

# Sugar Uptake Styles and Their Alliance with Health Facets Among the Indian Population: A Systematic Review

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## Abstract

**Introduction:** Sugar is considered as a double edged sword, associated with many metabolic effects. Studies depicting the relationship between sugars and their harmful effects on health in the context of the Indian population are fewer. The aim of this study was to systematically review data on sugars and their metabolic disturbances, and to produce evidence in the context of the Indian population.

**Methods:** The research question was developed based on PICO strategy. The search was limited to PubMed and EBSCO data bases over the period from 2005-2018, using advanced (Boolean) searching for attaining relevant articles. Articles with only substantial evidence were included, showing a relationship between sugars and their metabolic perturbations which were evaluated with their respective checklists.

**Results:** Pertaining to the inclusion criteria, 32 articles were retrieved, three were systematic reviews, 16 cross-sectional studies and 13 experimental trails. Regained articles were related to sugars and dental caries, sugars and obesity and serum lipids levels, and also sugars and Type-2 Diabetes (T2D) mellitus. The cross-sectional studies, randomized, non-randomized trials and systematic reviews fulfilled 72.7%, 45.68%, 60.90% and 71% of corresponding checklist items respectively.

**Conclusion:** This review suggests that carbohydrates are the main constituting diet and consumption assumes metabolic disturbances like hyperglycaemia, risk of T2D, insulin resistance syndrome, dyslipidaemia, increased triglyceride levels and as a leading risk factor for occurrence of caries.

**Keywords:** Sugars, Dietary Pattern, Sugar Intake, Metabolic Disturbances

## Introduction

Sugar has a bittersweet image in consideration of health. Sugar exists naturally in most foods that contain carbohydrates, such as fruits and vegetables, grains, and dairy. Diets which are rich in free sugars increase overall energy intake, which reduces nutrient quality by providing significant energy without specific nutrients, leading to unhealthy weight gain (obesity) and increased risk of various Non-Communicable Diseases (NCD's).<sup>1</sup> India's total sugar production was 32 million tonnes in the year 2017-2018 and was expected to rise 4.2% in the year 2018-2019.<sup>2</sup> As per the Sugar Year book, sugar consumption was around 33.8 million metric tonnes in 2016 and was around 25 million tonnes in 2017-2018.<sup>3</sup> In India, the diet is comprised of mainly refined carbohydrates, and mostly in the form of white rice constituting 66%-70% of total calorie intake and also sugar consumption both from traditional sources and Sugar-Sweetened Beverages

(SSBS) was very high.<sup>4,5</sup> After having food with carbohydrates, the digestive system breaks them into sugars which enters the bloodstream and thereby rises blood sugar levels. The type of carbohydrate, either a simple or complex carbohydrate, also has a role, where simple carbohydrates are easily digestible and rapidly enters the bloodstream and raises blood sugar levels. High dietary carbohydrates are associated with increased risk of T2D in India, where the prevalence of diabetes is 7.8%, and mortality due to diabetes is 2%, including all ages.<sup>6</sup> Consumption of a carbohydrate-rich diet is associated with a rise in Triglycerides (TG) and fall in Total Cholesterol (TC), High-Density Lipoprotein Cholesterol (HDL-C), and Low-Density Lipoprotein Cholesterol (LDL-C), which is a mark of dyslipidemia.<sup>7</sup> Seema Gulati and Anoop Misra spotlighted various forms of Indian foods containing natural or added sugars.<sup>5</sup>

Sugar plays a crucial role in dental caries where caries is evoked by the dissolution of the tooth structure by acids induced during the metabolism of dietary carbohydrates by oral bacteria.<sup>8</sup> Dental caries can be averted by avoiding dietary free sugars, despite that fruit juices labelled with no added sugar or free from sugars have substantial quantities of sugar and are equally cariogenic as fruit juices with added sugars.<sup>9</sup> Though sugar is associated with dental caries, the fact is sugar alone is not an only determinant factor for dental caries.<sup>10</sup>

Studies depicting the relationship between sugars and their ill effects on health in the context of the Indian population are limited. This paper aims to review data on sugars and their metabolic disturbances and to produce evidence in the context of the Indian population.

## Materials and Methods

This review included original articles showing the relationship between sugars and their metabolic perturbations in the context of the Indian population, which were published as full-text articles, where the search was limited to PubMed and EBSCO databases over the period from 2005 to 2018.

### Search Strategy

The research question was developed based on the PICO strategy, as shown in Table 1. PubMed and EBSCO databases were searched using keywords; sugar intake, sugar consumption, dietary pattern, dietary

carbohydrates, India, T2D mellitus, and glycaemic index. Advanced search strategy (Boolean searching) was carried out for attaining relevant articles. Boolean operators are simple words (AND, OR, NOT or AND NOT) used concurrently to combine or preclude keywords in a search, resulting in more focused and productive results. The word AND was used to narrow the results, OR to broaden the results, and NOT to exclude terms from search results. Phases of the search strategy are shown in Figure 1.

### Inclusion and Exclusion Criteria

An article is considered to be original research if it is the report of a study written by the researchers who performed the study with a specific hypothesis and detail their research methods and results along with exploration of possible implications. All articles which met this definition, i.e., cross-sectional, case-control, cohort studies, experimental trials, systematic reviews and meta-analysis showing a relationship between sugars and their metabolic effects in the context of the Indian population, published from 2005 to 2018 were included in this study. Narrative reviews, case reports, expert opinions, and in vitro trials were excluded from the study.

After applying the inclusion and exclusion criteria, each article was assessed with their respective checklists. A total score of checklist items followed by each article was obtained, and the mean score of items followed for each checklist was calculated.

**Table 1.** PICO Strategy Used for the Development of Research Question

P	I	Co
Population or problem Sugar Intake pattern	Interest Metabolic effects due to excess sugar intake	Context Indian population

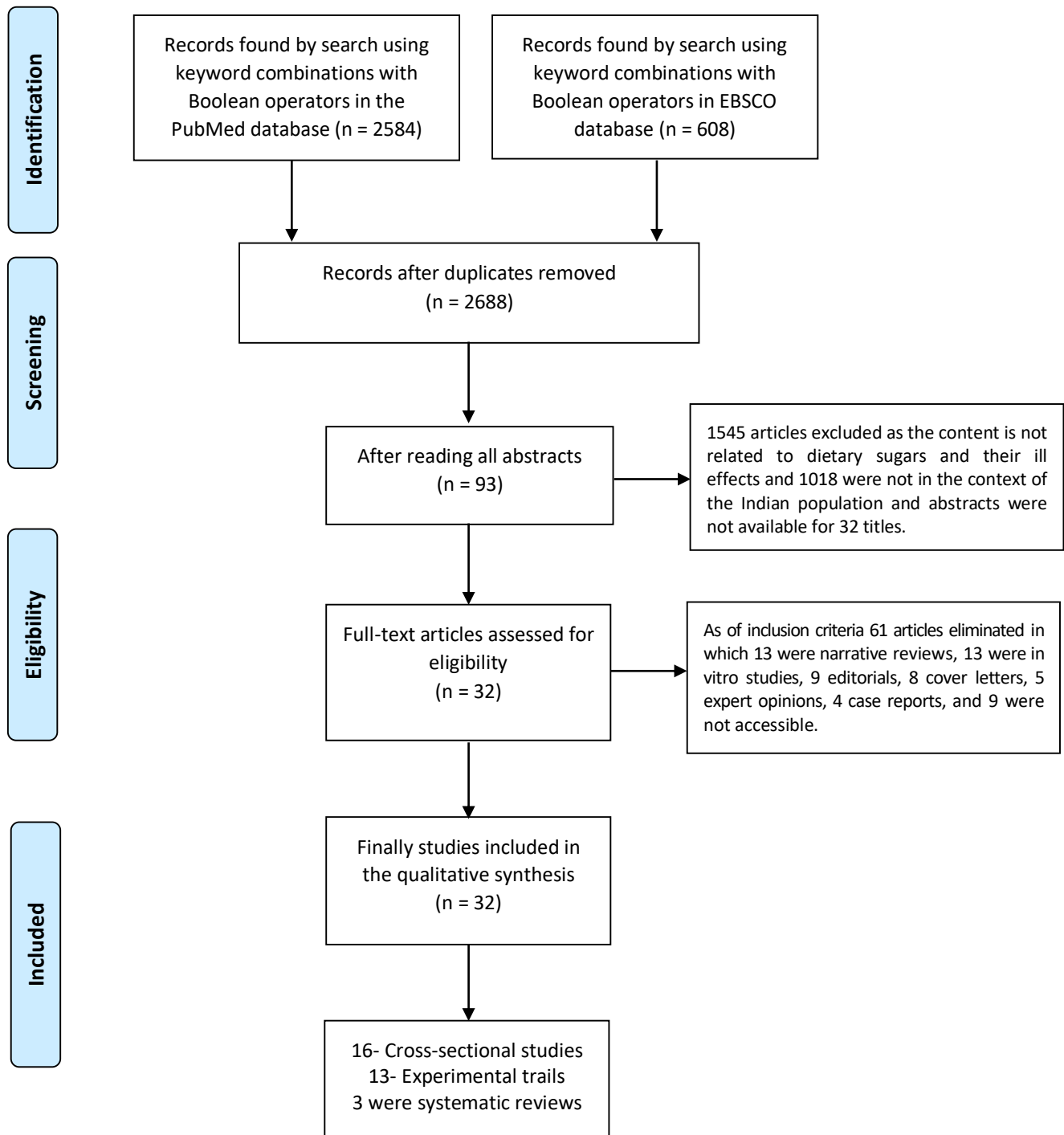
## Results

The cardinal aim of the study was to review data on the implied relationship of sugars and their related metabolic disturbances in the context of the Indian population. A total of 32 articles was retrieved after applying the inclusion and exclusion criteria (Figure 1). For every four years, there is an upsurge in the number published (Figure 2). Among the 32 articles, three were systematic reviews, 16 cross-sectional studies, and 13 experimental trails. In the amid of 32 articles, 14 articles were related to sugars and dental caries, 9 articles with reference to sugars and obesity and serum lipid levels, and 11 articles were related to sugars and

T2D. The mean percentage of checklist items followed by each category of studies have been presented in Table 2. Characteristics of studies included in review relating to sugars and dental caries, T2D, obesity and serum lipid levels are depicted in Tables 3, 4, and 5 respectively. At this point, 24 articles were indexed by both PUBMED and EBSCO, while five articles were exclusively indexed by PUBMED and three articles were exclusively indexed by EBSCO.

## Discussion

After an insight into the retrieved articles, the sugars and their metabolic disturbances are detailed under the



**Figure 1.** Literature Search Strategy for A Systematic Review on "SUGARS AND HEALTH".

headlines, introduction to sugars, sugars and T2D mellitus, sugars and obesity, sugars and dental caries, and dietary recommendations

**Introduction on Sugars**

A classification of dietary sugars adopted by the World Health Organization (WHO) and Food and Agriculture Organization (FAO) expert of the United

Nations, well classified about various groups of sugars, which is most helpful and essential to understand or interpret the potential adverse health effects.<sup>39</sup>

Undoubtedly sugars are simple carbohydrates which are the main energy sources, "burns" without yielding metabolic wastes, being turned into CO<sub>2</sub> and water, and releasing energy. An acronym "fats burn in the fire of carbohydrates," i.e., carbohydrates presence is necessary

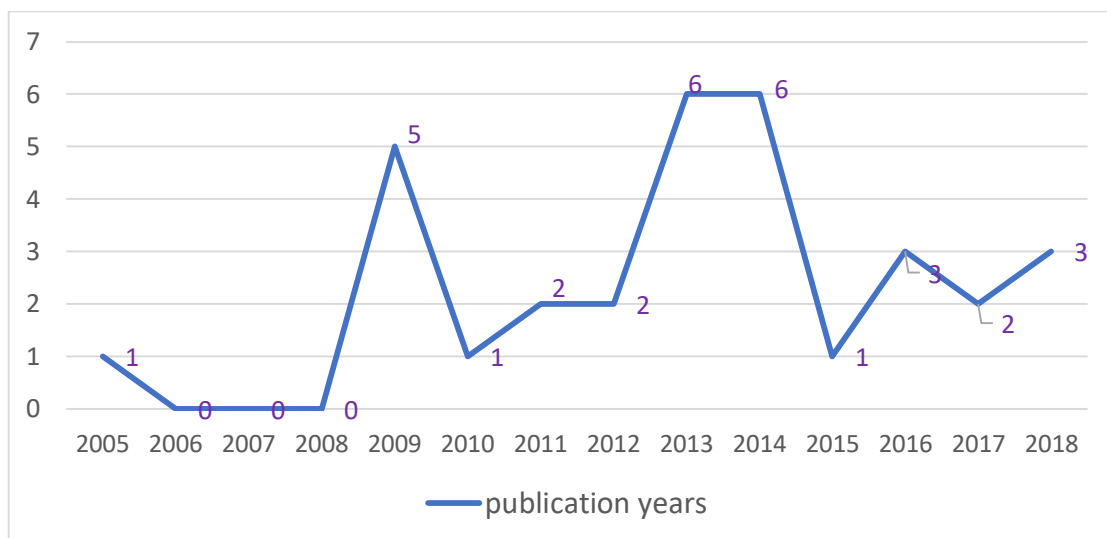


Figure 2. Distribution of Articles Pertaining to the Year of Publications.

Table 2. Evaluation of quality of articles according to standard checklists

S No	Type of studies	Number of studies	Checklist to be evaluated	Total number of checklist items	Mean Percentage of checklist items followed
1	Cross sectional studies	16	STROBE	22	72.7%
2	Non randomized trails	5	TREND	22	60.9%
3	Randomized trails	8	CONSORT	25	45.68%
4	Systematic reviews	3	PRISMA	27	71%

Table 3. Characteristics of Studies Related to Dietary Sugars and Dental Caries

Sugar form	Pattern of consumption/comparison	Effect/action	Main outcome
Starch, sucrose, sweets & soft drinks, and unfilled chocolates	Frequency of taking	Slower salivary clearance	Dental caries and early childhood caries <sup>11,12,13,14,15,16</sup>
Aerated drinks, refined carbohydrates	Exposure in b/w meals	Retention of food	Dental caries <sup>17</sup>
Paediatric liquid medicaments	Concentration	Lowering of plaque pH	Dental caries <sup>18</sup>
Sugar containing chewing gums	Sugar free gums	Higher mean plaque scores	Dental caries <sup>19,20,21</sup>
Sucrose	Glucose and fructose	Lowers plaque pH	Rampant caries <sup>22</sup>
Added sugar in milk	2-3 table spoons	Enamel demineralization	Dental caries <sup>23</sup>
Fruit juices labelled with added sugars	Labelled with added sugars	Equally cariogenic	Dental caries <sup>9</sup>

for normal fat metabolism. Contrarily, non-caloric benefits of carbohydrates comprising of slowing the gastric emptying time, rise in satiety and have a mouth to faecal transit time, and by their hydrophilic action, they inflate the stool weight and volume by 40-100%.<sup>40</sup> The term added sugar is sometimes used reciprocally with "free sugar" but is considered to include sugars and syrups added to foods during processing, food preparation, or at the table, but does not comprise of honey or fruit juices.<sup>39</sup> Added sugars are the main ingredients in SSBS, which includes the full spectrum

of aerated drinks, fruit drinks, energy drinks, and vitamin water drinks. However, artificial sweeteners are added sugars that are used as ingredients to both satisfy and in some cases provide added energy, based on which they are categorized as nutritive and non-nutritive sweeteners.

### Sugars and Type 2 Diabetes (T2D) Mellitus

The correlation between sugar consumption and adjusted risk of T2D was especially robust among South Asian populations, where even a modest increase in sugar

**Table 4.** Characteristics of Studies Related to Dietary Sugars and T2D

Sugar assessment/provision	Target population	Measured findings	Main outcome
Dietary assessment through FFQ	South Indian urban and rural population	Total energy intake	Risk of T2D <sup>25,26</sup>
Replacing white rice with brown rice	Indian adults	Glycaemic responses	Risk of T2D
Replacing white rice with brown rice & brown rice with legumes	Diabetic patients	Interstitial glucose levels	Reduced 24-h glucose responses <sup>28</sup>
Total carbohydrate assessment	Diabetic patients from endocrinology clinics in India	Post prandial blood sugar	Elevated PPBs levels <sup>4</sup>
Carbohydrate rich diet	Rural population	Fasting blood sugar levels	Increased fasting blood sugar levels <sup>29</sup>
Provision of carbohydrate rich Indian breakfast foods	Chinese & Indian adults	Glycaemic & insulinaemic index	Increased glycaemic response <sup>30</sup>
Sugar consumption	Indians	All possible sugar consumption data	Prone to NCD'S <sup>5,31</sup>
Coco cola and Pepsi availability	Delhi surroundings	Stocking and sales	Prone to diabetes <sup>32</sup>

**Table 5.** Characteristics of Studies Related to Dietary Sugars and Serum Lipid Levels

Diet measurement/provision	Subjects	Measured findings	Outcome
Sugar consumption through FFQ	8-15 year children	BMI	Obesity <sup>33,34</sup>
Sugar consumption	12 years	BMI	No Obesity <sup>35,36</sup>
Sugar consumption	Indians	All possible sugar consumption data	Abdominal adiposity and fat deposition <sup>37</sup>
Carbohydrate rich diet	Rural population	Fasting blood sugar levels	Increased TG, VLDC levels <sup>29</sup>
Pepsi and Coco cola	Indians	Stockings and sales	Obesity <sup>32</sup>
Provision of Mixed meal	T2D Indian adults	Insulin resistance	Rise in TG, fall in TC, HDL-C, LDL-C, IL-6 <sup>7</sup>
Dietary assessment through FFQ	South Indian urban and rural population	Total energy intake	Increased plasma HDL-C concertation <sup>38</sup>

intake (for example, 150 extra calories of added sugar) correlates with a significantly heightened risk for T2D.<sup>41,4</sup> In contrast, about 66-70% of total calorie intake in the modern Asian Indian diet comes from carbohydrates, and mostly in the form of refined sugar, white flour, and white rice.<sup>4</sup>

The WHO has described added sugar as a silent killer that is as deadly as tobacco—these two vices kill two people around the world every six seconds—one from sugar and one from tobacco.<sup>42</sup> The per capita sugar consumption of south Asia is positively correlated with the prevalence of diabetes mellitus.<sup>43</sup> The consensus group recommends a reduction in simple carbohydrates intake (50-60% of total energy), favourable intake of complex carbohydrates, and low GI foods for Asian Indians.<sup>44</sup>

The excessive intake of sugar along with other refined carbohydrates is a major factor driving the epidemics of T2D and CVD among the Asian Indian population.<sup>45</sup> A randomized controlled trial on the rural population of West Bengal, India detailed that long-term consumption of carbohydrate-rich diet results in increased levels of fasting blood glucose, TG, very low-density lipoprotein and fasting serum insulin level which have a significant

role in the development of insulin resistance syndrome, dyslipidemia, and subclinical inflammation.<sup>29</sup> A study by Narasimhan Sowmya et al., postulated that 74.7% of south Indian population exceeded the WHO recommendations for carbohydrates.<sup>25</sup>

In a study carried out among T2D mellitus group in India depicted that carbohydrates are alone constituting, about 64.1% of total energy from their whole diet, which is higher than the recommended level.<sup>4</sup> Refined grains alone constitute about 48.5% of the total energy among urban south Indians, which is positively associated with all components of metabolic syndrome and risk of T2D.<sup>26</sup> South Indian rural population dietary profile displayed unhealthy food choices due to high ingestion of refined cereals in the form of white rice and lower consumption of whole grains, pulses and legumes that can contribute to the development of metabolic non-communicable diseases such as diabetes, hypertension and heart disease.<sup>25</sup> Excess postprandial lipid levels are considered as a component of insulin resistance syndrome. A study by Joshi et al. among type-2 DM patients in India expressed that an increase in carbohydrate consumption, led to an increase in their 2 h PPBG levels.<sup>4</sup> In India, whole grain carbohydrates are being

replaced with refined carbohydrates, predominantly from rice, due to modern milling technology.

In addition to the quantity, the quality of carbohydrates is also important, particularly its ability to raise blood glucose levels. Quality of carbohydrate is nothing but whether it is a simple or complex carbohydrate. Simple carbohydrates are single monosaccharide units which are easily digestible that quickly raise the blood glucose levels. Complex carbohydrates however refer to polysaccharides, takes time to digest, are less sweet than simple carbohydrates and slowly raise the blood glucose levels.

Glucose raising effect of food is determined by a parameter called Glycaemic Index (GI). The glycaemic index indicates the glucose-raising effect of food in comparison with a standard glucose-containing equivalent amount of carbohydrate, which depicts how rapidly a carbohydrate breakdown into sugar in the bloodstream. Three Indian breakfast foods have high GI levels than the western breakfast foods suggesting that these foods are constituting of mainly simple carbohydrates.<sup>30</sup> Meanwhile, GI does not take into account the amount of carbohydrate. Another parameter called the glycaemic load, determines the combined effect of both the quantity and quality of carbohydrates consumed. Higher consumption of foods with high glycaemic load was associated with lower HDL-C and increased serum triglyceride in the south Indian population.<sup>38</sup> High dietary carbohydrates and glycaemic load are associated with increased risk of T2D in adult Asian Indians.<sup>24</sup> White rice is a staple Indian food and contributes almost half of the daily caloric intake. A randomized controlled trial for replacing white rice with brown rice and brown rice with legumes among overweight Asian Indians resulted in the drop of glycaemic load by 20% where glycaemic responses for brown rice and brown rice with legumes are significantly lower than that for white rice. Also, this replacement helped in reducing 24-hr glucose and fasting insulin responses.<sup>28</sup> Consumption of carbohydrate-rich meal is associated with a rise in TG and fall in TC, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, interleukin-6, and tumour necrotizing factor- $\alpha$  among normal individuals and people with T2D.<sup>7</sup> Increase in TG leads to a parallel decrease in high-density lipoprotein cholesterol secondary to a bidirectional lipid exchange between triglyceride-rich lipoproteins and high-density lipoprotein particles.<sup>46</sup>

### Sugars and Obesity

Dietary sugars affect blood pressure and serum lipids levels, leading to several metabolic events; accumulation of body fat and intra-abdominal fat increased free fatty acids and hypertriglyceridemia.<sup>47</sup> There was a direct relation between SSB consumption, which is the largest source of added sugars, with weight gain and obesity in children and adolescents.<sup>48</sup> Children's dietary habits with added sugars are a significant contributor to the global epidemic of childhood obesity. A cross-sectional study by Akhilesh et al., among children in Mangalore city, India had sentenced that children who are overweight and obese preferred sweet and fatty foods more frequently compared to children with a normal weight.<sup>34</sup>

Gupta et al., reported that on an average, there is about 1.8 cans of cola per week (540 ml/week) per person consumption among urban adolescents in India.<sup>49</sup> Consumption of one can of regular Pepsi (573 KJ) per day above the required daily need for an average woman for a year equates to a weight gain of 6.5 kg/year. In India, sales of the regular version of Pepsi is more compared to the diet version of Pepsi in Delhi, India, which may likely exacerbate obesity and diabetes trends.<sup>32</sup>

Fructose in diet after getting metabolized in subcutaneous adipocytes, is a subsequent inflammation in intracellular cortisol, which further leads to an increased flux of fatty acids out of the subcutaneous adipocytes allowing more substrate for fat storage into visceral fat tissue.<sup>50</sup> Dyslipidaemia in Asian Indians is usually characterized by hypertriglyceridemia, low levels of small dense LDL-C, which frequently occur with postprandial hyperlipidemia. An experimental trial on severely obese subjects with a high prevalence of diabetes or metabolic syndrome lost their weight over six months when on a carbohydrate-restricted diet than when on a calorie and fat-restricted diet, even after adjustment for weight loss, along with a relative improvement in insulin sensitivity and TG levels.<sup>51</sup>

### Sugars and Dental Caries

Dental caries is defined as a multifactorial, transmissible, infectious oral disease caused primarily by the complex interaction of cariogenic oral flora (biofilm) with fermentable dietary carbohydrates on the tooth surface over time.<sup>52</sup> Sucrose for years was advertised as the "arch-criminal" of dental caries because it was considered

to be more cariogenic than other sugars. Sucrose has been regarded as a cariogenic substrate owing to its capability to support the synthesis of extracellular glucans by streptococcus mutans through strengthening its accumulation in the plaque.

Many bacteria involved in the formation of dental biofilms may quickly metabolize sugars, producing acid by-products which can lead to demineralization of the tooth structure. Saliva plays a significant role in anticaries activity, owing to its cleaning actions as well as its acid-neutralizing, anti-solubility, and antimicrobial properties. The cariogenicity is attributed mainly by the form of the food product; that is, the physical consistency of the sugar-containing foods, which affects their retention time in the mouth and frequency of its consumption.

A high intake of liquid paediatric medicaments may produce unwanted dental side effects in children. The presence of a high concentration of fermentable carbohydrates in medicated syrups may facilitate the growth of streptococcus mutans, by rapidly metabolizing sugars to acids, thus initiating enamel demineralization.<sup>53</sup> Most of the liquid or chewable medications are usually made palatable by sweetening additives. The most commonly used sweetener by the pharmaceutical industry is sucrose.<sup>54</sup>

Sucrose-containing medications produced a significantly lower pH, which was not statistically different from plaque responses to 10% sucrose solution.<sup>18</sup> The medications regularly prescribed for HIV infected children had a high sucrose content added by pharmaceutical preparations, as a sweetener, preservative, thickening agent, an anti-oxidant, which has a high potential for increasing dental caries.<sup>55</sup>

Commercial sweeteners have less cariogenic potential than natural and artificial sugar substitutes. Least depth of enamel demineralization was seen with sucralose (commercial sweetener) followed by honey (natural sweetener), and the maximum with sucrose followed by glucose and palm sugar (artificial sugar substitutes).<sup>56</sup>

Early Childhood Caries (ECC) is a chronic childhood disease, which affects the teeth of infants as soon as they erupt. ECC has been defined as a decayed, missing or filled tooth in the primary dentition under 71 months of age and Severe ECC (SECC) as any smooth surface caries in children under three years of age.<sup>57</sup> A Significant association of ECC was observed with age, sucrose exposure in between meals, the total

frequency of sucrose exposure, and total sweet score.<sup>13</sup>

The role of saliva in the oral clearance of carbohydrate should be of prime concern since cariogenic properties are related to the retention time of carbohydrates in the mouth as a result of their acidogenicity. A short clearance time reduces the amount of time that sugar is available for acid production by the bacteria in the dental plaque. Slower clearance rates resulting in an increased risk of caries in the elderly during an artificially induced low secretion rate and for individuals with usually low secretion rates.

The clearance pattern of refined carbohydrates from saliva in children is both slower and shows a larger variation in the physiologic clearance of oral sugar than older children and adults.<sup>58</sup> The foods that were high in starch content such as cornflakes and potato chips exhibited slower salivary carbohydrate clearance.<sup>11</sup> Sugars that exist naturally in foods and those that are added in processed foods can be the source of fermentable carbohydrates and can initiate the process of caries. Chocolates form an important constituent of all the foods consumed by children, where the Indian market offers a wide range of chocolates. The cariogenic ability of chocolates, however, depends on other factors, such as sugar content, high frequency of intake, bedtime consumption and essential pH. Unfilled chocolates are more cariogenic than filled chocolates and candies, where milk chocolate contains casein, a milk phosphoprotein, and it stabilizes calcium and phosphate ions within the tooth, rendering it less vulnerable to demineralization processes.<sup>59</sup>

Sugar consumption pattern of 13-year school children in Belgaum city was very high, and there is a need to plan and organize a diet counselling program.<sup>15</sup> High percentages of teenagers are consuming aerated drinks and sweets/chocolates regularly in between meals in Mumbai city.<sup>17</sup> The acid-producing capacity of dental plaque is a proven factor for the initiation of dental caries, where the plaque pH varies with the intake of different sugars.

In order of preference in cariogenic potentiality, sucrose had a significant effect in lowering the pH of plaque, in rampant and moderate caries group, second in order is glucose followed by fructose.<sup>22</sup> On the other hand, increasing salivary flow rate increases pH, promotes enamel remineralisation and buffering capacity, and reduces caries.

Chewing sugar-free gum is a favourable way to

increase salivary flow. The ability to chew gum aids in caries control comes from the chewing action itself which stimulates saliva flow and the non-cariogenic sugar substitutes used as sweeteners. A study conducted in Mathura city has shown that the mean plaque scores by sugar-containing gums are higher when compared with sugar-free gums in 12- year old school children. However, there was no significant association between daily sugar intakes with dental caries.<sup>35</sup>

### Dietary Recommendations

- Taking into consideration, the rising prevalence of obesity and diabetes in India, the sugar intake should be less than 10% of the total energy intake per day.
- Oral health professionals must play a leadership role in reducing the children's consumption of SSBS, through nutrition workup in the paediatric oral health settings.
- Escalate awareness among consumers through depicting warning labels which show consequences of added sugars.
- SSBS taxation at a high tax rate, which could blunt the rising epidemics of obesity and T2D among rural and urban Indians.
- Infuse healthy eating habits among both children and adolescents.
- Policy and advocacy efforts by oral health professionals in reducing SSBS consumption.

### Conclusion

According to findings, carbohydrates are the main constituting diet among Indians, and this consumption assumes metabolic disturbances like hyperglycaemia, risk of T2D, insulin resistance syndrome, dyslipidaemia and increased triglyceride levels. Apart from the quantity of carbohydrates, quality of carbohydrates (glycaemic load and glycaemic index) is also an important consideration in the development of these metabolic disturbances. Sugar also has a direct relationship with dental caries, which is a leading risk factor for the occurrence of dental caries. Prevention strategies targeting these increased sugar consumptions in India, such as taxation on added sugar beverages, thereby limiting its harmful metabolic effects can be carried out. However, these strategies are unsuccessful without proper physical activities and active lifestyle. Quality of articles, depicting the relationship between sugars and their ill effects on human health are not satisfactory and there is a room for improvement.

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