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Original Research

Correlation between sugar consumption and caries experience among high school students a cross-sectional study

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ABSTRACT:
Background: Free sugars are a primary dietary determinant of dental caries, particularly in adolescents with frequent snacking and sugar-sweetened beverage (SSB) intake. This study assessed the relationship between sugar consumption and caries experience among high school students. **Methods:** A school-based cross-sectional study was conducted among 400 students aged 14–17 year. Caries experience was recorded using DMFT. Sugar exposure was assessed using a short food frequency questionnaire and a 24-hour recall, estimating daily free-sugars intake (g/day) and frequency of SSB and sugary snack consumption. Associations were examined using Spearman correlation, non-parametric group comparisons, and multivariable logistic regression for caries experience (DMFT≥1). **Results:** Overall, 59.0% had DMFT≥1, with mean DMFT 1.72±1.84. DMFT increased across free-sugars categories: <25 g/day (1.01±1.33), 25–50 g/day (1.63±1.71), and >50 g/day (2.54±2.12) ($p<0.001$). Free sugars ($\rho=0.34$), SSB frequency ($\rho=0.29$), and between-meal sugary snacking ($\rho=0.25$) correlated positively with DMFT (all $p<0.001$). Adjusted odds of DMFT≥1 were higher for >50 g/day (AOR 3.12) and daily SSB intake (AOR 2.21), while brushing ≥2/day was protective (AOR 0.56). **Conclusion:** Higher sugar intake and frequent sugary exposures were independently associated with greater caries experience, supporting school-based sugar reduction strategies.
Keywords: dental caries; free sugars; sugar-sweetened beverages; adolescents; DMFT

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INTRODUCTION

Dental caries remains one of the most prevalent chronic diseases affecting children and adolescents worldwide, with substantial impacts on quality of life, school performance, and healthcare costs [1,2]. Despite improvements in fluoride exposure and preventive services in many settings, caries continues to show strong social and behavioral patterning, particularly in school-age populations who increasingly consume sugar-rich snacks and sugar-sweetened beverages (SSBs) [3]. Contemporary global evidence consistently identifies free sugars as the principal dietary determinant for caries initiation and progression, acting through frequent acid challenges that drive enamel demineralization [4]. The World Health Organization (WHO) recommends reducing free-sugars intake to <10% of total energy intake and suggests further reduction to <5% to minimize caries risk across the life course [5]. The relationship between sugar intake and caries is best

explained not only by the quantity of sugars consumed but also by the frequency and form of exposure (sticky solids, sweetened beverages, between-meal snacking), which determine the duration and magnitude of plaque pH drops and the time available for remineralization [4,6]. In a landmark systematic review conducted to inform WHO guidance, restricting sugars intake was associated with reduced caries, and a dose–response relationship was supported across study designs and age groups [7]. Additional analyses have suggested that caries risk continues to increase even at relatively low levels of sugars intake, particularly when exposures are frequent [6].

Adolescence is a critical period for caries risk because dietary autonomy increases, peer-driven snacking becomes more common, and school environments may facilitate access to inexpensive sugary foods and beverages. At the same time, oral hygiene routines may be inconsistent and dental visits may be symptom-driven rather than preventive. These factors create a practical need for school-based surveillance data linking sugar exposure patterns to caries outcomes, enabling targeted interventions such as healthy-canteen policies, behavior change programs, and sugar-reduction strategies [3,5]. Indian and other middle-income settings report varied but often substantial caries experience among schoolchildren, highlighting the importance of local risk profiling to support community prevention [8-10].

Although the mechanistic link between sugars and caries is well-established, quantifying this relationship in specific school populations using feasible dietary tools (frequency-based questionnaires and simple estimates of daily free sugars) can provide actionable information for local health systems. Therefore, the present study aimed to evaluate the association between sugar consumption (quantity and frequency indicators) and dental caries experience measured using DMFT among high school students. We hypothesized that higher daily free-sugars intake and higher frequency of sugary exposures—particularly SSB consumption and between-meal sugar intake—would correlate with greater DMFT and higher odds of having caries experience.

MATERIALS AND METHODS

Study design, setting, and participants

A school-based cross-sectional study was conducted among high school students (ages 14–17 years) in an urban district in India. A multistage sampling approach was used. In stage one, six schools (three government and three private) were selected by simple random sampling from an official school list. In stage two, students were recruited using systematic sampling from class rosters in grades 9–12.

Students were eligible if they were enrolled full-time, provided assent, and had parental/guardian consent. Students undergoing orthodontic treatment, those with systemic conditions affecting salivary flow, or those who had used antibiotics within the prior two weeks were excluded.

Sample size

The minimum sample size was calculated assuming a modest correlation ($r = 0.20$) between sugar intake and DMFT, with 95% confidence and 80% power. The required sample was inflated for clustering within schools and non-response, resulting in a final target of ≥360. A total of 412 students were examined; complete dietary and clinical data were available for 400 participants and were included in analysis.

Ethical considerations

Ethical approval was obtained from the institutional ethics committee. Permissions were obtained from school authorities. Confidentiality was maintained through coded identifiers, and clinical findings were shared with students along with referral advice when treatment need was observed.

Measures and data collection

Dental caries experience: Caries experience was recorded using the DMFT index (Decayed, Missing due to caries, Filled Teeth) for permanent dentition, following standard WHO oral health survey procedures. Examinations were performed in a well-lit room using sterile mouth mirrors and WHO periodontal probes, with infection-control protocols. One examiner performed all examinations. Intra-examiner reliability was assessed in 40 re-examinations after one week; the kappa for caries recording was 0.86.

Sugar consumption: Dietary exposure was assessed using a structured, pre-tested questionnaire with two components:

1. a short food frequency section capturing weekly frequency of (a) SSBs, (b) confectionery/chocolates, (c) sweet bakery items, and (d) sweetened tea/coffee; and
2. a single-day 24-hour recall assisted by portion-size prompts. Daily free-sugars intake (g/day) was estimated using standard nutrition labels/household measures and categorized into three pragmatic groups: **<25 g/day**, **25–50 g/day**, and **>50 g/day**, aligning with WHO's conditional and strong recommendation thresholds as practical cut-offs for adolescent counseling [5].

Covariates: Data were collected on sex, age, type of school (proxy for socioeconomic gradient), toothbrushing frequency (≤1 vs ≥2 times/day), use of fluoridated toothpaste (self-report), and dental visit in the past year.

Statistical analysis

Data were analyzed using SPSS (v23). DMFT distribution was assessed; because DMFT was right-skewed, Spearman correlation was used for bivariate

associations between sugar indicators and DMFT. Group comparisons were performed using Mann–Whitney U or Kruskal–Wallis tests as appropriate. A multivariable logistic regression model estimated adjusted odds ratios (AOR) for caries experience (DMFT ≥1), entering free-sugars category and frequency indicators with covariates. Statistical significance was set at $p < 0.05$.

RESULTS

A total of 400 students (mean age 15.6 ± 1.1 years) were included. Overall, 236 students (59.0%) had caries experience (DMFT ≥1). Median DMFT was 1 (IQR 0–3), and mean DMFT was 1.72 ± 1.84.

Table 1. Participant characteristics and caries experience (n=400)

Variable	Category	n (%)	Mean DMFT ± SD	Caries experience (DMFT≥1) n (%)
Sex	Male	188 (47.0)	1.55 ± 1.73	104 (55.3)
	Female	212 (53.0)	1.87 ± 1.92	132 (62.3)
School type	Government	208 (52.0)	1.94 ± 2.01	132 (63.5)
	Private	192 (48.0)	1.48 ± 1.62	104 (54.2)
Brushing frequency	≤1/day	162 (40.5)	2.15 ± 2.05	112 (69.1)
	≥2/day	238 (59.5)	1.42 ± 1.65	124 (52.1)
Dental visit (past year)	No	278 (69.5)	1.86 ± 1.94	174 (62.6)
	Yes	122 (30.5)	1.41 ± 1.57	62 (50.8)

Narrative (Table 1): Caries experience affected 59% of students, with higher mean DMFT observed among government school students and those brushing once daily or less. Students reporting ≥2 daily brushing had lower mean DMFT and lower prevalence of caries experience than those brushing ≤1/day.

Table 2. Free-sugars intake category and DMFT (n=400)

Free sugars (g/day)	n (%)	Mean DMFT ± SD	Median (IQR)	Caries experience (DMFT≥1) n (%)
<25 g/day	118 (29.5)	1.01 ± 1.33	0 (0–2)	52 (44.1)
25–50 g/day	164 (41.0)	1.63 ± 1.71	1 (0–3)	98 (59.8)
>50 g/day	118 (29.5)	2.54 ± 2.12	2 (1–4)	86 (72.9)
Kruskal–Wallis		**p <0.001**		

Narrative (Table 2): A clear gradient was observed: students consuming >50 g/day had the highest mean and median DMFT and the greatest proportion with DMFT≥1. DMFT differed significantly across intake categories ($p<0.001$).

Table 3. Frequency of sugary exposures and caries experience (n=400)

Exposure frequency	Category	n (%)	Mean DMFT ± SD	Caries experience (DMFT≥1) n (%)
SSBs	≤2 times/week	168 (42.0)	1.23 ± 1.48	82 (48.8)
	3–6 times/week	148 (37.0)	1.78 ± 1.74	92 (62.2)
	Daily	84 (21.0)	2.63 ± 2.26	62 (73.8)
Sugary snacks (between meals)	≤2 times/week	146 (36.5)	1.18 ± 1.45	70 (47.9)
	3–6 times/week	172 (43.0)	1.83 ± 1.79	112 (65.1)
	Daily	82 (20.5)	2.48 ± 2.10	54 (65.9)

Narrative (Table 3): Students with daily SSB consumption demonstrated substantially higher DMFT and higher caries experience than those consuming SSBs ≤2 times/week. A similar frequency trend was observed for between-meal sugary snacking, supporting an exposure–response relationship.

Table 4. Correlation and multivariable model for caries experience (n=400)
A) Spearman correlations with DMFT

Variable	Spearman ρ	p-value
Free sugars (g/day)	0.34	<0.001
SSB frequency (times/week)	0.29	<0.001
Sugary snacks between meals (times/week)	0.25	<0.001
Brushing frequency (≥2/day vs ≤1/day)	-0.22	<0.001

B) Logistic regression outcome: Caries experience (DMFT ≥1)

Predictor	AOR	95% CI	p-value
Free sugars 25–50 g/day vs <25	1.72	1.03–2.86	0.038
Free sugars >50 g/day vs <25	3.12	1.76–5.52	<0.001
Daily SSBs vs ≤2/week	2.21	1.18–4.14	0.013
Brushing ≥2/day vs ≤1/day	0.56	0.35–0.90	0.016
Government vs private school	1.44	0.92–2.25	0.108

Narrative (Table 4): DMFT showed moderate positive correlations with free-sugars intake and sugary exposure frequencies and an inverse association with brushing frequency. After adjustment, higher free-sugars intake remained independently associated with caries experience, particularly >50 g/day (AOR 3.12). Daily SSB consumption also independently increased odds of DMFT≥1, while brushing ≥2/day was protective.

DISCUSSION

This cross-sectional study demonstrated a consistent and biologically plausible association between sugar consumption and caries experience among high school students. Both the quantity of free sugars (g/day) and frequency of sugar exposures (SSBs and between-meal sugary snacks) showed significant positive relationships with DMFT. Importantly, the association persisted after adjustment for brushing frequency and school type, suggesting that dietary sugars contribute independently to adolescent caries burden.

The observed gradient across free-sugars intake categories aligns with evidence that caries risk increases with higher sugars intake and that meaningful reductions in caries are achievable when sugars intake is restricted [11]. The findings also support the concept that even in fluoride-exposed populations, sugars remain a dominant upstream driver for caries development, because fluoride primarily modifies demineralization–remineralization dynamics rather than eliminating repeated acid challenges caused by frequent sugar intake [12]. The WHO recommendations that free sugars be limited to <10% energy, ideally <5%, reflect this caries-focused evidence base and provide an interpretable framework for adolescent counseling and school health policy [13].

Frequency effects were prominent in our data: students consuming SSBs daily had markedly higher DMFT than those consuming them ≤2 times/week. This supports the established mechanistic pathway in which beverages deliver sugars in a readily fermentable form, often consumed repeatedly through the day, thereby extending the “Stephan curve” acid exposure time and hindering remineralization. Population studies in adolescents have similarly reported that higher sweetened beverage intake is associated with worse dental outcomes, while healthier beverage patterns (e.g., milk, water) are relatively protective [14]. Our results also mirror evidence from school-based observational studies indicating sugary foods and drinks as behavioral risk factors for caries, reinforcing the need to address both beverage and snack choices in prevention programs [15].

From a public health perspective, these results are particularly relevant because adolescent sugar consumption is shaped by modifiable environments: school canteens, nearby vendors, and marketing. The high prevalence of caries experience (59%) in this cohort is consistent with the global picture that untreated caries and caries experience remain widespread and consequential, despite being largely preventable [1,2]. Global estimates have highlighted untreated caries as a highly prevalent condition, underscoring that clinical care alone is insufficient without population-level prevention and risk-factor control [16]. Additionally, the broader oral disease burden described in global health literature emphasizes common-risk-factor approaches, where sugar reduction benefits oral and general health simultaneously [1,13].

Toothbrushing frequency showed a protective association in our analysis, consistent with the understanding that fluoride toothpaste use and plaque disruption lower caries risk. However, brushing did not eliminate the dietary risk gradient; students with high sugars intake still had higher DMFT. This reinforces contemporary preventive paradigms: fluoride and oral hygiene are necessary but not sufficient when sugar exposures are frequent and high. Therefore, school interventions should prioritize reduction of daily SSB intake and between-meal sugary snacking, while continuing to promote twice-daily brushing with fluoridated toothpaste [17-20].

This study has several strengths: a school-based sample including both government and private schools, standardized clinical DMFT recording with good intra-examiner reliability, and dietary measurement capturing both quantity and frequency indicators. Nevertheless, limitations should be acknowledged. First, the cross-sectional design precludes causal inference and cannot establish temporality; however, reverse causation is unlikely to explain the observed patterns because sugar consumption typically precedes caries development. Second, dietary exposure relied on self-report (FFQ + single 24-hour recall), which may underestimate true intake due to recall and social desirability bias. Third, we used DMFT, which captures lifetime caries experience rather than current activity; early non-cavitated lesions may be missed, potentially attenuating associations. Future studies could

incorporate lesion-based systems (e.g., ICDAS) and repeated dietary recalls to strengthen exposure assessment [21-26].

Overall, the present findings support actionable school-based recommendations: reducing free-sugars intake, eliminating daily SSB consumption, restricting sale of sugary snacks in and around schools, and integrating nutrition counseling into oral health promotion. Aligning local adolescent programs with WHO sugar guidance is likely to yield meaningful caries reductions and improve adolescent well-being.

CONCLUSION

Higher free-sugars intake and more frequent sugary exposures were significantly associated with greater dental caries experience (DMFT) among high school students. Students consuming >50 g/day of free sugars and those reporting daily sugar-sweetened beverage intake exhibited the highest DMFT values and increased odds of caries experience, even after adjustment for toothbrushing frequency and school type. Twice-daily toothbrushing showed a protective association but did not remove the dietary risk gradient, indicating that oral hygiene alone may be insufficient when sugar exposure is high. These findings support school-based and community-level prevention strategies that prioritize reduction in free-sugars intake—especially sugar-sweetened beverages and between-meal sugary snacks—alongside reinforcement of fluoride toothpaste use and regular preventive dental visits. Integrating sugar reduction into adolescent health programs may provide substantial benefits for oral health and overall well-being.

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