



## Sugar-Sweetened Beverages and Cardiometabolic Health: How Strong is the Link?

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### Abstract

Sugary drinks, also categorized as sugar-sweetened beverages or soft drinks refer to any beverage with added sugar or other sweeteners (high fructose corn syrup, sucrose, fruit juice concentrates, and more). This include soda, pop, cola, tonic, fruit punch, lemonade (and other “ades”), sweetened powdered drinks, as well as sports and energy drinks. Sugar-sweetened beverages (SSBs) are a major source of added sugar in the diet. A robust body of evidence has linked habitual intake of SSBs with weight gain and a higher risk (compared with infrequent SSB consumption) of type 2 diabetes mellitus, cardiovascular diseases and some cancers, which makes these beverages a clear target for policy and regulatory actions. This review provides an update on the evidence linking SSBs to obesity, cardiometabolic outcomes and related cancers, as well as global trends in intake, alternative beverages and policy strategies targeting SSBs that have been implemented in different settings. Potential biological mechanism by which constituent sugars can contribute to these outcomes was also discussed. Strong evidence from cohort studies on clinical outcomes and clinical trials assessing cardiometabolic risk factors supports an aetiological role of SSBs in relation to weight gain and cardiometabolic diseases. Many populations show high levels of SSBs consumption and in low-income and middle income countries, increased consumption patterns are associated with urbanization and economic growth. More intensified policy efforts are required to limit intake of SSBs and the global burden of obesity and other chronic diseases.

**Keywords:** Sugar sweetened beverages, Cardiometabolic health, Obesity, Diabetes, Cancer.

### Introduction

Over the last 2 decades obesity has escalated to epidemic proportions around the world (Malik *et al.*, 2006). A rising consumption of sugar-containing soft drinks has been suggested as a major contributor to the obesity epidemic. The increase in intake of sugar-containing soft drink has coincided with rising body weights and energy intakes in several populations. In the USA, the per capita annual consumption of regular soft drink increased by 86% between 1970 and 1997 alone. During that period of time, the prevalence of obesity rose by 112% .Overweight and

obesity can have major costs for individuals and their families as well as for the health care systems. It increases the risk of developing type 2 diabetes and heart disease as well as doubles the risk of dying prematurely (Pischon *et al.*, 2008).

Type 2 diabetes has also emerged as a global public health concern, parallel to the global trends in the prevalence of obesity. Along with the increased consumption of soft drinks, there has been a rapid and large increase in the reported incidence of type 2 diabetes (Hu and Malik 2010; Greenwood *et al.*, 2014). In a systematic review by Vartanian *et al.*, (2011), high consumption of soft drinks was related to low consumption of milk, calcium, fruit and dietary fibres contributing to an overall poorer diet. In addition, the high intake of carbonated soft drinks during adolescence was significantly associated with reduced bone mineral density among girls aged 12 and 15 years. Calcium is found mainly in dairy products and is an essential nutrient for the structural integrity of bone and for maintaining bone density throughout life whereas, carbonated soft drinks contain mostly empty calories.

### **Effect of soft drinks on general health**

Soft drinks are often high in sugar content and acidity. Each gram of sugar contains 4 calories. In addition, they supply energy only and are of little nutritional benefit (Bucher and Siegrist 2015; Chi and Scott 2019). Several studies have shown that soft drink with high sugar and acid content consumption can contribute to detrimental general and oral health effects on children and adolescents including an increasing risk of overweight, obesity, type 2 diabetes, dental caries and dental erosion. Obesity has recently emerged as a major global health problem. The World Health Organisation (WHO) and Scientific Advisory Committee on Nutrition (SACN) recommend a diet where a maximum 5% of the energy comes from free sugars. The SACN (2015) reported that nearly a third of children aged 2-15 years living in the UK are overweight or obese, and that younger generations are becoming obese at earlier ages and staying so for longer. In the USA, two out of three adults and one out of three children are overweight or obese with over 18% of 6-19 year olds are above the 95th percentiles of body mass index (BMI), for age and gender (Ogden *et al.*, 2014).

### **Artificial sweeteners in soft drinks and general health**

Several artificial sweeteners are used to give diet soft drinks a sweet taste without sugar. They are called sugar substitutes because they provide the sweetness of sugars without the added calories, thus reducing the risk for obesity, and dental caries. However, their safety has been controversial. The breakdown product of these sweeteners has controversial health and metabolic effects. Some research has linked the consumption of artificial sweeteners with adverse health conditions including obesity, lymphomas, leukemias, cancers of the bladder, and brain, chronic fatigue syndrome, Parkinson's disease, Alzheimer's disease, multiple sclerosis, autism, and systemic lupus. The carcinogenic potential of artificial sweeteners, mainly aspartame and saccharine, has been investigated. Exposure to these chemicals was associated with an increased risk of brain tumours and cancer of the bladder, in both male and female mice, respectively. The ban on Saccharine use in the USA was withdrawn in 1991; nevertheless, all food and soft drinks containing Saccharine have to carry a warning label to indicate that "Saccharine is a potential

cancer causing agent”. Conversely, future research has failed to conclude that there is a clear causal relationship between aspartame, saccharine and other approved artificial sweeteners consumption, with health risks in humans at normal doses (Chattopadhyay *et al.*, 2014). Therefore, the FDA has concluded that these sweeteners are safe at current levels of consumption and, as a result, the decision of placing warning labels on all products that contain saccharine was overturned in 2000 (Tandel, 2011). Some commercial soft drinks are high in sugar content and acidity and, therefore, their consumption can contribute to detrimental oral and general health. There is a clear association of soft drink intake with increased energy intake and body weight is evident in the literature (Malik *et al.*, 2010; Vartanian *et al.*, 2011; Basu *et al.*, 2013; Powell *et al.*, 2017). Soft drinks apart from the low- and zero-calories categories contain high sugar content. A daily addition of one 350 mL can of sugar-sweetened carbonated soft drink which contains 150 kcal and 40-50 g of sugar to a typical diet with no reduction in other caloric sources can lead to a weight gain of 6.75 kg within 1 year in adults (Malik *et al.*, 2010). Moreover, soft drinks increase hunger, decrease satiety, and condition people to a high level of sweetness that produces a preference in other foods leading to excess energy intake. If normal dietary intake does not decrease by an equivalent amount of calories obtained from consuming soft drinks, then weight gain is very much to be expected (Malik *et al.*, 2010 ; Vartanian *et al.*, 2011).

Soft drinks can also contribute to type 2 diabetes through several mechanisms mainly by their ability to induce a weight gain, which is a risk factor for the development of the condition. In addition in the USA, some of these drinks contain high amounts of rapidly absorbable carbohydrates such as sucrose and high-fructose corn syrup (HFCS), a key ingredient in some of sugar-sweetened beverages. Though HFCS is not currently a key ingredient in sugar-sweetened beverages in the UK or EU, changes to the EU quota system on sugar policy since 2017 may influence addition of HFCS in the soft drinks in the future. These types of carbohydrates can lead to hepatic lipogenesis and high dietary glycaemic load resulting in inflammation, insulin resistance and impaired B cell function, thereby fuelling the development of type 2 diabetes (Hu and Malik, 2010 ; Caprio, 2012 ; Greenwood *et al.*, 2014).

The economic costs of obesity and its related ill-health are great too. In 2014/2015, it was estimated that the National Health Service (NHS) in the UK spent nearly £5.1 billion on the treatment of obesity and its related ill-health. A higher figure was reported in the USA where healthcare expenditures on overweight and obesity were estimated to be between \$150 billion and \$190 billion, attributing to 20% of total healthcare costs per year (Scharf and DeBoer, 2016). The consumption of artificial sweeteners has been found to promote weight gain rather than weight loss in several studies (Hampton 2008; Swithers and Davidson 2008; Pearlman *et al.*, 2017). These studies showed that these sweeteners induce insulin production into the blood and in the absence of blood sugar, hypoglycaemia and increased food intake occur resulting in overweight and obesity.

## **The role of caffeine in drinks**

Caffeine is a constituent of many soft drinks, with concentrations ranging from about 10 to 15 mg per 100 ml. Soft drinks are the second largest contributor to total caffeine intake, and are the primary source of caffeine for children and teenagers (Brown *et al.*, 2008). Energy drinks are

often high in caffeine to enhance the mental and physical performance, improve alertness, and concentration (Bunting *et al.*, 2013). The amount of caffeine in most of the energy drinks is usually three times the concentration in cola drinks. They are available in the market of more than 140 countries and are the fastest growing soft drink sector not only in the USA and UK but also worldwide (Seifert *et al.*, 2011). Although moderate consumption of caffeine can be tolerated by most healthy people, studies showed that its high consumption (> 400 mg per day) has been associated with adverse effects on health including anxiety, restlessness, aggression, headaches, and depression. A prolonged exposure to high intakes of caffeine, levels greater than 500-600 mg a day, can result in chronic toxicity leading to nervousness, nausea, vomiting, seizures and cardiovascular symptoms in severe cases (Seifert *et al.*, 2011; Bunting *et al.*, 2013; Jean 2017).

## **Sugar consumption and weight gain**

Rates of obesity are rising worldwide and added sugar, especially from sugar-sweetened beverages, is thought to be one of the main culprits. Sugar-sweetened drinks like sodas, juices and sweet teas are loaded with fructose, a type of simple sugar. Consuming fructose increases your hunger and desire for food more than glucose, the main type of sugar found in starchy foods. Additionally, excessive fructose consumption may cause resistance to leptin, an important hormone that regulates hunger and tells your body to stop eating. In other words, sugary beverages don't curb your hunger, making it easy to quickly consume a high number of liquid calories. This can lead to weight gain. Research has consistently shown that people who drink sugary beverages, such as soda and juice, weigh more than people who don't. Also, drinking a lot of sugar-sweetened beverages is linked to an increased amount of visceral fat, a kind of deep belly fat associated with conditions like diabetes and heart diseases. Bray *et al.*, (2004) reported that the consumption of beverages containing high fructose corn syrup (HFCS) has directly contributed to the obesity epidemic. This hypothesis was based on the observation that the increase in consumption of free fructose (especially as HFCS) and the rise in the prevalence of obesity have followed similar courses over the last 30 years.

## **Refined sugar and Cardiovascular Diseases**

High-sugar diets have been associated with an increased risk of many diseases, including heart disease, the number one cause of death worldwide. Evidence suggests that high-sugar diets can lead to obesity, inflammation and high triglyceride, blood sugar and blood pressure levels - all risk factors for heart disease. Additionally, consuming too much sugar, especially from sugar-sweetened drinks, has been linked to atherosclerosis, a disease characterized by fatty, artery-clogging deposits. A study in over 30,000 people found that those who consumed 17-21% of calories from added sugar had a 38% greater risk of dying from heart disease, compared to those consuming only 8% of calories from added sugar. Just one 16-ounce (473-ml) can of soda contains 52 grams of sugar, which equates to more than 10% of your daily calorie consumption, based on a 2,000-calorie diet. This means that one sugary drink a day can already put you over the recommended daily limit for added sugar. Animal studies have shown strong associations between high refined-sugar intake and the onset of arterial hypertension (Brown *et al.*, 2008). Rats who had their drinking water replaced with an 8% sucrose solution developed hypertension

and tachycardia that was evident within a week and was not related to weight gain (Bunag *et al.*, 1983).

## **Correlation between fructose and insulin resistance**

Fructose is a major constituent of sugar-sweetened beverages. In young healthy humans, a 25% reduction in insulin sensitivity has been documented after a 2-week high-sucrose diet. The fructose component is probably responsible for the onset of insulin resistance because supplementing a regular diet with 250 g fructose per day caused a significant reduction in insulin sensitivity in as little as 7 days, whereas the same amount of glucose had no effect. More recent studies reported that a high-fructose diet (3 g per kg body weight per day) led to dyslipidemia and hepatic insulin resistance (Brown *et al.*, 2008).

## **Government interventions**

Actions have been taken by few countries across the globe to tackle the obesity and dental caries. These include banning the sale of soft drinks in schools, restricting soft drinks advertising, modifying the composition of soft drinks and introducing tax on sugar-containing soft drinks. Sugar-containing soft drinks are banned for sale in schools in many countries. In the UK, strict rules on sales of high-sugar and -acid content soft drinks in school were instigated in 2007. Beverages with added sugar including energy drinks are not permitted. Also, some schools have banned their students from bringing energy drinks into school from outside (British Soft Drinks Association Annual Report 2016).

Furthermore, governments in some countries such as the UK applied restrictions in marketing soft drinks to children online and on television (Al-Mazyad *et al.*, 2017). Advertising is essential to the marketing of soft drinks with millions of dollars spent to promote their consumption. Food and beverage advertising increases the total demand and motivates brand switching (Powell *et al.*, 2017). Children and youths are exposed to advertising from not only television, but also billboards, magazines, signs in stores and public places such as airports and subway stations, and now increasingly on technology such as iPad apps, and video games as well as social media. Social media are a relatively new medium through which soft drink manufacturers can uniquely target young people. The increased usage and importance of social media for young people make them vulnerable to highly personalised and targeted digital marketing campaigns by the food and beverage industry. Brownbill *et al.*, (2018) explored how soft drinks are marketed to Australian young people, aged 13-25 years, through soft drink brand Facebook pages. The authors found that soft drink brands share highly engaging content on Facebook which seamlessly integrates their content into the lives of young people. Brands were found to align their products with common sociocultural values and practices such as masculinity, femininity, friendship, and leisure, which are regarded as important by young people today, thus portraying their products as having a normal place within their everyday lives. The results of the study suggested the need to monitor advertising via social media and the importance of understanding the exposure to, and impact on young people. Australia, Sweden, and Belgium as well as UK are among the countries that have banned television advertisement of food high in sugar and fat during children's programmes (Story and French 2004).

A number of countries across the globe have introduced a tax on sugar-containing soft drinks in an effort to reduce childhood obesity and dental caries including France, Finland, Hungary and Mexico (World Cancer Research Fund International 2008). Colchero *et al.*, (2016) reported a 10% decrease of sugar-based soft drinks consumption and a 4% increase in the purchase of healthier alternatives such as bottled plain water among the Mexican population following the introduction of a tax on soft drinks in 2014. In addition, 39 states in USA have applied a tax on sugar-containing soft drinks sold either in food premises and/or vending machines (Centre for Science in the Public Interest 2011). A new sugar tax on soft drinks, known as the soft drinks industry levy, was introduced in April 2018 on soft drinks with added sugar in UK to help tackle childhood obesity by reducing the consumption of soft drinks with added sugars. The levy applies to soft drinks that contain 5 grams or more of added sugar per 100 mL. Revenue from the levy is planned to be used to develop programmes that aim to reduce obesity and encourage physical activity for school age children (HM Revenue & Customs, 2016). This action is expected to reduce the consumption of sugar-containing soft drinks by 1.6%, and it is hoped that it will encourage soft drinks manufacturer to reduce the sugar content of their products. The consumption of soft drinks was found to have increased dramatically over the past several decades with the greatest increase among children and adolescents. Excessive intake of soft drinks with high sugar and acid content both regular and diet could cause detrimental impacts on dental and general health including dental caries, dental erosion, overweight, obesity and increased risk of type 2 diabetes. The sugar tax has raised the level of awareness; however, it is necessary to educate patients about the harmful effects of different types of soft drink as it is not always easy for individuals to know from drink labelling what they actually contain.

## Conclusion

Overwhelming evidence from both animal and human studies suggest that fructose, a kind of simple sugar found in abundance in sugar-laden beverages may play a key role in elevating metabolic and cardiovascular risk factor.

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