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# Exercise-Related Changes in Salivary Secretion and Protective Properties Implications for Dental Caries and Erosive Tooth Wear in Athletes - A narrative Review

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**Abstract**

**Background:** Saliva protects dental tissues, but its response to exercise is variable.

**Aim:** To examine exercise-related salivary changes and their relevance to dental caries and erosive tooth wear in athletes.

**Materials and methods:** Targeted, non-systematic searches of PubMed-indexed records and publisher websites were supplemented by reference checking. Human studies, reviews and guidance were critically synthesised, distinguishing salivary markers from clinical outcomes.
**Results:** Prolonged exercise with inadequate fluid replacement can reduce salivary flow. Responses depend on hydration, workload, collection method and beverage exposure. Salivary pH sometimes increases despite reduced flow. Protein concentration and secretion rate may change in opposite directions. Athlete surveys identify substantial dental disease, but do not establish salivary changes as its cause.

**Conclusions:** Saliva is a plausible modifying factor within a multifactorial pathway involving hydration, diet and sport-specific exposures. Prevention should integrate dental risk assessment with appropriate sports nutrition. Longitudinal studies linking repeated salivary measurements to incident lesions are needed.

**Key words:** sports dentistry; saliva; exercise; dehydration; dental caries; erosive tooth wear

## 1. Introduction

Oral disease can complicate an athlete's ability to eat comfortably, sleep and train. In a selected sample attending the London 2012 Olympic dental clinic, caries and dental erosion were recorded in 55% and 45%, respectively, and 18% reported an effect on training or performance [1]. These figures should not be interpreted as population estimates for all Olympians. Nevertheless, clinical examinations in other settings also document appreciable disease: a study of 187 professional male footballers found active caries in 37% and erosion in 53% [2]. The clinical problem therefore extends beyond occasional dental emergencies.

Recent articles in Quality in Sport address oral disease, sports nutrition and athletes' perceived performance limitations [3, 4]. Two more focused reviews consider sports drinks and the

relationship between nutrition and hard dental tissue disorders [5, 6]. These publications provide a relevant clinical context, while also revealing overlap between dietary exposure, hydration and salivary protection. A review organised around saliva can clarify how these factors interact without assuming that training itself is intrinsically damaging to teeth.

Saliva contributes to lubrication, oral clearance, acid buffering, mineral availability and biological defence [7]. Its secretion is regulated by autonomic pathways and varies with stimulation and physiological conditions [8]. Exercise can alter these conditions through fluid loss, changes in autonomic activity and concurrent food or drink intake. However, describing the athletic oral environment as uniformly dry and acidic obscures important findings. Some exercise protocols produce lower flow with higher whole-saliva pH, and others produce only modest changes [9, 10].

Caries and erosive tooth wear also require separate consideration. Caries involves a sugar-driven, biofilm-mediated imbalance between mineral loss and gain [11]. Erosive tooth wear involves chemical dissolution by acids without bacterial involvement, together with subsequent mechanical tissue loss [12]. Saliva modifies both processes, but a measurement relevant to one outcome is not automatically predictive of the other.

The aim of this narrative review is to examine exercise-related changes in salivary secretion and protective properties, evaluate their proposed links with caries and erosive tooth wear, and identify implications for prevention and research. Particular attention is given to the distinction between acute physiological responses, risk markers and demonstrated clinical disease. The contribution is a focused critical synthesis of overlapping literature, rather than a claim to be the first review of exercise and saliva.

## 2. Research materials and methods

### 2.1. Review design and literature identification

This narrative review was developed through targeted, non-systematic, web-assisted literature searches completed on 13 October 2026. Searches located PubMed-indexed records, accessible full texts and official publisher or journal pages. The Quality in Sport website was searched specifically for relevant articles. Reference lists of retrieved publications were used to identify additional foundational and clinical sources. The search was not designed to retrieve every eligible record and should not be interpreted as a systematic review.

Search terms combined concepts relating to exercise, endurance training, athletes, dehydration, salivary flow, salivary pH, buffering capacity, oral mucosal moisture, sports drinks, dental caries and erosive tooth wear. Targeted searches also checked individual titles, authors and identifiers. No independent search of subscription-only Scopus or Web of Science databases was conducted

### 2.2. Selection and evidence extraction

Sources were selected for relevance to human exercise-related salivary responses, athlete dental outcomes, salivary protective mechanisms or preventive guidance. English-language publications were prioritised, including foundational literature and recent studies from 2023–2026. Laboratory studies of beverage erosivity were not treated as substitutes for clinical disease evidence.

For primary studies, the synthesis considered design, sample characteristics, exercise conditions, hydration and beverage exposure, saliva collection method, sampling time, measured outcomes and major limitations. Full texts were consulted where accessible. For publications available only through an abstract or indexed record, interpretation was restricted to reported findings. Bibliographic metadata and identifiers were checked against official records.

### 2.3. Critical synthesis

Evidence was organised into salivary physiology, acute exercise and hydration responses, dietary and sport-specific exposures, and clinical dental outcomes. Appraisal was descriptive, considering selection bias, confounding, sample size, exposure measurement and the distinction between biomarkers and disease. No formal risk-of-bias score, certainty grading or meta-analysis was performed. Findings from different designs were not pooled. Reports from the same athlete cohort were recognised as related evidence rather than independent populations. These methods support a clinically oriented interpretation but leave the review vulnerable to selection and language bias.

### AI.

Artificial intelligence (AI) was used as an auxiliary tool in the preparation of this literature review for two primary purposes: to assist in the initial identification and organization of

relevant scientific literature, and to refine the English language (including grammar, style, clarity, and textual coherence). AI-generated suggestions were verified by the author, who bears full responsibility for the substantive accuracy of the content, the verification of cited literature, the interpretation of available data, and the final conclusions drawn. AI tools supported the writing process but did not replace the author's scholarly judgment.

## 3. Research results

### 3.1. Salivary protection involves several distinct functions

Salivary protection cannot be reduced to pH alone. Fluid supports the clearance of food residues and acids; buffering limits acid persistence; calcium and phosphate influence the balance between demineralisation and remineralisation; and the acquired pellicle modifies contact between acids and tooth surfaces [13]. Protection depends on the interaction of these functions, the site of exposure and the duration of an acid challenge.

Unstimulated saliva reflects secretion under resting conditions, whereas stimulated collection assesses a different physiological state. Measurements made during chewing or another stimulus may obscure drying experienced during prolonged activity. Collected volume is also not equivalent to flow rate unless the collection duration is known. Oral mucosal moisture is a related but separate measure.

Xerostomia describes the subjective sensation of dry mouth, while hyposalivation refers to objectively reduced secretion [14]. An athlete may experience dryness without persistently low measured flow. Conversely, an asymptomatic reduction may be detectable during a standardised test. A post-exercise decline from an individual's baseline does not itself diagnose chronic salivary gland dysfunction.

Whole-saliva pH represents the collected fluid at the sampling time, rather than the complete history of plaque or tooth-surface acid exposure. Moreover, a single universal critical pH is inappropriate: the tendency of mineral to dissolve depends on the ionic composition and degree of saturation of the surrounding fluid [15]. These distinctions affect interpretation of the exercise studies summarised in Table 1.

### 3.2. Exercise and dehydration can reduce flow, but responses are heterogeneous

Controlled dehydration research provides relatively direct evidence that fluid balance influences salivary output. Walsh et al. studied 15 men exercising in warm, humid conditions, comparing fluid restriction with replacement of losses. Without replacement, flow decreased while osmolality and total protein concentration increased; with replacement, flow and osmolality remained stable [16]. This experiment supports a contribution from dehydration under the tested conditions, without establishing a dental disease consequence.

In a comparison of 35 triathletes and 35 controls, Frese et al. found no difference in resting salivary parameters. However, the exercise subsample of 15 athletes showed reduced stimulated and unstimulated flow at maximum workload, accompanied by an increase in pH [9]. A reduction in secreted fluid and a shift in acidity can therefore occur in different directions. The study does not support describing the exercise response simply as acidification.

Mulic et al. similarly found heterogeneous responses among physically active young adults. Of 70 participants providing saliva around an exercise session, 64% showed a reduction in stimulated flow, while unstimulated flow increased and decreased in similar proportions [17]. The contrast between collection methods limits generalisations from a single salivary measure.

Field findings extend this picture. In 21 participants undertaking 120 minutes of slow distance exercise, Tanabe et al. observed reductions in flow, mucosal moisture and secretory immunoglobulin A secretion rate, while mean IgA concentration was numerically higher, without a statistically significant increase being reported [18]. Concentration can rise when fluid volume falls; it cannot be interpreted as increased delivery of protective protein. A broad review by Ntovas et al. also describes considerable variation in exercise-associated salivary changes across protocols and analytes [19]. Its coverage of many biochemical markers should not be mistaken for an equally extensive evidence base on dental outcomes.

### 3.3. Beverage exposure changes the observed pH and buffering response

Exercise and rehydration frequently occur together, making their separate effects difficult to identify. In an experiment involving ten young adults, Tanabe et al. compared five exercise conditions with different food and fluid combinations. Sports-drink conditions reduced salivary pH, while buffering capacity declined in all conditions except water-only rehydration [20]. These findings concern a combined exposure, rather than an unavoidable response to exercise.

Horswill et al. studied 50 participants across four exercise visits with different beverages and found relatively small changes in stimulated flow and pH [10]. Such findings caution against assuming major salivary impairment during every hydrated exercise session. They also do not establish that acidic drinks are harmless, because pre/post stimulated samples may miss brief acid challenges at tooth surfaces.

In a randomised rehydration study involving 68 children at a tennis camp, exercise did not significantly change salivary volume and increased pH. Subsequent rehydration increased volume but reduced pH, with a greater reduction after a sports drink than after water [21]. These results separate the exercise response from the beverage response, although they cannot establish long-term paediatric dental effects.

Tanabe-Ikegawa et al. investigated sports-drink dilution and water gargling during cycling. Water gargling attenuated some pH reductions, but responses differed between experimental conditions [22]. This is evidence of short-term modification of a salivary marker, rather than demonstrated prevention of caries or erosion. It does not establish an optimal dilution compatible with every athlete's nutritional requirements.

### 3.4. Sport-specific exposures and salivary markers do not consistently align with clinical disease

In a cross-sectional study of 90 swimmers and 90 rowers, Abdelrahman et al. found erosive wear in 60% and 25.6%, respectively. Flow declined after training in both groups, while pH increased among swimmers. The monitored pool became markedly acidic, reaching pH 3.24 [23]. Pool acidity represents a separate environmental exposure and prevents attribution of the observed erosion solely to saliva or swimming itself. The findings should not be extrapolated to appropriately maintained pools.

Recent football data also illustrate the separation between salivary associations and clinical outcomes. Günalan et al. examined 52 male adolescent elite players. Sports-drink consumption was associated with selected salivary measurements, but supplement consumption was not significantly associated with DMFT or erosion [24]. The small exposed subgroup and exploratory cross-sectional comparisons limit causal interpretation. The negative clinical findings should be retained rather than replaced by a presumed mechanism of harm.

**Table 1. Selected human studies linking exercise, hydration or sports beverages with salivary measurements.**

| Study | Design and population | Main finding | Interpretation limit |
|---|---|---|---|
| Walsh et al. (N. P. Walsh et al., 2004) [16] | Controlled exercise/fluid comparison; 15 men | Fluid restriction reduced flow and increased osmolality; replacement stabilised these measures | Heat/dehydration protocol; no dental outcomes |
| Frese et al. (Frese et al., 2015) [9] | 35 triathletes and 35 controls; exercise subsample 15 | Flow decreased and pH increased at maximal workload | Acute saliva findings did not demonstrate lesion incidence |
| Mulic et al. (Mulic et al., 2012) [17] | Cross-sectional dental study; saliva subsample 70 | Stimulated flow decreased in 64%; unstimulated responses varied | Age and recruitment differences; pre-existing lesions |
| Tanabe et al. (M. Tanabe et al., 2013) [20] | Repeated acute conditions; 10 adults | Drink/food conditions altered pH and buffering | Combined exposures; no clinical prevention endpoint |
| Angelopoulou et al. (Angelopoulou et al., 2023) [21] | Randomised rehydration comparison; 68 children | Exercise increased pH; sports-drink rehydration produced a larger subsequent fall | Acute paediatric surrogate outcomes |
| Abdelrahman et al. (Abdelrahman et al., 2023) [23] | 90 swimmers and 90 rowers | Flow fell; swimmers' pH rose; erosion differed between groups | Strong local pool-acidity exposure; cross-sectional design |

| Study | Design and population | Main finding | Interpretation limit |
|---|---|---|---|
| Tanabe et al. (G. Tanabe et al., 2025) [18] | Field before/after study; 21 participants | Flow and IgA secretion fell; mean IgA concentration was numerically higher | Small sample; concentration differs from secretion |
| Günalan et al. (Günalan et al., 2026) [24] | Cross-sectional study; 52 adolescent footballers | Selected salivary associations without significant clinical associations | Small exposed subgroup and unadjusted exploratory analyses |

### 3.5 Athlete dental surveys establish burden, rather than salivary mediation

Ashley et al.'s systematic review reported wide ranges of caries and erosion prevalence across heterogeneous elite-athlete studies and judged the overall evidence quality to be limited [25]. These ranges are not a pooled prevalence estimate. A later UK multisport study of 352 athletes reported caries in 49.1% and erosive wear meeting its specified BEWE threshold in 41.4%. Although 32% reported a composite oral-health-related sporting impact, only 5.8% specifically reported affected performance [26]. Composite symptom burden should therefore not be described as measured performance loss.

The related behavioural report from the same cohort found frequent sports-drink use alongside high self-reported twice-daily brushing [27]. This coexistence is clinically relevant but does not isolate saliva as the reason disease persisted. The two reports must not be counted as separate athlete populations.

Other samples reinforce the need for careful selection and outcome interpretation. Voluntary pre-Olympic screening in the Netherlands attracted 116 of 800 invited athletes and generated direct dental referrals in 43% of those screened [28]. In a 2025 university clinic cohort, Júdice et al. found caries in 47.4% of 114 elite athletes, without an association between disease burden and poorer oral-health-related quality of life [29]. These studies support clinical assessment, while illustrating that perceived wellbeing, treatment need and exercise-related salivary physiology are different outcomes.

## 4. Discussion

### 4.1 Saliva is a plausible modifier within a multifactorial pathway

The evidence supports a context-dependent model. Exercise may change fluid balance and secretion; concurrent nutrition or environmental exposure supplies acid or fermentable carbohydrate; and salivary protection influences the oral response. Baseline disease, fluoride exposure, biofilm, reflux, care access and recovery behaviour can modify the cumulative outcome. This model is a clinical interpretation of the assembled evidence, rather than a directly validated causal pathway.

For caries, reduced clearance could prolong carbohydrate exposure, but risk still depends on biofilm activity and repeated imbalance in mineral exchange [11]. For erosion, reduced protective fluid may prolong acid contact and alter the surface environment, although acid source, beverage composition and pellicle protection also matter [13, 30]. A fall in flow need not be accompanied by a fall in pH to be relevant. Equally, a normal post-exercise pH does not exclude an earlier local acid challenge.

This interpretation is consistent with the broader sports diet review by Schulze and Busse and the systematic review of physical activity and erosion by Nijakowski et al. [31, 32]. These syntheses place exercise within interacting exposures rather than establish an independent universal effect. The Quality in Sport review by Biskup et al. likewise describes inconsistent nutrition–disease associations and a modifying role for hydration, saliva and preventive factors [6] . Thus, salivary dysfunction is a reasonable candidate mediator, but its contribution to long-term disease remains insufficiently quantified.

### 4.2 Why the literature appears inconsistent

Several differences can explain apparently conflicting findings. Exercise intensity and duration affect physiological demand, while ambient heat and replacement of fluid losses alter dehydration. Sports drinks, meals and rinsing introduce additional exposures. Saliva may be collected at rest, during stimulation, immediately after exercise or after recovery, producing different snapshots of a changing system.

The measured endpoints also differ. A whole-saliva pH measurement cannot capture every acid episode, and stimulated flow may not represent conditions during mouth breathing.

Protein concentration is sensitive to the volume of fluid in which the protein is measured. Before/after measurements without an appropriate comparator cannot separate exercise from time, intake and environmental conditions. Small samples further increase uncertainty and reduce the reliability of subgroup findings.

Dental indices add another layer. DMFT reflects accumulated caries experience, including treated disease, while active lesion criteria describe a different clinical state. BEWE scores express erosive wear severity but do not identify the complete exposure history. Cross-sectional links between training, salivary markers and lesions cannot show that the marker preceded disease. Differences in diagnostic thresholds and recruitment consequently make simple comparisons of reported percentages misleading.

### 4.3 Practical implications for dental care and sports nutrition

Prevention should begin with an individual dental assessment rather than an assumption that all athletes have salivary hypofunction. History should address dryness during and outside training, beverage contact patterns, dental symptoms, reflux and medications, alongside clinical examination. Persistent dryness or suspected low secretion warrants assessment under standardised conditions [14]. Repeated measures may be useful when symptoms are clearly linked to long sessions, but a single post-exercise test should not become a disease diagnosis.

Dental advice must also preserve adequate fuelling and hydration. Sports nutrition guidance recognises context-dependent roles for carbohydrate and electrolyte intake [33]. Fluid replacement guidance similarly supports individualisation according to losses and exercise conditions [34]. The appropriate goal is therefore to limit avoidable oral exposure while meeting the athlete's physiological requirements. Blanket elimination of carbohydrate or indiscriminate dilution of sports drinks is not justified by the salivary studies reviewed here.

The sports-drink review in Quality in Sport provides a useful setting for discussing beverage composition and erosion prevention [5]. However, product pH alone does not determine clinical erosivity. Contact frequency, retention, acid properties, calcium content and the athlete's protective environment also matter [30]. Avoiding prolonged holding or swishing of acidic

products and using water to clear residues when practical are reasonable risk-reduction measures. Their ability to prevent new lesions in athletes has not been established by the acute saliva experiments.

Routine fluoride toothpaste use remains supported by general caries-prevention evidence [35]. Additional preventive treatment should follow the individual's assessed risk. Erosion requires assessment of extrinsic and intrinsic acids, clinical monitoring and tailored management [12]. Although early surface changes may be partly remineralised, this should not be described as regrowth of enamel already lost through wear. Recommendations need to distinguish established general dental care from interventions specifically validated in athletes (Table 2).

**Table 2. Clinical interpretation of salivary and dental findings in athletes.**

| **Finding** | **Interpretation** | **Practical response and evidence boundary** |
|---|---|---|
| Dryness during prolonged exercise | May reflect local drying or reduced secretion; does not establish chronic hyposalivation | Review hydration and symptoms; assess persistent problems clinically |
| Lower flow with stable or higher pH | Clearance and acidity are different dimensions | Consider both measures and exposure history; do not infer complete protection from pH |
| Increased protein concentration | May reflect less fluid rather than greater protein output | Interpret concentration with flow or secretion rate |
| Frequent acidic/carbohydrate product use | Plausible exposure contribution; nutritional purpose varies | Coordinate intake with sports nutrition; limit avoidable retention and additional exposures |
| Clinical caries or erosive wear | Requires diagnosis and management beyond saliva testing | Use fluoride-based caries prevention and targeted erosion management; monitor progression |

| Finding | Interpretation | Practical response and evidence boundary |
|---|---|---|
| Improved pH after water rinsing | Short-term surrogate improvement | A feasible adjunct when appropriate; long-term athlete dental benefit remains unproven |

The clinical rationale for such integrated care is compatible with the recent Quality in Sport reviews on oral health and sporting participation [3,4]. A contemporary synthesis by Needleman et al. also supports individualised prevention while acknowledging the need for stronger sport-specific intervention evidence [36]. Claims about improved performance should remain proportional to the underlying data: relieving dental symptoms is clinically valuable, but is not equivalent to demonstrating an objectively measured performance gain.

### 4.4 Research priorities and limitations of this review

The central research gap is a longitudinal link between salivary responses and incident dental lesions. Future cohorts should measure baseline dental status, repeated exercise exposure, hydration, food and beverage patterns, fluoride use and access to care, alongside standardized saliva collection and subsequent clinical examinations. Both stimulated and unstimulated measurements, collection duration, sampling timing and recovery should be reported. Studies of salivary proteins should include secretion rates where feasible.

Intervention research should test practical strategies that preserve performance nutrition: individualised fluid plans, changes in avoidable beverage contact, and risk-based dental prevention. Salivary markers can inform mechanisms, but new or progressing lesions should be included as outcomes. Statistical analyses should account for repeated observations, relevant confounding and multiple comparisons. Recruitment should also improve representation across sexes, ages, recreational and elite levels, and different sports.

This review has several limitations. Its targeted search may omit relevant evidence, and English-language prioritisation introduces language bias. Some conclusions rely on abstracts when full texts were unavailable. Descriptive appraisal offers less reproducibility than a formal systematic process. Much of the direct salivary literature comprises small acute experiments,

while dental epidemiology frequently involves selected samples. General preventive guidance is partly extrapolated to athletes. Consequently, this synthesis cannot provide pooled effect estimates, quantify saliva's independent contribution to disease, or establish the effectiveness of a sport-specific preventive package.

## 5. Conclusions

Exercise-related salivary changes depend on hydration, workload, collection method, beverage exposure and sampling time. Prolonged exercise with inadequate fluid replacement can reduce secretion, but exercise does not consistently acidify saliva. Higher whole-saliva pH can coexist with lower flow, and higher protein concentration can coexist with lower secretion rate.

Saliva is a plausible modifier of caries and erosive tooth wear within a broader interaction involving biofilm, diet, acids and preventive care. Available athlete surveys establish dental disease burden, but do not demonstrate that acute salivary responses cause subsequent lesions. Clinical care should integrate individual risk assessment, adequate hydration and fuelling, fluoride-based caries prevention and targeted erosion management. Longitudinal and intervention studies with clinical dental outcomes are needed to determine which salivary changes matter most and whether modifying them reduces disease.

## Disclosure

### Author Contributions

**Conceptualization:** [MD], [AK], [AS], [MP], [AB], [JM], [MW], [RD], [NK], [JP]

**Methodology:** [MD], [AK], [AS], [MP], [AB], [JM], [MW], [RD], [NK], [JP]

**Software:** Not applicable.

**Validation:** Not applicable.

**Formal analysis:** Not applicable.

**Investigation:** [MD], [AK], [AS], [MP], [AB], [JM], [MW], [RD], [NK], [JP]

**Resources:** [MD], [AK], [AS], [MP], [AB], [JM], [MW], [RD], [NK], [JP]

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**Conflicts of Interest**

The authors declare no conflict of interest.

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