Relationship Between Sugar Beverage Consumption, BMI And Caries Risk In Adolescents

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Abstract

Background: Sugar-sweetened beverages (SSBs) represent a significant source of added sugars in adolescent diets, potentially contributing to both obesity and dental caries. Understanding the interrelationships among these variables is essential for developing effective prevention strategies targeting adolescent health. Objective: This study aimed to investigate the relationship between sugar-sweetened beverage consumption, body mass index (BMI), and dental caries risk among adolescents, while exploring potential mediating and confounding factors. Methods: A cross-sectional study was conducted among 524 adolescents aged 12–17 years recruited from eight secondary schools. SSB consumption was assessed using a validated food frequency questionnaire. BMI was calculated from measured height and weight, with participants classified according to WHO age-specific criteria. Caries risk was evaluated using the DMFT index (Decayed, Missing, Filled Teeth) through clinical examination. Data analysis included descriptive statistics, correlation analysis, chi-square tests, ANOVA, and multivariate linear regression. Results: Mean SSB consumption was 4.8 ± 2.6 servings per week. Mean BMI was 22.4 ± 4.3 kg/m², with 28.6% classified as overweight/obese. Mean DMFT score was 3.2 ± 2.4. Significant positive correlations were observed between SSB consumption and BMI ($r=0.34$; $p<0.001$) and between SSB consumption and DMFT scores ($r=0.41$; $p<0.001$). High SSB consumers (≥7 servings/week) demonstrated significantly higher DMFT scores (4.6 ± 2.7) compared to low consumers (2.1 ± 1.8; $p<0.001$). Multivariate analysis confirmed SSB consumption as an independent predictor of both elevated BMI ($\beta=0.28$; $p<0.001$) and increased DMFT scores ($\beta=0.36$; $p<0.001$). Conclusion: Sugar-sweetened beverage consumption is significantly associated with both increased BMI and elevated caries risk in adolescents. Integrated public health interventions targeting SSB reduction may simultaneously address obesity and dental health concerns in this population.

Keywords: Sugar-sweetened beverages; dental caries; body mass index; adolescents; obesity; DMFT index.

1. Introduction

The global consumption of sugar-sweetened beverages (SSBs) has increased dramatically over recent decades, with adolescents representing one of the highest consuming demographic groups [1]. SSBs, defined as beverages containing added caloric sweeteners including sucrose, high-fructose corn syrup, or fruit juice concentrates, encompass sodas, sports drinks, energy drinks, sweetened teas, and fruit-flavored drinks [2]. These beverages contribute significantly to daily energy intake while providing minimal nutritional value, raising substantial public health concerns regarding their impact on youth health outcomes [3].

Adolescent obesity has reached epidemic proportions worldwide, with prevalence rates tripling over the past four decades in many developed nations [4]. Excessive body weight during adolescence is associated with numerous adverse health consequences, including type 2 diabetes, cardiovascular disease, metabolic syndrome, and psychosocial complications [5]. Dietary factors, particularly consumption of energy-dense, nutrient-poor foods and beverages, play a central role in the development of obesity [6]. Systematic reviews and meta-analyses have consistently identified SSB consumption as a significant contributor to weight gain and obesity risk in children and adolescents [7].

Dental caries remains the most prevalent chronic disease affecting children and adolescents globally, despite being largely preventable [8]. The World Health Organization estimates that approximately 60–90% of school-aged children experience dental caries in permanent teeth [9]. The cariogenic potential of sugars is well-established, with fermentable carbohydrates serving as substrates for acidogenic bacteria that demineralize tooth enamel [10]. SSBs present a particularly high caries risk due to their combination of high sugar content, acidic pH, and frequent consumption patterns [11].

Recent epidemiological evidence suggests potential interconnections between obesity and dental caries, though the relationship remains complex and somewhat controversial [12]. Both conditions share common dietary risk factors, particularly excessive sugar consumption, leading researchers to hypothesize that they may represent different manifestations of similar underlying behavioral and environmental determinants [13]. However, some studies have reported inverse or null associations, potentially reflecting the multifactorial nature of both conditions and methodological variations across investigations [14].

Several mechanisms may explain the relationship between SSB consumption and adverse health outcomes. From a metabolic perspective, liquid calories may not trigger satiety signals effectively, leading to incomplete caloric compensation and positive energy balance [15]. The rapid absorption of sugars from beverages may also contribute to insulin resistance and metabolic dysfunction [16]. Regarding oral health, the frequency of SSB consumption may be more detrimental than total sugar intake, as repeated acid attacks prevent adequate remineralization between exposures [17].

Contemporary adolescent beverage consumption patterns reflect broader societal changes including aggressive marketing, increased availability, and shifting cultural norms surrounding food and drink choices [18]. Understanding current consumption patterns and their health correlates is essential for designing effective interventions. Previous studies have often examined SSB relationships with obesity or dental caries independently, with fewer investigations exploring both outcomes simultaneously within the same population [19].

Despite accumulating evidence, several research gaps persist. Studies specifically examining the tripartite relationship among SSB consumption, BMI, and caries in adolescent populations remain limited. Furthermore, few investigations have utilized comprehensive assessment methods combining validated dietary instruments, measured anthropometric data, and standardized clinical dental examinations [20]. Additionally, most existing research originates from Western populations, with comparatively less data from diverse geographic and socioeconomic contexts.

The aim of this study was to investigate the relationship between sugar-sweetened beverage consumption, body mass index, and dental caries risk among adolescents. Specifically, we sought to: (1) describe current SSB consumption patterns; (2) examine associations between SSB consumption and BMI; (3) evaluate relationships between SSB consumption and caries experience; and (4) explore potential interactions among these variables while controlling for relevant confounders.

2.Materials and Methods

Study Design and Setting

This cross-sectional analytical study was conducted between March and August 2024 across eight secondary schools in an urban metropolitan district. Schools were randomly selected using cluster sampling methodology to ensure representation across diverse socioeconomic areas. The study protocol received approval from the Institutional Review Board for Health Sciences Research (Protocol Reference: IRB-HS-2024-0156) and adhered to the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from parents or legal guardians, with written assent from all participating adolescents.

Sample Size Determination

Sample size calculation was based on detecting a correlation coefficient of 0.15 between SSB consumption and DMFT scores, with 80% power and 5% significance level, yielding a minimum requirement of 346 participants. Anticipating potential incomplete data and non-participation, the target enrollment was set at 560 adolescents to ensure adequate statistical power for multivariate analyses.

Participants

Adolescents aged 12–17 years currently enrolled in participating schools were eligible for inclusion. Specific inclusion criteria comprised: (1) age between 12 and 17 years at enrollment; (2) residence in the study area for at least one year; (3) ability to complete dietary questionnaires independently or with minimal assistance; (4) willingness to undergo clinical dental examination. Exclusion criteria included: (1) diagnosed systemic conditions affecting metabolism or oral health (diabetes mellitus, thyroid disorders, Sjögren's syndrome); (2) current orthodontic appliances preventing accurate caries assessment; (3) use of medications affecting salivary function; (4) history of eating disorders; (5) special dietary requirements due to medical conditions.

Data Collection Instruments

Demographic Questionnaire: Participants completed a structured questionnaire collecting information on age, sex, grade level, parental education levels, household income category, and residence type. Additional items addressed oral hygiene practices (brushing frequency, fluoride toothpaste use, dental flossing) and dental service utilization patterns.

Beverage Consumption Assessment: SSB consumption was evaluated using a validated semi-quantitative food frequency questionnaire adapted for adolescent populations. Participants reported their usual consumption frequency and portion sizes for specific beverage categories over the preceding month: (a) carbonated soft drinks (regular); (b) fruit-flavored drinks; (c) sports drinks; (d) energy drinks; (e) sweetened tea and coffee beverages; (f) flavored milk drinks. Frequency options ranged from "never or less than once per month" to "three or more times daily." Standard serving sizes were defined as 250 mL (approximately 8 ounces). Total weekly SSB servings were calculated by summing consumption across all categories. Participants were categorized into low (<3 servings/week), moderate (3–6 servings/week), and high (≥7 servings/week) consumption groups.

Anthropometric Measurements: Height and weight were measured by trained research assistants using standardized protocols. Height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 213) with participants standing erect without shoes, heels together, and head positioned in the Frankfurt horizontal plane. Weight was measured to the nearest 0.1 kg using a calibrated digital scale (Seca 877) with participants wearing light clothing and no shoes. BMI was calculated as weight (kg) divided by height squared (m^2). Age- and sex-specific BMI z-scores and percentile rankings were determined using WHO growth reference data. Participants were classified as underweight (<5th percentile), normal weight (5th–84th percentile), overweight (85th–94th percentile), or obese (≥95th percentile).

Clinical Dental Examination: Dental caries experience was assessed using the DMFT index according to WHO criteria for oral health surveys. Examinations were performed by two calibrated dentists (inter-examiner kappa = 0.87; intra-examiner kappa = 0.91) under standardized conditions using natural light supplemented by headlamps, plane mouth mirrors, and WHO periodontal probes. Teeth were examined while wet, and compressed air was used when necessary. Each permanent tooth was classified as decayed (D), missing due to caries (M), or filled (F). Third molars were excluded from analysis. The DMFT score was calculated as the sum of decayed, missing, and filled permanent teeth per individual. Caries experience was categorized as low (DMFT 0–2), moderate (DMFT 3–5), or high (DMFT ≥6).

Procedure

Data collection occurred during regular school hours in designated examination rooms. Participants first completed the demographic and dietary questionnaires under supervision to ensure comprehension. Anthropometric measurements followed, conducted privately to minimize participant discomfort. Clinical dental examinations were performed last. All data were recorded on standardized forms and subsequently entered into a secure electronic database with double-entry verification.

Statistical Analysis

Statistical analyses were performed using SPSS version 28.0 (IBM Corporation, Armonk, NY, USA). Continuous variables were expressed as means with standard deviations, while categorical variables were presented as frequencies and percentages. Data normality was assessed using Shapiro-Wilk tests and visual inspection of histograms. Bivariate associations were examined using Pearson correlation coefficients for continuous variables and chi-square tests for categorical variables. Group comparisons were conducted using independent t-tests for two groups and one-way ANOVA with Tukey post-hoc tests for multiple groups. Multivariate linear regression models were constructed to identify independent predictors of BMI and DMFT scores, adjusting for potential confounders including age, sex, socioeconomic factors, and oral hygiene behaviors. Multicollinearity was assessed using variance inflation factors (VIF < 3 considered acceptable). Statistical significance was defined as $p<0.05$ for all analyses.

3.Results

Participant Characteristics

Of 560 adolescents invited, 524 completed all study components, yielding a participation rate of 93.6%. The mean age was 14.3 ± 1.6 years, with relatively equal sex distribution (51.1% female, 48.9% male). Demographic characteristics and oral health behaviors are summarized in Table 1.

Table 1: Demographic Characteristics and Oral Health Behaviors of Study Participants (N=524)

Variable	n (%) or Mean ± SD
Age (years)	14.3 ± 1.6
Sex	
Male	256 (48.9%)
Female	268 (51.1%)
Grade Level	
Middle school (7–9)	287 (54.8%)
High school (10–12)	237 (45.2%)
Parental Education (highest)	
Less than high school	86 (16.4%)
High school diploma	198 (37.8%)
University degree or higher	240 (45.8%)
Household Income	
Low	124 (23.7%)
Middle	276 (52.7%)
High	124 (23.6%)
Toothbrushing Frequency	
Once daily or less	112 (21.4%)
Twice daily	346 (66.0%)
More than twice daily	66 (12.6%)
Fluoride Toothpaste Use	
Yes	468 (89.3%)
No/Don't know	56 (10.7%)
Dental Visit (past 12 months)	
Yes	312 (59.5%)
No	212 (40.5%)
Daily Flossing	
Yes	142 (27.1%)
No	382 (72.9%)

Sugar-Sweetened Beverage Consumption Patterns

Mean total SSB consumption was 4.8 ± 2.6 servings per week. Carbonated soft drinks constituted the largest category (mean 2.1 ± 1.4 servings/week), followed by fruit-flavored drinks (1.3 ± 1.1 servings/week), sweetened tea/coffee (0.7 ± 0.8 servings/week), sports drinks (0.4 ± 0.6 servings/week), and energy drinks (0.3 ± 0.5 servings/week). Based on consumption categories, 28.4% (n=149) were classified as low consumers, 42.0% (n=220) as moderate consumers, and

29.6% (n=155) as high consumers. Male participants reported significantly higher SSB consumption than females (5.4 ± 2.8 vs. 4.2 ± 2.3 servings/week; t=5.12; p<0.001).

BMI and Weight Status

Mean BMI was 22.4 ± 4.3 kg/m². Weight status classification revealed 4.2% (n=22) underweight, 67.2% (n=352) normal weight, 18.1% (n=95) overweight, and 10.5% (n=55) obese. Combined overweight/obesity prevalence was 28.6%. Males demonstrated higher mean BMI than females (23.1 ± 4.5 vs. 21.8 ± 4.0 kg/m²; t=3.38; p<0.001).

Dental Caries Experience

Mean DMFT score was 3.2 ± 2.4 (range 0–14). Component analysis revealed mean decayed teeth of 1.8 ± 1.6, missing teeth of 0.3 ± 0.7, and filled teeth of 1.1 ± 1.4. Caries-free status (DMFT=0) was observed in 18.5% (n=97) of participants. Based on caries severity categories, 42.4% (n=222) had low caries experience, 36.8% (n=193) moderate, and 20.8% (n=109) high caries experience.

Associations Between SSB Consumption, BMI, and DMFT

Significant positive correlations were observed between SSB consumption and BMI (r=0.34; p<0.001), SSB consumption and DMFT scores (r=0.41; p<0.001), and BMI and DMFT scores (r=0.23; p<0.001). Comparison of variables across SSB consumption categories is presented in Table 2.

Table 2: BMI and DMFT Scores According to Sugar-Sweetened Beverage Consumption Categories

Variable	Low SSB (<3/week) n=149	Moderate SSB (3–6/week) n=220	High SSB (≥7/week) n=155	F/χ²	p-value
BMI (kg/m²)	20.8 ± 3.6	22.3 ± 4.1	24.4 ± 4.7	28.64	<0.001*
BMI z-score	0.24 ± 0.92	0.58 ± 1.04	1.02 ± 1.18	22.16	<0.001*
Weight Status				34.82	<0.001*
Underweight	10 (6.7%)	8 (3.6%)	4 (2.6%)		
Normal weight	116 (77.9%)	152 (69.1%)	84 (54.2%)		
Overweight	17 (11.4%)	42 (19.1%)	36 (23.2%)		
Obese	6 (4.0%)	18 (8.2%)	31 (20.0%)		
DMFT Score	2.1 ± 1.8	3.1 ± 2.2	4.6 ± 2.7	46.82	<0.001*
Decayed Teeth	1.1 ± 1.2	1.7 ± 1.5	2.7 ± 1.9	38.94	<0.001*
Missing Teeth	0.2 ± 0.5	0.3 ± 0.6	0.5 ± 0.9	8.76	<0.001*
Filled Teeth	0.8 ± 1.1	1.1 ± 1.3	1.4 ± 1.6	7.42	0.001*
Caries Category				52.68	<0.001*
Low (DMFT 0–2)	89 (59.7%)	94 (42.7%)	39 (25.2%)		
Moderate (DMFT 3–5)	44 (29.5%)	86 (39.1%)	63 (40.6%)		
High (DMFT ≥6)	16 (10.8%)	40 (18.2%)	53 (34.2%)		

*Statistically significant at p<0.05

Post-hoc analyses revealed significant differences between all pairwise comparisons for both BMI and DMFT scores (all p<0.05).

Multivariate Regression Analysis

Multivariate linear regression models examined independent predictors of BMI and DMFT scores (Table 3).

Table 3: Multivariate Linear Regression Analysis for Predictors of BMI and DMFT Scores

Predictors of BMI	β	95% CI	p-value
SSB consumption (servings/week)	0.28	0.19–0.37	<0.001*
Age (years)	0.14	0.06–0.22	0.001*
Sex (male)	0.12	0.03–0.21	0.008*
Low household income	0.09	0.01–0.17	0.034*
Physical activity (hours/week)	-0.16	-0.24– -0.08	<0.001*
Parental obesity history	0.22	0.14–0.30	<0.001*
Model R²	0.246		
Predictors of DMFT	β	95% CI	p-value
SSB consumption (servings/week)	0.36	0.28–0.44	<0.001*
Age (years)	0.18	0.10–0.26	<0.001*
Brushing frequency (<2x/day)	0.21	0.13–0.29	<0.001*
Non-fluoride toothpaste use	0.11	0.03–0.19	0.007*
Low household income	0.13	0.05–0.21	0.002*
No dental visit (past year)	0.15	0.07–0.23	<0.001*
BMI z-score	0.09	0.01–0.17	0.028*
Model R²	0.312		

*Statistically significant at $p<0.05$; β: Standardized regression coefficient; CI: Confidence Interval

Both models demonstrated acceptable fit and absence of multicollinearity (all VIF values <2.5). SSB consumption remained the strongest predictor of DMFT scores and a significant predictor of BMI after controlling for confounders.

4.Discussion

This study provides comprehensive evidence regarding the interrelationships among sugar-sweetened beverage consumption, body mass index, and dental caries risk in an adolescent population. Our findings demonstrate that SSB consumption is significantly and independently associated with both increased BMI and elevated caries experience, supporting the hypothesis that these outcomes share common dietary determinants.

The observed mean SSB consumption of 4.8 servings weekly aligns with recent surveys documenting substantial SSB intake among adolescents globally [21]. The predominance of carbonated soft drinks among SSB categories reflects persistent marketing influence and cultural preferences in this age group [22]. Higher consumption among males compared to females is consistent with established gender differences in beverage choices, potentially reflecting differential responses to advertising and social norms [23].

The positive association between SSB consumption and BMI supports extensive literature linking these variables. Our finding that high SSB consumers had mean BMI values 3.6 kg/m² higher than low consumers demonstrates clinically meaningful differences [24]. The dose-response relationship, with incremental increases across consumption categories, strengthens causal inference despite the cross-sectional design. Malik et al., in their comprehensive meta-analysis, reported similar effect sizes for SSB-obesity associations in pediatric populations [25].

Mechanisms underlying SSB-weight relationships involve multiple pathways. Liquid calories may bypass normal satiety mechanisms, failing to trigger compensatory reductions in solid food intake [26]. The rapid glycemic response to SSB consumption may promote insulin resistance and preferential fat deposition, particularly visceral adiposity [27]. Furthermore, SSB consumption often clusters with other unhealthy dietary and lifestyle behaviors, potentially amplifying obesity risk [28].

The robust association between SSB consumption and dental caries represents a central finding with significant public health implications. High SSB consumers demonstrated DMFT scores more than double those of low consumers (4.6 vs. 2.1), highlighting the substantial cariogenic impact of these beverages [29]. This relationship remained significant after controlling for oral hygiene behaviors and dental service utilization, suggesting that improved oral hygiene alone cannot fully compensate for high SSB consumption [30].

The cariogenic potential of SSBs relates to both their sugar content and acidic nature. Moynihan and Kelly, in their systematic review informing WHO sugar guidelines, established strong evidence for sugar-caries relationships, with SSBs representing particularly concentrated exposure [31]. Beyond fermentable sugars, the low pH of many SSBs (typically 2.5–3.5) contributes to dental erosion and may synergistically enhance caries development [32].

Our finding of a significant positive correlation between BMI and DMFT scores, though modest (r=0.23), contributes to ongoing debates regarding obesity-caries relationships. Hayden et al. conducted a meta-analysis revealing inconsistent findings across studies, potentially reflecting differences in age groups, diagnostic criteria, and confounding control [33]. The association observed in our data, coupled with independent effects of SSB consumption on both outcomes, supports the common risk factor approach proposed by Sheiham and Watt [34].

The multivariate models explaining 24.6% and 31.2% of variance in BMI and DMFT respectively indicate that while SSB consumption represents a significant contributor, additional factors influence both outcomes. Oral hygiene behaviors, dental service access, and socioeconomic factors all demonstrated independent associations with caries experience [35]. Similarly, physical activity and family obesity history significantly predicted BMI beyond dietary variables [36].

Socioeconomic disparities observed in our data merit attention. Lower household income was independently associated with both higher BMI and increased DMFT scores, consistent with social determinants of health frameworks [37]. These disparities may reflect differential access to healthy foods, healthcare services, and health information, compounded by targeted marketing of SSBs to disadvantaged communities [38].

Our findings carry important implications for public health policy and clinical practice. The shared dietary etiology of obesity and caries suggests that integrated interventions may efficiently address both conditions simultaneously. School-based nutrition education, restrictions on SSB marketing to youth, and fiscal policies such as sugar taxes represent promising population-level strategies [39]. At the individual level, dental professionals should incorporate dietary counseling into routine practice, particularly regarding SSB consumption [40].

Several limitations warrant acknowledgment. The cross-sectional design precludes causal inference regarding temporal relationships. Self-reported dietary data may be subject to recall bias and social desirability effects, though use of validated instruments minimizes these concerns. Our sample was drawn from urban schools, potentially limiting generalizability to rural populations. Additionally, unmeasured confounders including genetic factors, detailed dietary composition beyond SSBs, and environmental variables may influence observed associations.

Future research should employ longitudinal designs to establish temporal sequences and evaluate intervention effectiveness. Objective measures of dietary intake, including biomarkers, could enhance accuracy. Studies examining specific SSB types and consumption patterns (frequency vs. quantity) may inform more targeted recommendations. Investigation of effect modification by socioeconomic factors could support equity-focused intervention development.

5.Conclusion

This study demonstrates that sugar-sweetened beverage consumption is significantly associated with both elevated body mass index and increased dental caries experience among adolescents. These relationships persisted after adjustment for sociodemographic factors and behavioral confounders, supporting SSB consumption as an independent risk factor for both adverse outcomes. High consumers of sugar-sweetened beverages exhibited substantially greater BMI values and more than double the caries experience compared to low consumers, highlighting the considerable health impact of these beverages.

The identification of common dietary determinants for obesity and dental caries reinforces the value of integrated prevention approaches. Public health strategies aimed at reducing adolescent SSB consumption may yield dual benefits for metabolic and oral health outcomes. School-based interventions, parental education, environmental modifications limiting SSB availability, and policy measures addressing marketing and pricing represent promising avenues for comprehensive prevention.

Clinical practitioners in both dental and medical settings should routinely assess SSB consumption as part of preventive health counseling. Early identification of high-consuming adolescents enables targeted intervention before establishment of persistent dietary patterns and accumulation of disease burden. Collaborative approaches involving families, schools, healthcare providers, and policymakers are essential for creating environments supporting healthy beverage choices during this critical developmental period.

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