Problematics of sugar-sweetened beverage consumption in Slovenia and the world

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Abstract

The prevalence of cardiometabolic diseases has reached pandemic proportions; therefore, increasing attention is paid to lifestyle changes in the population, especially the eating habits and consumption of certain food groups. Epidemiological evidence shows that the consumption of sugar-sweetened beverages is associated with an increased risk of obesity, diabetes, and cardiovascular disease; furthermore, it is an indicator of individual's unhealthy lifestyle. Sugar-sweetened beverages are a source of so-called "empty calories" that have no nutritional value and represent the largest source of added energy and intake of added sugars, especially fructose. It has been shown that a reduction in sugar-sweetened beverage consumption leads to a decrease in body weight and a reduction in the risk of cardiometabolic diseases. The consumption of sugar-sweetened beverages is ranked among the 15 most common risk factors among the indicators of an unhealthy lifestyle. Consequently, it is reasonable to intensify awareness of the importance of abstaining from the consumption of sugar-sweetened beverages, especially in people with an increased risk of metabolic diseases and young people with an unhealthy lifestyle. In this article, sugar-sweetened beverages and their association with obesity, diabetes, cardiovascular diseases, as well as possible healthy alternatives to such beverages are described.

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1 Introduction

Two parallel epidemiological trends, i.e. increasing prevalence of obesity and increasing prevalence of type 2 diabetes have been observed in recent decades (1,2). A term »diabesity« has been coined to denote that type 2 diabetes and obesity frequently coexist and are closely interconnected (3). Cardiovascular diseases are the main complications associated with these two metabolic disorders and they represent the leading cause of mortality in Slovenia and worldwide (4,5).

Among the many factors implicated in the development of obesity, type 2 diabetes and cardiovascular diseases, increased attention is devoted to lifestyle, including eating habits. Growing public and scientific interest has been paid to the intake of sugar-sweetened beverages. They represent the highest source of energy and are the largest contribu-

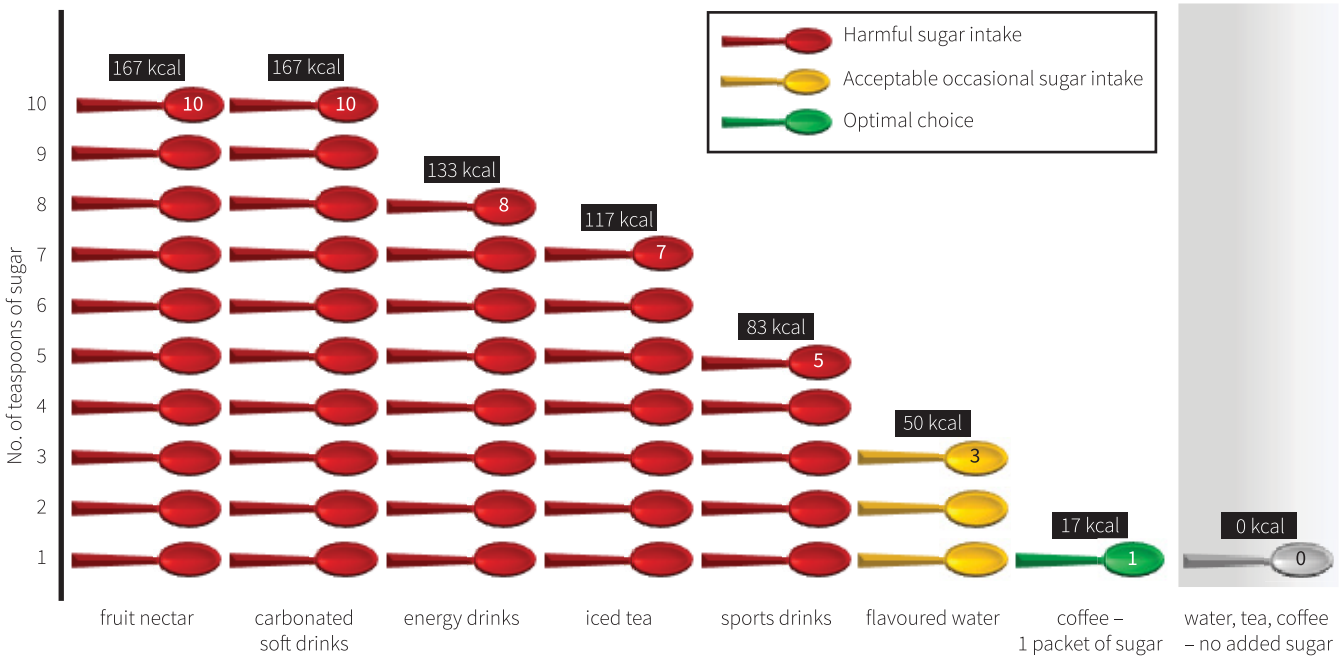

Figure 1: Sugar content, i.e. number of teaspoons (5 g) of sugar, in 500 mL of selected sugar-sweetened beverages. Black squares indicate equivalent calorie intake. Grey area indicates healthy alternatives to sugar-sweetened beverages.

tor to added sugar intake in both children and adults (6). The World Health Organisation (WHO) recommends reducing added sugar intake to less than 10 % of daily calorie intake (7). Sugar-sweetened beverage consumption may lead to increased body mass resulting from high sugar content, increased daily calorie intake, and failure of these beverages to provide satiety. Sugar-sweetened beverages tend to change taste and by activating taste-related pathways in the brain increase one's cravings for soft drinks (8). Fructose, found in food as sucrose or glucose-fructose syrup, has been increasingly used in the manufacturing of soft drinks (9). Because of its specific metabolism, fructose plays an important role in the development of metabolic and cardiovascular diseases (10-13).

This paper summarises the relevant literature and presents mechanisms and evidence for the causal relationship between the consumption of sugar-sweetened beverages and weight gain, type 2 diabetes and cardiovascular diseases.

2 Definition of sugar-sweetened beverages

Sugar-sweetened beverages include non-alcoholic beverages, fruit drinks and energy drinks, which contain sugar added by the manufacturer, cook or consumer; either glucose, fructose, dextrose, lactose, malt syrup, maltose, molasses, sucrose, trehalose, honey or brown sugar (9).

Fructose is found in sucrose (a disaccharide consisting of one glucose molecule and one fructose molecule derived

from sugarcane or sugar beet), known as table sugar. Fructose in monosaccharide form is naturally present in honey, fruit and some vegetables (14). High fructose corn syrup (HFCS), produced from cornstarch, is an important source of fructose in diet. HFCS is composed of either 42 % (HFCS-42) or 55 % fructose (HFCS-55), with the remaining sugar being glucose (9). HFCS-55 is approximately as sweet as sucrose and is therefore used for sweetening soft drinks. HFCS-42 is less sweet and is used in processed foods, including canned food (soups, fruit), cereals, baked food, candies and fast food items. HFCS has been increasingly used to sweeten beverages, mostly because it is cheaper than natural sugar. It should be pointed out that beverages sweetened with natural sugar contain fructose that accounts for 50 % of the total sugar content (14).

Sugar-sweetened beverages available on the market differ considerably in their sugar content. As shown in Figure 1, some soft drinks contain high amounts of sugar and this added sugar accounts for a considerable proportion of daily calorie intake. Some sugar-sweetened beverages (500 mL) contain up to 52 g of sugar (208 calories), which is 10 % of total daily intake (based on 2000 kcal/day) (9). The real sugar content in sugar-sweetened beverages may differ from that reported on the food label. Ventura et al. found that the actual content of sugar in soft drinks differed from that indicated on the label by 85–128 %. The greatest difference was established for non-bottled beverages, offered on tap in fast food restaurants. Calories provided by sugar-sweetened beverages are often referred to as »empty« calories; e.g. a can of sugar-sweetened drink contains 20 g of fructose and no important nutrients, as compared to a medium-sized orange that has 6 g of fructose in addition to other nutrients, such as vitamins and dietary fibre (15). In most studies *a unit* is defined as 355 mL of soft drink; cans that contain 235 mL are only rarely available on the market.

3 Sugar-sweetened beverage consumption in Slovenia and the world

In Slovenia, 14.8 % of adults consume sugar-sweetened beverages on a frequent basis, i.e. up to three times a week, however the proportion for young people is 24 %, according to the 2016 and 2014 estimates (16). A Slovene study of sugar-sweetened beverage consumption in adolescents aged 14 to 17 years showed that these beverages account for 9 % of daily calorie intake in boys and 10 % of daily calorie intake in girls. Beverages with added sugar, such as fruit nectars, syrups, sugar-sweetened teas, iced tea and fizzy soft drinks, accounted for 44 % of total daily fluid intake in boys (mean 683 mL daily) and 41 % in girls (mean 715 mL daily) (17).

The National Health and Nutrition Examination Survey (NHANES) conducted in the U.S. demonstrated that sugar-sweetened beverages are consumed daily by one-half of the population; one of four persons gets at least 200 calories and 5 % of individuals get at least 567 calories from soft drinks. Mean daily calorie intake from sugar-sweetened beverages in children and adolescents was 224 calories, i.e. approximately 11 % of the recommended total daily intake. In Great Britain, sugar-sweetened beverages accounted for 5.8 % of the total daily intake in children, 3 % in young adults and less than 2 % in older adults, similar proportions were documented in Australia. However, in Mexico this pro-

portion was substantially higher, i.e. approximately 10 % (18).

4 Impact of sugar-sweetened beverages on obesity development

Extensive research has confirmed that sugar-sweetened beverage consumption is linked to an increase in body weight and obesity risk (6,11,19-21). An average body weight gain of 1 kg per year was recorded (22-24). Increase in body weight was found to positively correlate with the intake of sugar-containing beverages (25). Greater weight gain was noted in individuals with genetic predisposition to obesity compared to the general population (26).

Based on more than 60 clinical trials, WHO reported that reducing intake of added sugars significantly decreased body weight in adults. Reducing intake of sugar-sweetened beverages resulted in a body weight loss of 0.8 kg, whereas continuing with such beverages consumption led to a weight gain of 0.75 kg. Such effects were not documented in children (7). Two prospective studies of the paediatric population demonstrated that individuals consuming greater amounts of sugars had a 55 % higher risk for developing obesity. Encouraging normal-weight and obese children and adolescents to give up drinking sugar-sweetened beverages had significantly reduced the risk of further weight gain (27,28).

The association between sugar-sweetened beverage consumption and obesity is most clearly demonstrated by large prospective studies of cohorts with long-term follow up and statistical analysis that does not negate the impact on total energy intake (20). Since drinking sugar-sweetened beverages increases total daily calorie intake, the statistical method with adjusted energy intake tends to underestimate the effect of sweetened beverages consumption on weight gain. This may explain why some studies failed to confirm this causal association (16,29). Obesity is a complex multifactorial disorder; therefore, it is not surprising that sugar-sweetened beverage consumption plays a relatively modest role in weight increase.

5 Impact of sugar-sweetened beverage consumption on the development of diabetes

Sugar-sweetened beverage consumption is associated with increased risk for the development of type 2 diabetes in men and women of all ages. A meta-analysis of eight prospective studies showed that consuming more than two sugar-sweetened beverages a day increases the risk for type 2 diabetes by 26 % as compared to a monthly intake of less than one such beverage. Participants of the studies were followed up for 4 to 20 years. The majority of studies included questionnaires on dietary habits (30). A ten-year follow-up study of the British population confirmed increased risk for the development of type 2 diabetes in individuals consuming sugar-sweetened beverages, independent of obesity. Consuming one unit of sugar-sweetened beverage a day increased type 2 diabetes risk by 21 % (31). Similar results were obtained in the European EPIC-InterAct study performed in eight European countries (32,33). In a meta-analysis, Imamura et al. showed that moderate consumption of sugar-sweetened beverages is associated with type 2 diabetes irrespective of obesity. Consuming one unit of sugar-sweetened beverage per day increased the incidence of type

2 diabetes by 18 %. The risk dropped to 13 % if effects of obesity were taken into consideration in the analysis. It was estimated that sugar-sweetened beverage consumption in the U.S. increased the number of all newly diagnosed type 2 diabetes cases by 8.7 % (10). Some studies confirmed the association between sugar-sweetened beverage consumption and increased risk for type 2 diabetes, yet this association was less evident after statistical adjustment for obesity (23,34). This may be explained by the fact that being overweight or obese *per se* puts these individuals at increased risk for type 2 diabetes, and also that they consume larger amounts of sugary beverages (35).

Consuming healthy alternatives to sugar-sweetened beverages (i.e. water, unsweetened tea or coffee, natural juices or artificially sweetened drinks) did not increase the risk of type 2 diabetes (31,36). Therefore, it is estimated that 3–15 % of newly diagnosed cases of type 2 diabetes could be prevented by giving up sugar-sweetened beverages or by restricting the intake of these beverages to less than 10 % of the total daily energy intake (31).

6 Impact of sugar-sweetened beverages on the development of cardiovascular diseases

Beverages with added sugar increase the risk for the development of cardiovascular diseases associated with atherosclerosis. Data from prospective studies showed that consuming sugar-sweetened beverages is linked to higher risk for developing arterial hypertension or dyslipidaemia. A large body of evidence has accumulated which suggests that sugar-sweetened beverage consumption increases systemic inflammatory parameters and is therefore indirectly involved in the development of coronary artery disease and stroke (37).

The prevalence of arterial hypertension among individuals who consume sugar-sweetened beverages on a regular basis (more than one unit daily) is by 12 % higher than among those who consume less than 0.6 unit per month. Increasing the intake by one unit a day, raises the risk for hypertension by 8 % (38). Brown et al. found that as a result of increasing the intake of sugar-sweetened beverages by one unit daily, systolic blood pressure increases by 1.6 mmHg and diastolic blood pressure by 0.8 mmHg (39). These relationships remained unchanged after statistical adjustment for body weight (38,39).

In their meta-analysis, Huang et al. demonstrated that the risk of coronary artery disease increased by 16 % when the intake of sugar-sweetened beverages was increased by one unit daily (40). In addition, in individuals who regularly consumed more than two units of sugar-sweetened beverages a day, the risk for coronary artery disease was by 35 % higher than in occasional consumers. The same observation was made after removing other factors from the analysis, which suggests an independent association between sugar-sweetened beverages and coronary artery disease (41). In persons consumingmore than one unit of sugar-sweetened beverages daily, stroke risk increased by 16 %. However, this association did not persist after the removal of other risk factors, suggesting that arterial hypertension and diabetes indirectly account for increased risk (42).

A recent meta-analysis performed by Narain et al indicates stronger relationships: consumption of sugar-sweetened beverages was found to increase the risk for myocardial infarction by 19 %, and by 22 % with each additional unit con-

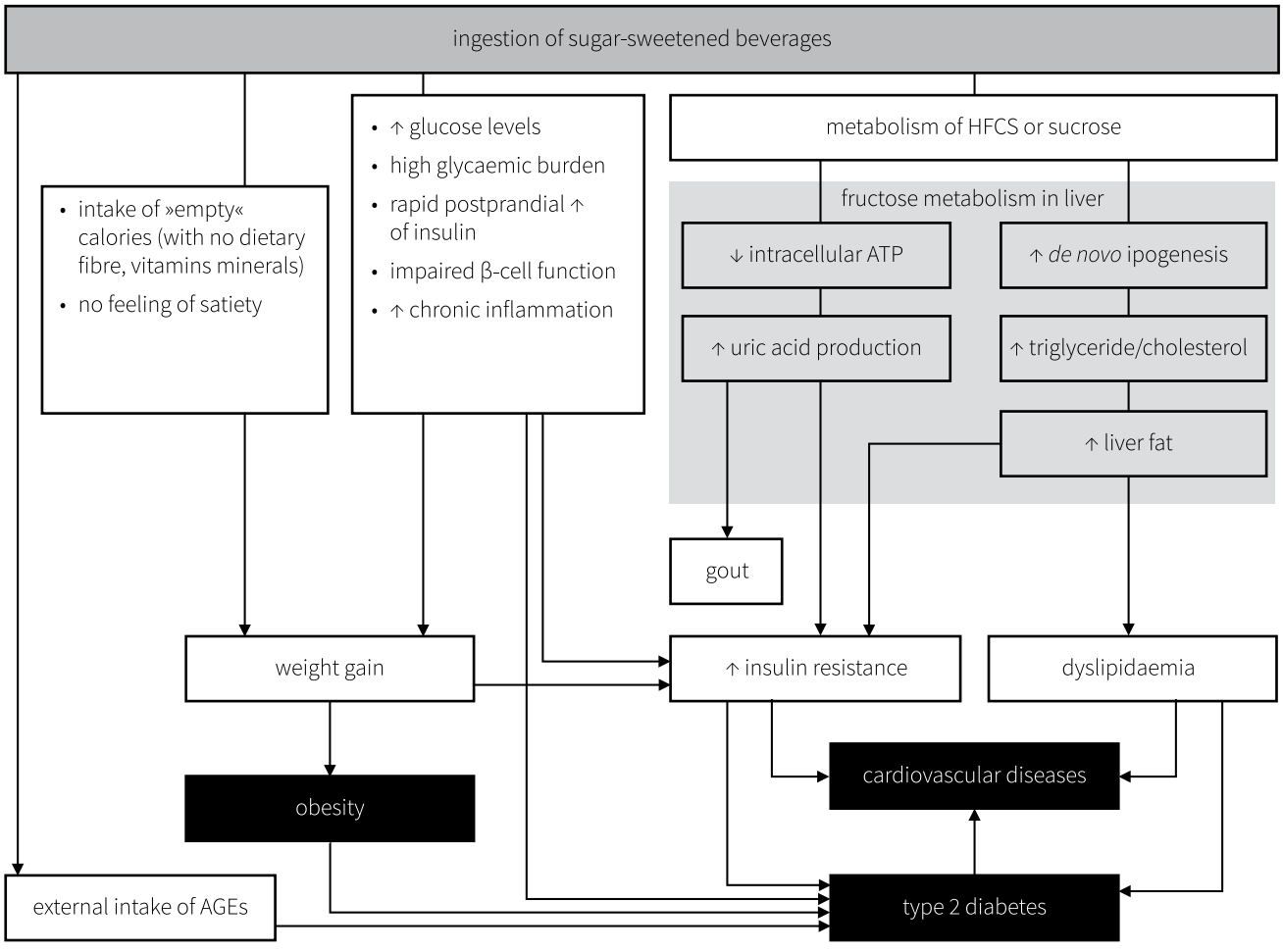

Figure 2: Direct and indirect associations between sugar-sweetened beverages and cardiovascular and metabolic diseases (obesity, type 2 diabetes). HFCS (high-fructose corn syrup), ATP (adenosine triphosphate), AGE (advanced glycation end products). Adapted from (47).

sumed daily. Consumers of sugar-sweetened beverages had a 33 % greater risk of stroke (43).

7 Possible mechanisms of metabolic and cardiovascular complications associated with sugar-sweetened beverage consumption

Consuming large amounts of sugar-sweetened beverages leads to weight gain. In addition, glycaemic burden increases and independently of obesity leads to the development of insulin resistance, impaired beta-cell function and chronic inflammation (44,45). Moreover, some sugar-sweetened beverages contain "cola" colour-forming advanced glycation end-products (AGE), generated during the process of caramelisation, which further increases the risk for type 2 diabetes development (46).

Fructose and glucose have similar molecular structure but differ in their absorption and metabolic pathways. Fructose is absorbed from the gut by the glucose transporter 5 (GLUT-5) and

then completely metabolised in the liver via insulin-independent pathways. As it does not stimulate insulin secretion or leptin secretion from adipose tissue, it indirectly contributes to weight gain (15). Fructose is metabolised to intermediate molecules, such as glyceraldehyde and dihydroxyacetone phosphate, which enter different metabolic pathways to form energy substrates, such as glucose, lactate, glycogen or fatty acids. Fructose bypasses the phosphofructokinase-1 step of glycolysis and therefore acts as a potent lipogenic substrate. High fructose intake, i.e. at least 25 % of total energy intake, tends to increase triglyceride synthesis. Increased fat production in the liver stimulates the production of VLDL (very low-density lipoproteins), which are rapidly metabolised into LDL (low-density lipoproteins) (47).

Additionally, hepatic intake of fructose leads to intracellular adenosine triphosphate depletion, thereby increasing the rate of uric acid production. This leads to metabolic complications and reduced nitric oxide production and thereby to endothelial dysfunction (9,47). Increased production of uric acid is associated with the development of arterial hypertension via impairment of endothelial function, stimulation of renal artery inflammation, activation of renin-angiotensin system and increase in renal sodium resorption (38).

Fructose has direct effects on the expression of pro-inflammatory genes, nuclear factor kB (NF-kB) and tumour necrosis factor (TNF), thereby creating pro-inflammatory environment, which stimulates atherosclerotic plaque formation (39,47). These mechanisms are shown in Figure 2.

8 Available healthy alternatives to sugar-sweetened beverages

Healthy alternatives to sugar-sweetened beverages include: water, 100 % fruit juice, coffee, tea and other artificially sweetened beverages (diet drinks). Water is the best choice, since it is calorie-free, inexpensive and easily accessible in Slovenia. Replacing one unit of sugar-sweetened beverages with water was found to decrease weight gain over four years by 0.49 kg. Substituting one unit of sugar-sweetened beverages by fruit juices mixed with water led to a 0.35 kg reduction in weight gain over four years (29). One hundred percent fruit juices contain some vitamins and other nutrients and constitute a healthy alternative to sugar-sweetened beverages. However, fruit juices contain a relatively high number of calories from sugars naturally occurring in fruit, mostly fructose, therefore the daily intake of these beverages should be restricted to 120–170 mL (47).

Extensive research has demonstrated that coffee and tea consumption decrease risk for cardiovascular diseases and type 2 diabetes, attributed to high polyphenol content.They are therefore recommended as healthy alternatives to sugar-sweetened beverages, yet with no added caloric sweeteners or cream. Other alternatives include artificially sweetened beverages (with aspartame, saccharin, acesulfame, neotame) that are very low in calories or contain zero calories. Long-term health effects of artificial sweeteners have not yet been fully investigated, however some studies

reported that they could increase therisk for cardiovascular events, especially stroke (43). Some studies suggest that intensive artificial sweeteners increase appetite and craving for sweets, therefore it is advisable to limit their use until more is known about their long-term effects on health and metabolism (29,47).

9 Strategies to reduce sugar-sweetened beverage consumption in Slovenia and the world

In 2005, the Ministry of Health of the Republic of Slovenia issued »Guidelines for healthy nutrition in educational institutions« with the aim to increase the availability of healthy food (beverages with no added sugar, low-sugar foods with better nutritional balance) in preschool institutionsand schools (48).The national School Nutrition Act published in the Official Gazette of the Republic of Slovenia in 2016 prohibits the availability of vending machines with sugar added beverages and sweet and salty snacks on school premises (49). Taxation of sugar-sweetened snacks and beverages is one of the options to promote healthier dietary habits in the population, yet in Slovenia the bill on special taxation of sugar- or artificially sweetened soft beverages was not passed. A new form of cooperation has evolved between food industry, government and non-governmental organisations and the *Responsibility Pact* was signed by the representatives of soft drink manufacturers. This document binds all manufacturers of sugar-sweetened beverages to commit themselves to responsible and transparent marketing of their products, and to promote healthy lifestyles. Data from the Ministry of Health indicate that the consumption of sugar-sweetened beverages per capita declined from 127 litres in 2010 to 92 litres in 2016. Reduced intake of sugar-sweetened beverages was recorded for adults, children and adolescents (50).

Consumption of free sugars in the UK was restricted to max. 5 % daily. Moreover, the government is considering a policy to make people stop drinking sugar-sweetened beverages. After the implementation of restrictive measures, the daily consumption of sugar-sweetened beverages in children and in adolescents dropped by 76 mL and 66 mL, respectively. However, the decrease reported for adults was only 13 mL a day and was not statistically significant (18). In 2017, tax on sugar-sweetened beverages was introduced in Portugal, Saudi Arabia, United Arab Emirates, Thailand, Catalonia and five U.S. states. Ireland, England, South African Republic, Estonia and Seattle and Washington planned to implement a tax on sugar-sweetened beverages in 2018 (51). After Canada introduced nutrition labelling that clearly indicated sugar content in sugar-sweetened beverages and their health effects, there was a significant decline in sales of these beverages (52).

Over the past decade the consumption of sugar-sweetened beverages has declined in economically developed countries, such as U.S. and Great Britain, but it has increased in other parts of the world, particularly in developing countries (29).

10 Contribution of sugar-sweetened beverages intake to global burden of disease

The Global Burden of Disease Study was based on data for 67 risk factors of chronic diseases (53). The estimates for sugar-sweetened beverages took into ac-

count direct effects of these beverages on disease burden, as well as their indirect effects associated with increased obesity risk. Intake of sugar-sweetened beverages ranks 12 among the 15 main unhealthy lifestyle indicators. It was estimated that in 2010, unhealthy dietary habits were responsible for 11.3 million deaths worldwide, of which 184,000 (i.e. 1.6 % of all deaths due to diet-related factors) were due exclusively to consumption of sugar-sweetened beverages (54,55). In a few countries only, intake of sugar-sweetened beverages accounted for a significantly larger proportion of disease burden because of higher average consumption. Mexico, one of the countries with the highest average intake, had the highest mortality rate attributable to consumption of sugar-sweetened beverages (12.1 %) (53).

These studies showed that in comparison with other risk factors, sugar-sweetened beverages consumption plays a relatively small part in the global burden of disease; however it may constitute a significant health risk in countries with high intake of these beverages (53-55).

11 Conclusion

A number of studies have shown that sugar-sweetened beverage consumption is linked to increased risk of obesity, type 2 diabetes and cardiovascular diseases. It is difficult to assess the impact of sugar-sweetened beverage intake alone, since other potential risk factors frequently coexist in the population (overweight, other cardiovascular risks, low socioeconomic status). Therefore, high-quality assessment methods should be used to determine the true effects of sugar-sweetened beverages on health. The high content of simple sugars in sugar-sweetened beverages is responsible for an increase in glucose and insulin levels, and accounts for a higher total intake of »empty« calories with no nutritional value. Reducing intake of sugar-sweetened beverages should be an important objective of public health improvement strategy. Encouraging people to reduce or give up their intake of sugar-sweetened beverages is a good step in this direction, and is particularly valuable in populations with increased risk for metabolic disease and in young people whose lifestyles as a whole tend to be unhealthy. Critics of these strategies argue that in the past labelling a single food group as unhealthy led to overconsumption of other, different food group. However, sugar-sweetened beverages are a major source of "empty" calories and can easily be replaced by healthy alternatives.

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