

# Sugar-sweetened beverages, effects on appetite and public health strategies to reduce the consumption among children: a review

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## Abstract

Sugar-sweetened beverages (SSBs) consumption have been of public health concern and a target of interventions due to their high consumption and burden in health-related consequences, particularly in children and adolescents. SSBs provide high energy intake with low nutritional value and are a major contributor for added and free sugars intake of Portuguese in all age-groups, especially adolescents. Despite its recognized effect on weight gain, it might also disrupt appetite regulation. Research on the effect of SSBs on appetitive traits is still scarce and unclear, and the current knowledge of these potential effects will be discussed in this review. This review also aims to describe public health strategies implemented to decrease SSBs consumption among children, particularly in Portugal, such as: (i) implemented taxation measures and its impact in sales and in preventable cases of disease and death, (ii) marketing regulations applied to children and adolescents, and ultimately (iii) the intention of application of a single Front-of-Package labeling system in all countries, aiming to increase consumers' food literacy.

**Keywords:** appetite, children, food policy, sugar-sweetened beverages, taxation

## Introduction

By definition, sugar-sweetened beverages (SSBs) are beverages containing added sweeteners, such as sucrose, high-fructose corn syrup or fruit juice concentrates.<sup>1</sup> These beverages have been a public health concern, especially in westernized countries.<sup>2</sup> Its consumption has been linked to harmful health-related factors, such as weight gain,<sup>1</sup> dental caries and insulin resistance in children,<sup>3</sup> and weight gain,<sup>1,4</sup> type 2 diabetes, metabolic syndrome and other chronic diseases in adults.<sup>5</sup>

SSBs consumption has shown a steady increase until the year 2000, followed by a continuous decline.<sup>6</sup> Simultaneously, these beverages have been replaced by beverages with lower sugar content or artificially sweetened and/or by smaller portions.<sup>4,6</sup> This change in consumption may be explained by the media coverage on foods high in sugar, recent nutrition guidelines and public health strategies aiming to reduce SSBs consumption.<sup>7</sup> Even though, global consumption remains high. According to a systematic review,<sup>2</sup> the global daily average consumption of SSBs

was estimated to be 137 mL in 2010 among adults. In children in the US, estimates suggest that 60.7% consume SSBs on a daily basis.<sup>6</sup> This eating behaviour seems to be adopted early in life, and children and adolescents are the largest consumers of SSBs worldwide.<sup>8,9</sup> Portugal followed this global trend, with daily SSBs consumption doubling from approximately 100 mL to 203.6 mL per inhabitant, on average, between 1990 and 2012.<sup>10</sup> A more recent study with data from the National Food, Nutrition and Physical Activity Survey (IAN-AF 2015/2016) reported that the daily average consumption of soft drinks and fruit nectars ( $\geq 220$  g/day) was 18%, with the highest daily consumption reported by adolescents (42%), and children (22%).<sup>11</sup> According to another recent study covering the same target population, SSBs showed to be a major contributor of added and free sugars in all age-groups, especially adolescents.<sup>12</sup>

The consumption of cheap, nutrient poor, processed products, such as SSBs, is more frequent among low-income households, which might be explained by their accessibility, low cost,<sup>13</sup> high palatability, and the social endeavour that makes them more appealing.<sup>14</sup> The relation between low income and unhealthy diets shows that food affordability is the key in these households, and that calories are priority over health benefits when food becomes less affordable.<sup>15</sup>

Besides the contribution of SSBs to a high energy intake with low nutritional value, it has been hypothesized that their consumption might disrupt appetite regulation,<sup>16,17</sup> being associated with greater general appetite and interest for food and drinks.<sup>18-23</sup> Research on the effect of SSBs on appetitive traits is still scarce and unclear, and the current knowledge of these potential effects will be discussed in this review. Thus, due to the high consumption of these beverages and its adverse health consequences, a variety of public health strategies have been proposed in the last years and implemented worldwide.<sup>9,24,25</sup>

In light of this, the current review aims to explore the effect of SSBs consumption on appetite and appetitive behaviours during childhood, as well as the public health strategies implemented to

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address the high prevalence of SSBs consumption among children, particularly in Portugal.

### SSBs consumption and appetite

Strong evidence supports the relationship between SSBs consumption and weight gain in children.<sup>1,26,27</sup> It is consensual that the consumption of SSBs contributes to weight gain due to a positive energy balance.<sup>27–29</sup> However, the mechanisms through which it occurs are not entirely clear. It has been suggested that SSBs consumption is associated with an increased food intake,<sup>30,31</sup> and this may be explained by the lack of caloric compensation of liquids, increasing total energy intake,<sup>20,29</sup> due to a lower satiation effect compared to solid foods.<sup>28,32</sup> Results from a systematic review and meta-analyses on the effects of food texture on satiety, published in 2020, showed that solid foods have a greater effect on reducing hunger sensations compared with liquid forms of foods.<sup>33</sup> Beverages also require less oral processing, have a faster gastric-emptying and orocecal transit times.<sup>34,35</sup> Another hypothesis is related with the lower increase of GLP-1 and insulin when consuming liquids and likewise a lower reduction in ghrelin.<sup>36</sup> Corroborating with this statement, Shearrer et al<sup>37</sup> concluded in their study with adolescents that habitual SSBs consumption appears to play a key role in moderating fullness responses possibly driven via ghrelin. In addition, consumption of added sugar in liquid forms might be associated with higher fasting glucose and insulin, and be a risk factor for the development of impaired glucose homeostasis and insulin resistance among youth at risk of obesity,<sup>38</sup> or even increase the risk for dyslipidaemia and cardiovascular disease in school age children.<sup>39</sup>

From other point of view, high palatable foods, such as SSBs, might trigger regulating systems, leading to overconsumption.<sup>16</sup> In more detail, palatable foods (usually high in sugar, fat, and salt) taste more intensively and this may result on a stronger effect on rewarding mechanisms, leading to release and/or up-regulation or reward mediators such as serotonin, dopamine and/or opiates related pathways.<sup>17</sup>

Thirst sensations, on the other hand, are stronger and more consistent compared to hunger sensations, and drinking to meet hydration needs is more likely than eating to meet energy needs.<sup>40</sup> In addition, it is very common to drink while eating,<sup>40</sup> especially in social events. Consequently, beverages may stimulate energy intake in several ways, with their consumption being associated with greater food intake.<sup>32</sup>

### SSBs consumption and appetitive behaviours

Appetitive behaviours are a wide and complex concept, developed under psychologic and social perspectives, including food preferences and choices, hedonic response, food acceptance and neophobia,<sup>41,42</sup> while appetite is defined as the internal driving force for the search, choice, and ingestion of food or simply the sensation of hunger.<sup>43</sup> However, there is a narrow relationship between them, and both are influenced by internal (eg, physiology) and external factors (eg, social and cultural factors).<sup>43,44</sup> So, beyond biological processes, what people eat depends on many factors. The determinants of food intake can be grouped into individual factors, social, physical, and macro-level environments, as described by Story et al.<sup>45</sup>

Cross-sectional studies have shown that SSBs consumption is positively associated with food approach behaviours, which are linked to child's general appetite and interest for food and drinks,

and negatively with food avoidant behaviours, which represent child's avoidance and lack of interest towards foods.<sup>19,21</sup> Research on the effects of SSBs consumption on appetitive behaviours using a prospective approach is still scarce.<sup>23</sup>

Providing a home environment with healthy eating options, avoiding unhealthy foods and attending places where they are available; promoting self-regulation of appetite, serving adequate amounts of food, as well as stimulating children to try new foods, by repeated exposure, may expand the chances of children to appreciate and consume nutritious foods and maintain health.<sup>46,47</sup> Caregivers have a pivotal role in shaping child eating behaviours, and are therefore an important target in public health interventions.

### Public health strategies to decrease SSBs consumption in children

Due to the effects of SSBs consumption on health, there are 2 major reasons to focus on these beverages in public health interventions: the excessive sugar consumption and its harmful health consequences, such as obesity and noncommunicable diseases,<sup>5,48</sup> and the decreased caloric compensation of these high-caloric beverages, suggesting that the reduction in their consumption would also reduce obesity risk.<sup>49</sup> In light of this, the World Health Organization (WHO) highly recommends decreasing the consumption of sugar and SSBs<sup>50,51</sup> and describes that policies should focus in aspects such as availability, affordability, acceptability and awareness. Thereby, it suggests measures targeting the food environment, the food system and behaviour change,<sup>48</sup> for example taxation, nutrition labeling, education interventions and individual counselling.<sup>9,48</sup>

In the US, Vercammen et al<sup>52</sup> investigated the perspectives from expert stakeholders on strategies to reduce SSBs consumption and increase water access and intake among 0 to 5-year-old children. In this study, stakeholders considered physical access to SSBs and education measures the most effective strategies.

In Portugal, the "Integrated Strategy for the Promotion of Healthy Eating (EIPAS)" was implemented in 2017, whose strategies meet the policies mentioned above.<sup>53</sup> Briefly, the EIPAS includes 4 strategic areas:<sup>53</sup> i) create healthier food environments; ii) improve quality and consumer accessibility to healthy food choices; iii) promote and develop literacy for consumers' healthy food choices; and iv) promote innovation and entrepreneurship focused on the area of healthy eating promotion. Each strategy area is composed of areas of intervention and has several actions to achieve these goals, and all of them might include actions to decrease SSBs consumption.<sup>53</sup>

### Taxation

Considering the high costs attributable to avoidable chronic diseases, such as obesity and its consequences,<sup>54</sup> over 45 countries, cities, and regions have implemented, until January 2021, taxation legislation on SSBs.<sup>49</sup>

The economic process of policies related to the regulation of SSBs is based on making consumers internalize the costs they impose on themselves and on others as a result from the high consumption of SSBs. The impact of SSBs taxation can be divided into 3 groups: (i) increases of prices leading to a decrease of purchases; (ii) development of formulas with lower sugar content by manufacturers; and (iii) effects on consumers' education, increasing awareness of the negative impacts of their consumption.<sup>55</sup>

Taxation strategies have shown to be effective,<sup>25,56–58</sup> as seen by the decreases on SSBs sales in many countries,<sup>25,30</sup> including Portugal.<sup>53</sup> In Portugal, taxes were implemented in 2017 (as part of EIPAS), and focused on nonalcoholic beverages with added sugar or sweeteners, while excluding many other liquid products with added sugar.<sup>55</sup> This taxation led to a drop in sales<sup>59</sup> (decrease of 6.6 million liters of SSBs sold per year) and product reformulations (decrease in average energy density of SSBs by 3.1 kcal/100 mL), which are considered the main advantages of this measure.<sup>55</sup> For this reason, in 2019, a new scheme was introduced, with 4 levels of taxation,<sup>60</sup> with an expected impact of avoiding or delaying, at least, 48 deaths per year. Children and adolescents were expected to be the most benefited with these measures, once they are the most loyal consumers of SSBs.<sup>61</sup> This was recently evidenced by Goiana-da-Silva et al,<sup>59</sup> which reported that taxation in Portugal seems to have prevented around 40 to 78 new cases of obesity, per year, between 2016 and 2018, with the biggest projected impact in adolescents between 10 and 18 years.

Beverages such as packed fruit juices and beverages with artificial sweeteners are currently not included in the taxation policies in Portugal, thus it is likely that these beverages become more available in the market, similarly to other countries that underwent taxation implementation.<sup>62–64</sup> Evidence from a systematic review suggests that SSB taxes implemented in jurisdictions around the world seem to be effective in reducing SSB purchases and dietary intake.<sup>65</sup> Several studies have shown that taxation significantly influences planned purchases and increases the probability of choosing healthy beverages. Moreover, SSBs taxes potentially reduce energy and sugar intake, according to another systematic review.<sup>66</sup>

## Marketing regulations

Unhealthy food marketing has been considered a significant risk factor for childhood obesity.<sup>67</sup> This is of particular concern given the fact that children are exposed to food marketing on a daily basis and in several environments, including their home and schools.<sup>68</sup>

Following the scientific evidence<sup>69</sup> and recommendations from health authorities,<sup>68</sup> several countries have implemented marketing restriction regulations, such as the UK and Chile, which resulted in less exposure to unhealthy food advertising.<sup>70,71</sup>

In Portugal, a law was implemented in 2019, which imposed restrictions to food marketing to children under 16 years of age.<sup>72,73</sup> In such wise, limits were established for foods high in energy, salt, sugar, saturated, and *trans* fatty acids.<sup>74</sup> National Portuguese monitoring showed that in 2020, compared to 2008, there was a decrease in the percentage of food and beverages advertisements targeting children and adolescents (27,1% vs 10,4%). However, the majority of advertisements (65,6%) did not meet the nutritional profile defined by the Portuguese General-Directorate of Health.<sup>75</sup> Therefore, and similarly to what has been recommend in Chile, this policy needs to be consistently monitored for compliance.<sup>71</sup>

## Nutrition labeling

Nutrition labeling which are easy to understand is one of the most successful measures aiming to promote healthier food choices.<sup>9,76</sup> According to a report from WHO, in 2018, the mandatory system endorsed in Europe is not easily understood by consumers.<sup>77</sup> This way, the Front-of-Package (FOP) system

has been adopted voluntarily by industries aiming to ease label interpretation, with the inclusion of endorsement logos, nutrient-specific warning labels, nutrient-specific interpretive labels, and summary indicator systems.<sup>77,78</sup> Beyond helping consumers to make healthier food choices, this might encourage industries in product reformulation. However, with the use of multiple formats of FOP systems in the market, consumers might get confused.<sup>79</sup>

According to Graça et al,<sup>53</sup> 40% of consumers in Portugal did not understand the current nutrition labeling model and this proportion increased to 60% among less educated consumers, supporting the development of an interpretative model of FOP label. A recent work from Graça et al<sup>53</sup> described that Portuguese consumers prefer symbolic, coloured and simple FOP schemes, and that traffic light schemes are better understood and result in faster decision-making at points of sale. Traffic light nutrition labeling in Portugal has been proposed in 2014 and 2017, but was rejected by the Portuguese Parliament, that recommended the development of an alternative model.<sup>80</sup> So far, Portugal does not have a mandatory nutrition labeling system, but traffic light schemes are popular and the Nutri-Score, which is a graphical coloured representation in 5 levels, has become more common in the last years.<sup>81</sup>

The WHO European Food and Nutrition Action Plan 2015 to 2020 defined the adoption of FOP labels as a priority policy. Along with, there is the intention of application of a single FOP labeling system in all countries.<sup>77,82</sup> The Nutri-Score system is currently used in 6 EU member states and voluntarily by some food chains. Some EU member states have proposed that this system should become mandatory, which is supported by scientists and consumers.<sup>83</sup>

Evidence has suggested that FOP labels for SSBs are promising public health measures and may improve consumers' health behaviours towards reduced SSB purchase and consumption.<sup>76</sup>

## Critical analysis and conclusions

Eating behaviours are shaped from early life. The (food) environment in which we live in is a major determinant of how, when and what we eat. SSBs consumption has been identified as an eating behaviour with a major contribution for added and free sugars intake of Portuguese from all ages, but particularly for adolescents.<sup>12</sup> Additionally, SSBs have been strongly linked to appetite de-regulation<sup>16,17,32,36,37</sup> and weight gain<sup>1,26,27</sup> among children. However, future studies should focus on how SSBs affect appetite regulation. There is a lack of research, especially using prospective analysis, minimizing reverse causality bias. It is also important to investigate the long-term effects of SSBs consumption in various health outcomes and also explore their effect according to their sugar content. In addition, it should be taken into consideration the differential effects of beverages with non-nutritive sweeteners, caffeine, carbonation, or yet other alternatives to SSBs that might emerge. This knowledge may help designing public health interventions.

In fact, SSBs have been a public health priority for interventions. Effective policies aiming to influence eating behaviours should have wide coverage, involving the food environment, the food system and behaviour change. These strategies need to focus on availability, affordability, acceptability of healthier food options and consumer's awareness.<sup>48</sup>

The accessibility and availability of foods is a major determinant of child food intake and, regarding this, parents play a pivotal role. Although they are not the unique responsible,

**Table 1****Measures/strategies to decrease sugar-sweetened beverages (SSBs) consumption.**

Measures*	How does it work?	(Expected) results	Possible negative outcomes
Sugar taxation	<ul style="list-style-type: none"> <li>Decreases SSBs purchases by increasing prices</li> <li>Stimulates the production of new formulas with lower sugar content</li> <li>Increases consumers' education/ awareness (indirectly)<sup>55</sup></li> </ul>	<ul style="list-style-type: none"> <li>Decreases the total amount of sugar intake</li> <li>May contribute, in long-term, to the prevention of obesity and its consequences<sup>55,59</sup></li> </ul>	<ul style="list-style-type: none"> <li>Introduction by the industry and promotion of alternatives/other beverages with high amount of sugar, not included in the taxation law (responses focused on nontaxed beverages)<sup>87</sup></li> <li>Switch of purchases to unhealthy alternatives<sup>64,65</sup></li> </ul>
Marketing regulation	<ul style="list-style-type: none"> <li>Decreases advertisements not meeting the required/accepted nutrition profile</li> <li>Stimulates the production of new formulas (with less energy, and sugar)<sup>74</sup></li> </ul>	<ul style="list-style-type: none"> <li>Better SSBs options available</li> <li>May contribute, in long-term, to the prevention of obesity and its consequences<sup>70,71</sup></li> </ul>	<ul style="list-style-type: none"> <li>The control of all marketing channels is complex, which might compromise the success of the measure<sup>73</sup></li> <li>Marketing strategies might target other public and still affect younger age-groups</li> </ul>
Nutrition labeling	<ul style="list-style-type: none"> <li>Facilitates the interpretation of nutrition values through a Front-Of-Package (FOP) system</li> <li>Increases consumers' education<sup>76</sup></li> </ul>	<ul style="list-style-type: none"> <li>Lead to well-informed choices</li> <li>Better formulas available</li> <li>May contribute, in long-term, to the prevention of obesity and its consequences<sup>76,77</sup></li> </ul>	<ul style="list-style-type: none"> <li>Industries/brands can choose the adopted system. The existence of multiple systems might be confusing for interpretation<sup>79</sup></li> <li>As it is voluntary action, some industries might not include any FOP</li> <li>Might contribute to health inequalities</li> <li>New formulas might seem a healthy option given the FOP, however be of poor nutrition quality</li> </ul>
Consumers' education	<ul style="list-style-type: none"> <li>Public awareness media campaigns</li> <li>Education of providers<sup>9,46</sup></li> </ul>	<ul style="list-style-type: none"> <li>Lead to well-informed choices</li> <li>Improvement of diet and nutrition</li> </ul>	<ul style="list-style-type: none"> <li>Might contribute to health inequalities, depending on the targets</li> </ul>
Healthier (food) environments	<ul style="list-style-type: none"> <li>Increase the availability of free safe drinking-water spots in all schools, parks, etc</li> <li>Make water the main beverage in all school meals</li> <li>Decrease bottled water prices</li> <li>Increase water visibility in retail settings</li> <li>Reduce density of SSBs vendors near schools</li> <li>Avoid unhealthy stores and fast-food<sup>45,46,52</sup></li> </ul>	<ul style="list-style-type: none"> <li>Replacement of SSBs consumption by healthier alternatives, such as water</li> <li>Better hydration state</li> <li>May contribute, in long-term, to the prevention of obesity and its consequences</li> </ul>	<ul style="list-style-type: none"> <li>Some measures might have undesirable and unexpected outcomes<sup>88</sup> (eg, not having SSBs available at school and in the surroundings might increase the consumption in other settings and in total)</li> </ul>

\* All measures/strategies need to focus on availability, affordability, acceptability of healthier food options and consumer's awareness, and need to be adapted continuously.

the foods available in places children attend, namely schools and children's facilities, restaurants, markets, and others, have a great influence in food choices and eating behaviours.<sup>46</sup>

Several public health interventions have been conducted aiming to reduce the consumption of SSBs.<sup>9,49,84</sup> The most commonly discussed public health strategies aiming to decrease the consumption of SSBs are summarized in Table 1. In this review, we described implemented taxation measures and their impact in sales and in preventable cases of disease and death, marketing regulations applied to children and adolescents, and ultimately the intention of application of a single FOP labeling system in all countries, with the goal of increasing consumers' food literacy.

Aiming to achieve the expected policies effectiveness, it is important to evaluate them regularly and, if necessary, develop reformulation of strategies. In the case of the sugar taxes, marketing regulations and nutrition labeling, it is necessary to analyse carefully how the industry and consumers respond to them. Industry may create new products, with healthier profiles, or products that fit the current regulations, but are still unhealthy options. For example, some packed fruit juices have a greater sugar content compared to some SSBs, despite reporting that "sugar is naturally present". Some products, such as flavoured milk or plant-based milk alternatives, may be high in sugar content and they are not included in the current taxation policy.<sup>85</sup>

As with the taxation policy, it is also crucial to investigate consumer purchases shifts and changes in eating behaviours. As beverages containing these sweeteners might be an alternative to SSBs, it would be important to investigate the long-term effects of non-nutritive sweeteners consumption.

It is useful and relevant to have feedback from the implemented measures in other countries on impacts/effects, in order to adapt our measures and preventing eventual undesirable effects. Policymakers and academics must collaborate in order to create an adjustable environment in which health policies can shape according to increasing health challenges in a more effective and efficient way.<sup>86</sup>

Public health interventions aiming to create healthier food environments and improve the quality and accessibility to healthy food choices for all the population as well as the improvement of food literacy are of high priority in a global world.

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## Conflicts of interest

The authors have no conflicts of interest to disclose.

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