible with a recommendation to keep added sugars intake <10% of total energy intake.

Since 2003, the World Health Organization has recommended that the intake of free sugars be limited to <10% of total daily energy intake.[11] Guidelines released by the World Health Organization in 2015 advised that people should reduce the amount of free sugars to <10% of their daily energy intake.[16] The World Health Organization further advised that a reduction to <5% of total energy intake per day would have additional benefits in reducing the risk of noncommunicable diseases (specifically excess weight gain and dental caries) in adults and children.[16] Five percent of total energy intake is equivalent to ≈25 g (≈6 teaspoons or ≈100 kcal) of sugar per day for an adult with a healthy body mass index (BMI).

CURRENT INTAKE LEVELS AND LEADING SOURCES

We used publically available data from the most recent cycles of the NHANES (2009–2012) to estimate current levels of added sugars intake.[17] These estimates may be conservatively low because it is well established that self-reported dietary assessments underreport.[18,19] Our analysis demonstrates that US children 2 to 19 years of age consume an average of 80 g added sugar daily (Table 1). Absolute intake is higher among boys than girls (87 versus 73 g), but there were no differences when intake was assessed in relation to total energy intake (16.1% for both). Added sugars intake increases with age (Figure). Intake of free sugars, the combination of added sugars and sugars that occur naturally in honey, syrups, and juices, is 91 g and 18.5% total energy.

Foods and beverages each contribute half of the added sugars in children's diets, 40 g each. The top contributors to added sugars intake include soda, fruit-flavored and sports drinks, and cakes and cookies. The contribution of added sugars to total energy intake is summarized by food or beverage source in Table 1. Table 3 illustrates sugars intake in teaspoons by sex and age group.[20] Previous research has suggested that most added sugars are consumed at home rather than away from home.[21]

SUGARS AND CVD RISK: BIOLOGICAL MECHANISMS

An ongoing debate exists as to whether fructose and glucose are similar in effect given that they are calorically matched but have markedly different metabolic fates in the human body. After consumption, digestion, and absorption, both fructose and glucose are absorbed into the portal circulation and taken up into the liver.[22] The liver has a major role in controlling the amount of glucose that reaches peripheral tissues after a meal. Increased glucose in the portal blood stimulates insulin secretion, leading to increased uptake of glucose into muscle and adipose, increased synthesis of glycogen, increased fatty acid synthesis in the adipose, increased amino acid uptake, and induction of lipoprotein lipase into muscle and adipose.[22] Fructose does not stimulate secretion of insulin to the same extent and is absorbed primarily into the liver where it stimulates de novo lipogenesis.[23] The pathway of de novo lipogenesis produces saturated fatty acids, and although it is not a major pathway in lean individuals (contributing just 10% of fatty ac-

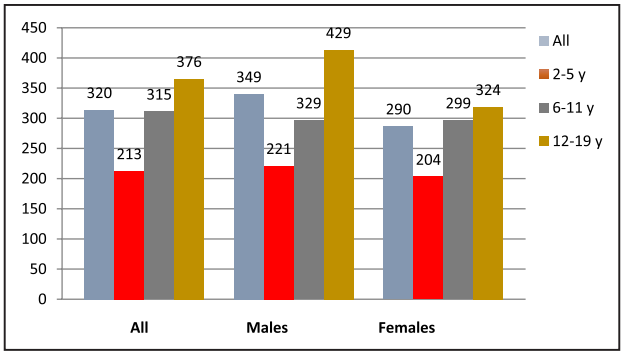

Figure. Mean daily kilocalories from added sugars among children and adolescents 2 to 19 years of age, by sex and age group: NHANES (National Health and Nutrition Examination Survey), 2009 to 2012.

ids in very-low-density lipoprotein triglyceride), in obese, insulin-resistant individuals, this pathway becomes important because carbohydrates may provide up to 50% of the saturated fatty acids in very-low-density lipoprotein triglyceride.[24] In 2014, a review of these mechanisms included the postulation that because of this effect dietary sugars may be "as atherogenic as dietary saturated fatty acids."[24] Whether the fructose or glucose causes adverse effects may be academically debatable but is less important from a clinical standpoint because most food and beverage sources outside of research studies include both sugars.

Genetics and How They Affect CVD Risk

A further challenge of understanding the role of sugars in CVD risk for children is the variability of response among individuals. This example of personalized response to a nutrient has confounded previous studies, but fortunately, recent investigations are revealing the underlying mechanisms. Genetics appear to have a profound influence on carbohydrate response. Davis et al[25] demonstrated this in a study of the PNPLA3 (*patatin-like phospholipase domain containing 3*) gene, in which a polymorphism of this gene modified the effect of dietary sugars on the presence of hepatic fat. Finally, but perhaps most obviously, the gut plays a critical role in nutrient absorption, response, and modification, and this is true for dietary sugars. At this point, little is known about the interaction between microbiome and added sugars in humans; this is an area that needs study, particularly given the data demonstrating relationships between the microbiome and CVD risk.[26]

Metabolic and Satiety Responses to Liquids Versus Foods

The form in which added sugars are consumed also may influence the metabolic effects. Sugar-sweetened beverages (SSBs) contribute a large number of calories to the American diet, and most are composed almost exclusively of just 2 ingredients, added sugars and water. This makes them a good vehicle for testing the effect of added sugars with minimal risk of confounding by other nutrients. As a result, nearly all clinical trials examining added sugars intake have been done with SSBs used as the exposure. Insight into the effect of sugar-sweetened food consumption might be gained through studies of foods high in total carbohydrates. Several short-term studies have shown that carbohydrates consumed as solids are more satiating then those consumed as liquids,[27–30] and subsequent calorie balance appears to be compensated for by the additional calories, resulting in less body weight gain.[27,31]

DiMeglio and Mattes[27] compared the effects of SSBs versus isocaloric jelly beans in a crossover study among 15 adults and demonstrated an increase in body weight

Table 3. Added Sugars: Means, Percentiles, and Standard Errors of Usual Intake, 2007 to 2010

			Added Sugars, teaspoons†							
	Age, y	n*	Mean (SE)‡	5% (SE)	10% (SE)	25% (SE)	50% (SE)	75% (SE)	90% (SE)	95% (SE)
Boys	1–3	774	9.4 (0.31)	3.1 (0.17)	4.1 (0.19)	5.9 (0.24)	8.6 (0.29)	12.0 (0.39)	15.7 (0.51)	18.2 (0.62)
	4–8	1001	15.7 (0.56)	6.5 (0.31)	7.9 (0.34)	10.9 (0.41)	14.8 (0.53)	19.6 (0.70)	24.6 (0.91)	28.1 (1.07)
	9–13	850	21.5 (0.46)	5.9 (0.30)	8.0 (0.31)	12.5 (0.36)	19.3 (0.43)	27.9 (0.62)	37.9 (0.91)	44.8 (1.19)
	14–18	808	24.6 (0.74)	7.3 (0.39)	9.7 (0.43)	14.7 (0.53)	22.2 (0.69)	31.9 (0.95)	42.8 (1.36)	50.2 (1.73)
Girls	1–3	715	8.4 (0.27)	2.7 (0.17)	3.5 (0.20)	5.2 (0.23)	7.7 (0.28)	10.8 (0.33)	14.3 (0.41)	16.7 (0.45)
	4–8	894	14.3 (0.37)	5.7 (0.27)	7.1 (0.30)	9.7 (0.33)	13.4 (0.37)	17.9 (0.44)	22.6 (0.57)	25.9 (0.68)
	9–13	867	17.8 (0.44)	6.0 (0.29)	7.7 (0.31)	11.2 (0.35)	16.3 (0.42)	22.7 (0.55)	29.8 (0.77)	34.7 (0.96)
	14–18	727	17.5 (0.54)	5.8 (0.34)	7.5 (0.37)	10.9 (0.43)	16.0 (0.52)	22.4 (0.65)	29.5 (0.90)	34.3 (1.10)

*Number of people in sample.
†One teaspoon of added sugars equals the same amount of total sugars as 1 teaspoon (4 g) of table sugar (sucrose).
‡Standard errors (*df*=32).
Data derived from Usual Dietary Intakes: Food Intakes, US Population, 2007–2010.[20]

Circulation. 2017;135:e1017–e1034. DOI: 10.1161/CIR.0000000000000439

over 4 weeks during the beverage condition but not with the jelly beans. Houchins et al[32] performed a randomized, crossover study to compare the short- and long-term (8 weeks) effects of fruits and vegetables in solid versus beverage form on appetite and energy intake. They found that hunger reduction was greater and subsequent food intake lower with solids compared with liquids in the short term, but there were no significant differences after 8 weeks. In a follow-up study, Houchins et al[30] provided energy-matched liquid and solid forms of fruits and vegetables to lean or overweight/obese adults for 8 weeks each. Although incomplete dietary compensation and weight gain occurred in both lean and overweight/obese groups during the beverage condition, results with the food condition were mixed. In the lean group, calorie compensation was precise, and there was no weight gain; however, in the overweight/obese group, compensation was poor, and there was significant weight gain.

Data are sparse on the impact of liquid versus solid sugars consumption in children. In a 6-year longitudinal study of 8- to 10-year-old children, Olsen et al[31] demonstrated a stronger association between liquid sucrose consumption and proxies of adiposity (BMI and waist circumference) compared with solid sucrose consumption. Lee et al[33] used data from a 10-year study with annual follow-up of adolescent girls to examine the association between added sugars intake and measures of adiposity. Before adjustment for total energy, each additional teaspoon of added sugars consumed in either beverages or foods over the previous year was positively associated with change in waist circumference (0.18 mm/teaspoon; $P<0.001$) and change in BMI z score (0.002 units per teaspoon; $P=0.003$). After adjustment for total energy, the association remained significant only for liquid added sugars and waist circumference (0.16 mm/teaspoon; $P=0.02$). This supports the association between added sugars consumed in either foods or beverages and weight gain is mediated by total energy intake but also suggests that liquid sugars may uniquely affect body fat distribution. These data support the reduction of all added sugars, but particularly SSBs, as a way to improve long-term cardiovascular health.

CVD RISK OUTCOMES ASSOCIATED WITH ADDED SUGARS INTAKE

Excess Weight Gain and Obesity

A preponderance of relevant literature supports a relationship between dietary sugars, specifically those found in SSBs, and increased adiposity in children. As described below, these studies range from large longitudinal studies to school-based, randomized, controlled trials with variable methods of dietary assessment and analyses (eg, not all adjust for total energy intake). Although evidence from cross-sectional studies has been mixed, many of these studies support a positive association between added sugar intakes and adiposity.[34–49]

Higher intakes of SSBs have been associated with increased obesity risk among children of all ages. A small amount of literature has examined the consumption of SSBs in infants and very young children. Early introduction of SSBs (before 12 months of age) has been evaluated and found to be associated with obesity at 6 years of age.[50] In toddlers consuming no SSBs compared with those consuming ≥2 SSBs per day, consuming no SSBs was protective against obesity.[51]

In the preschool-aged group (2–5 years), 3 longitudinal studies[52–54] and 1 retrospective study[55] concluded that a high SSB intake was associated with a higher BMI z score,[52] obesity at 5 to 7 years of age,[53] and risk of being overweight.[54] High intake of SSBs in preschoolers who were diagnosed as overweight or obese was associated with remaining overweight or obese 1 year later.[50] In children 5 to 12 years of age, soda intake[56] and SSB intake have been linked to increased BMI values and risk of being overweight or obese. A similar relationship was also found in adolescents; a higher intake of SSBs was associated with a higher BMI,[57,58] excess weight gain,[59] and increased adiposity and weight status.[60] Other studies have found no association with weight gain or adiposity in all age groups specifically when adjusted for total energy.[34,37–39,41,45,61–66] A few studies have shown mixed results in which SSBs were associated with BMI increases in their sample in girls[66] or boys[39] but not both.

The association between SSBs and various adiposity outcomes has been more consistent. Higher SSB intake has been linked specifically to higher skin-fold thickness,[63] waist circumference,[33,40] and excess body fat[44] in children and adolescents, as well as a decrease in fat accumulation, when SSBs were replaced with a noncaloric beverage.[67] Timing of SSB exposure may influence effects. For example, in the previously mentioned longitudinal study, SSB intake during infancy (<12 months of age) was associated with obesity at 6 years of age.[50]

Studies evaluating added and total sugars have been less consistent in their findings, possibly as a result in part of methodological issues. High levels of added sugars intake at 2 years of age have been linked to BMI z scores at 7 years of age,[68] but this finding has not been consistent. In a cross-sectional study, added sugars did not significantly change BMI z scores in 8- to 18-year-olds.[44] Total dietary sugars intake was found not to be predictive of BMI in a cross-sectional study using NHANES data for 1- to 18-year-olds.[49] However, studies that examined total sucrose consumption over time have found that a higher intake of sucrose is related to an increased BMI,[48] BMI z score,[31] and waist circumference[31] in children. A similar increase in total fat mass has

been reported in children and adolescents who have high intakes of total sugars,[35] fructose,[47] and juice.[69]

In summary, children and adolescents who have high intakes of dietary sugars (specifically from SSBs and added sugars) tend to have higher daily energy intakes compared with similar populations with lower intakes of dietary sugars. Higher SSB and added sugars intake has been strongly linked to excess weight gain and an increased risk of obesity. Importantly, the associations of added sugars intake and adverse outcomes in the longitudinal and cross-sectional studies may also be driven by other factors such as the home environment, a broader unhealthy diet, and activity behaviors. Additionally, in randomized, controlled trials in which children and adolescents switched from SSBs to noncaloric beverages,[67,70] reductions in weight were found, strengthening the likelihood that it is added sugars intake (at least in beverage form) that drives the causality of the findings.

Elevated Blood Pressure and Uric Acid Levels

An epidemiological link between sweeteners and hypertension has been suspected for many years, but distinguishing the effects from those of obesity has been challenging. Jalal and colleagues[71] evaluated this question in the NHANES data from 2000 to 2003. A strength of this data set, a survey of a representative sample of US adults and children, is the inclusion of both direct blood pressure measurement and dietary intake of fructose as determined by dietary questionnaire. The major finding was that there was a strong relationship between fructose intake and elevated systolic blood pressure that was independent of obesity.[71] Nguyen and colleagues[72] also found an independent relationship between sugary soft drinks and hypertension in adolescents. A converse observation that improvement in blood pressure during lifestyle modification was greatest with a greater reduction in dietary sweeteners was made in a large study of adults randomized to brief counseling on the DASH (Dietary Approach to Stop Hypertension) Diet.[73]

Direct clinical trials of fructose intake provide further support for a role of dietary sweeteners in the development of hypertension. Perez-Pozo et al[74] administered 200 g fructose per day to healthy overweight males. Over the 2-week study period, subjects had an average increase of 7 mm Hg in systolic blood pressure and 6 mm Hg in diastolic blood pressure. Brymora and colleagues[75] performed the converse experiment. Twenty-eight subjects were placed on a very low fructose diet in which they reduced their average intake from 59 to 12 g/d. After 6 weeks, the subjects had an average decrease of 6 mm Hg in both systolic and diastolic blood pressures.

The physiological link between fructose and increased blood pressure is likely indirect, acting through uric acid as an intermediary.[76–79] In adolescents, there is a close association between elevated serum uric acid and the onset of essential hypertension. The Moscow Children's Hypertension Study found hyperuricemia (>8.0 mg/dL) in 9.5% of children with normal blood pressure, 49% of children with borderline hypertension, and 73% of children with moderate and severe hypertension.[80] The Hungarian Children's Health Study followed up all 17634 children born in Budapest in 1964 for >13 years and also identified hyperuricemia as a risk factor for hypertension.[81] In a small study, Gruskin[82] compared adolescents (13–18 years of age) with essential hypertension with age-matched, healthy control subjects with normal blood pressures. The hypertensive children had both elevated serum uric acid (mean >6.5 mg/dL) and higher peripheral renin activity. In a racially diverse population referred for the evaluation of hypertension, Feig and Johnson[83] observed that the mean serum uric acid level was 3.6 mg/dL in children with white-coat hypertension or normal blood pressure and significantly higher, 6.7 mg/dL, in children with primary hypertension. Results from 2 small, clinical trials suggest that uric acid contributes directly to the development of hypertension in adolescents.[84,85] Serum uric acid reduction, whether by reduced production or increased clearance, significantly improved elevated blood pressure.

In summary, both epidemiological and clinical trial evidence suggests that excessive fructose intake results in increased blood pressure in children and young adults. There are data that this effect can be mitigated by urate-lowering therapy consistent with the hypothesis that the hypertensive effect of dietary sugars is mediated by the induction of hyperuricemia. Current evidence suggests that added sugars are a source of excess fructose and that reduction of fructose from added sugars is likely to decrease uric acid, possibly improving blood pressure in children. However, further research on this topic is needed to test whether a reduction in added sugars results in improved blood pressure in children.

Dyslipidemia

The majority of studies that evaluated lipid markers in children and associations with sugars, sucrose, fructose, or SSBs were cross-sectional. Of these studies, 2 had mixed findings of increased glucose or homeostasis model assessment–estimated insulin resistance (HOMA-IR) and systolic blood pressure with increased SSBs but no association with high-density lipoprotein (HDL) and triglyceride levels.[86,87] The remaining 9 cross-sectional studies demonstrated positive associations between increasing amounts of added sugars and higher triglyceride and/or lower HDL levels.[40,88–95] As expected, low-density lipoprotein and/or total cholesterol was less related and/or inversely associated with added sugars consumption in some studies.[86,94,95]

One of the older studies, published in 1980, was unique because it included children who consumed very low amounts of sugar, which is rare in today's culture.[94] Morrison et al[94] examined cross-sectional data from

Circulation. 2017;135:e1017–e1034. DOI: 10.1161/CIR.0000000000000439

1669 school children (75% white and 24% black), including total sucrose obtained from 24-hour recalls and measured blood lipids. Plasma triglycerides were positively correlated and total cholesterol was negatively correlated with dietary sucrose; this association remained after adjustment for age, race, and sex. When children were divided into low (1st–10th percentile) versus intermediate and high consumers of sucrose, after adjustment for demographics, triglycerides rose with higher sucrose, HDL fell, and total plasma cholesterol fell as sucrose intake increased. Notably, the average consumption of the low group was very low, ranging from 8 to 24 g/d (3.5%–6.8% of calories per day). The average consumption of sucrose of the intermediate group was between 42 and 80 g/d (9%–10% of calories per day), and the consumption of the high consumers was up to 17% of total calories per day. For triglycerides, there was a significant difference between the intermediate and high groups.

Four longitudinal studies included lipids as an outcome. All longitudinal studies confirmed an association between increased SSBs, sucrose, or added sugars and increased triglycerides plus lower HDL.[57,96–98] The Lee et al[98] study included 10-year follow-up of >2000 racially diverse children who were 9 and 10 years of age at baseline. In low consumers of added sugars (<10% of total calories) compared with higher consumers, there was a 0.26-mg/dL annual increase (improvement) in HDL levels over the 10 years. This added up to a 2.2 mg/dL higher HDL in the low consumers of added sugars.

There has been 1 intervention study in obese children comparing usual diet with a fructose-free study-provided diet. After 9 days of fructose-free diet, significant reductions were seen in triglycerides, low-density lipoprotein, blood pressure, and insulin sensitivity.[99]

In summary, although there are limited intervention studies, the preponderance of evidence from the available cross-sectional and longitudinal studies weighs in favor of improved triglycerides and HDL in children with low consumption of added sugars. Although traditionally triglycerides and HDL have not been a primary focus for decreasing CVD risk, newer data demonstrate that a high ratio of triglycerides to HDL predicts smaller dense low-density lipoprotein, a strong cardiovascular risk factor.[100] More studies are needed in this area, particularly focusing on the relationships of added sugars consumption in children and small dense low-density lipoprotein, HDL function, non–HDL cholesterol, and direct measurements of cardiovascular health such as carotid intima-media thickness and brachial vasodilation.

Nonalcoholic Fatty Liver Disease

NAFLD has increased in the US population at an alarming rate, particularly among children.[101] NAFLD is a disease of lipid metabolism in which excess triglycerides accumulates in hepatocytes in the setting of increased adiposity, hypertriglyceridemia, and increased free fatty acid flux to the liver caused by insulin resistance. The role of sugar intakes in NAFLD is only partially understood.

Nine articles were available that examined sugar intake and its correlation with hepatic steatosis in children. Of the 4 cross-sectional studies, 2 studies reported an association between increased sugars intake and higher liver fat[25] or blood measurements of liver inflammation,[102] 1 study had conflicting findings,[103] and 1 study did not show a relationship between total sugars or fructose and hepatic steatosis.[104] A large, longitudinal study that examined fructose consumption and NAFLD in 592 adolescents using ultrasound to identify hepatic steatosis found that energy-adjusted fructose intake at 14 years of age was independently associated with increased odds of NAFLD at 17 years of age.[105] Reduction in added sugars has often been included as a part of a healthier lifestyle approach to treat NAFLD, and the combination of higher fiber, increased vegetables, greater physical activity, and added sugars reduction has been shown to be effective in reducing hepatic fat.[106] However, the level of contribution of added sugars reduction to the positive findings in this type of intervention is unknown.

Few intervention studies that specifically targeted added sugars and liver outcomes in children are available. A 4-week randomized, controlled, clinical trial compared type of sugar (fructose versus glucose) in a eucaloric beverage study in children with NAFLD and found that hepatic fat did not change when glucose was substituted for fructose, although insulin resistance and systemic inflammation improved.[107] A small 6-month pilot study comparing education on a low-fat diet with education on a low-fructose diet found significant improvement in oxidized low-density lipoprotein and a strong trend of improvement in alanine amino transferase after a low-fructose diet educational intervention.[103]

In summary, although the cross-sectional data that exist to date conflict, the 1 large longitudinal study available suggests a relationship between fructose consumption in children and hepatic fat. More research is needed, in particular because NAFLD does not occur in isolation and is almost always accompanied by 1 or all of the following: visceral obesity, hypertriglyceridemia, low HDL, high non–HDL cholesterol, and insulin resistance.[108] Measuring outcomes of this clinical fatty liver syndrome after added sugars reduction may be a better marker of improvement compared with studying hepatic fat or inflammation levels alone. Important research gaps in this area are the lack of longitudinal and randomized studies testing sugar reduction or substitution as a treatment for NAFLD in children, the lack of information on dose effect of added sugars on NAFLD or the associated CVD risk factors, and the role of early sugars exposure on NAFLD. These specific areas of knowledge are critical for guiding future practice and public health recommendations. For now, it appears that a diet low in added sugars for

overweight children with NAFLD is beneficial on the basis of the evidence to date and can be recommended especially given the low risk of harm and the lack of nutrient value of added sugars.

Insulin Resistance and Diabetes Mellitus

The effects of added sugars on insulin sensitivity have been measured as primary or secondary outcomes in a number of pediatric studies. A 2-year longitudinal study by Wang et al[87] studied the associations between SSBs and their effect on glucose-insulin homeostasis among youth. The population included children between 8 and 10 years of age with at least 1 obese biological parent. Participants were classified as normal weight, overweight, or obese. Adipose measures, fasting glucose, fasting insulin, HOMA-IR, and the Matsuda insulin sensitivity index were measured. The data showed that a higher consumption (10 g/d) of added sugars from liquid sources was associated with 0.04-mmol/L higher fasting glucose, 2.3-mmol/L higher fasting insulin, a 0.1-unit higher HOMA-IR, and a 0.4-unit lower Matsuda insulin sensitivity index in all participants. These observed increases were statistically significant in children who were classified as overweight/obese but not among the normal-weight children. A cross-sectional study by Welsh et al[95] of 2157 US adolescents in NHANES between 1999 and 2004 also showed a positive correlation between added sugars and HOMA-IR among overweight adolescents but not among those with normal weight.

Heden et al[109] showed that moderate amounts of fructose- or glucose-sweetened beverages for 2 weeks did not differentially alter metabolic health in male and female adolescents when the 2 beverages were compared. The study was a counterbalanced, single-blind study with 40 male and female adolescents but was limited by its short duration. Contrary to this study, Jin et al[107] demonstrated in a slightly longer 4-week double-blind, randomized, controlled intervention study among Hispanic adolescents who were overweight with NAFLD that fructose beverage consumption increased insulin, HOMA-IR, and adipose insulin resistance, whereas glucose beverage consumption was associated with lower insulin and HOMA-IR.

In summary, studies in this area are inconclusive. To date, added sugars appear to have a relationship with insulin resistance in children who are overweight, but this finding was not demonstrated in normal-weight children.

EVIDENCE OF DOSE RESPONSE TO ADDED SUGARS INTAKE

In our literature review, we found no studies directly testing what dose of added sugars in the diet of children would have no harmful effect on CVD risk. The following is a summary of the results of studies from each section above that indicate a level above which an increase in ≥1 cardiovascular risk factors was observed.

Cross-Sectional Studies

- Children consuming 3.5% to 6.8% of calories as sucrose (the lowest consumption group) had lower triglycerides and higher HDL than higher consumers.[94]
- Children consuming no SSBs compared with those consuming an average of 11.8 oz/d had lower C-reactive protein, smaller waist circumference, and higher HDL cholesterol.[40]
- Each additional SSB equivalent (≈1 cup or 8 oz) consumed by children daily was associated with a 5% increase in HOMA-IR, a 0.16-mm increase in systolic blood pressure, a 0.47-cm increase in waist circumference, a 0.90-percentile increase in BMI for age, and a 0.48-mg/dL decrease in HDL concentrations. The low consumers in this analysis consumed a mean of 0.1 oz of SSBs per day.[91]
- Adolescents who consumed >10% of their total energy as added sugars had lower HDL levels, higher triglycerides, and higher low-density lipoprotein cholesterol levels than those who consumed less. Overweight or obese adolescents had higher insulin resistance (as assessed with HOMA-IR).[95]

Prospective Cohort

- Adolescents consuming <10% of their total calories as added sugars had higher HDL cholesterol levels than those consuming more.[98]
- Children who consumed ≈10% of calories from sucrose had a poorer diet quality and significantly decreased height compared with lower consumers.[48]
- Infants who drank ≥3 servings of SSBs per week had twice the odds of obesity at 6 years of age.[50]
- Annual changes in BMI *z* score and waist circumference among girls increased significantly with each additional teaspoon of added sugar.[98]

Experimental Studies

- In a randomized, controlled trial in school children, 1 SSB daily contributed an additional 104 cal from added sugars (≈5% of a 2000-cal diet) and increased body weight compared with a noncaloric beverage daily.[67]

Thus, there is consistent evidence that cardiovascular risk increases as added sugars consumption increases. Very low consumption (0.1 oz of SSBs per day) is associated with lower CVD risk indicators. The "sweet spot" at which level of consumption added sugars could be

Circulation. 2017;135:e1017–e1034. DOI: 10.1161/CIR.0000000000000439

enjoyed but without an adverse cardiovascular health effect is currently unknown.

DIET QUALITY AND ADDED SUGARS INTAKE

Decreased Diet Quality

Few studies have reported variations in nutrient adequacy (ie, decreased diet quality) based on intakes of added sugars; however, a study that examined this variation suggested displacement of micronutrients with increasing amounts of sugars intake.[110] Results from 10 years of follow-up in the National Growth and Health Study reported low intakes of vitamins A, D, and E, calcium, and potassium among adolescent girls across all 3 age ranges (9–13, 14–18, and 19–20 years).[111] These adolescents consumed >40% of total energy (>750 kcal/d) from solid fats and added sugars compared with the recommended limits ranging from 120 kcal/d for sedentary girls to 160 kcal/d for moderately active girls.

Diet quality may also be affected by total sugars intake and sources of sugars intakes. Frary and colleagues[112] reported added sugars data in children and adolescents from the 1994 to 1996 and 1998 Continuing Survey of Food Intakes by Individuals database (US Department of Agriculture). Whereas intake of presweetened dairy foods (ie, flavored milk or yogurts), beverages, and fortified cereals favorably affected levels of micronutrients, SSBs, sugars and sweets, and sweetened grains adversely affected diet quality. An Australian cross-sectional study of children 2 to 16 years of age based on two 24-hour recalls examined high glycemic carbohydrates, not sugars, and found that children who had a higher glycemic index of carbohydrates were more likely to fail to meet certain recommended nutrients, including calcium, and iodine.[113] A longitudinal study of Finnish children that collected dietary information annually from infancy to 9 years of age found that the highest consumers of sucrose tended to receive less vitamin E, niacin, calcium, iron, zinc, and dietary fiber compared with average and low consumers of sucrose.[49] The lowest consumers of sucrose also consumed more grains, vegetables, and dairy products,[49] thus supporting the idea that children who consume added sugars in high levels are consuming fewer of the micronutrients that are important for health.

A cross-sectional analysis of data from 2005 to 2008 NHANES reported that dietary sodium intake among US children and adolescents 2 to 18 years of age was positively associated with SSB consumption.[114] The average dietary sodium intake was 3056 mg/d, well in excess of the recommended 2300 mg/d. The authors predicted that with reductions in sodium intake, SSB intake and thus calories from sugars intake would decrease. Among those who consumed SSBs, each additional 390 mg of sodium per day was associated with an increase of 32 g of SSBs per day.

Another potential consequence of higher sugars intake, especially in liquid form (eg, SSBs), is increased total energy intake that is not compensated for by reduced energy intake during meals.[115] Sugary beverages were found to conflict in flavor with vegetables, thereby suggesting that "combo meals" that include SSBs are typically not served with vegetables, whereas water or milk is better accepted. Reduction of SSBs could decrease energy intake in children, as demonstrated in a study by Briefel et al.[116] Briefel and colleagues used diet modeling and reported that switching from SSBs and flavored milks to unflavored low-fat milk at meals and water between meals saved on average 205 kcal/d, an ≈10% reduction in total energy intake.

Increased Diet Quality

Empty calories in children's diets should be limited to the amount that fits their energy and nutrient needs. The American Academy of Pediatrics Council on School Health and Committee on Nutrition advises using the minimal amount of added sugars necessary to promote the palatability, enjoyment, and consumption of nutrient-rich food items.[117] Thus, it is important to be judicious when including added sugars in children's diets. SSBs, sweets, and sweetened grains are more likely to have a negative impact on diet quality, whereas sweetened dairy products and presweetened cereals may have a positive impact.[112] Examples of foods that may have a positive impact include sweetened dairy products such as low-fat or fat-free flavored milk, sweetened yogurt, and high-fiber breakfast cereals. Fat-free flavored milk intake is associated with higher intakes of shortfall nutrients such as calcium and potassium and is not associated with adverse effects on BMI measures.[118] Furthermore, lower-calorie low-fat or fat-free milk with reduced added sugars appears to be acceptable to school-aged children.[119,120] Consuming ready-to-eat cereal at breakfast was associated with improved weight and nutrient adequacy in black children.[121] However, compared with low-sugar cereals, high-sugar cereals increase children's total sugar consumption and reduce the overall nutritional quality of their breakfast.[122] From these studies, it is apparent that when children consume added sugars, it is better if the sugars are in foods and beverages that enhance, not diminish, the nutrient quality of the diet.

EARLY INTRODUCTION OF ADDED SUGARS

Children have a strong preference for a sweet taste, and early introduction of added sugars in the diet of infants and toddlers may promote sweet taste preference[123] or may reflect other factors in the feeding environment. (Early introduction of SSBs [before 12 months of age] is associated with an increased likelihood of consuming SSBs ≥1 time/day at age 6 years.[53]) Recent research demonstrating the use of sucrose and glucose, which are sweeter than lac-

tose (the sugar found in breast milk), in infant formulas[124] highlights the need for research in this area. We found no studies evaluating added sugars and infant formulas. Given the importance of this early period on growth and future obesity and metabolic risk, this is a critical research need.

ALTERNATIVES TO ADDED SUGARS

As part of this scientific statement, a review of the literature on nonnutritive sweeteners (NNSs; noncaloric artificial sweeteners) in children was performed because NNSs are often considered a tool to replace added sugars to help lower energy intake. The key words nonnutritive sweeteners, artificial sweeteners, noncaloric sweeteners, and children were searched, with few relevant articles identified.[125] This highlights a major gap in information that has also been noted in the adult literature.[126,127] NNS-flavored beverages have been used as comparison groups in several pediatric trials of SSBs.[67,70] However, the studies were not designed to examine the effects of NNSs and did not include a water comparison group.

Currently, consumption of NNSs is low in children, although it has increased over time. The AHA's position on NNSs for adults is that, when used judiciously, NNSs substituted for added sugars in foods and beverages could help people reduce their calorie intake to reach and maintain a healthy body weight, as long as the substitution does not lead to consuming additional calories as compensation.[127] The American Academy of Pediatrics concluded that data on NNSs are scarce in terms of the long-term benefits for weight management in children and adolescents or the consequences of long-term consumption.[117] Because of the lack of research in children, a recommendation either for or against the routine use of NNSs in the diets of children cannot be made at this time.

RESEARCH GAPS

As discussed above, important gaps exist in the knowledge of sugars in children. Longitudinal studies, intervention studies, and randomized, controlled trials are urgently needed to provide high-quality data for policy decisions. Specific remaining questions that are research priorities include the following:

- Is there a threshold of added sugars below which there are no negative effects on cardiovascular health?
- Is there a direct linear relationship between increasing cardiovascular risk outcomes and added sugars intake? For example, is 1% better than 5%, which is better than 10%? Does this change by age?
- Are the risks associated with added sugars consumption lower if the sugars are consumed in foods instead of in beverages?
- Does routine use of NNSs have adverse metabolic effects in children?
- Can the food industry move to gradually lower the amount of sugars added to foods, and if so, what is the expected outcome?
- Does sugar from 100% juice have biological and cardiovascular health effects in children similar to those of added sugars from SSBs?

COMMITTEE RECOMMENDATIONS

On the basis of the existing literature and in combination with expert opinion, the following recommendations are made:

1. In randomized, controlled trials in which children and adolescents switch from SSBs to noncaloric beverages, reductions in weight were found, strengthening the likelihood that it is added sugars intake (at least in beverage form) that drives the causality of the findings. Therefore, it is recommended that children and adolescents limit their intake of SSBs to 1 or fewer 8-oz beverages per week (*Class I; Level of Evidence A*).
2. In the absence of dose-assessment studies, we can only extrapolate from observational studies. On the basis of the studies showing an association between decreased CVD risk factors and a low consumption of added sugars and the high potential benefit-to-risk ratio, it is reasonable to recommend that children and adolescents consume ≤25 g (100 cal or ≈6 teaspoons) of added sugars per day (*Class IIa; Level of Evidence C*).
3. Because there is minimal room for nutrient-free calories in the habitual diets of very young children, added sugars should be avoided in the diet of children <2 years of age (*Class III; Level of Evidence C*).

CONCLUSIONS

Our comprehensive review of the available evidence found that associations with increased CVD risk factors are present at levels far below US children's current added sugars consumption levels. Current evidence supports the associations of added sugars with increased energy intake, increased adiposity, increased central adiposity, and increased dyslipidemia, all of which are demonstrated CVD risk factors. Importantly, the introduction of added sugars during infancy appears to be particularly harmful and should be avoided. Although added sugars can mostly likely be safely consumed in low amounts as part of a healthy diet, little research has been done to establish a threshold between adverse effects and health, making this an important future research topic.

FOOTNOTES

The American Heart Association makes every effort to avoid any actual or potential conflicts of interest that may arise as a

Circulation. 2017;135:e1017–e1034. DOI: 10.1161/CIR.0000000000000439

result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest.

This scientific statement was approved by the American Heart Association Science Advisory and Coordinating Committee on February 22, 2016, and the American Heart Association Executive Committee on March 23, 2016. A copy of the document is available at http://professional.heart.org/statements by using either "Search for Guidelines & Statements" or the "Browse by Topic" area. To purchase additional reprints, call 843-216-2533 or e-mail kelle.ramsay@wolterskluwer.com.

The American Heart Association requests that this document be cited as follows: Vos MB, Kaar JL, Welsh JA, Van Horn LV, Feig DI, Anderson CAM, Patel MJ, Munos JC, Krebs NF, Xanthakos SA, Johnson RK; on behalf of the American Heart Association Nutrition Committee of the Council on Lifestyle and Cardiometabolic Health; Council on Clinical Cardiology; Council on Cardiovascular Disease in the Young; Council on Cardiovascular and Stroke Nursing; Council on Epidemiology and Prevention; Council on Functional Genomics and Translational Biology; and Council on Hypertension. Added sugars and cardiovascular disease risk in children: a scientific statement from the American Heart Association. *Circulation.* 2017;135:e1017–e1034. doi: 10.1161/CIR.0000000000000439.

Expert peer review of AHA Scientific Statements is conducted by the AHA Office of Science Operations. For more on AHA statements and guidelines development, visit http://professional.heart.org/statements. Select the "Guidelines & Statements" drop-down menu, then click "Publication Development."

Circulation is available at http://circ.ahajournals.org.

DISCLOSURES

Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
Miriam B. Vos	Emory University School of Medicine	None	None	None	None	None	None	None
Cheryl A.M. Anderson	University of California San Diego School of Medicine	None	None	None	None	None	None	None
Daniel I. Feig	University of Alabama at Birmingham	None	None	None	None	None	None	None
Rachel K. Johnson	University of Vermont	None	None	None	None	None	Milk Processor Education Program*	None
Jill L. Kaar	University of Colorado Anshutz Medical Campus	None	None	None	None	None	None	None
Nancy F. Krebs	University of Colorado	None	None	None	None	None	None	None
Jessica Cruz Munos	Emory University Department of Pediatrics	None	None	None	None	None	None	None
Mahesh J. Patel	Merck Research Laboratories	None	None	None	None	None	None	None
Linda V. Van Horn	Northwestern University	None	None	None	None	None	None	None
Jean A. Welsh	Emory University	None	None	None	None	None	Sugar Board/ presentation on trends in added sugar intake among toddlers*	None
Stavra A. Xanthakos	Cincinnati Children's Hospital Medical Center	None	None	None	None	None	None	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

Reviewer Disclosures

Reviewer	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
Christopher Gardner	Stanford University	None	None	None	None	None	None	None
Samuel S. Gidding	Alfred I. duPont Hospital for Children Nemours Cardiac Center	NIH (TODAY study echo reading center)†	NIH (CARDIA echo reading center)†; NIH (Center for Translational research)*	None	None	None	None	None
Sheela N. Magge	Children's National Medical Center	None	None	None	None	None	None	None

This table represents the relationships of reviewers that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all reviewers are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

REFERENCES

1. Morrison JA, Glueck CJ, Woo JG, Wang P. Risk factors for cardiovascular disease and type 2 diabetes retained from childhood to adulthood predict adult outcomes: the Princeton LRC Follow-up Study. *Int J Pediatr Endocrinol*. 2012;2012:6. doi: 10.1186/1687-9856-2012-6.
2. Ceponiene I, Klumbiene J, Tamuleviciute-Prasciene E, Motiejunaite J, Sakyte E, Ceponis J, Slapikas R, Petkeviciene J. Associations between risk factors in childhood (12-13 years) and adulthood (48-49 years) and subclinical atherosclerosis: the Kaunas Cardiovascular Risk Cohort Study. *BMC Cardiovasc Disord*. 2015;15:89. doi: 10.1186/s12872-015-0087-0.
3. Pacifico L, Chiesa C, Anania C, De Merulis A, Osborn JF, Romaggioli S, Gaudio E. Nonalcoholic fatty liver disease and the heart in children and adolescents. *World J Gastroenterol*. 2014;20:9055–9071. doi: 10.3748/wjg.v20.i27.9055.
4. Welsh JA, Sharma AJ, Grellinger L, Vos MB. Consumption of added sugars is decreasing in the United States. *Am J Clin Nutr*. 2011;94:726–734. doi: 10.3945/ajcn.111.018366.
5. Jacobs AK, Anderson JL, Halperin JL, ACC/AHA Task Force Members, Anderson JL, Halperin JL, Albert NM, Bozkurt B, Brindis RG, Curtis LH, DeMets D, Fleisher LA, Gidding S, Hochman JS, Kovacs RJ, Ohman EM, Pressler SJ, Sellke FW, Shen WK, Wijeysundera DN. The evolution and future of ACC/AHA clinical practice guidelines: a 30-year journey: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Circulation*. 2014;130:1208–1217. doi: 10.1161/CIR.0000000000000090.
6. Cummings JH, Stephen AM. Carbohydrate terminology and classification. *Eur J Clin Nutr*. 2007;61(suppl 1):S5–S18. doi: 10.1038/sj.ejcn.1602936.
7. Food and Agriculture Organization of the United Nations. *Carbohydrates in Human Nutrition: Report of a Joint FAO/WHO Expert Consultation: Food and Agriculture Organization*. April 1997; reprinted 1998. http://www.fao.org/docrep/w8079e/w8079e00.htm. Accessed October 20, 2015.
8. Otten JJ, Hellwig JP, Meyers LD, eds. *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements: Institute of Medicine of the National Academies*. Washington, DC: National Academies Press; 2006.
9. Garza C, Murphy S, Deckelbaum R, Dwyer J, Grundy S, Johnson R, Kumanyika S, Lichtenstein A, Stampfer M, Tinker L, Weinsier R. *Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans, 2000*. Washington, DC: US Government Printing Office; 2000.
10. Report of the Great Britain Panel on Dietary Sugars, Committee on Medical Aspects of Food Policy. *Dietary Sugars and Human Disease*. London, UK: Her Majesty's Stationery Office; 1989.
11. World Health Organization. *Nutrition and the Prevention of Chronic Diseases: Report of a Joint WHO/FAO Expert Consultation*. Geneva, Switzerland: World Health Organization; 2004. WHO Technical Report Series No. 916.
12. Gidding SS, Dennison BA, Birch LL, Daniels SR, Gillman MW, Gilman MW, Lichtenstein AH, Rattay KT, Steinberger J, Stettler N, Van Horn L; American Heart Association; American Academy of Pediatrics. Dietary recommendations for children and adolescents: a guide for practitioners: consensus statement from the American Heart Association [published corrections appear in *Circulation*. 2005;112:2375 and *Circulation*. 2006;113:e857]. *Circulation*. 2005;112:2061–2075. doi: 10.1161/CIRCULATIONAHA.105.169251.
13. US Department of Agriculture and US Department of Health and Human Services. *Dietary Guidelines for Americans, 2010*. Washington, DC: US Government Printing Office; December 2010. http://www.health.gov/dietaryguidelines/dga2010/DietaryGuidelines2010.pdf. Accessed October 15, 2015.
14. Johnson RK, Appel LJ, Brands M, Howard BV, Lefevre M, Lustig RH, Sacks F, Steffen LM, Wylie-Rosett J; on behalf of the American Heart Association Nutrition Committee of the Council on Nutrition, Physical Activity, and Metabolism and the Council on Epidemiology and Prevention. Dietary sugars intake and cardiovascular health: a scientific statement from the American Heart Association. *Circulation*. 2009;120:1011–1020. doi: 10.1161/CIRCULATIONAHA.109.192627.
15. US Department of Health and Human Services. *Scientific Report of the 2015 Dietary Guidelines Advisory Committee*. Washington, DC: US Government Printing Office; 2015. http://www.health.gov/dietaryguidelines/2015-scientific-advisory-report/PDFs/Scientific-Report-of-the-2015-Dietary-Guidelines-Advisory-Committee.pdf. Accessed October 15, 2015.
16. World Health Organization. Guidelines: sugars intake for adults and children: WHO guidelines approved by the Guidelines Review Committee. 2015. http://www.ncbi.nlm.nih.gov/pubmed/25905159. Accessed October 15, 2015.
17. CDC National Center for Health Statistics. National Health and Nutrition Examination Survey: 2011–2012: data documentation, codebook, and frequencies rates. 2014. http://wwwn.cdc.gov/nchs/nhanes/2011–2012/DR1IFF_g.htm. Accessed November 20, 2015.

18. Trumbo P, Schlicker S, Yates AA, Poos M; Food and Nutrition Board of the Institute of Medicine, The National Academies. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids [published correction appears in *J Am Diet Assoc*. 2003;103:563]. *J Am Diet Assoc*. 2002;102:1621–1630.
19. Freedman LS, Commins JM, Moler JE, Arab L, Baer DJ, Kipnis V, Midthune D, Moshfegh AJ, Neuhouser ML, Prentice RL, Schatzkin A, Spiegelman D, Subar AF, Tinker LF, Willett W. Pooled results from 5 validation studies of dietary self-report instruments using recovery biomarkers for energy and protein intake. *Am J Epidemiol*. 2014;180:172–188. doi: 10.1093/aje/kwu116.
20. National Cancer Institute, Division of Cancer Control & Population Sciences. Usual Dietary Intakes: Food Intakes, U.S. Population, 2007–10: Epidemiology Research Program website. http://epi.grants.cancer.gov/diet/usualintakes/pop/2007–10/. Updated May 20, 2015. Accessed November 1, 2015.
21. Ervin RB, Kit BK, Carroll MD, Ogden CL; Centers for Disease Control and Prevention's National Center for Health Statistics, Division of Health and Nutrition Examination Surveys. *Consumption of Added Sugar Among U.S. Children and Adolescents, 2005–2008*. Washington DC: National Center for Health Statistics; 2012. Data Brief No. 87.
22. Geissler C, Powers H. *Human Nutrition*. 12th ed. Philadelphia, PA: Churchill Livingstone Elsevier; 2011.
23. Parks EJ, Skokan LE, Timlin MT, Dingfelder CS. Dietary sugars stimulate fatty acid synthesis in adults. *J Nutr*. 2008;138:1039–1046.
24. Jacome-Sosa MM, Parks EJ. Fatty acid sources and their fluxes as they contribute to plasma triglyceride concentrations and fatty liver in humans. *Curr Opin Lipidol*. 2014;25:213–220. doi: 10.1097/MOL.0000000000000080.
25. Davis JN, Lê KA, Walker RW, Vikman S, Spruijt-Metz D, Weigensberg MJ, Allayee H, Goran MI. Increased hepatic fat in overweight Hispanic youth influenced by interaction between genetic variation in PNPLA3 and high dietary carbohydrate and sugar consumption. *Am J Clin Nutr*. 2010;92:1522–1527. doi: 10.3945/ajcn.2010.30185.
26. Wong JM. Gut microbiota and cardiometabolic outcomes: influence of dietary patterns and their associated components. *Am J Clin Nutr*. 2014;100(suppl 1):369S–377S. doi: 10.3945/ajcn.113.071639.
27. DiMeglio DP, Mattes RD. Liquid versus solid carbohydrate: effects on food intake and body weight. *Int J Obes Relat Metab Disord*. 2000;24:794–800.
28. Pan A, Hu FB. Effects of carbohydrates on satiety: differences between liquid and solid food. *Curr Opin Clin Nutr Metab Care*. 2011;14:385–390. doi: 10.1097/MCO.0b013e328346df36.
29. Haber GB, Heaton KW, Murphy D, Burroughs LF. Depletion and disruption of dietary fibre: effects on satiety, plasma-glucose, and serum-insulin. *Lancet*. 1977;2:679–682.
30. Houchins JA, Tan SY, Campbell WW, Mattes RD. Effects of fruit and vegetable, consumed in solid vs beverage forms, on acute and chronic appetitive responses in lean and obese adults. *Int J Obes (Lond)*. 2013;37:1109–1115. doi: 10.1038/ijo.2012.183.
31. Olsen NJ, Andersen LB, Wedderkopp N, Kristensen PL, Heitmann BL. Intake of liquid and solid sucrose in relation to changes in body fatness over 6 years among 8- to 10-year-old children: the European Youth Heart Study. *Obes Facts*. 2012;5:506–512. doi: 10.1159/000341631.
32. Houchins JA, Burgess JR, Campbell WW, Daniel JR, Ferruzzi MG, McCabe GP, Mattes RD. Beverage vs. solid fruits and vegetables: effects on energy intake and body weight. *Obesity (Silver Spring)*. 2012;20:1844–1850. doi: 10.1038/oby.2011.192.
33. Lee AK, Chowdhury R, Welsh JA. Sugars and adiposity: the long term effects of consuming added and naturally occurring sugars in foods and beverages. *Obes Sci Pract*. 2015;1:41–49.
34. Coppinger T, Jeanes Y, Mitchell M, Reeves S. Beverage consumption and BMI of British schoolchildren aged 9-13 years. *Public Health Nutr*. 2013;16:1244–1249. doi: 10.1017/S1368980011002795.
35. Davis JN, Alexander KE, Ventura EE, Kelly LA, Lane CJ, Byrd-Williams CE, Toledo-Corral CM, Roberts CK, Spruijt-Metz D, Weigensberg MJ, Goran MI. Associations of dietary sugar and glycemic index with adiposity and insulin dynamics in overweight Latino youth. *Am J Clin Nutr*. 2007;86:1331–1338.
36. Denova-Gutiérrez E, Jiménez-Aguilar A, Halley-Castillo E, Huitrón-Bravo G, Talavera JO, Pineda-Pérez D, Díaz-Montiel JC, Salmerón J. Association between sweetened beverage consumption and body mass index, proportion of body fat and body fat distribution in Mexican adolescents. *Ann Nutr Metab*. 2008;53:245–251. doi: 10.1159/000189127.
37. Gibson S, Neate D. Sugar intake, soft drink consumption and body weight among British children: further analysis of National Diet and Nutrition Survey data with adjustment for under-reporting and physical activity. *Int J Food Sci Nutr*. 2007;58:445–460. doi: 10.1080/09637480701288363.
38. Gómez-Martínez S, Martín A, Romeo J, Castillo M, Mesena M, Baraza JC, Jiménez-Pavón D, Redondo C, Zamora S, Marcos A. Is soft drink consumption associated with body composition? A cross-sectional study in Spanish adolescents. *Nutr Hosp*. 2009;24:97–102.
39. Jimenez-Aguilar A, Flores M, Shamah-Levy T. Sugar-sweetened beverages consumption and BMI in Mexican adolescents: Mexican National Health and Nutrition Survey 2006. *Salud Publica Mex*. 2009;51(suppl 4):S604–S612.
40. Kosova EC, Auinger P, Bremer AA. The relationships between sugar-sweetened beverage intake and cardiometabolic markers in young children. *J Acad Nutr Diet*. 2013;113:219–227. doi: 10.1016/j.jand.2012.10.020.
41. LaRowe TL, Moeller SM, Adams AK. Beverage patterns, diet quality, and body mass index of US preschool and school-aged children. *J Am Diet Assoc*. 2007;107:1124–1133. doi: 10.1016/j.jada.2007.04.013.
42. Lewis CJ, Park YK, Dexter PB, Yetley EA. Nutrient intakes and body weights of persons consuming high and moderate levels of added sugars. *J Am Diet Assoc*. 1992;92:708–713.
43. Linardakis M, Sarri K, Pateraki MS, Sbokos M, Kafatos A. Sugar-added beverages consumption among kindergarten children of Crete: effects on nutritional status and risk of obesity. *BMC Public Health*. 2008;8:279. doi: 10.1186/1471-2458-8-279.
44. Nicklas TA, O'Neil CE, Liu Y. Intake of added sugars is not associated with weight measures in children 6 to 18 years: National Health and Nutrition Examination Surveys 2003-2006. *Nutr Res*. 2011;31:338–346. doi: 10.1016/j.nutres.2011.03.014.
45. O'Connor TM, Yang SJ, Nicklas TA. Beverage intake among preschool children and its effect on weight status. *Pediatrics*. 2006;118:e1010–e1018. doi: 10.1542/peds.2005-2348.
46. O'Neil CE, Nicklas TA, Liu Y, Franklin FA. Impact of dairy and sweetened beverage consumption on diet and weight of a multiethnic population of Head Start mothers. *J Am Diet Assoc*. 2009;109:874–882. doi: 10.1016/j.jada.2009.02.012.
47. Pollock NK, Bundy V, Kanto W, Davis CL, Bernard PJ, Zhu H, Gutin B, Dong Y. Greater fructose consumption is associated with cardiometabolic risk markers and visceral adiposity in adolescents [published correction appears in *J Nutr*. 2013;143:123]. *J Nutr*. 2012;142:251–257. doi: 10.3945/jn.111.150219.
48. Ruottinen S, Niinikoski H, Lagström H, Rönnemaa T, Hakanen M, Viikari J, Jokinen E, Simell O. High sucrose intake is associated with poor quality of diet and growth between 13 months and 9 years of age: the special Turku Coronary Risk Factor Intervention Project. *Pediatrics*. 2008;121:e1676–e1685. doi: 10.1542/peds.2007-1642.

49. Song WO, Wang Y, Chung CE, Song B, Lee W, Chun OK. Is obesity development associated with dietary sugar intake in the U.S.? *Nutrition*. 2012;28:1137–1141. doi: 10.1016/j.nut.2012.03.008.
50. Pan L, Li R, Park S, Galuska DA, Sherry B, Freedman DS. A longitudinal analysis of sugar-sweetened beverage intake in infancy and obesity at 6 years. *Pediatrics*. 2014;134(suppl 1):S29–S35. doi: 10.1542/peds.2014-0646F.
51. Davis JN, Koleilat M, Shearrer GE, Whaley SE. Association of infant feeding and dietary intake on obesity prevalence in low-income toddlers. *Obesity (Silver Spring)*. 2014;22:1103–1111. doi: 10.1002/oby.20644.
52. DeBoer MD, Scharf RJ, Demmer RT. Sugar-sweetened beverages and weight gain in 2- to 5-year-old children. *Pediatrics*. 2013;132:413–420. doi: 10.1542/peds.2013-0570.
53. Lim S, Zoellner JM, Lee JM, Burt BA, Sandretto AM, Sohn W, Ismail AI, Lepkowski JM. Obesity and sugar-sweetened beverages in African-American preschool children: a longitudinal study. *Obesity (Silver Spring)*. 2009;17:1262–1268. doi: 10.1038/oby.2008.656.
54. Dubois L, Farmer A, Girard M, Peterson K. Regular sugar-sweetened beverage consumption between meals increases risk of overweight among preschool-aged children. *J Am Diet Assoc*. 2007;107:924–934. doi: 10.1016/j.jada.2007.03.004.
55. Welsh JA, Cogswell ME, Rogers S, Rockett H, Mei Z, Grummer-Strawn LM. Overweight among low-income preschool children associated with the consumption of sweet drinks: Missouri, 1999-2002. *Pediatrics*. 2005;115:e223–e229. doi: 10.1542/peds.2004-1148.
56. Phillips SM, Bandini LG, Naumova EN, Cyr H, Colclough S, Dietz WH, Must A. Energy-dense snack food intake in adolescence: longitudinal relationship to weight and fatness. *Obes Res*. 2004;12:461–472. doi: 10.1038/oby.2004.52.
57. Ambrosini GL, Oddy WH, Huang RC, Mori TA, Beilin LJ, Jebb SA. Prospective associations between sugar-sweetened beverage intakes and cardiometabolic risk factors in adolescents. *Am J Clin Nutr*. 2013;98:327–334. doi: 10.3945/ajcn.112.051383.
58. Ludwig DS, Peterson KE, Gortmaker SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. *Lancet*. 2001;357:505–508. doi: 10.1016/S0140-6736(00)04041-1.
59. Tam CS, Garnett SP, Cowell CT, Campbell K, Cabrera G, Baur LA. Soft drink consumption and excess weight gain in Australian school students: results from the Nepean study. *Int J Obes (Lond)*. 2006;30:1091–1093. doi: 10.1038/sj.ijo.0803328.
60. Fiorito LM, Marini M, Francis LA, Smiciklas-Wright H, Birch LL. Beverage intake of girls at age 5 y predicts adiposity and weight status in childhood and adolescence. *Am J Clin Nutr*. 2009;90:935–942. doi: 10.3945/ajcn.2009.27623.
61. Newby PK, Peterson KE, Berkey CS, Leppert J, Willett WC, Colditz GA. Beverage consumption is not associated with changes in weight and body mass index among low-income preschool children in North Dakota. *J Am Diet Assoc*. 2004;104:1086–1094. doi: 10.1016/j.jada.2004.04.020.
62. Johnson L, Mander AP, Jones LR, Emmett PM, Jebb SA. Is sugar-sweetened beverage consumption associated with increased fatness in children? *Nutrition*. 2007;23:557–563. doi: 10.1016/j.nut.2007.05.005.
63. Jensen BW, Nielsen BM, Husby I, Bugge A, El-Naaman B, Andersen LB, Trolle E, Heitmann BL. Association between sweet drink intake and adiposity in Danish children participating in a long-term intervention study. *Pediatr Obes*. 2013;8:259–270. doi: 10.1111/j.2047-6310.2013.00170.x.
64. Valente H, Teixeira V, Padrão P, Bessa M, Cordeiro T, Moreira A, Mitchell V, Lopes C, Mota J, Moreira P. Sugar-sweetened beverage intake and overweight in children from a Mediterranean country. *Public Health Nutr*. 2011;14:127–132. doi: 10.1017/S1368980010002533.
65. Berkey CS, Rockett HR, Field AE, Gillman MW, Colditz GA. Sugar-added beverages and adolescent weight change. *Obes Res*. 2004;12:778–788. doi: 10.1038/oby.2004.94.
66. Nissinen K, Mikkilä V, Männistö S, Lahti-Koski M, Räsänen L, Viikari J, Raitakari OT. Sweets and sugar-sweetened soft drink intake in childhood in relation to adult BMI and overweight: the Cardiovascular Risk in Young Finns Study. *Public Health Nutr*. 2009;12:2018–2026. doi: 10.1017/S1368980009005849.
67. de Ruyter JC, Olthof MR, Seidell JC, Katan MB. A trial of sugar-free or sugar-sweetened beverages and body weight in children. *N Engl J Med*. 2012;367:1397–1406. doi: 10.1056/NEJMoa1203034.
68. Herbst A, Diethelm K, Cheng G, Alexy U, Icks A, Buyken AE. Direction of associations between added sugar intake in early childhood and body mass index at age 7 years may depend on intake levels. *J Nutr*. 2011;141:1348–1354. doi: 10.3945/jn.110.137000.
69. Faith MS, Dennison BA, Edmunds LS, Stratton HH. Fruit juice intake predicts increased adiposity gain in children from low-income families: weight status-by-environment interaction. *Pediatrics*. 2006;118:2066–2075. doi: 10.1542/peds.2006-1117.
70. Ebbeling CB, Feldman HA, Chomitz VR, Antonelli TA, Gortmaker SL, Osganian SK, Ludwig DS. A randomized trial of sugar-sweetened beverages and adolescent body weight. *N Engl J Med*. 2012;367:1407–1416. doi: 10.1056/NEJMoa1203388.
71. Jalal DI, Smits G, Johnson RJ, Chonchol M. Increased fructose associates with elevated blood pressure. *J Am Soc Nephrol*. 2010;21:1543–1549. doi: 10.1681/ASN.2009111111.
72. Nguyen S, Choi H, Lustig R, Hsu C. The association of sugar sweetened beverage consumption on serum uric acid and blood pressure in a nationally representative sample of adolescents. *J Pediatr*. 2009;154:807–813.
73. Chen L, Caballero B, Mitchell DC, Loria C, Lin PH, Champagne CM, Elmer PJ, Ard JD, Batch BC, Anderson CA, Appel LJ. Reducing consumption of sugar-sweetened beverages is associated with reduced blood pressure: a prospective study among United States adults [published correction appears in *Circulation*. 2010;122:e408]. *Circulation*. 2010;121:2398–2406. doi: 10.1161/CIRCULATIONAHA.109.911164.
74. Perez-Pozo SE, Schold J, Nakagawa T, Sánchez-Lozada LG, Johnson RJ, Lillo JL. Excessive fructose intake induces the features of metabolic syndrome in healthy adult men: role of uric acid in the hypertensive response. *Int J Obes (Lond)*. 2010;34:454–461. doi: 10.1038/ijo.2009.259.
75. Brymora A, Flisiński M, Johnson RJ, Goszka G, Stefańska A, Manitius J. Low-fructose diet lowers blood pressure and inflammation in patients with chronic kidney disease. *Nephrol Dial Transplant*. 2012;27:608–612. doi: 10.1093/ndt/gfr223.
76. Fox IH, Kelley WN. Studies on the mechanism of fructose-induced hyperuricemia in man. *Metabolism*. 1972;21:713–721.
77. Hallfrisch J. Metabolic effects of dietary fructose. *FASEB J*. 1990;4:2652–2660.
78. Mazzali M, Hughes J, Kim YG, Jefferson JA, Kang DH, Gordon KL, Lan HY, Kivlighn S, Johnson RJ. Elevated uric acid increases blood pressure in the rat by a novel crystal-independent mechanism. *Hypertension*. 2001;38:1101–1106.
79. Mazzali M, Kanellis J, Han L, Feng L, Xia YY, Chen Q, Kang DH, Gordon KL, Watanabe S, Nakagawa T, Lan HY, Johnson RJ. Hyperuricemia induces a primary renal arteriolopathy in rats by a blood pressure-independent mechanism. *Am J Physiol Renal Physiol*. 2002;282:F991–F997. doi: 10.1152/ajprenal.00283.2001.
80. Rovda Iul, Kazakova LM, Plaksina EA. Parameters of uric acid metabolism in healthy children and in patients with arterial hypertension [in Russian]. *Pediatriia*. 1990;8:19–22.
81. Török E, Gyárfás I, Csukás M. Factors associated with stable high blood pressure in adolescents. *J Hypertens Suppl*. 1985;3:S389–S390.
82. Gruskin AB. The adolescent with essential hypertension. *Am J Kidney Dis*. 1985;6:86–90.

83. Feig DI, Johnson RJ. Hyperuricemia in childhood primary hypertension. *Hypertension*. 2003;42:247–252. doi: 10.1161/01.HYP.0000085858.66548.59.
84. Feig DI, Soletsky B, Johnson RJ. Effect of allopurinol on blood pressure of adolescents with newly diagnosed essential hypertension: a randomized trial. *JAMA*. 2008;300:924–932. doi: 10.1001/jama.300.8.924.
85. Soletsky B, Feig DI. Uric acid reduction rectifies prehypertension in obese adolescents. *Hypertension*. 2012;60:1148–1156. doi: 10.1161/HYPERTENSIONAHA.112.196980.
86. Perichart-Perera O, Balas-Nakash M, Rodríguez-Cano A, Muñoz-Manrique C, Monge-Urrea A, Vadillo-Ortega F. Correlates of dietary energy sources with cardiovascular disease risk markers in Mexican school-age children. *J Am Diet Assoc*. 2010;110:253–260. doi: 10.1016/j.jada.2009.10.031.
87. Wang JW, Mark S, Henderson M, O'Loughlin J, Tremblay A, Wortman J, Paradis G, Gray-Donald K. Adiposity and glucose intolerance exacerbate components of metabolic syndrome in children consuming sugar-sweetened beverages: QUALITY cohort study. *Pediatr Obes*. 2013;8:284–293. doi: 10.1111/j.2047-6310.2012.00108.x.
88. Aeberli I, Zimmermann MB, Molinari L, Lehmann R, l'Allemand D, Spinas GA, Berneis K. Fructose intake is a predictor of LDL particle size in overweight schoolchildren [published correction appears in *Am J Clin Nutr*. 2008;88:1707]. *Am J Clin Nutr*. 2007;86:1174–1178.
89. Bel-Serrat S, Mouratidou T, Börnhorst C, Peplies J, De Henauw S, Marild S, Molnár D, Siani A, Tornaritis M, Veidebaum T, Krogh V, Moreno LA. Food consumption and cardiovascular risk factors in European children: the IDEFICS study. *Pediatr Obes*. 2013;8:225–236. doi: 10.1111/j.2047-6310.2012.00107.x.
90. Bel-Serrat S, Mouratidou T, Santaliestra-Pasías AM, Iacoviello L, Kourides YA, Marild S, Molnár D, Reisch L, Siani A, Stomfai S, Vanaelst B, Veidebaum T, Pigeot I, Ahrens W, Krogh V, Moreno LA; IDEFICS Consortium. Clustering of multiple lifestyle behaviours and its association to cardiovascular risk factors in children: the IDEFICS study. *Eur J Clin Nutr*. 2013;67:848–854. doi: 10.1038/ejcn.2013.84.
91. Bremer AA, Auinger P, Byrd RS. Relationship between insulin resistance-associated metabolic parameters and anthropometric measurements with sugar-sweetened beverage intake and physical activity levels in US adolescents: findings from the 1999-2004 National Health and Nutrition Examination Survey. *Arch Pediatr Adolesc Med*. 2009;163:328–335. doi: 10.1001/archpediatrics.2009.21.
92. Frank GC, Berenson GS, Webber LS. Dietary studies and the relationship of diet to cardiovascular disease risk factor variables in 10-year-old children: the Bogalusa Heart Study. *Am J Clin Nutr*. 1978;31:328–340.
93. Glueck CJ, Waldman G, McClish DK, Morrison JA, Khoury P, Larsen R, Salz K, Rifkind BM, Mattson FH. Relationships of nutrient intake to lipids and lipoproteins in 1234 white children: the Lipid Research Clinics Prevalence Study. *Arteriosclerosis*. 1982;2:523–536.
94. Morrison JA, Larsen R, Glatfelter L, Boggs D, Burton K, Smith C, Kelly K, Mellies MJ, Khoury P, Glueck CJ. Interrelationships between nutrient intake and plasma lipids and lipoproteins in schoolchildren aged 6 to 19: the Princeton School District Study. *Pediatrics*. 1980;65:727–734.
95. Welsh JA, Sharma A, Cunningham SA, Vos MB. Consumption of added sugars and indicators of cardiovascular disease risk among US adolescents. *Circulation*. 2011;123:249–257. doi: 10.1161/CIRCULATIONAHA.110.972166.
96. Williams CL, Strobino BA. Childhood diet, overweight, and CVD risk factors: the Healthy Start project. *Prev Cardiol*. 2008;11:11–20.
97. Ruottinen S, Rönnemaa T, Niinikoski H, Lagström H, Saarinen M, Pahkala K, Kaitosaari T, Viikari J, Simell O. Carbohydrate intake, serum lipids and apolipoprotein E phenotype show association in children. *Acta Paediatr*. 2009;98:1667–1673. doi: 10.1111/j.1651-2227.2009.01399.x.
98. Lee AK, Binongo JN, Chowdhury R, Stein AD, Gazmararian JA, Vos MB, Welsh JA. Consumption of less than 10% of total energy from added sugars is associated with increasing HDL in females during adolescence: a longitudinal analysis. *J Am Heart Assoc*. 2014;3:e000615. doi: 10.1161/JAHA.113.000615.
99. Lustig RH, Mulligan K, Noworolski SM, Tai VW, Wen MJ, Erkin-Cakmak A, Gugliucci A, Schwarz JM. Isocaloric fructose restriction and metabolic improvement in children with obesity and metabolic syndrome. *Obesity (Silver Spring)*. 2016;24:453–460. doi: 10.1002/oby.21371.
100. Burns SF, Lee SJ, Arslanian SA. Surrogate lipid markers for small dense low-density lipoprotein particles in overweight youth. *J Pediatr*. 2012;161:991–996. doi: 10.1016/j.jpeds.2012.06.013.
101. Welsh JA, Karpen S, Vos MB. Increasing prevalence of nonalcoholic fatty liver disease among United States adolescents, 1988–1994 to 2007–2010. *J Peds*. 2013;162:496–500.e1. doi: 10.1016/j.jpeds.2012.08.043.
102. Mager DR, Patterson C, So S, Rogenstein CD, Wykes LJ, Roberts EA. Dietary and physical activity patterns in children with fatty liver. *Eur J Clin Nutr*. 2010;64:628–635. doi: 10.1038/ejcn.2010.35.
103. Vos MB, Weber MB, Welsh J, Khatoon F, Jones DP, Whitington PF, McClain CJ. Fructose and oxidized low-density lipoprotein in pediatric nonalcoholic fatty liver disease: a pilot study. *Arch Pediatr Adolesc Med*. 2009;163:674–675. doi: 10.1001/archpediatrics.2009.93.
104. Mollard RC, Sénéchal M, MacIntosh AC, Hay J, Wicklow BA, Wittmeier KD, Sellers EA, Dean HJ, Ryner L, Berard L, McGavock JM. Dietary determinants of hepatic steatosis and visceral adiposity in overweight and obese youth at risk of type 2 diabetes. *Am J Clin Nutr*. 2014;99:804–812. doi: 10.3945/ajcn.113.079277.
105. O'Sullivan TA, Oddy WH, Bremner AP, Sherriff JL, Ayonrinde OT, Olynyk JK, Beilin LJ, Mori TA, Adams LA. Lower fructose intake may help protect against development of nonalcoholic fatty liver in adolescents with obesity. *J Pediatr Gastroenterol Nutr*. 2014;58:624–631. doi: 10.1097/MPG.0000000000000267.
106. Grønbæk H, Lange A, Birkebæk NH, Holland-Fischer P, Solvig J, Hørlyck A, Kristensen K, Rittig S, Vilstrup H. Effect of a 10-week weight loss camp on fatty liver disease and insulin sensitivity in obese Danish children. *J Pediatr Gastroenterol Nutr*. 2012;54:223–228. doi: 10.1097/MPG.0b013e31822cdedf.
107. Jin R, Welsh JA, Le NA, Holzberg J, Sharma P, Martin DR, Vos MB. Dietary fructose reduction improves markers of cardiovascular disease risk in Hispanic-American adolescents with NAFLD. *Nutrients*. 2014;6:3187–3201. doi: 10.3390/nu6083187.
108. Jin R, Le NA, Liu S, Farkas Epperson M, Ziegler TR, Welsh JA, Jones DP, McClain CJ, Vos MB. Children with NAFLD are more sensitive to the adverse metabolic effects of fructose beverages than children without NAFLD. *J Clin Endocrinol Metab*. 2012;97:E1088–E1098. doi: 10.1210/jc.2012-1370.
109. Heden TD, Liu Y, Park YM, Nyhoff LM, Winn NC, Kanaley JA. Moderate amounts of fructose- or glucose-sweetened beverages do not differentially alter metabolic health in male and female adolescents. *Am J Clin Nutr*. 2014;100:796–805. doi: 10.3945/ajcn.113.081232.
110. Moore LL, Singer MR, Qureshi MM, Bradlee ML, Daniels SR. Food group intake and micronutrient adequacy in adolescent girls. *Nutrients*. 2012;4:1692–1708. doi: 10.3390/nu4111692.
111. Striegel-Moore RH, Thompson D, Affenito SG, Franko DL, Obarzanek E, Barton BA, Schreiber GB, Daniels SR, Schmidt M, Crawford PB. Correlates of beverage intake in adolescent girls: the National Heart, Lung, and Blood Institute Growth and Health Study. *J Pediatr*. 2006;148:183–187. doi: 10.1016/j.jpeds.2005.11.025.
112. Frary CD, Johnson RK, Wang MQ. Children and adolescents' choices of foods and beverages high in added sugars are associated

with intakes of key nutrients and food groups. *J Adolesc Health*. 2004;34:56–63.
113. Louie JC, Buyken AE, Brand-Miller JC, Flood VM. The link between dietary glycemic index and nutrient adequacy. *Am J Clin Nutr*. 2012;95:694–702. doi: 10.3945/ajcn.111.015271.
114. Grimes CA, Wright JD, Liu K, Nowson CA, Loria CM. Dietary sodium intake is associated with total fluid and sugar-sweetened beverage consumption in US children and adolescents aged 2-18 y: NHANES 2005-2008. *Am J Clin Nutr*. 2013;98:189–196. doi: 10.3945/ajcn.112.051508.
115. Cornwell TB, McAlister AR. Contingent choice: exploring the relationship between sweetened beverages and vegetable consumption. *Appetite*. 2013;62:203–208. doi: 10.1016/j.appet.2012.05.001.
116. Briefel RR, Wilson A, Cabili C, Hedley Dodd A. Reducing calories and added sugars by improving children's beverage choices. *J Acad Nutr Diet*. 2013;113:269–275. doi: 10.1016/j.jand.2012.10.016.
117. Council on School Health; Committee on Nutrition. Snacks, sweetened beverages, added sugars, and schools. *Pediatrics*. 2015;135:575–583.
118. Murphy MM, Douglass JS, Johnson RK, Spence LA. Drinking flavored or plain milk is positively associated with nutrient intake and is not associated with adverse effects on weight status in US children and adolescents. *J Am Diet Assoc*. 2008;108:631–639. doi: 10.1016/j.jada.2008.01.004.
119. Yon BA, Johnson RK. Elementary and middle school children's acceptance of lower calorie flavored milk as measured by milk shipment and participation in the National School Lunch Program. *J Sch Health*. 2014;84:205–211. doi: 10.1111/josh.12135.
120. Yon BA, Johnson RK, Stickle TR. School children's consumption of lower-calorie flavored milk: a plate waste study. *J Acad Nutr Diet*. 2012;112:132–136. doi: 10.1016/j.jada.2011.09.011.
121. Williams BM, O'Neil CE, Keast DR, Cho S, Nicklas TA. Are breakfast consumption patterns associated with weight status and nutrient adequacy in African-American children? *Public Health Nutr*. 2009;12:489–496. doi: 10.1017/S1368980008002760.
122. Harris JL, Schwartz MB, Ustjanauskas A, Ohri-Vachaspati P, Brownell KD. Effects of serving high-sugar cereals on children's breakfast-eating behavior. *Pediatrics*. 2011;127:71–76. doi: 10.1542/peds.2010-0864.
123. Liem DG, Mennella JA. Sweet and sour preferences during childhood: role of early experiences. *Dev Psychobiol*. 2002;41:388–395. doi: 10.1002/dev.10067.
124. Walker RW, Goran MI. Laboratory determined sugar content and composition of commercial infant formulas, baby foods and common grocery items targeted to children. *Nutrients*. 2015;7:5850–5867. doi: 10.3390/nu7075254.
125. Foreyt J, Kleinman R, Brown RJ, Lindstrom R. The use of low-calorie sweeteners by children: implications for weight management. *J Nutr*. 2012;142:1155S–1162S. doi: 10.3945/jn.111.149609.
126. Gardner C. Non-nutritive sweeteners: evidence for benefit vs. risk. *Curr Opin Lipidol*. 2014;25:80–84. doi: 10.1097/MOL.0000000000000034.
127. Gardner C, Wylie-Rosett J, Gidding SS, Steffen LM, Johnson RK, Reader D, Lichtenstein AH; on behalf of the American Heart Association Nutrition Committee of the Council on Nutrition, Physical Activity and Metabolism, Council on Arteriosclerosis, Thrombosis and Vascular Biology, Council on Cardiovascular Disease in the Young, and the American Diabetes Association. Nonnutritive sweeteners: current use and health perspectives: a scientific statement from the American Heart Association and the American Diabetes Association. *Circulation*. 2012;126:509–519. doi: 10.1161/CIR.0b013e31825c42ee.