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Sugar in Infants, Children and Adolescents: A Position Paper of the European Society for Paediatric Gastroenterology, Hepatology and Nutrition Committee on Nutrition

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ABSTRACT

The consumption of sugars, particularly sugar-sweetened beverages (SSBs; beverages or drinks that contain added caloric sweeteners (ie, sucrose, high-fructose corn syrup, fruit juice concentrates), in European children and adolescents exceeds current recommendations. This is of concern because there is no nutritional requirement for free sugars, and infants have an innate preference for sweet taste, which may be modified and reinforced by pre- and postnatal exposures. Sugar-containing beverages/free sugars increase the risk for overweight/obesity and dental caries, can result in poor nutrient supply and reduced dietary diversity, and may be associated with increased risk of type 2 diabetes mellitus, cardiovascular risk, and other health effects. The term ''free sugars,'' includes all monosaccharides/disaccharides added to foods/beverages by the manufacturer/cook/consumer, plus sugars naturally present in honey/syrups/unsweetened fruit juices and fruit juice concentrates. Sugar naturally present in intact fruits and lactose in amounts naturally present in human milk or infant formula, cow/goat milk, and unsweetened milk products is not free sugar. Intake of free sugars should be reduced and minimised with a desirable goal of <5% energy intake in children and adolescents aged ≥2 to 18 years. Intake should probably be even lower in infants and toddlers <2 years. Healthy approaches to beverage and dietary consumption should be established in infancy, with the aim of preventing negative health effects in later childhood and adulthood. Sugar should preferably be consumed as part of a main meal and in a natural form as human milk, milk, unsweetened dairy products, and fresh fruits, rather than as SSBs, fruit juices, smoothies, and/or sweetened milk products. Free sugars in liquid form should be replaced by water or unsweetened milk drinks. National Authorities should adopt policies aimed at reducing the intake of free sugars in infants, children and adolescents. This may include education, improved labelling, restriction of advertising, introducing standards for kindergarten and school meals, and fiscal measures, depending on local circumstances.

Key Words: [illegible]

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> **What Is Known**
>
> - The consumption of sugar-sweetened beverages and free sugars in children is too high.
> - Sugar-sweetened beverages/free sugars increase the risk for dental caries and overweight/obesity, can result in poor nutrient, supply and reduced dietary diversity, and may be associated with increased cardiovascular risk.
>
> **What Is New**
>
> - This Position paper reviews the terminology, classification, and definitions of sugars and sugar-sweetened beverages; current recommendations and intakes in children/adolescents; evidence on the development of sweet taste and preference for sweet foods; evidence on health effects in infants, children, and adolescents; and provides recommendations and practical points on the intake of free sugars in the paediatric population.

Sugars are found naturally in fruits, vegetables, some grains, human milk, milk, and milk products (naturally occurring sugar), but are also added to foods during processing, preparation, or at table (1) (Tables 1 and 2). The added sugars sweeten the flavour of foods and beverages, improve their palatability, and are used to preserve food and to confer functional attributes, such as viscosity, texture, body, and colour (browning capacity).

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TABLE 1. Chemical classification and dietary sources of sugars

Sugars	Components	Dietary sources
Monosaccharides	Glucose	Fruits, plant juices, honey, rice drink
	Galactose	Milk and milk products (occurs in milk, bonded to glucose to form lactose)
	Fructose	Ripening fruits (berries), honey (in the free state alongside glucose); often bonded to glucose to form sucrose
Disaccharides	Sucrose (glucose + fructose)	Table/cane/beet sugar, honey, corn syrup, soy formula milk
	Lactose (glucose + galactose)	Milk and milk products, human milk and formula milk
	Maltose (glucose + glucose)	Maltobiose or malt sugar derived from starch hydrolysis (of: maize, corn, wheat, tapioca, potatoes, corn/glucose syrup) or produced with glucose caramelisation; found in germinating seeds (barley), malt, and rice drink

TABLE 2. Current definitions used for sugars in dietary recommendations (4,5,7,10,11)

Dietary recommendations	Total sugars	
WHO (5), SACN (7)	Free sugars (extrinsic sugars): sugars not contained within the cellular structure; (a) sugars (monosaccharides and disaccharides) added to foods and beverages by the manufacturer, cook or consumer; (b) sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates	Naturally occurring (intrinsic sugars): sugars naturally incorporated within intact plant cell walls (eg, incorporated into the cellular structure of foods; sugars in intact fruits or vegetables), lactose, and galactose in milk
EFSA (10)	Added sugars: sucrose, fructose, glucose, starch hydrolysates (glucose syrup, high-fructose syrup, isoglucose) and other isolated sugar preparations used as such or added during food preparation and manufacturing	Indigenous sugars: sugars naturally present in foods such as fruits, vegetables, cereals, lactose in milk products
US (4,11)	Added sugars: sugars and syrups that are added to foods during processing and preparation	Naturally occurring sugars: lactose in milk, fructose in fruits

EFSA = European Food Safety Authority; SACN = The UK Scientific Advisory Committee on Nutrition; US = United States.

A healthy, well-balanced diet contains naturally occurring sugars as integral components of whole foods (ie, within whole fruits, vegetables, milk and dairy products, and some grains). Added sugars provide sensory effects to foods and promote enjoyment, but although they may be required in some clinical situations, they are not a necessary component of the diet in healthy children. By providing calories without other essential nutrients (2), they can displace nutrient-dense foods and contribute to poor health outcomes, which is of special concern in children. Excessive consumption of sugars has been linked with several metabolic abnormalities and adverse health conditions (3).

The aim of this paper is to review the terminology, classification, and definitions of sugars and sugar-containing beverages; current recommendations for intake of sugars and beverages; intakes of sugars, sugars-sweetened foods/beverages in children/adolescents; evidence on the development of sweet taste and preference for sweet foods; evidence on the health effects of sugar and sugar-containing beverages in infants, children, and adolescents; what sugars should be replaced by; and provide recommendations and practical points on the intake of free sugars in the paediatric population, with a focus on establishing healthy dietary practices and preventing health problems. The paper focuses on the general paediatric population.

METHODS

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I.H. is the Secretary and M.F. is the Chair of Committee on Nutrition.

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TERMINOLOGY, CLASSIFICATION AND DEFINITIONS OF TYPES OF SUGARS AND SUGARS CONTAINING BEVERAGES IN THE DIET

Sugar is a ubiquitous term, but is not easy to define and measure. The term ''total sugars'' refers to the combination of naturally occurring sugars and free sugars (of which added sugars are a subgroup). ''Sugar-containing'' means foods and beverages that contain sugar. Previous analytical methods measured only the total sugars in foods. Nutrient databases and nutrition labels include values for total sugars (2). Recently, a precise step-by-step method that enables systematic calculation of free sugars content of foods and beverages was developed within the University of Toronto's Food Label Information Program Canada. A comprehensive assessment of total sugars and free sugars levels of 15,342 products was obtained. Free sugar accounted for 64% of total sugar content (8).

Various definitions of sugars are used in different contexts, for example, in chemical classification (Table 1), current dietary recommendations (Table 2), research studies, regulations and food labelling.

Sugars: Chemical Classification and Relative Sweetness

The term ''sugars'' describes mono- and di-saccharides. The 3 principal monosaccharides—hexoses (6-carbon sugars)—are glucose, fructose, and galactose, which are the building blocks of naturally occurring di-, oligo-, and polysaccharides. Carbohydrates are a major source of energy in the diet and include a range of compounds containing carbon, hydrogen, and oxygen. Carbohydrates are divided into 3 groups: mono- and di-saccharides (degree of polymerisation [DP] 1–2; i.e., sugars (Table 1), oligosaccharides (DP 3–9; eg, maltodextrins), and polysaccharides (DP $\geq$ 10) (7).

Sweetness is a gustatory response evoked by sugars and sweeteners. The initiation of a taste response involves the interaction of a stimulant molecule with a receptor located at the taste-cell plasma membrane. Sweetness is defined relative to sucrose, which has a sweetness value of 1.00 (or 100%). The relative sweetness of sugars differs. Fructose is the sweetest (relative sweetness: 1.17), followed by sucrose (1.00), glucose (0.74), maltose (0.33), galactose (0.32), and lactose (0.16) (9).

Definitions for Sugars Used in Dietary Recommendations and Research Studies

The updated WHO definition of ''free sugars'' is ''monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook, or consumer (i.e. added sugars), plus sugars naturally present in honey, syrups, fruit juices, and fruit juice concentrates (i.e. non-milk extrinsic sugars)'' (5). This term describes sugars that may have physiological consequences different from intrinsic sugars incorporated within intact plant cell walls or lactose naturally present in milk. The UK Scientific Advisory Committee on Nutrition (UK SACN) also adopted the definition ''free sugars'' (7).

The European Food Safety Authority (EFSA) defines sugars as ''total sugars,'' including both indigenous sugars naturally present in foods (ie, ''naturally occurring sugars'') such as fruit, vegetables, cereals, and lactose in milk products, and added sugars. The term ''added sugars'' refers to sucrose, fructose, glucose, starch hydrolysates (glucose syrup, high-fructose syrup, isoglucose), and other isolated sugar preparations used as such, or added during food preparation and manufacturing (10).

The United States (US) dietary reference intakes define ''added sugars'' as sugars and syrups that are added to foods during processing and preparation. Added sugars do not include naturally occurring sugars such as lactose in milk and fructose in fruits (11).

The different terminology used in dietary recommendations is challenging. The EFSA and US definitions of ''added sugars'' (10,11) do not include sugars present in unsweetened fruit and vegetable juice and fruit juice concentrate, all of which are, however, captured in the definition of free sugars (5). The US definition of ''added sugars'' further excludes sugars found in jellies, jams, preserves, and fruit spreads, while the EFSA definition also does not include honey; all of these are included in the definition of free sugars (5). In the US, there is now a mandatory requirement to include ''added sugars,'' in grams under ''Total Sugars'' and as % Daily Value on labels (12).

In research studies, exact definitions of sugars are often omitted, making it difficult to determine what was under investigation. In epidemiological studies, sugars consumption is often underestimated (13,14). Recently Nash et al (15) validated an expensive dual-isotope model based on red blood cell carbon (delta^{13}C) and nitrogen (delta^{15}N) isotope ratios that explained a large percentage of the variation in self-reported sugars intake. Red blood cell, plasma, and hair isotope ratios predict sugars intake and provide data that will allow comparison of studies using different sample types. This is a useful technique, but it is currently too expensive for use in epidemiological studies. In epidemiological studies, it is often easier to assess intake of sugar-sweetened beverages (SSBs) as these can be counted in food frequency instruments (2).

Definitions for Sugars Used in Regulations and Food Labelling

The terminology used in regulations and on food labels differs from that used in dietary recommendations. In Europe, there is no mandatory labelling of added or free sugars and only ''total sugar'' has to be declared (10,16).

Of specific relevance to infants, the WHO (5) and SACN (7) definitions of ‘‘free sugars’’ do not mention human milk and infant formulas. The compositional requirements of infant formulas and follow on formulas require a total glycaemic carbohydrate content of 9 to 14 g/100 kcal, with a minimum 4.5 g/100 kcal of lactose. For infant formulas, lactose is the preferred sugar, whereas sucrose, glucose, and fructose are not permitted (17–19). Glucose and sucrose may, however, be added to infant formulae manufactured from protein hydrolysates to mask the bitter taste. For follow-on formulas, the addition of sucrose and fructose may be considered acceptable, because most infants will be exposed to these sugars in complementary foods. If honey is used (for follow on formulas only), it has to be treated to destroy spores of *Clostridium botulinum* (17).

Interestingly, it is permitted to add free sugars to processed cereal-based foods and baby foods for infants and young children. It is stated: ‘‘if sucrose, fructose, glucose, glucose syrups or honey are added to ‘processed cereal-based foods’, i.e. simple cereals which are or have to be reconstituted with milk or other appropriate nutritious liquids or to rusks and biscuits which are to be used either directly or, after pulverisation, with the addition of water, milk; the amount of added carbohydrates from these sources shall not exceed 7.5 g/100 kcal’’ (20).

The health claims ‘‘no added sugar’’ and ‘‘naturally occurring sugars’’ on foods for infants, children, and adolescents are in accordance with ‘‘Regulation No 1924 on nutrition and health claims on foods’’ (21), but not with the WHO definition of ‘‘free sugars’’ and ‘‘naturally occurring sugars’’ (= ‘‘intrinsic sugars’’) (5) (Table 2)). Labels on foods for infants, children, and adolescents may therefore state ‘‘no added sugars’’ despite the fact that they contain ‘‘free sugars,’’ which need to be limited in the diet. With the current terminology in European regulations and food labelling, ‘‘free sugars’’ are ‘‘hidden’’ and consumers may not be aware that they are present in foods and beverages.

Sugars containing Beverages: Sugar sweetened Beverages and Fruit Juices

SSBs, also called sugar or nutritively sweetened drinks/beverages, are beverages that contain added caloric sweeteners such as sucrose, high-fructose corn syrup, and fruit juice concentrates. They include the full spectrum of soft drinks, carbonated soft drinks, fruitades, fruit drinks, sports drinks, energy and vitamin water drinks, sweetened iced tea, cordial, squashes, fruit syrup, and sweetened lemonade (22). The high-fructose corn syrup that is commonly used in beverages contains 55% fructose and 45% glucose derived from corn, whereas sucrose consists of 50% fructose and 50% glucose (23,24).

Fruit juices are not SSBs (23). Usually they have superior nutritional composition to SSBs, as they contain potassium, vitamins A and C and some are fortified with vitamin D and/or calcium, but they contain similar amounts of free sugars (5%–17% of sucrose, glucose, fructose, and/or sorbitol) and energy (23–71 kcal/100 mL) (24) to SSBs and have similar potential to promote weight gain in children (25,26). Table 3 shows the main groups of SSBs and fruit juices with the ranges of energy and free sugars content (24). Smoothies are not included in the definition of SSBs, even though they contain free sugars. It is also important to note that sweetened milks (eg, chocolate milks, chocolate soy drinks) are also not included in the definition of SSBs, although they contain 3.6 to 11.5 g of free sugars/100 mL and are commonly consumed by children and adolescents (24).

CURRENT RECOMMENDATIONS FOR INTAKE OF SUGARS AND BEVERAGES

The WHO recommends limiting the intake of free sugars to <10% of total energy intake (strong recommendation) based on moderate quality evidence from observational studies of dental caries, and suggests that a reduction to <5% would have additional benefits in reducing the risk of dental caries (conditional recommendation) in children and adults (5). The UK SACN review recommends the average population intake of free sugars should be <5% of total dietary energy from 2 years upwards. This figure was based on calculations of the mean reduction in free sugars intake needed to lower mean population energy intakes by 100 kcal/day with the aim of addressing energy imbalance and leading to a moderate degree of weight loss in the majority of individuals, assuming a baseline of 10% sugars intake as per previous UK recommendations. They further recommend that the contribution of free sugars toward recommended total carbohydrate intake should, in people with a healthy body mass index (BMI) and in energy balance, be replaced by starches, sugars contained within the cellular structure of foods and lactose naturally present in milk and milk products. In overweight individuals, the reduction of free sugars should be part of decreasing energy intake. Finally, they recommend that the consumption of SSBs should be minimised in children and adults (7). Five percent of daily energy for a 3-year-old girl is equivalent to <13 g of free sugars/day, (that is, <3 teaspoons), which is present in an average 170 mL (81–260 mL) of fruit

TABLE 3. Energy values, free sugar content and teaspoons of sugar in some sugar-containing beverages (sugar-sweetened beverages and fruit juices) (24)

	Energy (kcal/100 mL)		Free sugars (g/100 mL)		Free sugars (g (tsp)/500 mL)	
Sugars-containing beverages	min	max	min	max	min	max
SSBs*						
Flavoured water	4	18	1	4	5 (1)	22 (5)
Sports drinks	26	32	4	6	20 (5)	32 (8)
Ice teas	20	40	5	10	25 (6)	49 (12)
Energy drinks	45	49	11	13	55 (14)	65 (16)
Sweetened carbonated beverages/soda	34	51	9	13	44 (11)	67 (17)
Fruit nectars†	24	60	5	16	27 (7)	79 (20)
Fruit juices‡	23	71	5	17	24 (6)	87 (22)

Fruit juices = 100% fruit part; Fruit nectars = 25–50% fruit part; tsp = tea spoon (1 tsp = 4 g sugars). SSB = sugar-sweetened beverage.
*[illegible]
†[illegible]
‡[illegible]

TABLE 4. Calculated recommended intake from free sugars in relation to daily energy intake and expressed as teaspoons of sugar (5,7,168)

	Recommended energy intake at medium physical activity level, kcal/day		Free sugars (<5% of daily energy intake) (<g/day (<tea spoons/day))	
Age, y	Girls	Boys	Girls	Boys
2–<4	1.200	1.300	15 (3.5)	16 (4)
4–<7	1.500	1.600	18 (4.5)	20 (5)
7–<10	1.800	1.900	22 (5.5)	23 (5.5)
10–<13	2.000	2.200	24 (6)	27 (6.5)
13–<15	2.200	2.600	27 (6.5)	32 (8)
15–<19	2.300	3.000	28 (7)	37 (9)

nectar for example (Tables 3 and 4) (24). The AHA recommends that children consume $\leq$25 g (100 kcal or $\sim$6 teaspoons) of added sugars/day and to avoid added sugars for children <2 years of age. This recommendation is based on decreasing cardiovascular disease risk among children (excess weight gain and obesity, elevated blood pressure and uric acid levels, dyslipidemia, nonalcoholic fatty liver disease), insulin resistance and type 2 diabetes mellitus (T2D) and also to maintain diet quality (4). Several other scientific associations have called for reductions in consumption of SSBs for prevention of obesity and chronic diseases (27–32).

The recommended fluid for thirst for infants after the introduction of solid foods is water. Infants should not be given sugar-containing drinks in bottles or training cups and children should be discouraged the habit of a child sleeping with a bottle (33). The recommended beverages for children and adolescents are water, mineral water, or/and (fruit or herbal) tea without added sugars (34).

It should be noted that existing recommendations focus on free or added sugars rather than on total sugars, as there is consistent evidence that free and added sugars are the major contributor to the weight gain, obesity, dental caries, and other adverse health effects (see later). ''Naturally occurring sugars'' as integral components of whole foods (ie, within whole fruits, vegetables, some grains, and dairy products), that also contribute to the ''total sugar intake,'' are of less concern as they are less likely to be overconsumed and contain a wide range of bioactive health-enhancing nutrients, fibre, antioxidants, and phytochemicals that reduce inflammation and improve endothelial function. Indeed, evidence in adults suggests that weight gain during a 4-year period is inversely associated with intake of naturally occurring sugars (35), whereas in another analysis, low intakes of fruits, vegetables, whole grains, or nuts and seeds or a high dietary intake of salt were reported to be individually responsible for 1.5% to >4% of the global disease burden (36). It is also more practical to recommend a minimised intake of added/free sugars than to set a limit for total sugars.

INTAKES OF SUGARS, SUGARS SWEETENED FOODS, AND BEVERAGES IN CHILDREN AND ADOLESCENTS

Comparison of the intake of sugars and SSBs between countries is difficult, as studies use different definitions for sugar-containing beverages. According to the European Society for Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) Position Paper on Complementary Feeding no sugars should be added to complementary foods and fruit juices or SSBs should be avoided (33). In a study in 5 European countries it was, however, found that these liquids are frequently given to breast-fed and particularly to formula fed infants during the first months of life. Infants given energy providing liquids showed lower intakes of infant formula and solids (37).

The current food environment is characterised by a cheap and abundant sugars supply (38). Added sugars contribute about 14% of daily energy intake in 2 to 9 years old children in Europe (39) and 2 to 18 years old in the USA (40). In Slovenian adolescents aged 15 to 16 years mean intake of free sugars constituted 16% of daily energy intake (130 g/day) in boys and 17% (110 g/day) in girls (41).

Consumption of SSBs has increased dramatically in recent decades among children and adults (42). In the UK, soft drinks provided almost a third of the intake of non-milk extrinsic sugars in children aged 11 to 18 years. Biscuits, buns, cakes, and puddings, confectionery, and fruit juice were also significant contributors. There is a socioeconomic gradient, with higher sugars intakes in lower-income groups (7). A study among adolescents aged 12 to 17 years from 9 European countries reported consumptions of 424 mL of sugar-containing beverages/day (228 mL SSBs, 63 mL sweetened tea, and 133 mL fruit juice) (43). A German study reported a soft drink consumption of 480 mL/day in boys and 280 mL/day in girls aged 12 to 17 years (44). A Slovenian study reported SSBs (including sweetened tea and syrups) consumption of 683 and 715 mL/day in boys and girls aged 14 to 17 years; higher than the intake of milk and milk products (513 and 479 g/day in boys and girls) (45). Fruit juice consumption was 114 and 102 mL/day in boys and girls. SSBs contributed 9% and 10% of total energy intake in boys and girls, representing the primary source of free sugars in the diet of Slovenian adolescents (41,45). In a cross-sectional survey of 200,000 adolescents aged 11 to 15 years from 43 countries and regions across Europe and North America, the prevalence of daily soft drink consumption tended to increase between ages 11 and 15 years, especially in boys (46). There is a lack of studies in younger children.

THE DEVELOPMENT OF SWEET TASTE AND PREFERENCE FOR SWEET FOODS

Innate and Programmed Preferences for Tastes

Taste is simply defined as the sensation arising from the taste system, but flavour is considered a more inclusive term for the complex of sensory cues, including olfaction, taste and touch systems (47). An infant's experience with flavours begins early, in utero via amniotic fluid and later during breast-feeding, where flavours from the mother's diet are experienced (48,49). Infants have innate preference for sweet, salty, and umami tastes, and innate rejection of sour and bitter tastes (47,50–52). Newborns prefer sugar solutions to water (47,53) and sweeter solutions over less sweet solutions (47,54) possibly because that ingestion of sweet sugars leads to endogenous opioid release (47,55). This effect is used in neonatal practice for procedural pain relief in infants (56–58).

Individual sensitivity to and preference for sweet foods is determined not only by presence or absence of sugars on sweet taste receptors, but also by genetic sensitivity to taste including polymorphisms in the gene for sweet taste receptors TAS1R (59–61).

Programming of preference for certain tastes and palatable food is a complex process involving systems that regulate appetite and food preferences at a central level (altered development of systems regulating motivation, reward, and perception of taste). There are also other influences; for example prenatal exposure to cocaine is associated with greater preference for sweet taste in newborns (62). In rats, a similar effect has been shown with morphine (63). Epigenetic changes may also contribute to the programming effect; however, the precise mechanisms still remain poorly understood (64–68).

Innate Preference for Energy dense Foods

Along with preference for sweet taste, we are also predisposed to prefer energy-dense foods, thus ''healthy'' foods given as complex carbohydrates and vegetables which are not sweet, salty, and energy-dense are initially rejected by children (47). Especially in young children, sweet taste by itself is probably not the main regulator of food intake. Young children show so-called ''caloric compensation,'' adjustment of food intake based not primarily on sweetness, but on energy content of a previous preload meal given up to 1 hour before eating a self-selected meal. This mechanism seems not to be present in older children (9–10 years old) and in adults (69). Preference for energy-dense foods was advantageous in the past when food resources were scarce. In today's obesogenic environment, this can contribute to development of overweight and obesity (47).

Postnatal Taste and Flavour Learning

Children's food choices and preferences are influenced not only by genetic predisposition to certain tastes, but also by food availability and by cultural and parental influences, and they track through childhood and into adulthood (49,70–73). Acceptance of basic taste in weaning may be different among breast-fed and formula-fed infants (49,74,75). Formula-fed infants are exposed to a constant flavour, a predominantly sweet taste. Human milk also has a sweet taste, but additionally exposes the infant to varying flavours and aromas, depending on the nutrition of the mother. Facial responses to various taste solutions at 3 months of age before weaning did not show any difference between breast-fed and formula-fed infants and were consistent with inborn preference for sweet and salty tastes (49). In an observational study, breast-fed infants, however, had a greater acceptance of new foods and flavours at 2 to 8 months of age versus formula-fed infants (70). Breast-feeding was also associated with greater diversity in foods and lower intake of juice at 9 months of age and healthier meat and vegetable dietary pattern at 2 to 8 years of age (70,76). Longer exclusive breast-feeding was associated with higher vegetable intake at age of 5 years and longer breast-feeding duration has consistently been related to higher fruits and vegetables intake in young children (77,78). In a recent study by Perrine et al (79) in 1355 children, frequency of consumption of water, fruits, and vegetables was positively associated, whereas the intake of SSBs was inversely associated, with any breast-feeding duration be it partial or exclusive. These are, however, observational studies and it is not possible to determine whether these associations are causal.

Despite the innate preference for sweet tastes, children are also typically phobic to new foods, especially to sour fruits, vegetables, and protein foods. Food neophobia is highly heritable, as shown in twin studies (80). Sweet taste is preferred, but only in familiar food contexts and is influenced by the increase in the availability of sweet products associated with urbanisation (59,81). Sweet and fat taste preferences vary across geographical regions even in Europe and are related to weight status in European children. Sweet preference, however, is not always related to consumption of sweet food (82). Acceptance of novel foods in infants can be enhanced by exposure to variety of flavours (83). A positive correlation was observed between sensitivity to bitter taste and sweet taste perception (59) and between salty and sweet taste preferences (84). Children have the ability to learn preferences for foods made available to them, thus innate preference for sweet taste can be partly modified by experience with food even in early infancy (47,85,86).

Are Interventions to Modify Taste Preferences Effective?

Observational studies show inconclusive results in the association between feeding experience during foetal development and early infancy and later taste preferences (52,87,88). Exposure to palatable foods high in fat and sugars before birth via maternal intake or in early infancy may lead to overall increase in food intake and increased preference for palatable foods after weaning (64).

Mother's choices of drinks for their young children are also influenced by various social, environmental, and behavioural factors, such as child age, child preference, and temperament, grandparents' influence and sweetened drinks given as a reward (89). Caution is required when trying to introduce strategies to encourage children to consume nonpreferred foods. These feeding practices may lead to children disliking rather than accepting these foods and restriction of energy-dense, sweet, salty, and fatty foods may promote their liking for and intake of those foods (47,90). It seems that the best opportunity for promoting patterns of preference consistent with healthier diets may be to focus on the young (47). In 7 to 16-year-old children, sensory preferences did not change within 12 months in a long-term outpatient obesity lifestyle intervention programme based on behaviour and exercise therapy and a nutritional course including session on taste training (91).

Intervention studies trying to show effects of repeated exposure to specific foods on food preference have some methodological pitfalls. Novel whole food products (consisting of many taste combinations) are often used for testing, which does not allow discrimination between individual taste dimensions. Using novel foods also makes it difficult to distinguish the effect of reduction in food neophobia from an increase in preference for the specific taste (92). Attempts have been made to develop reliable methods to test taste sensitivity and aversion even in young children (93,94). Liem and de Graaf (92) have shown that exposure to sweet orangeade in 9 years old children (age range 6–11 years) for 8 days increases preference for sweet orangeade, but not in adults. It is not clear whether this effect is stable over time and if it is possible to extrapolate it to other sugar-rich food.

In a recent systematic review by Nehring et al (52) (published after the cut-off date of the literature search), the hypothesis that foetuses and infants exposed to sweet, salty, sour, bitter, umami, or specific tastes show greater acceptance of that same taste later in life was explored. The authors identified 20 studies (15 intervention and 5 observational), of which 10 studies in 13 subgroups examined the effect of exposure to sweet tastes. All were conducted in infants below 1 year of age. Of these, 6 showed a statistically significant increase in intake, whereas 7 showed no difference. Subgroups not finding an effect had smaller sample sizes. Based on intervention studies alone, the authors concluded that it is not clear whether exposure to sweet taste affects the later intake of sweet-flavoured foods.

Persistence of Learned Preferences

Infants routinely fed sweetened water by their mothers show a greater preference for sweetened water at 6 months (47,85), 2 years (92,95), 6 years (96), and 6 to 10 years of age (97). A prospective study among 166 girls from US reported that soda (carbonated SSB or artificially sweetened beverages) drinkers at age 5 years continued to have higher mean consumption of sodas at 7 to 15 years of age (98). These mostly observational studies suggest that SSB intake during infancy and early childhood may influence SSB intake in later childhood and continue through adolescence, but they do not allow causal inferences.

Children prefer higher concentrations of sucrose in water than do adults (84). They are less well able to discriminate between different sucrose concentrations than adolescents, and adolescents in turn have higher optimal preferred sucrose concentrations than adults. The age effects are similar for sucrose in water and sucrose in lemonade (99). Children at 8 to 9 years of age have a much higher density of taste pores and thus greater sensitivity to sucrose than adults (100). Eating habits with preferences for fatty and sweet food are likely to persist at least during early childhood. The Bogalusa Heart study has shown in a prospective manner that persistence of eating behaviours appears to begin as early as age 2 years, and consistency of intake levels of several nutrients including total sugars and sucrose lasts until at least 4 years of age (72). The preference for sweet taste seems to decline with age (101).

INTAKE OF SUGARS, SUGARS SWEETENED FOODS BEVERAGES, AND HEALTH OUTCOMES IN CHILDREN ADOLESCENTS

The WHO commissioned a systematic review and meta-analysis on the association of sugars intake and body weight (5,6) as well as dental caries (see below) (5,102) in children and adults. The systematic review on the association between sugars intake and body weight in children and adults included 30 RCTs (5 in children) and 38 prospective cohort studies (21 in children) (5,6). The UK SACN also performed a systematic review and meta-analysis and reviewed the relationships between carbohydrates, including sugars, sugars-sweetened foods and SSBs, and health, including body weight and dental caries in children, adolescents. and adults (7). The 2 reviews employed different inclusion criteria for studies; the WHO considered a wider evidence base including studies of shorter duration, nonrandomised trials, population and cross-sectional studies (5,6) compared with SACN (7). A summary of the 2 reviews focussing on outcomes in the paediatric age group, and their conclusions and recommendations is provided in Table 6 in Appendix 3 (Supplemental Digital Content 3, *http://links.lww.com/MPG/B104*), and the main conclusions are described in the following sections along with data published since these reviews.

Intake of Sugars Sugar sweetened Beverages and Body Weight or Adiposity in Children and Adolescents

E t o a H r Inta o • u ar sw t n B v ra s an or • u ars

The WHO meta-analysis of 5 prospective cohort studies in children revealed that after 1-year follow-up a higher consumption of SSBs was associated with a 55% higher risk of becoming overweight/obese versus those with the lowest intake. Among free living people consuming ad libitum diets, intake of free sugars or SSBs is associated with body weight (5,6). SACN reviewed evidence from prospective cohort studies and RCTs on the relationships between all types of carbohydrates in diet, including sugars, sugar-sweetened foods and SSBs, and health in children, adolescents, and adults. They highlighted several associations between sugars intake and body weight, BMI, body fatness as a part of other health parameters.

A recent longitudinal study examined the association between SSB intake during infancy and obesity at age 6 years in 1189 US children. The odds for obesity were 71% higher for any SSB intake and 92% higher for SSB introduction before age 6 months compared with children who had no SSB intake during infancy. The odds of obesity at 6 years among children who consumed ≥3 SSBs/week (1 SSB = 230 mL; 106 kcal) between 10 and 12 months was twice that of children who were not fed SSBs (103). A cross-sectional study assessed the effects of SSBs on obesity prevalence in 2295 2 to 4-year-olds. High intakes of SSBs were linked to increases in obesity prevalence. Compared with ≥2 SSB/day, no SSB intake was associated with a 28% reduction in obesity prevalence (104).

A recent longitudinal, multicentre study investigated associations between SSB consumption in childhood and adolescence with subsequent changes in body fatness in early adulthood at 6- and 12-year follow-up. They enrolled 283 Danish children aged 9 years and collected data at 9, 15, and 21 years. Subjects who consumed >1 serving of SSB/day at age 15 years had larger increases in BMI and waist circumference (WC) than nonconsumers over the subsequent 6 years. Subjects who increased their SSB consumption from age 9 to 15 years also had larger increases in BMI and WC from 15–21 years than those with no change in consumption (105).

E t o u Inta o • u ar sw t n B v ra s an or • u ars

The WHO meta-analysis of 5 RCTs in children that reduced SSBs and sugar-sweetened foods showed no change in body weight measured by standardised BMI or BMI *z* score. Evidence was found to be less consistent in children than in adults due to low compliance with dietary advice. Nutrition education alone as an intervention to reduce free sugars intake had a limited effect (6). The meta-analysis, however, did not include 2 more recent studies, which (106,107) overcame the limitations of previous trials, and a case-control study (108).

The double-blind placebo-controlled trial by de Ruyter et al (106) randomised 641 normal-weight Dutch children aged 5 to 11 years to an 18-month intervention (250 mL sugar-free, sucralose-sweetened beverage/day; 0 g sucrose (=0 kcal/serving)) versus a control group (250 mL SSBs, 26 g sucrose (=104 kcal/serving)). Compliance was measured by urinary sucralose. After 18 months, children receiving the noncalorically sweetened beverage had lower BMI *z* score, skinfold thickness, waist-to-hip ratio, and less fat mass compared to children receiving SSBs. A reduction of 104 kcal from SSBs/day (~5% of daily energy at the diet 2000 kcal/day) was associated with 1.01 kg lower weight gain for 1.5 years in normal weight children. The results were similar for dropouts. This study had good retention rates, was sufficiently powered and provided evidence that masked replacement of SSBs with noncaloric beverages reduces weight gain and fat accumulation in normal-weight children.

Ebbeling et al (107) randomly assigned 224 overweight and obese US adolescents who regularly consumed SSBs or 100% fruit juice (1.7 serving/day at baseline in both groups) to intervention (home delivery of water or noncaloric beverages for 1 year in place of SSBs) or a control group with the usual consumption. After 1-year of active intervention, the intervention group consumed significantly fewer SSBs (mean weight (mean difference ± SEM −1.9 ± 0.9 kg; $P = 0.04$) and had a smaller increase in BMI (mean difference ± SEM −0.57 ± 0.28 kg/m^2; $P = 0.045$) versus control group. Both groups were followed up for an additional year without any intervention. At 2 years, the consumption of SSBs was lower in the intervention group (mean ± SEM 0.4 ± 0.5 vs 0.8 ± 0.8 servings/day in control group), but there was no significant difference in weight or BMI between the groups. These RCTs provide some evidence that decreasing consumption of SSBs, as a part of active intervention, may reduce childhood obesity (106,107). They suggest an inadequate energy compensation (degree of voluntary reduction in intake of other foods/drinks) for energy delivered as sugars. Both studies were included by SACN after their initial systematic review and contributed to upgrading their recommendation (7).

A cluster RCT of a school-based education programme in 644 English children aged 7 to 11 years (overweight: 19% girls, 21% boys; obese: 10% girls, 11% boys in the study group and similar in the control group) produced a reduction in carbonated beverages, included noncalorically sweetened and SSBs, consumed. This was associated with a reduction in the number of overweight and obese children after the 1-year intervention (included in WHO (5,6) and SACN reviews (7,109)), but not 2 years after the educational programme was discontinued (110). This results supports a benefit of reducing SSB consumption as part of an active intervention programme on childhood obesity, but points to the need for continuing intervention to promote a healthy food environment and healthy behaviours in children to maintain the effect (107,110).

A RCT investigated the effect of decreasing SSBs consumption on body weight in US adolescents (13–18 years). Environmental intervention for 25 weeks almost completely eliminated SSBs consumption. The beneficial effect of reducing SSBs consumption on body weight increased with increasing baseline body weight. Decreasing SSBs consumption had a beneficial effect on body weight only in children in the upper tertile of BMI (included in WHO) (5,6,111).

Behavioural Modifications

Additionally to the reviews by WHO (5,6) and SACN (7), a systematic review and meta-analysis of studies in children, adolescents and adults by Malik et al (112) concluded that SSB consumption promotes weight gain. Sensitivity analyses of RCTs in children showed more pronounced benefits in preventing weight gain in SSB substitution trials than in school-based educational programs and among overweight compared with normal-weight children. Kaiser et al (113) performed a meta-analysis of studies in children and adults that added SSBs to diets and reported dose-dependent increases in weight. A meta-analysis of studies attempting to reduce SSB consumption in children and adolescents showed an equivocal effect on BMI in all subjects, whereas there was greater weight loss/less weight gain in subjects who were overweight at baseline. Thus, the effect of SSBs may be more pronounced in obese children. These RCTs are trials of behavioural modifications and the findings are affected by intervention intensity and limited by adherence (114).

Intake of Sugars Sugar sweetened Beverages and Oral Health or Dental Caries

Sucrose is the most cariogenic sugar (33). It can form glucans that enable bacterial adhesion to teeth and limit diffusion of acid and buffers in the plaque (115,116). Dental diseases are the most prevalent noncommunicable diseases worldwide (5,117,118). Their treatment consumes 5% to 10% of healthcare costs in industrialised countries (5,117,119). SSBs intake is associated with increased risk of dental caries due to sugars and acidity that results in enamel erosion (120–122). Also the frequency of SSBs and sugar-containing foods consumption as well as oral hygiene play a role. In some studies, results are adjusted for tooth brushing frequency.

The WHO systematic review included studies if they reported an intervention to alter sugars intake, provided information on dental caries and lasted at least 1 year. Observational studies were included if they reported absolute or partial change in sugars intake and information on dental caries. Studies that reported solely on the frequency of sugars intake were excluded. The majority of studies were conducted in children (1 nonrandomised intervention study, 50 observational studies). Eighty-four percent of studies in consumption of SSBs (125). The econometric analysis of Basu et al (126) ascertained that sugars meets the Bradford Hill criteria for causation for diabetes, including dose, duration, directionality, and precedence.

There are several RCTs in adults using diets differing in the proportion of sugars in relation to blood pressure (127–131). In a cross-sectional study in adolescents, consumption of fructose and added sugars from SSBs was associated with higher blood pressure (132). The SACN concluded that there was not enough evidence on the effect of sugars intake on cardiovascular diseases to draw conclusions (7); however, a number of studies published since this review suggest possible associations between sugars consumption and cardiovascular risk factors. A prospective cohort study suggested a significant relationship between added sugars consumption in adults and increased risk for cardiovascular disease mortality (133). A systematic review and meta-analysis in adults on the association between sugars intake and blood pressure and lipids concluded that dietary sugars influence diastolic blood pressure and serum lipids. In trials that lasted $\geq$8 weeks, higher consumption of sugars was associated with higher blood pressure independent of the effect of sugars on body weight (134). A possible effect of sugars on blood pressure is also suggested by some reviews in children, adolescents and adults (135,136).

Two studies showed a relationship between sugars consumption and markers of cardiovascular disease in adolescents (137,138). In a study of 559, 14 to 18-year-old adolescents living in the southern US higher total fructose consumption (free fructose + 50% of free sucrose) was positively associated with multiple markers of increased risk for cardiovascular disease and T2D. The relationships were independent of likely potentially confounding factors including physical activity, socioeconomic status, energy intake, and fibre consumption and were modified by visceral obesity (137). Whether fructose has specific metabolic effects is still controversial (139).

In a cross-sectional study of 2157 US adolescents aged 12 to 18 years consumption of added sugars was positively associated with multiple measures known to increase cardiovascular disease risk. Added sugars intake was negatively correlated with mean high-density lipoprotein-cholesterol levels, whereas positively with low-density lipoprotein-cholesterol and triglycerides levels. Among overweight and obese adolescents, added sugars were positively correlated with the insulin resistance index (138).

A recent scientific statement from the AHA reviewed cardiovascular disease risk outcomes associated with added sugars including excess weight gain/obesity, elevated blood pressure and uric acid levels, dyslipidemia, and nonalcoholic fatty liver disease in children (risk factors). They cite several epidemiological and clinical trials studies where ''excessive fructose intake resulted in increased blood pressure in children and young adults'' and concluded that added sugars are a source of excess fructose, whereas the reduction of fructose from added sugars is likely to decrease uric acid, possibly improving blood pressure in children (4).

Other Possible Health Effects of Sugars containing Beverages

Malabsorption of sugars from fruit juice, especially when consumed in excessive amounts or even in nonexcessive amounts (ie, 240 mL of apple juice) in susceptible infants and children, can result in chronic diarrhoea, flatulence, bloating, and abdominal pain, and growth faltering in children (140–143) as well as in adults (144). Withdrawal of apple juice from the diets of susceptible children was curative in all cases (140).

SSBs and fruit juices given to infants may displace human milk or infant formula, which may adversely affect nutrient supply and decrease dietary quality (7). Consumption of SSBs in children and adolescents is also associated with inadequate intake of calcium, iron, and vitamin A (145,146).

Metabolic and Satiety Responses to Fluid Versus Solid Forms of Sugars

The form (liquid or solid) of dietary intake is related to energy balance. In a 6-year longitudinal study of 359 Danish children aged 8 to 10 years, liquid sucrose consumption was more strongly associated with changes in WC and BMI z scores compared with solid sucrose consumption (147). Lee et al (148) used data from a 10-year study of 2021 US girls aged 9 to 10 years at baseline to determine if the association with adiposity varies by the form (liquid vs solid) of sugars consumed. Before total energy adjustment, each additional teaspoon of liquid or solid added sugar was significantly associated with an increase in WC and BMI *z* score. After adjustment for total energy intake, the association remained statistically significant only between liquid added sugars and WC among all subjects and between solid added sugars and WC among overweight/obese subjects only. There was no significant association with naturally occurring sugars. These findings suggest a positive association between added sugars intake (liquid and solid) and BMI that is mediated by total energy intake and an association with WC that is independent of it.

Studies in adults suggest whole foods are more satiating than liquid foods and that people do not compensate well for calories consumed as liquids by eating less food (130,149,150). A whole food decreases food intake at subsequent meals, whereas fibre added to a drink is not effective (2). Study participants consumed fewer calories at lunch after consuming apples compared to equal calories as apple sauce, apple juice, or apple juice with added fibre (151). Whole carrots were associated with lower calorie intake compared to carrot juice or a carrot juice cocktail that contained all the nutrients in carrots (152). In lean and obese adults, liquid foods elicited a weaker compensatory dietary response than solid foods (watermelon juice vs watermelon). Energy intake was 12.4% higher on the days the liquid forms of the high-carbohydrate foods were ingested, due to weaker satiety effect (153). Fruit juices have no nutritional advantages over whole fruits and, as they lack fibre, they are consumed more quickly than whole fruits (25).

WHAT SHOULD SUGARS BE REPLACED WITH IN PRODUCTS, OR IN THE DIET?

Effect of Replacing Sugars containing Beverages With Water or Milk

A randomised, controlled cluster trial conducted by Muckelbauer et al (154) in 32 elementary schools in 8-year-old German children tested an education programme with environmental interventions (provision of drinking water in 17 schools; 15 control schools) and showed a modest reduction in the amount of SSBs consumed, which was associated with a 31% lower adjusted risk of overweight and obesity. A systematic review from 6 electronic databases from inception to November 2013 included 6 cohort studies and 4 RCTs in children and adults and showed a potential beneficial effect on long-term body weight management when SSBs are replaced by water, tea, coffee (in adults) or, in some studies, low-calorie artificially sweetened beverages. The optimal beverage alternative to SSBs may vary according to age group and/or disease outcome (155).

A study examined the association between different types of beverage intake and substitution of SSBs by water, milk, or 100% fruit juice in relation to 6-year change in body fatness. A cohort of 358 children aged 9 years who participated in the Danish part of the European Youth Heart Study was followed for development of body fatness over 6 years. SSB intake was associated with long-term changes in body fatness in children. Replacing SSBs with water or milk, but not 100% fruit juice, was inversely associated with body fatness development (156).

Secondary analysis of a nationally representative cross-sectional study of 3098 US children and adolescents (aged 2–19 years) found that each additional 235 mL serving of SSB corresponds to 106 kcal/day higher total energy intake. Replacing SSBs with water was associated with a significant decrease in total energy intake; each 1% of replacement was associated with 6.6 kcal lower daily energy intake and this reduction was not negated by compensatory increase in other food or beverages. The authors calculated that replacing all SSBs with water would result in an average net reduction of 235 kcal/day (157).

A secondary analysis of data from a 1.5-year RCT designed to prevent overweight among Danish children (aged 2–6 years) showed that every 100 g/day increase in sugary drink intake was associated with 0.10 kg and 0.06 unit increases in body weight and BMI *z* score. Substitution of 100 g sugar-containing beverages/day with 100 g milk/day was inversely associated with Δ weight and Δ BMI *z* score. Sugary drink consumption was associated with body weight gain among young children with high predisposition for overweight (158).

A 16-week intervention trial in 8 to 10-year-old Chilean children showed that replacing SSBs with milk may have beneficial effects on lean body mass and growth, with no changes in percentage body fat (159).

A systematic review of studies in adults showed that drinking water versus SSBs or fruit juices before a meal was associated with a lower energy intake. In short-term feeding trials in adults drinking SSBs or fruit juices before a meal was associated with 7.8% or 14.4% higher total energy intake compared with drinking water (160). Findings suggest a role of water in reducing energy intake and obesity prevention.

Effect of Replacing Sugars With Non nutritive Sweeteners

Non-nutritive Sweeteners (NNS or noncaloric sweeteners) are low in calories or have no calories and include artificial sweeteners (aspartame, acesulfame-K, saccharin, sucralose, neotame, advan-

SUMMARY AND CONCLUSIONS

Regarding the terminology, classification and definitions of sugars and sugar-containing beverages

- [illegible]
- [illegible]

Regarding current recommendations and intakes of sugars, sugars-sweetened foods/beverages in children/adolescents

- [illegible]
- [illegible]

Regarding the development of sweet taste and preference for sweet foods

- [illegible]
- [illegible]
- [illegible]

Regarding the evidence on health effects of sugars/sugar-containing beverages in infants, children and adolescents

- [illegible]
- [illegible]
- [illegible]

Regarding what sugars should be replaced by

- [illegible]
- [illegible]

Based on These Conclusions, the ESPGHAN Committee on Nutrition Recommends

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

SUGGESTED FUTURE RESEARCH DIRECTIONS

- [illegible]
- [illegible]
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- [illegible]

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