Effect of Sugar Sweetened Beverages on dental caries among adults:
A Systematic Review

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Abstract
Background
Dental caries is one of the most common disease in the modern times and has reached epidemic proportions. Looking into the high prevalence rate of dental caries and increased consumption of sugar sweetened beverages (SSB) present study aimed to evaluate and compare the evidences regarding the effect of the amount and frequency of SSB consumption on dental caries among adult population around the world.

Methods
A systematic literature review was performed using 4 databases (PubMed, Google Scholar, One Search, Medline EBSCOhost). A total of 13 articles, reports, and journals were collected and analyzed

Results
A total of 13 studies were included in the study. Of which 8 studies assessed the amount and frequency of SSB consumption on dental caries, and 5 studies focused only the amount of SSB consumption on dental caries. The literature indicates that higher and the more frequent the consumption of SSBs, the higher is the probability of dental caries.

Conclusion
All the studies constantly demonstrated that there is need to control, limit, and manage their intake of SSBs, as they could degenerate not only an adult’s dental health but one’s overall wellness. To establish guidelines more studies are needed to fully assess and compare both amount and frequency of SSB consumption and determine which could strongly affect the development of dental caries.

Keywords: dental caries, sweet, sugar, beverage, adults, tooth decay, sugar sweetened beverage.
Introduction
Dental caries (also known as tooth decay or cavity) is an emerging fundamental oral health problem throughout the world as nearly 80% of the population are affected worldwide. The disease is widely spread around the globe and all populations (Chenicheri et al., 2017). It is estimated that the consumption of sugary beverages increased by 62% in 2018 as compared to 2008 (Petersen & Galea, n. d.). Consumption of sugar-sweetened beverages is greater in young adults as compared to young children and older population (Islam, S. Khan, & A. Khan, 2007; Heller, Burt, & Eklund, 2001). It was found 90% of adults above 20 years had dental caries (Heng, 2016). Cariogenicity is influenced by the type of carbohydrate, quantity and frequency of consumption, oral hygiene, exposure to fluoride, and pit and fissure sealants. Sugar-sweetened beverages (SSBs) are considered common sources of dietary sugars, containing added sweeteners (Bernabé et al., 2014). A key reason for the looming rates of SSB consumption is the fact that the drinks are “cheap and readily available. Exposure to a higher frequency of sugars in between meals shows higher caries activity compared to consumption with meals (M. Mishra & S. Mishra, 2011). According to M. Mishra and S. Mishra, four and more soft drinks consumed in between meals are associated with a 179% increase in odds of having high dental caries. The primary purpose of the current research study was to identify and integrate existing data and information on the association between sugar-sweetened beverages or SSBs and dental caries experiences among the adult population and also aimed to summarize whether the general frequency or amount of SSB consumption by adults is a significant risk factor for dental caries.

Methodology
The research questions of this study were developed based on the PEO Format/ Model, which is defined as the determination of Population, Exposure, and Outcome of the research study.

<table>
<thead>
<tr>
<th>PEO Format</th>
<th>Factors Identified in the Current Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Adults having dental caries</td>
</tr>
<tr>
<td>Exposure</td>
<td>Consumption of Sugar Sweetened Beverages</td>
</tr>
<tr>
<td>Outcome</td>
<td>Impact of consumption, including amount and frequency SSBs on dental caries</td>
</tr>
</tbody>
</table>

Source: Developed for the Research

Research Questions
The two research questions generated through the PEO format are:

Research Question 1 (RQ1): What is the relationship between sugar sweetened beverages (SSBs) and dental caries among the adult population?

Research Question 2 (RQ2): Does the amount or frequency of SSB consumption has a greater effect on dental caries of adult patients?

Search Strategy
The search strategy that was applied in this study was based on the PRISMA (Preferred Reporting Items for Systematic Review) guidelines. Google Scholar, PubMed, Medline, EBSCOhost and One Search databases were searched using search strategy to identify all the relevant literature. The literature that fulfilled the inclusion and exclusion criterion were used in the present study review.
**Inclusion criteria**
All research studies selected are primary studies that are qualitative, quantitative and mixed method approaches with a grey literature that was originally published in English language between 1997-2000. The population included in the research studies was adults with an age group of 19.y and above. The primary research question should be focused on the relationship between sugar-sweetened beverages (sodas, tea, coffee, milkshakes) and dental caries.

**Exclusion criteria**
All the research studies that are based on secondary studies such as literature review, systematic reviews, and meta-analysis which are published in another language before the year 1997, population below 19.y old, studies that are focused on oral health care and relationship between sugar-sweetened beverages and dental caries.

By using the keywords and applying the inclusion-exclusion criteria discussed above, more than 15,427 research studies were retrieved. Although there were duplicate studies in the search result from the different databases, these identical studies were discarded by assessing the titles of the research articles. The screening of the titles also helped in removing the studies which were not relevant to the research question. After the first phase of assessing the titles, the second phase was comprised of the screening of the abstract of the research studies. This resulted in the removal of the studies which were based on secondary studies or population under the age of 19 years. After the final screening and evaluation by the primary investigator, details of individual studies were extracted. A total of 13 studies were selected to be included in this systematic review.

**Table 2.3. PRISMA based selection of studies for the Systematic Review**

<table>
<thead>
<tr>
<th>Records identified through Google scholar (n=15,200)</th>
<th>Records identified through PubMed (n=204)</th>
<th>Records identified through other (EBSCOhost, Onesearch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Records after duplicated were removed (n= 15,013)</td>
<td>Records screened (n=15,013)</td>
<td>Records excluded (As most of the articles focused on children, fluoride exposure, oral health care) (n= 13,973)</td>
</tr>
<tr>
<td>Full text article assessed for eligibility (n=18)</td>
<td></td>
<td>Full text articles excluded- as they were review articles (n=5)</td>
</tr>
</tbody>
</table>
Results

Of the 13 studies included most of them focused exclusively on SSB’s and dental caries. Two studies focused on oral hygiene, dietary habits and dental caries (Jain & Gary, 2014; Maru & Narendran, 2012). One study focused on all the risk factors for dental caries (Jamieson, Roberts-Thomson, & Sayers, 2010). Out of 13 studies included, 3 studies conducted interviews, 3 studies designed questionnaires, 1 study had a 4-day food diary for measuring SSB consumption, 4 studies analyzed the data from NHANES III and 2 studies analyzed data using 2012 Behavioral Risk Factor Surveillance System. Six of 13 studies used DMFT/DMFS as a measure for identifying dental caries and others have conducted clinical oral examinations.

Research Question 1: What is the relationship between sugar sweetened beverages (SSBs) and dental caries among the adult population?

Results from all 13 studies are summarized in table 4.2. Twelve of the 13 studies indicated that the higher the consumption of the SSBs, higher the risk for the adult population to develop or experience dental caries. In particular, they emphasized that the adult population experiences dental caries due to their exposure and access to SSBs. Also, researchers who completed the analyzed studies above, they shared that SSBs could indeed lead to various negative impacts on the health of the adults. In this case, the analysis focused on the implications for the development and worsening of dental caries, substantiating the strong link between the two variables. In a study by Jamel et al., (1997) the relationship between sweet preference and dental caries were stronger in the rural groups (r = +0.58, P<0.001) compared to the urban group. According to Maru and Narendran (2012), the commonest exposure to sugar was from sweetened tea (p<0.05). According to Forshee and Storey, 2004, SSBs especially carbonated soft drinks, are not associated with the poor dental health of the adults (R² = 0.18), or the older age group (R² = 0.24). According to these conclusions, study number 4 does not determine any relationship between SSB consumption and dental caries among the adult population. One of the 13 studies (study number 13) gives a conclusion that the relationship between SSB and dental caries could not be determined as limiting SSB only reduced dental caries but not eliminate it completely (AOR range = 1.82–7.84) (Lundeen et al., 2018). From the analysis of 13 studies, considering the effect size and direction the odds of having dental caries increases with the consumption of SSB. This shows a positive correlation between SSB consumption and dental caries increment among the adult population.

<table>
<thead>
<tr>
<th>Themes</th>
<th>Number of References</th>
<th>Percentage of References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determining a positive correlation between SSB consumption and dental caries among the adult population</td>
<td>12</td>
<td>92%</td>
</tr>
<tr>
<td>Determining no relation</td>
<td>1</td>
<td>8%</td>
</tr>
</tbody>
</table>
between SSB consumption and dental caries among the adult population

| Relationship is undetermined | 1 | 8% |

Source: Developed for the Research

Table 4.2. Breakdown of the Studies Referencing RQ1

<table>
<thead>
<tr>
<th>Study Number</th>
<th>Primary Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Number 1 (Bernabé et al, 2014)</td>
<td>“A positive association was found between frequency of SBS consumption and 4-year net DMFT increment, regardless of participants’ socio-demographic and behavioural characteristics.” (p. 952) “Drinking sugar-sweetened beverages on a daily basis is related to greater caries risk in adults.” (p. 952) 0 SSB/day: N = 493; 95% Confidence Interval (CI) = (0.57–0.78) 1–2 SSB/day: N= 236; 95% CI = (0.67–0.98) 3+ SSB/day: N = 210; 95% CI = (0.70–1.06)</td>
</tr>
<tr>
<td>Study Number 2 (Jamel et al., 1997)</td>
<td>These findings, together with those showing that sweet preference changes with exposure to sugars; the more sugars people consumed the higher their threshold for sweetness, indicates that exposure to sugar increases the intake sugar and the risk of dental caries. (p. 212) The strong positive association between sweet preference and dental caries is unsurprising. Sweet preference changes with exposure to sugars. (p. 215) N = 4152 “Sweet preference and dental caries relationship were stronger in the rural groups (r = +0.58, P&lt;0.001) than in the urban groups (r = +0.24, P&lt;0.001).” (Abstract)</td>
</tr>
<tr>
<td>Study Number 3 (Jain &amp; Gary, 2014)</td>
<td>“Those with dental caries had a much higher sugar-sweetened beverage consumption at 212 ounces for the 4-day study period than those without dental caries at 170 ounces (P &lt; 0.05). Snack food consumption was also much greater in those with dental caries (16 ounces) than in those without caries (9 ounces) (P &lt; 0.05).” (p.65) N = 76; p &lt; 0.05 (for all)</td>
</tr>
<tr>
<td>Study Number 4 (Forshee &amp; Storey, 2004)</td>
<td>Beverages have a weak, but statistically significant, relationship with DMFS among the older age groups only. Regular professional dental care was associated with lower DMFS among the older age groups. Age and ethnicity are the strongest predictors of DMFS. Young adults have fewer DMFS regardless of dietary factors. This study suggests that carbonated soft drinks are not associated with poor dental health. Useful strategies to reduce dental caries involve good personal dental hygiene, regular use of fluoridated toothpastes and mouthwashes, and regular care by dental professionals. (p. 1805) P &lt; 0.05 Ages 25–40 years: N= 4143; R² = 0.18 Ages 41–60 years: N=1796; R² = 0.15</td>
</tr>
<tr>
<td>Study Number 5 (Maru &amp; Narendran, 2012)</td>
<td>Ages over 60 years: N= 3721; R²= 0.24</td>
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<tr>
<td>The most common sugar exposure was sweetened tea; 75% consumed the beverage at least once a day. More than 80% of the subjects had untreated caries with mean DMFT and DMFS scores of 5.1 ± 3.9 and 13.8 ± 17.8, which lacked any gender differences. (Abstract) N = 189; P &lt; 0.05</td>
<td></td>
</tr>
</tbody>
</table>

| Study Number 6 (Jamieson, Roberts-Thomson, & Sayers, 2010) | “Our study has shown that, in an Australian Aboriginal young adult cohort, risk indicators for dental caries included social determinants such as household size, dietary behaviors such as regular consumption of soft drink and sweets, dental behavior such as non-ownership of a toothbrush and dental anxiety.” (p. 218) N = 141 (19-20 years age); p<0.05 SSB consumption every day/ few time a week: AOR 82.3; 95% CI (78.0–86.6) SSB consumption ≤ 1/week: Adjusted Odds Ratio (AOR) = 66.4; 95% CI = (58.5–74.3) |

| Study Number 7 (Heller et al., 2001) | DMFS and soda consumption were generally seen in persons over age 25. No differences in DMFS, relative to soda consumption, were seen in persons under age 25, or in analyses of dfs for children under age 12. The observed associations could be due to the cumulative effects of the long-term consumption of sugared soda (p. 1949) N = 15,570, p < 0.05 |

| Study Number 8 (Hardy et al., 2018) | “Daily consumption of SSBs was prevalent among adolescents. Daily intakes of ≥2 cups daily was consistently associated with higher odds of oral health impacts” (p.10) N = 3458; Adjusted OR = 5.21; 95% CIs = 2.67, 10.18 |

| Study Number 9 (Kim, Park & Lin, 2018) | “Tooth loss was positively associated with SSB intake frequency; the odds of losing 1–5 teeth were higher among adults drinking SSBs.” (p. 1) N = 22,526; P < 0.05 - Odds of losing 1–5 teeth were higher among adults drinking SSBs SSB>0–<1 times/day: OR = 51.44; 95% CI = (51.16–1.79) SSB 1–2 times/day: OR = 51.58, 95% CI = (51.25–1.99) SSB >2 times/day: OR = 51.97, 95% CI = (51.51–2.58) - The odds of losing >6 teeth were higher among adults drinking SSBs SSB 1–2 times/day: OR = 52.20, 95% CI = (51.15–4.22) SSB>2 times/day: OR = 52.81, 95% CI = (51.37–5.76) |

| Study Number 10 (Vega-López et al., 2018) | “This study confirmed the association between added sugar intake and self-reported dental outcomes among adults of Mexican origin and points to an urgent need to improve dietary behaviors in this population.” (p. 1) N= 326; P <0.05 |

| Study Number 11 (Song, Han, Ko, Y. Park, Ryu & J. Park, 2016) | “Consumption of carbonated beverages was positively associated with the risk of periodontal disease in Korean adults.” (p. 1) N = 5517 Beverage ≤1/month: AOR = 1.109; 95% CI = 0.804,1.528 Beverage ≤1/week: AOR = 1.404; 95% CI = 1.035,1.906 Beverage >2/week: AOR = 1.466; 95% CI =1.059,2.029 |
European Journal of Molecular & Clinical Medicine
ISSN 2515-8260 Volume 07, Issue 10, 2020

Study Number 12
(Zaidi et al., 2018)

“The dentine hypersensitivity is strongly associated with consumption and time to exposure of carbonated drinks.” (p. 71)
“Current study reported higher prevalence of mild levels of dental sensitivity problems among consumers of carbonated drink.” (p. 72)
N = 137; P = 0.045; R = 0.830

Study Number 13
(Lundeen et al., 2018)

These recommendations were informed by a systematic review of the evidence pertaining to amount of sugars and dental caries risk, which showed evidence of moderate quality from cohort studies that limiting free sugars to #10% of energy reduced, but did not eliminate, dental caries. Even low levels of dental caries in children are of concern because caries is a lifelong progressive and cumulative disease. (p. 149)
We found that respondents with obesity had significantly higher odds of consuming SSBs 1 or more times per day than underweight or normal-weight respondents. (p. 2) – focused on weight and overall health, not dental caries.
N = 75,029; p<0.001 for all
AOR range (18-54 years vs ≥55 years) = 1.82–7.84
SSB < 1/day: 41.5% intake; 95% CI = (40.4–42.6)
SSB ≥ 1/day: 32.1% intake; 95% CI = (31.0–33.2)

Source: Developed for the Research

Research Question 2: Does the amount or frequency of SSB consumption has greater effect on dental caries of adult patients?

The second research question of the study asked if the amount or frequency of SSB consumption or rate of SSB consumption has led to a higher impact on dental caries of adult patients. Results from all 13 studies are summarized in table 4.3. From the exhaustive analysis, it was uncovered that there exists a dose-response relationship between the frequency of SSB consumption and the impact on dental caries. Of the 13 studies reviewed, 8 research studies highlighted and explained how the increased and continuous exposure to SSBs could increase and intensify the dental caries of the adults (Bernabé et al, 2014; Hardy et al., 2018; Heller et al., 2001; Jain & Gary, 2014; Jamel et al., 1997; Kim, Park & Lin, 2018; Lundeen et al., 2018; Vega-López et al., 2018). According to Hardy (2018) the odds of oral health impacts being two- to three-fold higher (AOR = 2.41, 95% CI = (1.11–5.26)) among adolescents who drink two or more cups daily of SSBs. Also, increased frequency of SSB drinking were likely to have increased odds of tooth loss (OR = 52.81,95%CI = (51.37–5.76)) among young adults (Kim, Park & Lin, 2018). Four of the 13 studies have undetermined the relationship between frequency of SSB’s consumed and effect on dental caries among adults, as the frequency of the SSBs intake was not compared in these studies (Jamieson, Song, Han, Ko, Y. Park, Ryu & J. Park, 2016; Lundeen et al., 2018; Maru & Narendran, 2012; Roberts-Thomson, & Sayers, 2010).

Table 4.3. Display of Themes Addressing RQ2

<table>
<thead>
<tr>
<th>Themes</th>
<th>Number of References</th>
<th>Percentage of References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determining a positive relationship between the frequency of SSB</td>
<td>8</td>
<td>62%</td>
</tr>
</tbody>
</table>
consumption and impact on dental caries

| Relationship is undetermined | 4 | 31% |
| Determining that there is no relationship between the frequency of SSB consumption and impact on dental caries | 1 | 8% |

Source: Developed for the Research

Table 4.4 Breakdown of the Studies Referencing RQ2

<table>
<thead>
<tr>
<th>Study Number</th>
<th>Extract of the study</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Study Number 1</strong> (Bernabé et al., 2014)</td>
<td>“There seems to be a dose–response relationship between frequency of SSB consumption and caries increment in adults. That association was consistent across socio-demographic characteristics, and more importantly, use of fluoride toothpaste.” (p. 952) 0 SSB/day: N = 493; 95% CI = (0.57–0.78) 1–2 SSB/day: N = 236; 95% CI = (0.67–0.98) 3+ SSB/day: N = 210; 95% CI = (0.70–1.06)</td>
</tr>
<tr>
<td><strong>Study Number 2</strong> (Jamel et al., 1997)</td>
<td>“Urban populations used more sugar in their tea. Drinking tea with two or more teaspoons of sugar per cup was strongly associated with increased caries.” (p. 216) N = 4152 “Sweet preference and dental caries relationship was stronger in the rural groups (r = +0.58, P&lt;0.001) than in the urban groups (r = +0.24, P&lt;0.001).” (Abstract)</td>
</tr>
<tr>
<td><strong>Study Number 3</strong> (Jain &amp; Gary, 2014)</td>
<td>“The amount of sugar-sweetened beverages, snack food consumption, plaque index, and age showed statistically significant relationships with the outcome variable-dental caries (P &lt; 0.05).” (Abstract) N = 76; p &lt; 0.05 (for all)</td>
</tr>
<tr>
<td><strong>Study Number 4</strong> (Forshee &amp; Storey, 2004)</td>
<td>“Overall, our findings dispute the recent reports that average consumption of sweetened beverages, especially regular carbonated soft drinks, may be a serious threat to good dental health” (p. 1816). P &lt; 0.05 Ages 25–40 years: N = 4143; R² = 0.18 Ages 41–60 years: N = 1796; R² = 0.15 Ages over 60 years: N = 3721; R² = 0.24</td>
</tr>
<tr>
<td><strong>Study Number 5</strong> (Maru &amp; Narendran, 2012)</td>
<td>“Results indicate high levels of dental caries as well as dental treatment needs among the study participants.” (P.385) N = 189; P &lt; 0.05</td>
</tr>
<tr>
<td><strong>Study Number 6</strong> (Jamieson,</td>
<td>Our study has shown that, in an Australian Aboriginal young adult cohort a higher prevalence of untreated dental decay was observed among those who consumed carbonated soft drink, fruit drinks or sweets every day or a few times</td>
</tr>
<tr>
<td>Study Number</td>
<td>Study Details</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------</td>
</tr>
<tr>
<td>7 (Heller et al., 2001)</td>
<td>“DMFS were seen in the four highest age groups (ages 25 years and older), with caries generally increasing with more sugared soda consumption servings per day”</td>
</tr>
<tr>
<td>8 (Hardy et al., 2018)</td>
<td>“There was a dose-response for total SSB intake with the odds of oral health impacts being two- to three-fold higher among adolescents who drink two or more cups daily of SSBs, compared with adolescents who do not drink SSBs”</td>
</tr>
<tr>
<td>9 (Kim, Park &amp; Lin, 2018)</td>
<td>“In conclusion, we observed individuals drinking increased frequency of SSBs were likely to have increased odds of tooth loss among young adults aged 18–39 years in the United States”. (p. 6) N = 22,526; P &lt; 0.05 - Odds of losing 1–5 teeth were higher among adults drinking SSBs SSB&gt;0–&lt;1 times/day: OR = 51.44; 95%CI = (51.16–1.79) SSB 1–2 times/day: OR = 51.58, 95%CI = (51.25–1.99) SSB &gt;2 times/day: OR = 51.97, 95%CI = (51.51–2.58) - The odds of losing &gt;6 teeth were higher among adults drinking SSBs SSB 1–2 times/day: OR = 52.20, 95%CI = (51.15–4.22) SSB&gt;2 times/day: OR = 52.81,95%CI = (51.37–5.76)</td>
</tr>
<tr>
<td>10 (Vega-López et al., 2018)</td>
<td>Participants who reported greater added sugar intake were more likely to have reported the presence of a toothache in the preceding 12 months, having been prescribed antibiotics for dental reasons, being less likely to floss daily, have reported eating or drinking within 1 hour before bed and have lower psychological acculturation (p. 1) N= 326; P &lt; 0.05</td>
</tr>
<tr>
<td>11 (Song, Han, Ko, Y. Park, Ryu &amp; J.</td>
<td>“Therefore, consumption of carbonated beverages may be considered to be an independent risk indicator of periodontal disease and we suggest that periodontal health of nonobese individuals may benefit from reduction of carbonated beverage consumption.” (p. 6) N = 5517 Beverage ≤1/month: AOR = 1.109; 95% CI = 0.804,1.528 Beverage ≤1/week: AOR = 1.404; 95% CI = 1.035,1.906</td>
</tr>
</tbody>
</table>
Park, 2016) Beverage >2/week: AOR = 1.466; 95% CI =1.059,2.029 P<0.05

**Study Number 12** (Zaidi et al., 2018)

“The dentine hypersensitivity is strongly associated with consumption and time to exposure of carbonated drinks.” (p. 71)

N = 137; P = 0.045; R = 0.830

**Study Number 13** (Lundeen et al., 2018)

“We found that respondents with obesity had significantly higher odds of consuming SSBs 1 or more times per day than underweight or normal-weight respondents.” (p. 2)

N = 75,029; p<0.001 for all

AOR range (18-54 years vs ≥55years) = 1.82–7.84

SSB < 1/day: 41.5% intake; 95% CI = (40.4–42.6)

SSB ≥ 1/day: 32.1% intake; 95% CI = (31.0–33.2)

Source: Developed for the Research

**Discussion**

The dietary risk factors for dental caries include a variety of juices and soft drinks, cocoa, breakfast cereals, yogurt, lemonades, cookies, ice-creams, chocolates, and jams. This indicates that sugar beverages come under the vital risk factors of dental diseases (Bernabé, 2016; Karlajainen, 2007; Schulte & Tsakos, 2019).

**Research Question 1: What is the relationship between sugar sweetened beverages (SSBs) and dental caries among the adult population?**

The selected studies in this review used a variety of measures to find the amount of SSB consumption but, the amount of sugar additives was not measured. Jain & Gary, (2014) declared that there is a strong relationship between the demographic variables of the participants which were linked to factors such as, beverage consumption, dental care, and the Decayed, Missed, and Filled Surfaces (DMFS) score of the individual. The findings of Feldens et al. (2019) also showed that participants with greater age and prolonged consumption of beverages reported with a greater DMFS score. According to Sunkyung et al. (2017), 26% of US adults lost one or more teeth is strongly associated with their SSB intake.

Out of the 13 studies, twelve studies associated the consumption of SSBs as a risk indicator of dental caries among the adult population caries (Bernabé et al., 2014; Jamel et al., 1997; Jain & Gary, 2014; Maru & Narendran, 2012; Jamieson, Roberts-Thomson, & Sayers, 2010; Heller et al., 2001; Hardy et al., 2018; Kim, Park & Lin, 2018; Vega-López et al., 2018; Song, Han, Ko, Y. Park, Ryu & J. Park, 2016, and Zaidi et al., 2018).

However, study 13, Lundeen et al. (2018), concluded that the amount of sugar intake from SSBs cannot be estimated. This could be because only the frequency of SSB consumption was considered rather than volume. Therefore, the study could not determine the relationship between SSBs and dental caries among the adult population. Study number 4, by Forshee and Storey (2004), disputed the previous reports that average consumption of sweetened beverages, especially regular carbonated soft drinks, maybe a serious threat to good dental health. The study claimed that there is little or no association between regular carbonated soft drinks (RCSD) consumption and decayed, missing, or filled surfaces due to disease (DMFS). The study concluded that prevalence of dental caries rely on good personal and dental hygiene, regular use of fluoridated toothpaste and mouthwashes, and regular care by dental professionals.
Research Question 2: Does the amount or frequency of SSB consumption has a greater effect on dental caries of adult patients?

Bernabé et al., (2014) examined the participants for every two months to monitor the SSB intake and it has been found that the adults who consume one to three sweetened drinks a day reported with 31% - 33% incidence rate of dental caries. Prevalence of dental caries increases with a higher frequency of SSB consumption because increased frequency of exposure to carbohydrates present in the SSBs extend the duration of acid production on tooth surface, thereby increasing prevalence of dental caries (Karjalainen, 2007; Skafida & Chambers, 2018; Wilder, Kaste, Handler, Chapple-McGruder, & Rankin, 2016).

Song et al. (2016) addressed the fact that the effect of SSBs differed in terms of the increased amount and frequency of SSB consumption. Laitala, Vehkalahti, and Virtanen (2018) conducted a randomized controlled trial in which, one group was exposed to the increased amount of SSB whereas the control group was exposed to the higher frequency of SSB consumption. The net amount of the carbohydrate contained in the SSB was kept similar in both the groups. It was found that the emergence of dental caries was different in both the groups as the frequency-controlled group has reported with a higher dental caries index (Lundeen et al., 2018). Jamel et al. (1997) posited that drinking tea with two or more teaspooons of sugar per cup was strongly associated with increased dental caries. Furthermore, Kim et al. (2018) claimed that an increased frequency of SSBs has the tendency of leading to increased odds of tooth loss among young adults aged 18–39 years in the United States. Also, Hardy et al. (2018) revealed that the “daily consumption of each SSB was significantly associated with oral health impacts, and the odds of oral health impacts are highest among adolescents who drank diet soft drinks”.

Finally, 8 studies concluded that the rate of dental caries and oral health implications were higher among adults who have a higher frequency of intake (between 1-2 times a day) of SSBs (Jain & Gary, 2014; Jamel et al., 1997; Kim, Park & Lin, 2018; Bernabé et al., 2014; Hardy et al., 2018; Heller et al., 2001; Lundeen et al., 2018; Vega-López et al., 2018). However, Forshee and Storey (2004) claimed that the consumption of SSB is not a risk indicator to an individual’s good dental health status, and they disputed the previous reports that average consumption of sweetened beverages, especially regular carbonated soft drinks, may be a serious threat to good dental health.

Literature focusing on the frequency of SSB consumption was found to be limited. Research is needed to compare and evaluate the effect of frequency and amount of SSB consumption in relation to dental caries. In the present review, most of the studies support that the increased frequency of SSB consumption had more effect compared to the amount of SSBs consumed. The studies determined that increased damage in dental caries could not be solely determined based on the increased amount or frequency of SSBs consumed. Instead, the researchers or scholars argued that factors such as dental treatment, other dietary habits, and demographics must also be investigated.

Therefore, the relationship must be explored further to find the risk factors strongly associated with dental caries. There is a need for prevention and treatment programs, and awareness about dental disease prevention. The studies revealed that urbanization and the concomitant increased exposure to sugars containing products increase the threshold for sweetness, and while urban populations use more sugar in their tea, drinking tea with two or more teaspoons of sugar per cup was strongly associated with increased caries.

Selection bias is evident in some of the studies, for example, Maru et al. (2012) focused on volunteers who only attended a dental clinic. The studies were majorly cross-sectional
researches, for example, in Jamieson et al. (2010), the dental component of Wave III was cross-sectional, which led to no assumptions of causality. Also, study by Forshee and Storey (2004), is limited, as the current dietary consumption patterns measured in a cross-sectional survey like NHANES III could not detect causal relationships, and some potentially important variables might not be included in NHANES III. Unfortunately, Jain et al. (2014) used only visual and tactile means for the collection of caries data, and it failed to acknowledge indicators such as past experience of decay, socioeconomic status, family history, and daily oral hygiene.

Future research directions that stem from the previous studies should be longitudinal studies that will determine how changes in dietary behavior throughout an individual’s life affect dental carriers and not cross-sectional studies. Future studies should aim to examine and compare both amount and frequency of sugar intake from other foods and oral health impacts because the properties of sugars' intake from SSBs or solid foods can be distinct.

**Conclusion**

The most significant risk factor for dental caries is found to be the sugar in different forms. This systematic review explored the relationship between SSBs and dental caries which is indeed positive and robust. Studies reported that more considerable amount and increased frequency of SSB consumption resulted in a greater prevalence of oral diseases and higher DMFT index scores. Comparison of the effect of the amount and frequency of SSB consumption on dental caries is also made and it is found that greater rate of SSBs consumption is more harmful to the oral health as compared to the more significant amount of the SSBs consumed. Therefore, it can be concluded that the increased frequency of SSBs adversely impact the oral health. Further studies are warranted to better explore the findings of the present study.

**References**
