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# Sports supplement consumption, dental health, and salivary parameters in adolescent elite football players: A cross-sectional study

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## Abstract

**Background** Adolescent athletes frequently use sports supplements (SS) to enhance their performance. However, the increased consumption of SS has raised concerns regarding potential long-term associations with oral and dental health outcomes. This study aimed to examine the relationship between sports supplement use and dental health status, including the DMFT index and dental erosion, as well as salivary parameters of adolescent football players.

**Methods** Data on personal characteristics and SS use were collected from 52 participants. Dental health was assessed using the Decayed, Missing, and Filled Teeth (DMFT) index, Visual Dental Erosion Examination Index, and the Basic Erosive Wear Evaluation. Salivary parameters were analyzed using the GC Check Buffer.

**Results** The most frequently consumed SS were sports drinks (17.3%), sports bars (17.3%), and vitamin C (13.5%). No significant relationship was found between regular SS consumption and the DMFT index or dental erosion. However, the consumption of sports drinks was significantly associated with resting salivary pH, stimulated salivary volume (mL), and stimulated salivary pH ($p < 0.05$).

**Conclusions** In this cohort, sports drink consumption was associated with salivary parameters, including salivary pH and stimulated saliva volume, in exploratory unadjusted analyses. These findings may indicate hypothetical salivary changes, although no corresponding clinical differences in DMFT or erosion were detected in this sample. Consequently, awareness regarding sports drink use among adolescent athletes should be increased as a precautionary measure.

**Keywords** Adolescent, Dietary supplements, Soccer, Dental health, Saliva

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## Background

The World Health Organization defines health as "a state of complete physical, mental, and social well-being and not merely the absence of disease or disability" [1]. Indirectly, total health status is affected by physiological health, psychological state, social relationships, and environmental factors. Oral health, a crucial component of overall health, is particularly significant in adolescents, a sensitive population. Good oral health contributes to an individual's ability to perform daily activities comfortably [2, 3]. It is reported that establishing oral care as a habit during this period, when an individual's lifestyle is being determined, contributes to the protection and improvement of oral and dental health [4]. Al Anouti et al. state that increased tooth brushing frequency is a protective factor against dental caries, empowering individuals to take control of their oral health [5]. Oral care habits acquired during adolescence also play a significant role in promoting overall health [4]. Additionally, most research on adolescent oral health has focused on sugary and acidic drinks [6–9].

Sports supplements (SS) are products intended to enhance dietary intake or performance, encompassing hydration solutions, macronutrient powders, ergogenic aids, and micronutrients. They are also reported to significantly affect oral and dental health. In particular, sports drinks used to improve hydration and performance are reported to contain relatively high levels of carbohydrates, salt, and citric acid and have been found to trigger erosive tooth wear when consumed in large amounts during exercise [10]. Following this consumption pattern, several studies have reported that adolescent athletes' excessive intake of high-sugar, acidic beverages may significantly increase their DMFT index [11, 12]. Furthermore, Silva and colleagues identified energy drink consumption as a risk factor for dental erosion in athletes [13], a finding consistent with other research involving adolescent populations, which found that isotonic drinks contribute to erosive dental lesions [14]. Consequently, frequent consumption of these beverages throughout the day has also been reported to decrease salivary pH [15–18].

Elite adolescent athletes are a key group, as their intense training and frequent supplement use may increase oral health risks. Previous studies focused specifically on the dental effects of only sports drinks [19, 20]. However, the modern sports nutrition landscape includes a much wider variety of SS, such as sports foods, macronutrient powders, and vitamin and mineral supplements [21]. Despite documented risks associated with beverages, there remains a significant research gap regarding the impact of this whole, multi-form spectrum of supplements on comprehensive oral health indicators. Based on this, we hypothesized that various SS consumptions can influence salivary parameters and dental health indicators in elite football (soccer) players aged 14–17 years. Additionally, there is a lack of research evaluating the relationship of SS on comprehensive indicators, including the DMFT index, dental erosion, and salivary parameters simultaneously. Therefore, more inclusive research is needed to examine these associations in adolescent athletes. The primary objective of this study was to examine the association between SS usage profiles, dental health, and salivary parameters in adolescent elite male footballers aged 14–17 years in Türkiye.

## Materials and methods

### Study design

This cross-sectional study included a comprehensive data collection process. The minimum sample size for the present study was determined using an a priori power analysis conducted with G*Power v3.1. Because one of the primary outcomes of interest was the association between SS use and dental health indicators, the calculation was based on a two-tailed point-biserial correlation model. A moderate expected effect size was assumed ($r$ = 0.375), guided by Cohen's conventional benchmarks for effect size interpretation [22]. With a Type I error rate of $\alpha = 0.05$ and a target power of $1-\beta = 0.80$, the required minimum sample size was estimated as 50 participants. After obtaining institutional permission from the football club, the study was initiated with the approval of the Üsküdar University Clinical Research Ethics Committee [Meeting Date: 22.03.2023; Meeting No: 02]. All procedures were conducted in accordance with the principles outlined in the Declaration of Helsinki. Since all participants were under 18, written informed consent was obtained from their parents or legal guardians prior to their inclusion in the study. Additionally, assent was obtained from the adolescent participants themselves. Participant data were anonymized and handled in a confidential manner.

Participants were recruited from the U14, U15, U16, and U17 youth academy teams of a professional Super League football club in İstanbul, Türkiye. The study was conducted at the club's main training facilities, where athletes from different age groups follow a standardized athletic training program. While these players are enrolled in various schools throughout the city, they represent a unified high-performance group managed under a single athletic infrastructure. A total of 59 male adolescent players aged 14–17 years were assessed during scheduled weekly club visits. Participants arrived at the training facilities one hour prior to their sessions and were assessed sequentially (maximum of two at a time). All study procedures were completed in approximately 15–20 min per participant.

To ensure the highest methodological standardization and eliminate inter-examiner bias, both saliva collection and subsequent analyses were performed by a different single qualified dentist. Consequently, participants were not processed simultaneously; instead, they were assessed sequentially. This approach was intentionally adopted to maintain strict consistency in the collection technique and to ensure each participant was closely monitored. All sessions commenced in the late afternoon, immediately prior to the scheduled evening training sessions, ensuring that all samples were collected within a narrow, consistent time window to minimize circadian influence.

To ensure consistency and account for circadian variations, these assessments were conducted at the same time of day and on the same day of the week, immediately before the athletes' regular 60–90-minute late-afternoon training sessions. Furthermore, to maintain a standardized oral environment and minimize confounding effects on salivary pH and flow rate, a strict pre-assessment protocol was enforced. Participants were required to avoid any strenuous exercise for 24 h prior to the session, ensuring they were in a rested state and had not performed any physical activity on the day of testing. Additionally, participants restricted all solid food intake for at least 2 h. In accordance with the saliva analysis kit's standard manufacturer instructions, they were also strictly instructed to avoid all other beverages, water intake, smoking, and toothbrushing for at least 1 h before the examination. Compliance with all fasting, dietary, and behavioral restrictions was verbally verified by the investigators prior to commencing sample collection.

Inclusion criteria required enrolment in the club's youth academy, availability for the late-afternoon pre-training assessment, and completion of the study procedures, including the questionnaire, dental examination, and saliva sampling, as applicable. All participants were required to be active members of the club's youth academy for at least 6 months. Exclusion criteria were incomplete questionnaire data and clinical assessments that prevented exposure or outcome ascertainment. Seven players were excluded for these reasons, resulting in a final analytic sample of 52 participants. Tobacco and nicotine use were assessed in the data collection form, and no participant reported current use. While the primary analytical sample remained at 52, some salivary parameters had missing data due to insufficient sample volume. Specifically, saliva hydration was available for 47 participants, while other salivary markers were successfully analyzed for 50 participants. These missing values occurred randomly and were handled using pairwise deletion in the statistical analyses.

### Data collection process

The data collection form included questions on socio-economic status, anthropometric parameters, and eating behaviors (fruit juice and acidic drinks). It also covered medication use (e.g., aspirin), disease conditions (e.g., reflux), allergies (e.g., asthma), sports and training programs, SS use, and oral hygiene habits. General dietary and oral health habits were evaluated using a multi-categorical frequency scale, such as 'Never' or 'Rarely.' For specific multiple-response behavior questions, participants could select up to three options. This approach followed the original, validated survey instrument design. The entire comprehensive questionnaire was administered to all participants ($n = 52$) without any conditional logic or filtering.

Supplement consumption-related questions were adapted from previously used questionnaires, applied in different countries and branches to evaluate athletes' supplement use. The questionnaire items and supplement categorization were informed by the systematic review and meta-analysis conducted by Knapik et al. [23], in which this instrument was reviewed and classified among established tools for assessing supplement use in athlete populations. To ensure its appropriateness for the current study, we selected a version that has been previously applied to similar youth elite athlete cohorts (aged 12–17 years) in the literature [24]. In this context, sports drinks, sports gels, sports bars, sports confectionary, electrolytes, whey, animal, plant-based proteins, casein, amylopectin, cyclodextrin, dextrose, carbohydrate powder, isomaltulose, maltodextrin, iron, calcium, vitamin D, zinc, multivitamins, mineral complexes, probiotics, prebiotics, omega-3, omega-6, vitamin C, caffeine, beta-alanine, bicarbonate, beetroot juice, creatine monohydrate, glycerol, carnitine, coconut oil, essential amino acids, chitosan, pre-workout formulas, ginseng, magnesium, alpha-lipoic acid, 5-HTP, branched chain amino acids, leucine, quercetin, phosphate, fruit polyphenols, antioxidants (N-acetyl cysteine), menthol, quinine, curcumin, ketones, and fish oil consumptions were evaluated.

Although the data collection form initially categorized regular supplement use as 1–2 times per week, 3–4 times per week, and more than 5 times per week, the data were subsequently analyzed as yes/no, since the number of people using supplements twice a week was very low. Consequently, SS exposure was analyzed strictly as a binary variable, classifying individuals into two baseline groups: 'users' (those consuming a specific supplement at least once per week) and 'non-users.'

### Dental examination

The dental examinations, including the DMFT (decayed (D), missing (M), filled (F) teeth (T)) index, the Basic Erosion Wear Examination (BEWE), and the Visual Erosion

Dental Examination (VEDE) Index scoring, were performed by a dentist with over 10 years of experience in the field. Because the examiner was not involved in questionnaire administration or data entry, the dentist remained blinded to participants' sports supplement consumption throughout the clinical assessments. Formal intra-examiner calibration with repeat scoring was not conducted as part of the study protocol.

#### *DMFT index determination*

In this study, the DMFT index was explicitly selected for its feasibility in large-scale settings and to ensure comparability with existing epidemiological surveillance studies. The DMFT index, a landmark in dental health assessment, was developed by Klein, Palmer, and Knutson (1938) to evaluate dental caries. It has become an essential tool for monitoring trends in dental caries distribution. The DMFT, which describes the number of dental caries in an individual, quantifies caries prevalence and is calculated by summing the number of caries [25]. The WHO has adopted this index for oral health assessment in its oral health assessment form for national oral health surveys [26]. This index is valid, reproducible, and reliable, and provides a rapid assessment. It is still used to evaluate and compare the caries status of population groups worldwide. To ensure maximum internal consistency, all examinations were performed by a single, experienced clinician who routinely uses the DMFT index in daily clinical practice. While several studies acknowledge that higher-sensitivity indices, such as ICDAS, can capture earlier non-cavitated lesions and may be preferable in future work aimed at early detection [27–29], the DMFT index remains the preferred tool for maintaining consistency with global and national benchmarks.

Examination of dental caries in permanent teeth involves assessing all 32 permanent teeth, including wisdom teeth, using a metallic periodontal probe (Community Periodontal Index-probe) and a plane mouth mirror. Non-cavitated lesions are excluded from the index [27]. Each tooth is assigned a single score. For example, secondary caries found in a restored tooth receives only a D score. Only teeth lost due to decay should be recorded as missing teeth. Teeth with a poor prognosis requiring extraction should also be included in this category. The tooth is still considered present when only the tooth roots remain. Teeth with fissure sealant or fixed dental prosthesis/bridge abutment, unique crown, or veneer/implant code are not included in DMFT calculations. The DMFT score in adults can range from 0 to 32. A score of 32 is the maximum, meaning every permanent tooth has been affected by dental caries (i.e., decayed, missing, or filled) [26]. The sum of three numbers creates the DMFT value. For example, 4-3-9 = 16 DMFT means four teeth are decayed, three are missing, and nine are filled. It also means that 12 teeth are intact. The average number of DMFTs is calculated by dividing the sum of individual DMFT values by the total population.

#### *Basic erosive wear assessment*

Bartlett et al. introduced the BEWE, developed for general clinical use. This index is based on dividing the patient's mouth into six regions [17 – 14=1st region, 13–23 = 2nd region, 24–27 = 3rd region, 37 – 34=4th region, 33–43 = 5th region, and 44–47 = 6th region], scoring the teeth most affected by erosion in each region, and summing the final scores [30]. The total score and this method determine the severity of erosion, which is one of the most commonly used indices today [*Supplemental Table 1*].

#### *Visual erosion dental examination*

Mulic et al. developed the VEDE Index as a modified version of Lussi's index published in 1996. The researchers found the BEWE index to be inadequate, as it scores only the highest value in each of the six regions of the mouth. They recommended that all tooth surfaces be evaluated separately. In addition, unlike the BEWE index, the VEDE index provides more detailed scoring, particularly when dentin is exposed [31]. The VEDE scoring system is given in *Supplemental Table 2* [31].

* The presence of dental erosion was operationally defined using a combined threshold: a participant was classified as erosion (+) if they scored above zero on either the VEDE or BEWE indices (VEDE > 0 or BEWE > 0). This inclusive criterion was chosen to ensure that any early-stage or localized erosive wear was fully captured. In cases of discordance (observed in only one participant), we categorized the individual as erosion-positive to adopt a conservative approach, ensuring that any potential evidence of dental erosion was not overlooked. To ensure the robustness of the findings and rule out the potential overestimation of outcomes, the statistical analyses were re-evaluated using an alternative, stringent joint threshold for erosion-positive status (VEDE > 0 and BEWE > 0). These findings are presented in Supplemental Table 3.

### Saliva analysis

The GC Saliva Check Buffer kit is a widely used tool for saliva analysis, providing an assessment of both resting and stimulated saliva. It evaluates key parameters, including saliva quantity and quality, pH, and buffering capacity. In strict accordance with the manufacturer's guidelines, saliva sampling was conducted immediately prior to the scheduled training session to evaluate the baseline parameters under the standardized pre-assessment conditions detailed above. After the procedures were explained to the participants, saliva samples were collected, handled, and evaluated precisely according to the kit protocol.

#### *Testing resting saliva*

In the initial stage, the hydration level of unstimulated saliva was visually assessed. The lower lip was turned upside down, and the labial mucosa was gently blotted with gauze. The minor salivary glands were observed under adequate lighting. If the period in which saliva droplets begin to form in the minor salivary glands located in this region is more than 60 s, the resting saliva secretion is determined as low; if it is between 30 and 60 s, it is normal, and if it is less than 30 s, it is considered high. In the second stage, the participant was asked to spit into a cup to evaluate the viscosity of unstimulated saliva. Intraoral visual examinations were also performed on the participants. The saliva collection container was evaluated by examining it on a dark background. Unstimulated saliva is healthy and has a clear, watery consistency. A foamy, sticky, and bubbly appearance of saliva indicates increased viscosity. In the third stage, to determine the pH of unstimulated saliva, the pH test strip was placed on the saliva sample, and the strip's color was checked after 10 s, before it dried. The color of the pH test strip was evaluated according to the kit guidelines. A saliva pH of 5.0-5.8 indicates it is highly acidic, and a pH of 6.0-6.6 indicates it is moderately acidic. pH 6.8–7.8 is the healthy saliva pH range [32, 33].

#### *Testing stimulated saliva*

The participant was asked to chew the piece of wax for 30 s, then continue chewing while spitting it into the measuring cup for an additional 5 min. The amount of saliva collected in the graduated disposable cup was determined, and the pH was measured. If the amount of saliva collected was below 3.5 ml, the stimulated saliva secretion was recorded as very low; if it was between 3.5 and 5 ml, it was recorded as low. Stimulated saliva secretion in participants with saliva volume over 5.0 ml was considered normal.

In the last stage, buffering capacity was determined using the stimulated saliva collected in the previous stage. The buffering test strip, which had 3 test pads, was removed from its package and placed on a tissue with the test side facing up. One drop of stimulated saliva was placed on each pad, and excess saliva was removed by turning the strip 90 degrees. After waiting 2 min, the colors seen on the buffering test pad were scored according to the kit manual. If the total score is between 0 and 5, the buffering capacity is considered very low; between 6 and 9, it is considered low; and between 10 and 12, it is considered normal [32, 33].

### Statistical analysis

The data were analyzed using Jamovi (*Version 2.6.44*). Statistical analyses were conducted using a 95% confidence interval, and results with $p<0.05$ were considered statistically significant. The dependent variables were DMFT, dental erosion, and salivary parameters, while the independent variable was SS consumption. In this study, the absence of dental erosion was defined as a score of zero on both the VEDE and BEWE indices. Categorical variables were analyzed using the Chi-square test; however, Fisher's exact test was used for variables with small cell counts ($n<5$) to ensure statistical validity. Additionally, Odds Ratios (OR) with 95% confidence intervals (CI) were calculated to assess the associations. Due to the exploratory nature of the study and to preserve statistical power, no formal multiple-testing adjustment was performed. Because of the limited sample size, it was not possible to adjust for potential confounding factors, including daily intake of acidic drinks, consumption of sweets, or oral hygiene habits. Consequently, all statistical comparisons in this study are unadjusted and should be regarded solely as exploratory associations.

Since the Shapiro-Wilk test showed that the data were not normally distributed, non-parametric tests were used in the analysis. The Mann-Whitney U test was used for comparisons between two independent groups, and the Kruskal-Wallis test was applied for comparisons involving more than two groups. An exception was made for resting salivary hydration, which demonstrated a normal distribution and was therefore analyzed using the parametric Student's t-test. To support interpretation of the findings, OR with 95% CI were calculated for categorical comparisons, and effect sizes were included to assess the magnitude of group differences. Furthermore, given the small subgroup sample sizes, exact p-values and specific effect size metrics were consistently reported throughout the text and tables to ensure diagnostic transparency.

## Results

### Personal characteristics

Participants were male adolescent elite football players (100%). They were recruited from a professional Super League club and its youth academy program in Istanbul. The mean age of the participants was $14.4\pm1.34$ years, with a mean height of $172\pm9.4$ cm, and a mean weight of $58.4\pm10.8$ kg. The highest league levels played by the participants were 1.9% in U13, 48.1% in U14, 7.7% in U15, 15.4% in U16, 13.5% in U17, 7.7% in U19, and 5.8% in the Super League. The number of training sessions among participants was reported as $3.3\pm0.5$ days/week. The distribution of participants' training durations was 3.8% for 30–60 min, 67.3% for 60–90 min, and 28.8% for 90–120 min. Regarding behavioral patterns of supplement use, participants were permitted to select multiple

**Table 1** Frequencies of personal characteristics such as parental education status, aspirin use, nutrition, supplement use and oral hygiene

| Parameters | Subgroups | n (%) |
|---|---|---|
| *Parents education status (Mother n (%); Father n (%))* | Primary school | 24 (46.2%); 20 (38.5%) |
| | High school | 17 (32.7%); 22 (42.3%) |
| | University | 9 (17.3%); 9 (17.3%) |
| | Other | 2 (3.8%); 1 (1.9%) |
| *Aspirin use* | Yes | 13 (25%) |
| | No | 39 (75%) |
| *Acidic beverage consumption* | Every day | 5 (9.6%) |
| | A few times a week | 27 (51.9%) |
| | A few times a month | 9 (17.3%) |
| | Rarely | 9 (17.3%) |
| | Never | 2 (3.8%) |
| *Chocolate and sugar consumption* | Every day | 3 (5.8%) |
| | A few times a week | 27 (51.9%) |
| | A few times a month | 11 (21.2%) |
| | Rarely | 11 (21.2%) |
| *Sports supplements use* | Yes | 16 (30.8%) |
| | No | 36 (69.2%) |
| *Tooth brushing frequency* | Once a day | 20 (38.5%) |
| | 2–3 times a day | 24 (46.2%) |
| | Every other day | 3 (5.8%) |
| | Very rarely | 4 (7.7%) |
| | Never | 1 (1.9%) |
| *Would you go to the dentist for a check-up without complaints?* | Yes | 9 (17.3%) |
| | No | 43 (82.7%) |

options for specific survey items. Among the athletes who reported detailed usage patterns, the most frequent intervals for SS use were training days ($n = 9$) and a combination of training and competition days ($n = 6$). The primary motivations identified for using these products were to improve sports performance ($n = 18$) and to maintain overall health ($n = 11$). Additionally, the decision to use supplements was predominantly self-determined ($n = 12$) or guided by a coach/trainer ($n = 6$). In addition to supplement consumption, participants showed variation in their oral health behaviors. The frequency of changing toothbrushes among adolescents was reported as follows: 50.0% changed their toothbrushes every 3 months, 38.5% every 6 months, 9.6% once a year, and 1.9% every 2 years. Tooth brushing techniques likewise showed diversity, with 15.4% from top to bottom, 21.2% from right to left, 19.2% by rubbing, and 44.2% in all directions. In line with these behavioural patterns, the most consumed SS were determined as sports drinks (17.3%), sports bars (17.3%), vitamin C (13.5%), omega-3 (11.5%), multivitamin complex (7.7%), iron (7.7%), vitamin D (7.7%), caffeine (5.8%), and magnesium (5.8%). Allergies were detected in 21.2% of the participants, but no cases of reflux were reported. To ensure robust reporting, a primary inclusive definition

**Table 2** Descriptive statistics of participants' DMFT index, dental erosion, and salivary parameters

| Parameters | n | Mean ± SD | Median (Min – Max) | IQR |
|---|---|---|---|---|
| DMFT score | 52 | 4.31 ± 3.17 | 4 (0–12) | 4 |
| VEDE score | 52 | 0.045 ± 0.080 | 0.00 (0–0.32) | 0.04 |
| BEWE score | 52 | 0.654 ± 0.947 | 0.00 (0–4) | 1.00 |
| Resting saliva hydration (seconds)* | 47 | 26 ± 10.4 | 24.00 (8–55) | 14.3 |
| Resting saliva pH | 52 | 6.85 ± 0.266 | 6.80 (6.60–7.60) | 0.40 |
| Stimulated saliva volume (mL) | 50 | 9.36 ± 3.58 | 8.00 (3–20) | 3.75 |
| Stimulated saliva pH | 50 | 7.33 ± 0.296 | 7.40 (6.60–7.80) | 0.40 |
| Stimulated saliva buffering capacity score | 52 | 7.17 ± 1.70 | 7.00 (4–10) | 1.25 |

Sample size variations across analyses ($n = 47$, $n = 50$, or $n = 52$) are due to insufficient sample volume or analytical constraints during testing

*Resting saliva hydration showed normal distribution, other parameters showed non-normal distribution

was applied, yielding a dental erosion prevalence of 42.3% ($n$=22), with 30 participants (57.7%) classified as erosion (-).The overall prevalence of dental erosion was 40.4% ($n$= 21) using the dual-index-positive definition. A total of 31 participants (59.6%) were classified as erosion (-).

Apart from these, the percentage distributions of the participants' socio-demographic characteristics (1), consumption of chocolate, sugar, and acidic beverages (2), SS use (3), tooth brushing frequency, and irregular dental check-up habits (4) are given in Table 1.

### Dental examination and salivary parameters

Descriptive statistical analysis of the DMFT index, dental erosion-related scores (VEDE and BEWE), and salivary parameters was given in Table 2. The mean of the DMFT index score was 4.31 ± 3.17. The level of dental erosion among participants was relatively low, as indicated by the VEDE and BEWE scores.

According to Fig. 1, resting saliva hydration levels were classified as low (1.9%), normal (32.7%), and high (65.4%). Resting saliva viscosity was reported as sticky/foamy in 19.2%, foamy/bubbly in 38.5%, and watery/clear in 42.3% of the participants. Additionally, approximately 90% of the participants demonstrated normal stimulated salivary secretion. Finally, the buffering capacity of stimulated saliva was very low in 15.4% of participants, low in 71.2%, and normal or high in 13.5%.

### DMFT index related analyses

A significant relationship was found between visiting the dentist only when necessary and the DMFT index (U = 110; *p = 0.043; rrb: 0.432*). No significant relationship was found between the DMFT index and the use

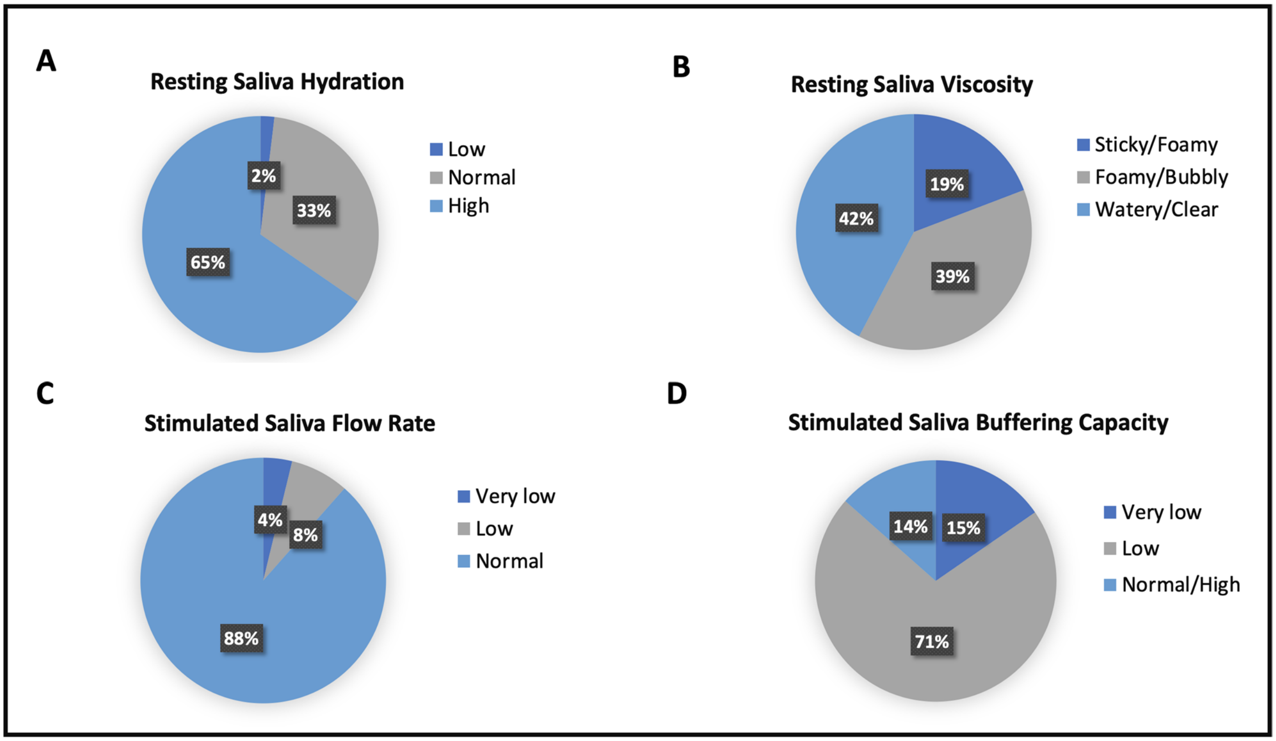


**Fig. 1** Distributions of resting saliva hydration (**A**), resting saliva viscosity (**B**), stimulated saliva secretion (**C**) and stimulated saliva buffering capacity (**D**)

of aspirin, the presence of allergies, the consumption of sugar, chocolate, and acidic beverages, parental education level, the frequency of toothbrushing and toothbrush replacement, and the brushing technique.

Importantly, no significant relationship was found between supplement consumption, the primary focus of the study, and the DMFT index. Moreover, none of the supplement types consumed by the participants showed a statistically significant relationship with the DMFT index (Table 3).

### Dental erosion related analyses

The study found a statistically significant relationship between aspirin use and tooth erosion ($X^2$= 5.15, $p = 0.049$, $\Phi = 0.32$), with implications for dental care. Furthermore, no significant relationship was found between dental erosion and personal characteristics, including sociodemographic factors, dietary habits, and oral hygiene practices. Notably, there was no significant relationship between dental erosion and SS consumption. For a more detailed analysis, please refer to Table 4.

To ensure the robustness of our primary findings, a sensitivity analysis was performed using a more stringent threshold for erosion-positive status (VEDE > 0 and BEWE > 0). Although this more restrictive classification reduced the cohort size by one case, it confirmed the consistency of our results, with the associations remaining statistically non-significant (Supplementary Table 3).

### Salivary parameters related analyses

According to Fig. 2, resting saliva hydration was significantly associated with SS consumption (t(45)=-2.11; *p = 0.041; Cohen's d: -0.673*). The relationship between each supplement and salivary parameters was also analyzed.

Among the supplement categories analysed, only sports drink consumption was significantly associated with selected salivary parameters. In this context, participants' consumption of sports drinks is significantly related to stimulated saliva volume (mL) (U = 92.0; *p = 0.043; rrb = 0.452*). However, no significant association was found between the use of general or specific supplements according to the classification of stimulated saliva secretion.

In Table 5, resting *(U = 105; p = 0.026; rrb: 0.457)* and stimulated saliva pH *(U = 77; p = 0.015; rrb: 0.542)* were significantly associated with sports drink consumption. However, there was no significant relationship between SS consumption and either resting or stimulated saliva pH.

Apart from that, no significant relationship was observed between resting saliva viscosity or stimulated saliva buffering capacity and the consumption of general or specific SS (Supplemental Tables 4 and 5). Detailed descriptive statistics, including group counts and exact p-values for these parameters, are provided in the supplementary materials.

**Table 3** Comparison of DMFT scores between sports supplement users and non-users

| Parameters | Users *n*(%) | Non-users *n*(%) | Statistics | *p* | Effect Size (rrb) |
|---|---|---|---|---|---|
| | DMFT Median (IQR) | DMFT Median (IQR) | | | |
| Sports supplements | 16 (30.8)<br>5.00 (3.25) | 36 (69.2%)<br>4.00 (5.25) | U = 236 | 0.304 | 0.181 |
| Sports bar | 9 (17.3%)<br>4.00 (3.00) | 43 (82.7%)<br>4.00 (4.50) | U = 179 | 0.724 | 0.077 |
| Sports drink | 9 (17.3%)<br>6.00 (2.00) | 43 (82.7%)<br>4.00 (4.50) | U = 120 | 0.074 | 0.382 |
| Omega 3 | 6 (11.5%)<br>3.50 (5.75) | 46 (88.5%)<br>4.00 (4.00) | U = 125 | 0.719 | -0.094 |
| Vitamin C | 7 (13.5%)<br>6.00 (5.50) | 45 (86.5%)<br>4.00 (4.00) | U = 157 | 0.989 | -0.006 |
| Vitamin D | 4 (7.7%)<br>5.00 (2.50) | 48 (92.3%)<br>4.00 (4.50) | U = 87.5 | 0.782 | 0.088 |
| Vitamin complex | 4 (7.7%)<br>6.50 (1.50) | 48 (92.3%)<br>4.00 (4.25) | U = 46 | 0.087 | 0.521 |
| Iron | 4 (7.7%)<br>5.50 (1.50) | 48 (92.3%)<br>4.00 (4.50) | U = 76.5 | 0.511 | 0.203 |
| Caffeine | 3 (5.8%)<br>4.00 (2.50) | 49 (94.2%)<br>4.00 (4.00) | U = 67 | 0.813 | -0.088 |
| Magnesium | 3 (5.8%)<br>6.00 (0.50) | 49 (94.2%)<br>4.00 (4.00) | U = 47 | 0.304 | 0.361 |

*Abbreviations*: *U* Mann-Whitney U test, *p* significance level, *rrb* Rank-Biserial Correlation

Users are defined as participants consuming the specific supplement ≥ 1 time/week. The complete underlying distributions are strictly presented as group-specific frequencies (n) and percentages (%) for all categorical comparisons

**Table 4** Statistical analysis of relationship between dental erosion and consumption of SS

| Parameters | Subgroups | Erosion (+) | Erosion (-) | OR | 95% CI | $p^a$ |
|---|---|---|---|---|---|---|
| Sports supplements | Yes<br>No | 5 (9.6%)<br>17 (32.7%) | 11 (21.2%)<br>19 (36.5%) | 0.508 | 0.14–1.76 | 0.368 |
| Sports bar | Yes<br>No | 4 (7.7%)<br>18 (34.6%) | 5 (9.6%)<br>25 (48.1%) | 1.11 | 0.26–4.73 | 1.000 |
| Sports drink | Yes<br>No | 2 (3.8%)<br>20 (38.5%) | 7 (13.5%)<br>23 (44.2%) | 0.329 | 0.06–1.77 | 0.272 |
| Vitamin C | Yes<br>No | 1 (1.9%)<br>21 (40.4%) | 6 (11.5%)<br>24 (46.2%) | 0.190 | 0.02–1.71 | 0.216 |
| Vitamin D | Yes<br>No | 1 (1.9%)<br>21 (40.4%) | 3 (5.8%)<br>27 (51.9%) | 0.429 | 0.04–4.42 | 0.629 |
| Vitamin complex | Yes<br>No | 1 (1.9%)<br>21 (40.4%) | 3 (5.8%)<br>27 (51.9%) | 0.429 | 0.04–4.42 | 0.629 |
| Iron | Yes<br>No | 0 (0%)<br>22 (42.3) | 4 (7.7%)<br>26 (50.0%) | 0.131 | 0.00–2.56 | 0.128 |
| Caffeine | Yes<br>No | 2 (3.8%)<br>20 (38.5%) | 1 (1.9%)<br>29 (55.8%) | 2.90 | 0.24–34.2 | 0.567 |
| Magnesium | Yes<br>No | 2 (3.8%)<br>20 (38.5%) | 1 (1.9%)<br>29 (55.8%) | 2.90 | 0.24–34.2 | 0.567 |
| Omega 3 | Yes<br>No | 1 (1.9%)<br>21 (40.4%) | 5 (9.6%)<br>25 (48.1%) | 0.238 | 0.02–2.20 | 0.226 |

*Abbreviations*: [a] Fisher's exact test, *OR* Odds Ratio, *CI* Confidence Intervals, *p* significance level

The complete underlying distributions are strictly presented as group-specific frequencies (n) and percentages (%) for all categorical comparisons. Erosion (+) if VEDE > 0 or BEWE > 0

## Discussion

The modern sports nutrition ecosystem has evolved beyond traditional hydration solutions to a multimodal, complex consumption model encompassing ergogenic aids, macronutrient powders, vitamins, minerals, and probiotics [34]. In this context, elite adolescent soccer players represent a critical risk group for oral health, given their widespread use of SS aimed at maximizing both physiological development and performance. This study provides important information regarding the potential risk posed by sports drinks to the dental health of adolescent athletes by altering salivary

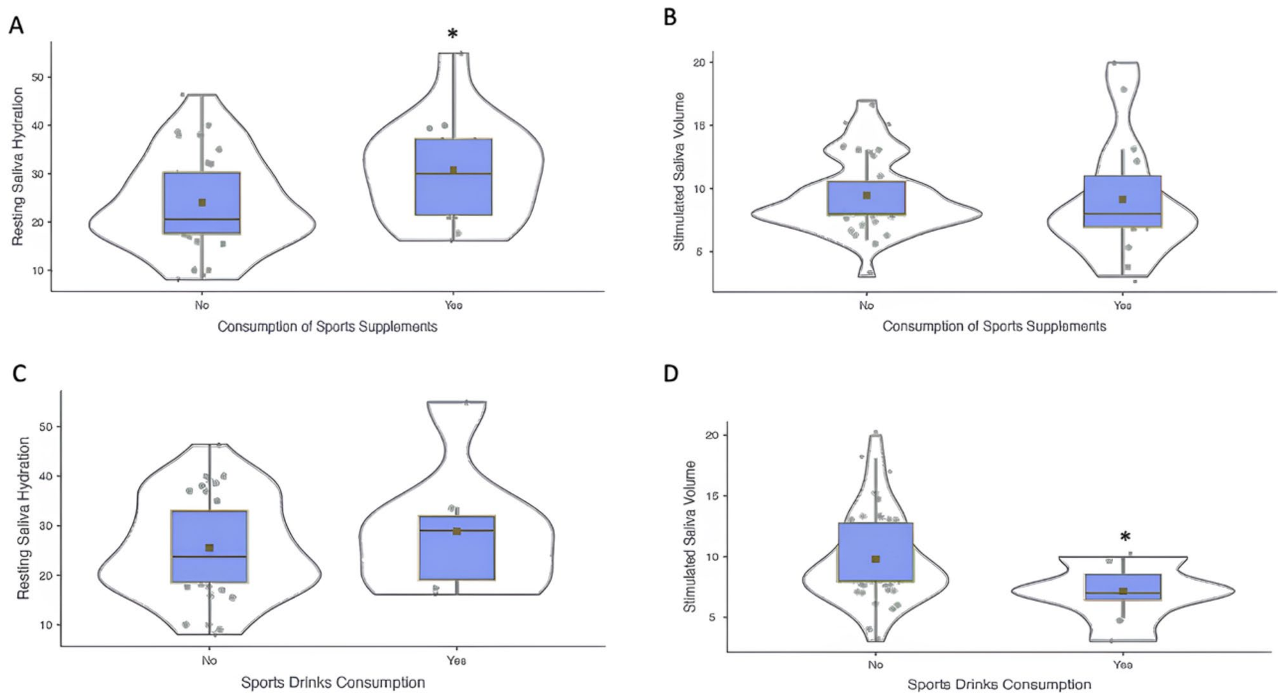


**Fig. 2** Comparison of resting saliva hydration and stimulated saliva volume based on the use of SS and sport drinks: Violin boxplots showing the distribution of resting saliva hydration (seconds) and stimulated saliva volume (mL) according to (**A-B**) sports supplement consumption and (**C-D**) sports drink consumption. Note: Detailed statistical distributions are as follows: (**A**) Resting salivary hydration (Supplement users: $n=14$, Median [IQR] = 30.0 [15.4] s vs. non-users: $n=33$, Median [IQR] = 20.6 [12.4] s; $p=0.041$*); (**B**) Stimulated saliva volume (Supplement users: $n=15$, Median [IQR] = 8.00 [4.00] mL vs. non-users: $n=35$, Median [IQR] = 8.00 [2.50] mL; $p=0.278$); (**C**) Resting salivary hydration (Sports drink consumers: $n=7$, Median [IQR] = 29.0 [12.6] s vs. non-consumers: $n=40$, Median [IQR] = 23.7 [14.2] s; $p=0.436$); (**D**) Stimulated saliva volume (Sports drink consumers: $n=8$, Median [IQR] = 7.00 [2.00] mL vs. non-consumers: $n=42$, Median [IQR] = 8.00 [4.75] mL; $p=0.043$*). Each plot visualizes the spread of the data including median values and variability. Mann-Whitney U test (except for resting hydration which used Student's t-test) was used for comparisons. * indicates $p<0.05$

composition. Notably, clinical endpoints like DMFT and erosion showed no significant association with consumption in this dataset. The limited statistical power and low erosion prevalence might influence these results. Nevertheless, our comprehensive approach provides valuable insights into the oral health of this population. Targeted interventions should be considered as a preventative strategy, making this study design a significant contribution to the oral health and sports medicine literature.

The use of SS has become a widespread practice among both professional and amateur athletes to improve performance and maintain health. A recent study in the literature on Turkish adult football players found that 87.2% of athletes used supplements, with sports drinks being the most commonly consumed product at 63.2% [21]. In the present study, the rate of supplement use among adolescent athletes was lower at 30.8%. This difference can be explained by competition level and age. Indeed, a study of adult football players found that professional players consumed significantly more supplements than amateurs [21]. In both studies, the fact that sports drinks (63.2% vs. 17.3%) and vitamin C were among the most frequently preferred supplements confirms the general trend towards these products among athletes. In the current study, adolescents primarily use these supplements to improve athletic performance (27.7%) and maintain health (16.9%), findings that parallel the motivations of adult athletes reported in the literature [21].

Routine dental check-ups may be sufficient to support oral hygiene practices and address health-related issues, thereby resulting in lower DMFT scores. Consistently, this study found a significant relationship between dental check-ups and the DMFT index ($p < 0.05$). Similarly, Tudoroniu et al. consistently found an association between dental check-ups and dental health in Romanian adolescents [35]. However, Karabekiroğlu et al. reported no significant difference in general DMFT scores between adolescents who visited the dentist regularly and those who did so irregularly [36]. In another study conducted with adolescents, no statistically significant relationship was found between the frequency of dentist visits and the DMFT index [37]. These inconsistencies may also be attributed to differences in sample characteristics such as sex, age, and physiological status.

No significant relationships were found between tooth brushing frequency and direction in adolescents, nor between these parameters and dental examination variables, such as the DMFT index and dental erosion. This

**Table 5** Comparison of resting and stimulated saliva pH based on the use of sport supplements and sport drinks.

| Parameters | Group | *n* | Median (IQR) | Statistics | *p*-value |
|---|---|---|---|---|---|
| Resting Saliva pH | Supplement (-) | 36 | 6.80 (0.40) | U = 258.0 | 0.542 |
| (by Supplement) | Supplement (+) | 16 | 6.80 (0.45) | | |
| Stimulated Saliva pH | Supplement (-) | 35 | 7.40 (0.40) | U = 244.0 | 0.690 |
| (by Supplement) | Supplement (+) | 15 | 7.40 (0.60) | | |
| Resting Saliva pH | Sports Drink (-) | 43 | 6.80 (0.40) | U = 105.0 | 0.026* |
| (by Sports Drink) | Sports Drink (+) | 9 | 6.60 (0.20) | | |
| Stimulated Saliva pH | Sports Drink (-) | 42 | 7.40 (0.40) | U = 77.0 | 0.015* |
| (by Sports Drink) | Sports Drink (+) | 8 | 7.00 (0.45) | | |

Sample size variations across analyses ($n = 50$, or $n = 52$) are due to missing data resulting from technical limitations and analytical constraints during specific salivary parameter assays. Because these continuous variables followed a non-normal distribution, the complete data profiles are rigorously presented using group-specific sample sizes (n), Medians, and Interquartile Ranges (IQR). *Resting saliva hydration showed normal distribution, other parameters showed non-normal distribution

Statistical comparisons were made using the Mann-Whitney U test

* indicates $p < 0.05$

may be related to the lack of a significant difference in the behaviours of the adolescent athletes in the study regarding maintaining oral hygiene, given their similar sociocultural levels. Similarly, Milona et al. reported that tooth brushing frequency had no significant effect on the DMFT index. They also noted that adolescents who brushed their teeth at least twice a day did not have significantly lower DMFT scores than those who brushed less often [37]. Supporting this finding, another similar study reported no significant difference in tooth brushing frequency between the DMFT index [38]. In addition, several similar study designs have reported no statistical significance between dental erosion and toothbrushing frequency [39, 40].

Antihistamines, frequently used in the treatment of allergic diseases, reduce saliva secretion and oral pH, which may be associated with the DMFT index scores. In this context, Yılmaz et al. observed a significant decrease in the DMFT index with increasing duration of drug use in rhinitis patients [41]. On the other hand, many studies have not found a relationship between allergic rhinitis and the DMFT index [42, 43]. Similar to this evidence, no significant relationship was found between allergy and the DMFT index in this study. This situation may be related to the fact that a large percentage of the study participants (96.2%) did not use allergy medication. Therefore, allergic disease did not affect the DMFT index in this study.

Acetylsalicylic acid, the active ingredient in aspirin, can cause tooth erosion by lowering the pH of the mouth. Aspirin has been reported in several studies to cause measurable and observable tooth erosion in children [44, 45]. Consistently, the present study reported a significant relationship between aspirin use and tooth erosion ($p < 0.05$).

Parents' educational level is another key factor in adolescents' dental examination parameters. Chandio et al. discovered a correlation between parents' educational level and the mean DMFT index in adolescents [46]. Similarly, Pakpour et al. stumbled upon a correlation between high DMFT scores and low family education in adolescents [47]. Interestingly, Wang et al. found a statistically significant relationship between the mother's education level and dental erosion in adolescents, but not between the father's education level and dental erosion [48]. Several studies have also reported a significant association between parental education level and dental erosion [49, 50]. The lack of a significant relationship between adolescents' parents' education levels and dental health parameters in the current study was attributed to participants' similar sociocultural and educational levels.

Dietary patterns and nutrient intake can influence dental health. In this context, various studies have found a strong relationship between snack consumption and tooth loss and/or dental erosion [51–56]. Additionally, Méjean et al. demonstrated that salivary composition is associated with dietary intake, particularly carbohydrates [57]. The current study found no significant relationship between adolescents' consumption of sugar, chocolate, and acidic beverages and dental examination parameters. This outcome could be related to adolescent athletes paying attention to their appearance and having similar eating habits. Similar to our findings, Çelik et al. reported no significant relationship between chocolate consumption frequency and DMFT index in young adults [58].

The literature reports that consuming SS and acidic, carbohydrate-containing sports drinks increases the risk of tooth decay and dental erosion [59–61]. Consistently, it has been determined that consuming carbohydrate- and citric acid-rich foods, such as gels, bars, or energy drinks, throughout the day and during exercise can significantly increase the risk of tooth decay [62]. This study found no significant relationships between general SS, specific supplement use, and dental health parameters, including DMFT and erosion. It may be related to differences in the duration variation and the number of supplements used by participants. Similar to our outcomes, several studies have reported that sports drink consumption and dental erosion are not associated [63, 64]. However, these conflicts underscore the need for more comprehensive research to fully understand the relationship between sports nutrition products and oral health.

On the other hand, the relationship between SS consumption and salivary parameters is a complex and highly relevant area of research for sports medicine researchers. SS consumption can affect oral health by altering salivary composition and saliva flow rates [65, 66]. A significant relationship was found between the participants' SS consumption and resting saliva hydration time ($p < 0.05$). It is well known that food and beverage consumption are among the factors that can alter saliva flow rate [67]. Based on existing literature, consuming dietary supplements may affect saliva hydration by altering saliva flow rate. Adequate saliva production is crucial for maintaining dental health and optimal sports performance. For instance, Otsuki et al. showed that supplementation with Chlorella could attenuate decreases in saliva secretion rates during intense training periods. They suggested that certain supplements may help maintain oral hydration and salivary function during strenuous physical activity [68]. This study found differences in stimulated saliva secretion among adolescents who consumed SS ($p = 0.09$) or sports drinks ($p = 0.07$). No significant results were observed for other supplements, which may be attributed to the limited sample sizes within these specific subgroups.

In this exploratory analysis, participants' consumption of sports drinks was associated with decreased resting salivary pH, stimulated salivary volume, and stimulated salivary pH ($p < 0.05$). Similarly, a study by Angelopoulou et al. reported a significant decrease in saliva pH among young adults who consumed sports drinks [16]. Another study reported a significant decrease in saliva pH in the sports drink group compared to the control group [18]. It is considered that sports drinks, particularly their simple carbohydrates and acidic content, can alter the pH of saliva and the oral microbiota. This situation indicates a potential pathway that could contribute to the development of dental erosion and other dental problems in adulthood. Therefore, awareness should be raised about the importance of understanding and managing the relationship of sports supplements' consumption and salivary parameters.

Furthermore, more research is needed to fully understand the potential erosive effects of various types of SS on dental structures. For instance, citrate and glutamate in SS can lead to dental enamel corrosion, which may be exacerbated by changes in saliva composition and flow rate due to supplementation [65]. In this study, no supplements other than sports drinks were found to be associated with oral and dental health parameters. This is likely attributable to the limited sample sizes within these specific supplement subgroups, combined with the participants' generally irregular and infrequent supplement use.

This study has several limitations. For instance, its cross-sectional design does not allow for causal inference regarding SS use and dental health. Using self-reported data on supplement intake may reduce the accuracy of the results. The small sample size, the absence of an external non-athlete control group, the low dental erosion rate, and the homogeneity of the samples' socioeconomic and educational status limit the ability to assess associations between many parameters and oral health. Indeed, the decision to exclude an external control group was based on the need to minimize confounding variables. Since all participants were from the same elite academy, they shared similar training environments and nutritional support. Introducing community-based sedentary controls would have introduced uncontrollable differences in lifestyle and dietary patterns that could affect salivary parameters.

While the overall sample size meets the requirement for moderate effect sizes, the study may be underpowered to detect significant associations for rare clinical outcomes, such as dental erosion. It may also be underpowered within very small subgroups, and findings should be interpreted as exploratory for these specific variables. Because this study is exploratory, multiple-testing corrections were not applied. In this context, several subgroups consuming different supplements had small sample sizes (3 to 9 users), which increases the risk of false-positive results. P-values near 0.05 should be interpreted with caution. They are less reliable under these conditions. All supplement-specific associations, including those for sports drinks, are exploratory and serve to generate hypotheses. Larger studies are needed to confirm these findings. Given the limited sample size ($n = 52$), conducting a robust multivariable analysis was not feasible. This prevented control for potential confounding variables. Salivary parameters, including pH, volume, DMFT, and dental erosion, are influenced by several concurrent factors measured in this study. These include daily intake of acidic beverages, consumption of confectionery, medication use, and individual oral hygiene practices. The analytical approach relied primarily on univariable pairwise comparisons without adjustment for these variables. Therefore, the findings should be regarded as unadjusted, exploratory associations rather than definitive causal relationships.

One limitation of this study is the DMFT index's limited ability to detect early caries. Additionally, the low erosion rate and limited statistical power within the sample may have influenced the findings. Future research should incorporate advanced diagnostic systems such as ICDAS and employ longitudinal designs to more accurately monitor changes in oral health.

A further limitation of this study is the absence of intra-examiner reliability assessment or repeat scoring for the dental examinations. All examinations were conducted by a single experienced dentist to ensure consistency. However, the lack of repeat scoring and formal calibration may introduce measurement bias, particularly given the reliance on visual indices. Additionally, only a limited range of salivary parameters was assessed. These parameters were selected based on their established validity and feasibility for field-based collection. Although they provide a useful baseline, the clinical buffer kit employed is not fully comparable to laboratory-based quantitative salivary assays. Consequently, the salivary and erosive findings should be regarded as screening-level outcomes rather than precise physiological measurements, which restricts the strength of any definitive mechanistic interpretation. Future research incorporating more complex biochemical markers could facilitate a more comprehensive physiological interpretation of the results.

Lastly, higher oral hygiene awareness and lower SS consumption also pose potential selection bias or confounding factors limitations. Lastly, while toothbrushing frequency was recorded, the specific timing of toothbrushing (e.g., relative to meal or supplement consumption) was not assessed. Future studies should consider including the timing of oral hygiene practices to provide more granular insights into their protective effects.

## Conclusion

In conclusion, this study highlights that sports drink use was associated with selected salivary parameters in exploratory unadjusted analyses, whereas no significant associations were detected with DMFT or erosion in this cohort. The statistical constraints and low erosion prevalence within this sample might have influenced these clinical parameters, meaning that the observed salivary modifications did not translate into verified clinical outcomes. Nevertheless, our comprehensive strategy, which combines questionnaires, dental examinations, and saliva analysis, provides valuable insights into this population. This study design contributes to the oral health and sports medicine literature by highlighting potential risk factors that warrant further longitudinal investigation. To fully evaluate these beverage choices and systematically monitor hypothetical long-term clinical consequences, larger longitudinal studies are needed.

### Abbreviations

| | |
|---|---|
| BEWE | Basic erosive wear examination |
| DMFT | Decayed, missing, and filled teeth |
| VEDE | Visual dental erosion examination index |
| SS | Sports supplements |

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12903-026-09185-7.

Supplementary Material 1

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### Authors' contributions

E.G., K.B., Ş.Y., S.K., and F.B.K. conceptualized the research project and conducted data collection. S.Y., Y.V., S.S., and B.S. developed the methodology and wrote the original draft. E.G., G.Ö., M.K., and M.Ö. performed the statistical analysis, contributed to writing the original draft, and participated in review and editing. B.Ö. and E.G. conceptualized and supervised the project, contributed to writing the original draft, and participated in review and editing. All authors approved the final manuscript for publication.

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### Data availability

Data will be made available on reasonable request from the corresponding author.

## Declarations

### Ethics approval and consent to participate

This study was approved by the Üsküdar University Clinical Research Ethics Committee [Meeting Date: 22.03.2023; Meeting No: 02]. All procedures were conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from all participants and their parents or legal guardians prior to their inclusion in the study. Then, participant data were anonymized and handled confidentially.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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