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

Mounika Merugu

BDS, Mamata Dental College, Telangana, India
MPH, San Diego State University, California, USA.
Email: mounika.mergu91@gmail.com

Sileshini Kodali

BDS ,Mamata Dental College, Telangana, India,
MPH, Nova Southeastern University, Florida, USA.
kodalisileshini@gmail.com

Roshan Cherian

BDS, MDS, MSc. OMFS (Glas), FICOI (USA)
Director, Lakeside Centre for Health Promotion, Bengaluru , Karnataka, India.
Email: dr.roshancherian@gmail.com

Patel Kishan SanjayKumar

BDS, Ahmedabad Dental College and Hospital, Ahmedabad, Gujarat , India.

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 2.1. PEO Format as Applied in the Current Research Study

PEO Format	Factors Identified in the Current Study
Population	Adults having dental caries
Exposure	Consumption of Sugar Sweetened Beverages
Outcome	Impact of consumption, including amount and frequency SSBs on dental caries

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
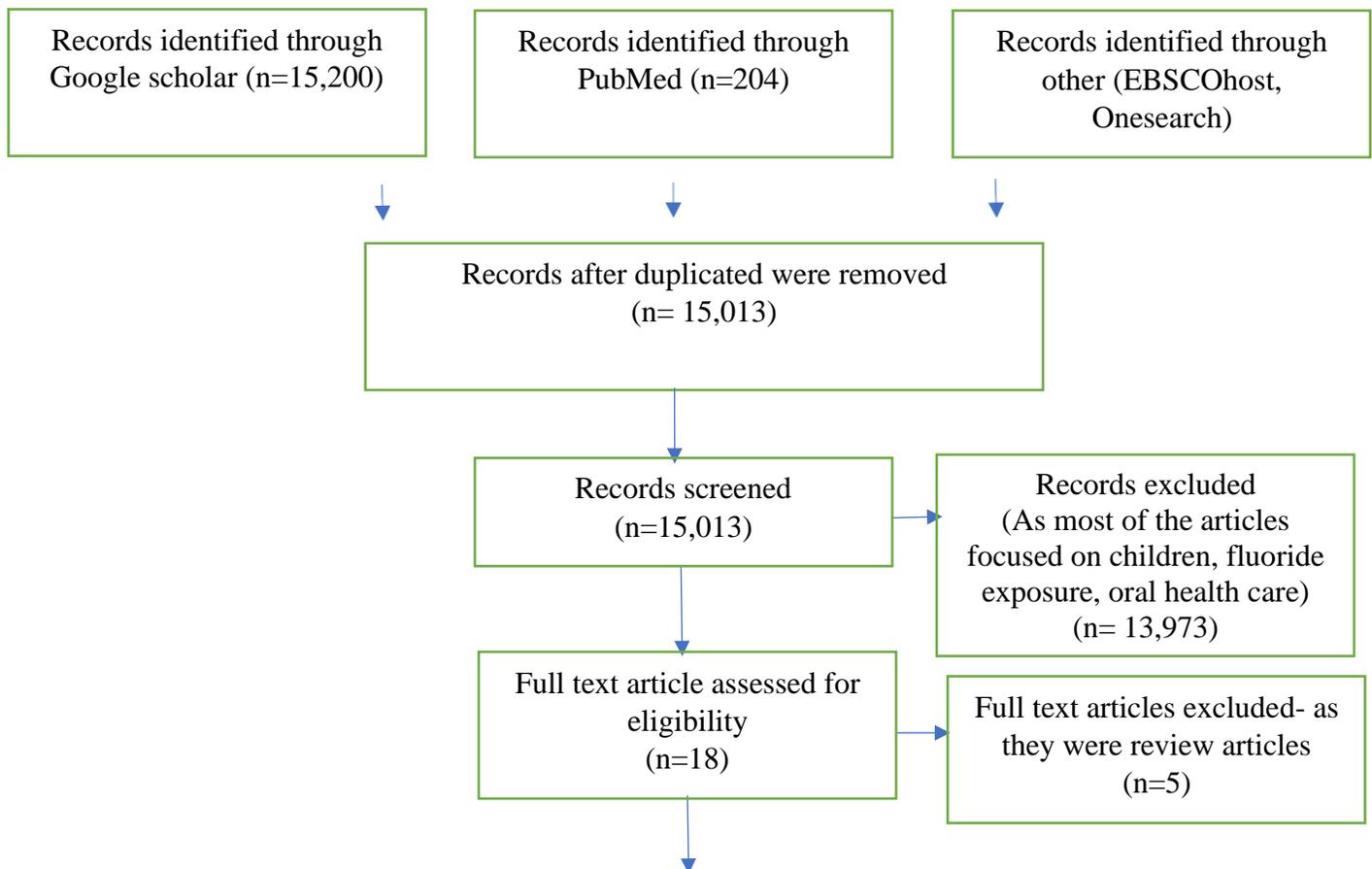
> Number of studies included in
> study
> (n=13)

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 dairy 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 ($R^2 = 0.18$), or the older age group ($R^2 = 0.24$). 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 4.1. Display of Studies Addressing RQ1

Themes	Number of References	Percentage of References
Determining a positive correlation between SSB consumption and dental caries among the adult population	12	92%
Determining no relation	1	8%

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

Study Number	Primary Findings
Study Number 1 (Bernabé et al, 2014)	"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)
Study Number 2 (Jamel et al., 1997)	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<0.001) than in the urban groups (r = +0.24, P<0.001)." (Abstract)
Study Number 3 (Jain & Gary, 2014)	"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 < 0.05). Snack food consumption was also much greater in those with dental caries (16 ounces) than in those without caries (9 ounces) (P < 0.05)." (p.65) N = 76; p < 0.05 (for all)
Study Number 4 (Forshee & Storey, 2004)	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 < 0.05 Ages 25–40 years: N= 4143; $R^2 = 0.18$ Ages 41–60 years: N=1796; $R^2 = 0.15$

	Ages over 60 years: N= 3721; R^2= 0.24
Study Number 5 (Maru & Narendran, 2012)	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 < 0.05
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

	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) "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 ≥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

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

Themes	Number of References	Percentage of References
Determining a positive relationship between the frequency of SSB	8	62%

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

Study Number	Extract of the study
Study Number 1 (Bernabé et al, 2014)	"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)
Study Number 2 (Jamel et al., 1997)	"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 ($r = +0.58$, $P<0.001$) than in the urban groups ($r = +0.24$, $P<0.001$)." (Abstract)
Study Number 3 (Jain & Gary, 2014)	"The amount of sugar-sweetened beverages, snack food consumption, plaque index, and age showed statistically significant relationships with the outcome variable-dental caries ($P < 0.05$)." (Abstract) N = 76; $p < 0.05$ (for all)
Study Number 4 (Forshee & Storey, 2004)	"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). $P < 0.05$ Ages 25–40 years: N= 4143; $R^2 = 0.18$ Ages 41–60 years: N=1796; $R^2 = 0.15$ Ages over 60 years: N= 3721; $R^2 = 0.24$
Study Number 5 (Maru & Narendran, 2012)	"Results indicate high levels of dental caries as well as dental treatment needs among the study participants." (P.385) N = 189; $P < 0.05$
Study Number 6 (Jamieson,	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

Roberts-Thomson, & Sayers, 2010)	weekly, or who consumed milk once a week or less often. (p.217) N = 141 (19-20 years age); p<0.05 SSB consumption every day/ few times a week: AOR 82.3; 95% CI (78.0–86.6) SSB consumption ≤ 1/week: AOR = 66.4; 95% CI = (58.5–74.3)
Study Number 7 (Heller et al., 2001)	"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". (p.1951) If the cariogenic effect of sugared soda on caries is cumulative, then statistically significant differences in caries might not be evident until after many years of high sugared soda consumption. (p. 1952) N = 15,570, p < 0.05
Study Number 8 (Hardy et al., 2018)	"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" (p.5) "Reductions in the frequency and volume of these beverages could have significant impact on adolescents' oral health, and potentially influence weight status." (p. 11) N= 3458 <1 cup/day AOR = 0.82; 95% CI = (0.43– 1.58) 1-2 cups/day AOR = 1.15; 95% CI = (0.58– 2.27) >2cups/day AOR = 2.41, 95% CI = (1.11– 5.26)
Study Number 9 (Kim, Park & Lin, 2018)	"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 < 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)	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 < 0.05
Study Number 11 (Song, Han, Ko, Y. Park, Ryu & J.	"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

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 teaspoons 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

1. Arifa, M.K., Ephraim R., et al. (2019). Recent advances in dental hard tissue remineralization: A review of literature. Int J Clin Pediatr Dent,12(2):139–144.

2. Armfield, J. M., Spencer, A. J., Roberts-Thomson, K. F., & Plastow, K. (2013). Water fluoridation and the association of sugar-sweetened beverage consumption and dental caries in Australian children. Am J Public Health, 103(3), pp. 494-500. doi:10.2105/AJPH.2012.300889.

3. Beaglehole, R. H. (2015). Dentists and sugary drinks. The Journal of the American Dental Association, 146(2), 73–74. doi:10.1016/j.adaj.2014.11.023

4. Bernabé E, Vehkalahti M. M., Sheiham A., Aromaa A., & Suominen A. L. (2014). Sugar-sweetened beverages and dental caries in adults: A 4-year prospective study. J Dent., 42(8):952-958. doi:10.1016/j.jdent.2014.04.011.

5. Bernabé E, Vehkalahti M. M., Sheiham A., Aromaa A., & Suominen A. L. (2016). The shape of the dose-response relationship between sugars and caries in adults. Journal of Dental Research, 95(2), pp. 167-72.

6. Chenicheri, S., R, U., Ramachandran, R., Thomas, V., & Wood, A. (2017). Insight into oral biofilm: Primary, secondary and residual caries and phyto-challenged solutions. The Open Dentistry Journal, 11(1), 312–333. doi:10.2174/1874210601711010312

7. Feldens, C. A., Kramer, P. F., Vargas-Ferreira, F. (2019). The role of diet and Oral hygiene in dental caries. In Pediatric Restorative Dentistry, pp. 31-55. Springer, Cham.

8. Forshee, R. A. & Storey, M. L. (2004). Evaluation of the association of demographics and beverage consumption with dental caries. Food Chem Toxicol, 42(11), pp. 1805-1816. doi:10.1016/J.FCT.2004.06.012.

9. Hardy, L. L., Bell, J., Bauman, A., Mihrshahi, S. (2018). Association between adolescents'

consumption of total and different types of sugar-sweetened beverages with oral health impacts and eight status. Australian and New Zealand Journal of Public Health, 42(1), pp. 22-6.

10. Heller, K. E., Burt, B. A, & Eklund, S. A. (2001). Sugared soda consumption and dental caries in the United States. J Dent Res, 80(10), pp. 1949-1953. doi:10.1177/00220345010800101701.

11. Heng, C. (2016). Tooth Decay Is the Most Prevalent Disease. Federal Practitioner, 33(10), pp. 31-33.

12. Jain, P. & Gary, J. J. (2014). Which is a stronger indicator of dental caries: oral hygiene, food, or   beverage? A clinical study. Gen Dent. 62(3):63-68. Retrieved from: http://www.ncbi.nlm.nih.gov/pubmed/24784517

13. Jamel, H. A., Sheiham A., Watt, R. G., & Cowell, C. R. (1997). Sweet preference, consumption of sweet tea and dental caries; studies in urban and rural Iraqi populations. Int Dent J., 47(4):213-217. Retieved from: http://www.ncbi.nlm.nih.gov/pubmed/9532462.

14. Jamieson, L. M., Roberts-Thomson, K., & Sayers, S. (2010). Dental caries risk indicators among Australian Aboriginal young adults. Community Dent Oral Epidemiol, 38(3), pp. 213-221. doi:10.1111/j.1600-0528.2009.00519.x.

15. Karlajainen, S. (2007). Eating Patterns, Diet and Dental Caries. Dent Update, 34(5), pp. 295-298.

16. Kim, S., Park, S., & Lin, M. (2017). Permanent tooth loss and sugar-sweetened beverage intake in US young adults. Journal of Public Health Dentistry, 77(2), pp. 148-54.

17. König, K. G., Schmid P., Schmid, R. (1968). An apparatus for frequency-controlled feeding of small rodents and its use in dental caries experiments. Arch Oral Biol, 13(1):13-26. http://www.ncbi.nlm.nih.gov/pubmed/5237553. Accessed December 10, 2018.

18. Laitala, M. L., Vehkalahti, M. M., Virtanen, J. I. (2018). Frequent consumption of sugar-sweetened beverages and sweets starts at early age. Acta Odontologica Scandinavica, 17;76(2):105-10.

19. Leedy, P. D. & Ormrod, J. E. (2015). Practical research: Planning and design. Essex: Pearson Education Limited.

20. Lundeen, E. A, Park, S., Pan L., &Blanck, H. M. (2018). Daily intake of sugar-sweetened beverages among US adults in 9 states, by state and sociodemographic and behavioral characteristics, 2016. Preventing chronic disease,15, E154.

21. Mantzari, E., Hollands, G. J., Pechey, R., Jebb, S., Marteau, T. M. (2018). Perceived impact of smaller compared with larger-sized bottles of sugar-sweetened beverages on consumption: A qualitative analysis. Appetite, 1(120), pp. 171-80.

22. Marshall, T. A. (2013). Preventing dental caries associated with sugar-sweetened beverages. The Journal of the American Dental Association, 144(10), pp. 1148-52.

23. Maru A. M, & Narendran S. (2012). Epidemiology of dental caries among adults in a rural area in India. J Contemp Dent Pract, 13(3), pp. 382-388. http://www.ncbi.nlm.nih.gov/pubmed/22918014. Accessed November 4, 2018.

24. Matsuoka, Y., Fukai, K. (2015). Adult dental caries and sugar intake. HSHC, 15(2015).

25. Mishra, M. B., & Mishra S. (2011). Sugar-sweetened beverages: General and oral health hazards in children and adolescents. Int J Clin Pediatr Dent, 4(2):119-123. doi:10.5005/jp-journals-10005-1094.

26. Moynihan, P. (2016). Sugars and Dental Caries: Evidence for Setting a Recommended Threshold for Intake. Advances in Nutrition, 7(1), 149–156. https://doi.org/10.3945/an.115.009365

27. Moynihan, P., Makino, Y., Petersen, P. E., & Ogawa, H. (2018). Implications of WHO Guideline on Sugars for dental health professionals. Community dentistry and oral epidemiology, 46(1), pp. 1-7.

28. Nadelson, S. & Nadelson, L.S. (2014). Evidence-based practice article reviews using CASP tools: A method for teaching EBP. Worldviews on Evidence-Based Nursing, 11(5),   pp. 344-346.

29. Park, S., Ayala, G. X., Sharkey, J. R., & Blanck, H. M. (2019). Knowledge of health conditions associated with sugar-sweetened beverage intake is low among US Hispanic adults. American Journal of Health Promotion, 33(1), pp. 39-47.

30. Petersen, P.E., Galea G., (n. d.). Diet and oral health. World Health Organization.

31. Pitts, N. B., Zero, D. T., Marsh, P. D., Ekstrand, K., Weintraub, J. A., Ramos-Gomez, F., … Ismail, A. (2017). Dental caries. Nature Reviews Disease Primers, 3, 17030. doi:10.1038/nrdp.2017.30

32. Ryan, C., Hesselgreaves, H., Wu, O., Paul, J., Dixon-Hughes, J., & Moss, J. G. (2018). Protocol for a systematic review and thematic synthesis of patient experiences of central venous access devices in anti-cancer treatment. Systematic Reviews, 7(1). doi:10.1186/s13643-018-0721-x

33. Schulte, A. G., Tsakos, G. (2019). The Joint ORCA-EADPH symposium on sugar: The oral health perspective–a commentary. Caries research, 53(2), pp. 145-8.

34. Skafida, V., & Chambers, S. (2018). Positive association between sugar consumption and dental decay prevalence independent of oral hygiene in pre-school children: A longitudinal prospective study. Journal of Public Health, 40(3), pp. 275-83.

35. Song, I. S., Han, K., Ko, Y., Park, Y. G., Ryu, J. J., & Park J. B. (2016). Associations between

the consumption of carbonated beverages and periodontal disease: The 2008–2010 Korea national health and nutrition examination survey. Medicine, 95(28).

36. Sunkyung, K., Sohyun P., Mei, L. (2017). Permanent tooth loss and sugar-sweetened beverage intake in U.S. young adults. Journal of Public Health Dentistry. ISSN 0022-4006

37. Thomas, J., & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. BMC Medical Research Methodology, 8(1). doi:10.1186/1471-2288-8-45

38. Young, D. A., Featherstone J. D. B, Roth J. R. (2007). Curing the silent epidemic: caries management in the 21st century and beyond. J Calif Dent Assoc, 35(10):681-685. Retrieved from: http://www.ncbi.nlm.nih.gov/pubmed/18044376.

39. Vega-López, S., Lindberg, N. M., Eckert, G. J., Nicholson, E. L., & Maupome, G. (2018). Association of added sugar intake and caries-related experiences among individuals of Mexican origin. Community dentistry and oral epidemiology, 46(4), pp. 376-84.

40. WHO. (2010). Oral health information systems. World Health Organization. Retrieved from: http://www.who.int/oral_health/action/information/surveillance/en/.

41. WHO. (2018). Reducing consumption of sugar-sweetened beverages to reduce the risk of childhood overweight and obesity. World Health Organization. Retrieved from: https://www.who.int/elena/titles/ssbs_childhood_obesity/en/. Published 2018.

42. WHO. (2017). Sugars and dental caries. World Health Organization.

43. Weed, D. L. (2018). The need for systematic reviews in oncology. JNCI: Journal of the National, 110(8), pp. 812-814.

44. Wilder, J. R., Kaste, L. M., Handler, A., Chapple-McGruder, T., & Rankin, K. M. (2016).

The association between sugar-sweetened beverages and dental caries among third-grade students in Georgia. Journal of Public Health Dentistry, 76(1), pp.76-84.

45. Zaidi, A., Karim, A. A., Mohiuddin, S., Khan, A., Syed, A., Jehangir, M., & Afzal, I. (2018). Dental sensitivity associated with consumption of fizzy drinks: A cross sectional study.   The Pakistan Journal of Medicine and Dentistry, 7(4),