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The impact of sports drinks and diet on dental erosion in athletes: a narrative review

Authors:

Marcelina Malinowska [MM]

University Clinical Hospital No. 2 of the Medical University of Lodz, ul. Stefana Żeromskiego 113, 90-549 Lodz

https://orcid.org/0009-0005-0149-7586

malinowska21051991@gmail.com

Martyna Bartela [MB]

University Clinical Hospital No. 2 of the Medical University of Lodz, ul. Stefana Żeromskiego 113, 90-549 Lodz

https://orcid.org/0009-0002-7941-3037

bartelamartyna@gmail.com

Abstract

Background: Enamel erosion is a growing issue marked by the irreversible loss of hard dental tissues due to chemical processes not involving bacteria. This condition mainly affects physically active individuals and young adults. A key contributing factor is the consumption of foods and beverages with low pH. Athletes may be at higher risk due to reduced salivary flow during intense physical activity and frequent intake of energy and isotonic drinks, which are characterized by low pH and organic acids.

Objective: The aim of this study was to review the impact of diet and sports drinks on enamel erosion in athletes and to discuss preventive strategies.

Materials and methods: A narrative literature review was conducted using peer-reviewed articles published between 2015 and 2021. Relevant studies were identified through PubMed and Google Scholar. The analysis included review articles, observational studies, and clinical studies evaluating the impact of sports drinks and dietary factors on dental erosion in athletes.

Results: Consumption of low-pH products promotes erosive lesions. Reduced salivary flow further increases the risk. Preventive measures, including dietary changes and the use of fluoride and calcium-phosphate compounds, may reduce enamel erosion in athletes.

Keywords: dental erosion, sports drinks, diet, athletes, enamel

Content

1. Introduction

Enamel erosion is a pathological process characterized by the loss of hard dental tissues resulting from the action of both exogenous and endogenous non-bacterial acids [1,2,14]. In recent years, there has been a notable increase in the prevalence of this phenomenon, particularly among the adolescent and young adult populations [4,5,6]. This escalation may be attributed to contemporary dietary trends, lifestyle choices, and a substantial consumption of low pH products [7,13]. The primary contributors to enamel erosion appear to be acidic carbonated beverages, isotonic drinks, and fruit juices [15,17,18]. These products often contain organic acids that can lower the oral pH below the critical threshold for enamel, which is approximately 5.5 [7,9]. Under such conditions, the dissolution of hydroxyapatite crystals occurs, leading to

a gradual loss of minerals from the tooth surface [3,21].Athletes represent a particularly vulnerable demographic due to their consumption of isotonic and energy drinks during periods of intense physical exertion, which serves to hydrate the body, replenish minerals, and enhance energy levels [10,36]. Engaging in strenuous activity also leads to a reduction in saliva production, which plays a crucial protective role within the oral cavity [24,26]. Saliva contributes to the neutralization of acids through the presence of buffering compounds and aids in the remineralization of enamel due to its calcium and phosphate ion content [24,25]. Frequent consumption of products with low pH in conjunction with decreased saliva secretion may facilitate the development of erosive lesions [12,13]. In light of the increasing popularity of sports beverages and the rise in physical activity levels among the general population, it is essential to consider the impact of diet and lifestyle choices on the oral health of athletes [10,38].

2.1 Diet as a Risk Factor for Enamel Erosion

Diet represents one of the critical factors contributing to enamel erosion [7, 13]. Enamel erosion refers to the irreversible loss of hard dental tissues due to the influence of acidic agents, which may be either exogenous or endogenous in origin [1, 14]. These factors include acids that are not produced by bacteria [1, 2]. It is imperative to differentiate the process of erosion from that of caries, wherein demineralization of the tooth surface occurs because of acids generated by microbial activity [8]. In contemporary society, enamel erosion has emerged as a prevalent phenomenon, predominantly attributed to dietary acids, particularly from the consumption of carbonated energy drinks, isotonic beverages, and various acidic food products [13, 15, 17].

The diets of athletes often include high quantities of acidic fruits, juices, and a significant amount of isotonic and energy drinks, as well as dietary supplements in both liquid and effervescent forms [10,38].Upon the consumption of such products, a decrease in the pH level within the oral cavity occurs [9,21]. It is widely accepted that the critical pH for hydroxyapatite crystals is approximately 5. 5 [7,9]. When the pH falls below this threshold, the dissolution of the crystals commences, leading to irreversible loss of dental hard tissues [3,21]. Additionally, it is important to consider the buffering capacity of saliva, the presence of acquired pellicle, and the individual susceptibility of the patient [24,26]. It is also important to consider the titratable acidity of beverages and food, which refers to the phenomenon of maintaining an acidic environment despite the buffering action of saliva [23]. A product with a moderately low pH but high titratable acidity will demonstrate a greater potential for erosion compared to a product with a very low pH yet low titratable acidity [23]. The type of acid present in the product is

also significant. Citric acid, for instance, is commonly used in the production of energy drinks and isotonic beverages [15,16]. This acid possesses a substantial buffering capacity, which contributes to the prolonged maintenance of an acidic environment within the oral cavity [16]. This occurs because citric acid binds calcium, thereby preventing the saturation of the solution with minerals that would otherwise inhibit the erosion process [16,21]. An essential aspect to consider is the frequency of exposure of dental hard tissues to acidic agents. Frequent exposure to acids is more detrimental to dental tissues than a single intake of a large quantity of acids [22]. Athletes often consume small amounts of liquids; however, this behavior is repeated frequently [38]. Consequently, this leads to an increased risk of erosion in the hard tissues of teeth due to the regular contact with acids [12,38].The consumption of substantial quantities of acidic fruits, such as oranges, lemons, limes, and grapefruits in the form of juices, as well as liquid or carbonated dietary supplements, is also significant among athletes [7,13]. These products are characterized by a low pH and possess a greater capacity for contact with tooth surfaces compared to whole fruits [17,18]. This results in a prolonged reduction in oral pH, thereby initiating the erosion process [9,21]. Another significant factor influencing dental health is the action of saliva. The buffering agents present in saliva facilitate the gradual neutralization of dietary acids and the restoration of a normal, safe pH level [24,25]. Saliva also plays a role in partially cleansing the surfaces of teeth [24]. Furthermore, it contains calcium and phosphate ions, which are essential for the remineralization of the hard tissues of teeth [24,26]. However, frequent consumption of acidic products may render the protective functions of saliva insufficient [13].

Additionally, in physically active individuals, a transient decrease in saliva secretion has been observed, thereby diminishing the oral cavity's defensive capacity against acids [12,37].It is important to emphasize that a diet high in acids does not lead to immediate dental erosion. Instead, this is a prolonged process influenced by several factors, including the pH of the consumed products, the frequency of their intake, the quantity of saliva produced, individual tissue susceptibility, and the practice of brushing teeth immediately after exposure to acids. In such instances, the dental tissues may be partially dissolved, and mechanical brushing may inadvertently remove some of the exposed surface of the teeth [22,30].

2.2 The Impact of Isotonic Beverages on Enamel Demineralization

Isotonic beverages are formulated products designed to rapidly replenish fluids and electrolytes lost during physical activity [36]. They possess osmolarity levels that are comparable to those of bodily fluids, which facilitates their swift absorption within the gastrointestinal tract

[36].The primary objective of utilizing isotonic beverages is to maintain hydration during prolonged exertion, as well as to provide energy. Consequently, these beverages typically contain substantial amounts of carbohydrates (6–8%), caffeine, and various nutritional components, including riboflavin, niacin, vitamins B6 and B12, sodium, potassium, phosphorus, and taurine [36]. Moreover, these beverages commonly incorporate phosphoric or citric acid, which contribute to their chemical stability and flavor profile [15,16]. However, a significant drawback of these constituents is their contribution to the low pH levels of the beverages [17,18]. Numerous studies indicate that the pH of such beverages generally ranges between 3. 0 and 4. 0 [17,18]. A table is provided that outlines the pH values of commonly consumed beverages by physically active individuals, alongside their erosive potential [17,18].

Table 1. Examples of beverage pH and their erosive potential

Type of beverage	Example product	Approximate pH	Erosive potential
Isotonic drinks	Gatorade	2.9 – 3.3	High
Isotonic drinks	Powerade	3.0 – 3.5	High
Energy drinks	Red Bull	3.3 – 3.8	High
Energy drinks	Monster Energy	3.0 – 3.4	High
Carbonated beverages	Coca-Cola	2.4 – 2.7	Very high
Carbonated beverages	Sprite	3.2 – 3.5	High
Fruit juices	Orange juice	3.3 – 4.2	Moderate to high
Fruit juices	Apple juice	3.3 – 4.0	Moderate
Functional beverages	Flavored water	3.0 – 4.0	Moderate

The implications of this phenomenon on the dental erosion process are significant. Research indicates that the dissolution of enamel prisms commences shortly after the consumption of acidic beverages and progresses over time [20,21]. The surface of human teeth progressively exhibits increased roughness upon exposure to such beverages [19,21]. Citric acid, a triprotic acid, binds with calcium, thereby hindering the rapid saturation of the solution with minerals that could potentially mitigate the erosion process [15,16].Frequent consumption of acidic beverages and high-acidity foods, coupled with unhealthy dietary habits, may lead to a gradual loss of minerals in the hard tissues of the teeth [21,23]

2.3 The Role of Saliva in the Development of Enamel Erosion among Athletes

Saliva serves as a primary defensive factor within the oral cavity, playing a crucial role in protecting teeth against the process of erosion [24,26]. It facilitates the dilution of acids that are introduced through dietary intake [24]. Notably, saliva contains buffering systems that contribute to the neutralization of these acids [25,26]. The primary buffer present is bicarbonate, which is essential for maintaining stable pH levels within the oral environment [24]. Additionally, saliva comprises phosphate and protein buffers [25]. Another important aspect includes the presence of calcium and magnesium ions, which are instrumental in the remineralization of partially damaged hard dental tissues [26]. Furthermore, the existence of saliva prevents the accumulation of food residues on tooth surfaces, allowing for their effective clearance [24]. During intense physical exertion, a gradual dehydration of the body occurs, which subsequently leads to a reduction in salivation [37].

This phenomenon negatively impacts oral health, as the decreased saliva production diminishes its protective capacity [24, 37]. For individuals engaged in sports, this condition is often manifested as a sensation of dryness in the oral cavity [37]. Consequently, athletes are particularly susceptible to the development of erosive lesions within the dentition due to the reduced salivary secretion combined with the frequent consumption of small amounts of isotonic beverages [12, 38]. Changes in the properties of saliva during physical activity are summarized in the accompanying table.

Table 2. Changes in salivary properties during physical exercise

Parameter	Change during exercise	Potential impact on enamel
Salivary flow	Decreased	Reduced acid neutralization
Salivary pH	Decreased	Increased risk of demineralization
Buffering capacity	Reduced	Slower acid neutralization
Hydration status	Decreased	Oral dryness

2.4 Prevention of Enamel Erosion in Athletes

From a scientific perspective, a key approach to preventing enamel erosion appears to be the reduction of the consumption of foods and beverages with low pH, such as energy and isotonic drinks, as well as dietary supplements in liquid or effervescent forms, which commonly contain vitamin C [29,30]. Another significant aspect is the minimization of the frequency of contact

between low pH products and the surfaces of teeth [29,31]. The more frequent consumption of small quantities of such products is likely to exert a more detrimental effect than a single large portion consumed at one time [22,30]. Additionally, the actions taken immediately following acid exposure are of considerable importance. Rinsing the oral cavity with water can help dilute acids and facilitate their neutralization [29]. The contact with low pH products results in the gradual dissolution of hydroxyapatite crystals, which implies that the tooth surfaces become increasingly rough and more susceptible to mechanical damage [20,21]. Consequently, it is critical to refrain from brushing teeth immediately after the consumption of acidic substances. The bristle action may mechanically remove partially dissolved crystals from the tooth surface [31]. A waiting period of 30 to 60 minutes post-exposure to acids is advisable [31].Another significant aspect of oral health maintenance is the application of fluoride compounds.

The mechanism of their action involves the incorporation of fluoride ions into the structure of hydroxyapatites, resulting in the formation of fluoroapatites. This process reduces the critical pH threshold for dental demineralization, thereby increasing the tooth structure's resistance to acid attacks [27,34]. Moreover, these ions facilitate the remineralization process by enhancing the incorporation of calcium and phosphate ions into the surface of the teeth [27,28]. In clinical practice, fluoride prophylaxis encompasses both professional treatments conducted in dental offices and home-based interventions. These include professional fluoride applications utilizing varnishes, gels, or solutions, as well as home care methods, such as the use of high-fluoride content toothpaste and fluoride rinses [27,34].An essential component of preventive care also involves the use of calcium and phosphate compounds. These agents support remineralization processes by increasing the availability of these ions within the oral environment and decelerating the formation of erosive lesions [31,35]. Particular attention is given to compounds such as amorphous calcium phosphate (ACP) and casein-phosphate complexes (CPP-ACP), which possess the ability to stabilize calcium and phosphate ions in the oral cavity [31,32]. Such substances contribute to the re-deposition of minerals in enamel areas that have previously lost their constituents [31,32].Research indicates that the use of products containing calcium and phosphates can lead to an improvement in the surface hardness of enamel and a reduction in its sensitivity to acidic environments [31,32]. These products operate primarily by increasing the concentration of mineral ions in saliva and subgingival fluid, thereby facilitating remineralization processes and diminishing the dissolution of hydroxyapatite crystals [27,31].Such interventions are particularly critical for athletes, who, by consuming products that significantly lower the pH within the oral cavity, are at risk of experiencing erosive changes [12,38]. It is

also essential to acknowledge the role of adequate hydration. During periods of intense physical exertion, the body gradually becomes dehydrated, which consequently leads to a reduction in saliva production, an important defensive factor within the oral environment [24,37]. Saliva contains buffering agents that gradually neutralize acids, thus protecting tooth surfaces from demineralization [24]. Additionally, athletes are encouraged to schedule regular dental check-ups, as this practice fosters the early detection of erosive changes and the implementation of preventive measures [29,30].

3. Discussion

Erosion is an increasingly prevalent phenomenon observed within the human population [4,5,6]. Athletes represent a particularly vulnerable group, as their engagement in intense physical exertion often leads to dehydration. Consequently, they frequently resort to the consumption of energy drinks and isotonic beverages [10,38]. The diet of individuals involved in athletic training typically comprises a significant amount of food products characterized by low Ph levels, such as citrus fruits and dietary supplements with acidic properties [7,13]. Numerous studies have documented the low Ph levels of energy and isotonic drinks, with their average Ph ranging from 3. 0 to 4. 0 [17,18]. In comparison to the critical Ph level for hydroxyapatite the primary constituent of enamel, which is approximately 5. 5 it becomes evident that such products pose substantial risks to dental integrity, leading to gradual dissolution of the tooth surface [7,9,21]. Notably, citric acid plays a crucial role in this context, as it possesses the ability to chelate calcium and phosphate ions [15,16].According to the findings from numerous laboratory and clinical studies, the interaction of dental enamel with beverages of low Ph results in a gradual loss of mineral content and an increase in surface roughness of the teeth [19,20,21]. This process may be particularly exacerbated by frequent consumption of small quantities of such beverages during training or competitive events, leading to repeated reductions in oral Ph levels [22,38]. Under these circumstances, the body's natural protective mechanisms may prove insufficient for effectively neutralizing erosive factors [24,26].It is essential to emphasize that the etiology of dental erosion is multifactorial and cannot be attributed solely to the consumption of acidic foods and beverages [1,14]. Saliva plays a significant protective role in this context, as it neutralizes acids in the oral cavity through its buffering capacity and aids in remineralization due to the presence of calcium and phosphate ions [24,25,26]. However, during periods of intense physical exertion, the volume of saliva produced decreases significantly,

leading to a sensation of dry mouth, which considerably diminishes the saliva's defensive capabilities [37]. Therefore, maintaining proper hydration is a critical factor in mitigating these adverse effects [36,37].In the context of preventing erosive changes, appropriate preventive measures are of significant importance. These measures include the reduction of the consumption of products with low Ph, the rinsing of the oral cavity with water immediately after intake, the avoidance of brushing teeth immediately after exposure to acid attacks, as well as the implementation of both professional and home fluoride prophylaxis, and the use of products containing calcium and phosphates [27,29,31,35].

In summary, available data indicate that physically active individuals, particularly athletes, may constitute a population at heightened risk for the development of enamel erosion [12,38]. This susceptibility primarily arises from the frequent consumption of isotonic beverages, alterations in saliva secretion during physical exertion, and specific dietary habits [12,37,38]. Therefore, it is imperative to enhance awareness regarding the impact of diet and sports drinks on oral health, as well as to promote preventive measures within this patient group [29,30].

4. Conclusions

1. A diet rich in products with low Ph levels contributes to the development of erosive changes in dental hard tissues.

2. Isotonic and energy drinks typically have a Ph range of 3.0 to 4.0, which promotes the progression of erosive lesions.

3. Athletes may represent a population at increased risk for dental erosion due to frequent consumption of low Ph products, reduced salivary secretion during physical exertion, and specific dietary patterns.

4. Saliva plays a crucial role in the body's defense mechanisms due to its acid-neutralizing properties and its support for remineralization processes; however, during periods of physical activity, the secretion of saliva is significantly diminished.

5. Preventive measures, including the use of fluoride-containing products, calcium compounds, and phosphates, as well as regular dental check-ups, may help mitigate the risk of dental erosion among athletes.

Declarations

Author's contribution

Conceptualization: Marcelina Malinowska

Software: Martyna Bartela

Formal analysis: Martyna Bartela, Marcelina Malinowska

Investigation: Marcelina Malinowska

Resources: Marcelina Malinowska

Data curation: Martyna Bartela

Writing-rough preparation: Martyna Bartela

Writing-review and editing: Marcelina Malinowska

Supervision: Martyna Bartela

Project administration: Martyna Bartela, Marcelina Malinowska

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The authors deny any conflict of interest.

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