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ENERGY AND PRE-WORKOUT AND THE RISK OF EROSIVE TOOTH WEAR AND DENTAL CARIES AMONG ATHLETES AND PHYSICALLY ACTIVE ADOLESCENTS – A LITERATURE REVIEW

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ABSTRACT

The growing consumption of energy and pre-workout drinks among adolescents and physically active individuals raises significant concerns regarding their impact on oral health. This literature review summarizes current knowledge on the effects of these beverages on hard dental tissues, focusing on risk factors among active patients. An analysis of medical literature from PubMed, Scopus, Web of Science, and Google Scholar was conducted, including peer-reviewed articles (in vitro, in situ, clinical, and survey studies) published between 2020 and 2026. Keywords used: energy drinks, teeth, acid beverage, erosion, enamel. Results show that energy and pre-workout drinks have an extremely low pH (averaging 3.3) and high titratable acidity, which rapidly reduces enamel microhardness. Sugar-free variants, although lacking cariogenic potential, are equally erosive. Athletes constitute a high-risk group due to physiological hyposalivation during exercise, which, combined with beverage consumption around training time, prevents natural acid neutralization. This necessitates proactive preventive measures in dental practices. It is crucial to educate patients on delaying tooth brushing immediately after acid exposure to avoid irreversible post-erosive abrasion. Professional remineralization and close monitoring of orthodontic patients are also necessary.

KEYWORDS

Enamel Erosion, Energy Drinks, Athletes, Sports Medicine, Dental Prevention, Saliva

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1. Introduction

Enamel erosion (ETW – Erosive Tooth Wear) poses a growing challenge in modern dental practice. Unlike classic dental caries, whose etiology is based on acids produced by cariogenic bacteria, erosion is a chronic, localized, and initially painless process of hard tooth tissue loss resulting from the direct chemical action of exogenous acids (Martínez et al., 2024). The main source of these acids in the modern patient's diet is low-pH beverages, including the increasingly popular energy drinks and liquid sports supplements.

Rapid changes in eating habits and lifestyles have made adolescents and young adults the primary at-risk group. Energy drinks are commonly consumed by people who spend many hours in front of screens, including computer gamers and esports athletes. In this group, these beverages often replace water or sleep, with the aim of prolonging wakefulness and increasing concentration. This results in a drastically prolonged exposure of tooth tissues to an aggressive acidic environment (Tanner et al., 2020). As epidemiological studies show, this problem also has a distinct gender-based dimension. Among high school students, more than a quarter report daily consumption of acidic beverages, with boys statistically much more likely than girls to choose unhealthy options (such as energy drinks) (Melbye et al., 2020).

The second group of consumers, which is extremely important from a clinical perspective, consists of physically active individuals. In addition to traditional energy drinks, these patients regularly consume pre-workout supplements, whose corrosive potential is equally dangerous. Survey data show that over half of amateur athletes regularly take this type of supplement. This practice most often occurs immediately before a training session, with the goal of artificially boosting perceived energy levels (Martínez et al., 2024). Unfortunately, increased consumption goes hand in hand with a profound lack of health awareness gaps in patients' basic education regarding the nature of enamel erosion directly correlate with increased frequency of consumption of low-pH beverages (Melbye et al., 2020).

Research Objective. The objective of this review is to summarize the current state of knowledge regarding the effects of energy and pre-workout drinks on hard dental tissues, with a particular focus on adolescents and athletes, and to formulate practical preventive guidelines for dentists aimed at curbing this phenomenon in the dental office setting.

Research Problems. What are the key chemical parameters determining the erosive potential of energy and pre-workout drinks? What are the mechanisms of damage to the ultrastructure of enamel and dentin caused by these beverages? How do the specific consumption habits of athletes and adolescents increase the risk of erosive tooth wear?

Research Hypotheses. Energy and pre-workout drinks exhibit high erosive potential due to their specific chemical properties, leading to rapid degradation of hard dental tissues. Furthermore, adolescents and physically active individuals constitute a high-risk group due to behavioral patterns and physiological factors (e.g., exercise-induced hyposalivation), necessitating targeted preventive dental care.

2. Research materials and methods

Procedure / Test protocol.

This review was based on a detailed analysis of English-language medical literature collected using leading scientific databases, including PubMed, Scopus, Web of Science, and Google Scholar. The main focus was on peer-reviewed research articles (including in vitro and in situ analyses as well as survey studies) published between 2020 and 2026. The process of searching for and selecting source materials was based on the use of the following keywords: energy drinks, teeth, acid beverage, erosion, and enamel.

2.1. Participants.

As this article is a comprehensive literature review, no human or animal participants were directly involved in this study. The research and subsequent conclusions are based exclusively on the analysis of previously published, peer-reviewed clinical data and literature.

2.3. Data collection and analysis / Statistical analysis.

Data collection involved a systematic screening, evaluation, and qualitative extraction of findings from the selected scientific literature. As this is a narrative review, no original empirical statistical analysis was conducted by the authors. The synthesis focuses on summarizing, comparing, and interpreting data reported in the primary sources.

3. Research results

3.1. Chemical parameters and erosive potential of energy drinks

The key factor determining a beverage's erosive potential is its acidity (pH). Under physiological conditions, the oral cavity maintains a pH within the safe range of 6.8–7.2. Demineralization of hard tissues begins when this value drops below the so-called critical pH, which is approximately 5.5 for enamel (for dentin and root cementum, this threshold is even higher, ranging from 6.2 to 6.7). According to the results of extensive in vitro analyses covering several dozen of the most popular energy and pre-workout drinks on the market, their average pH is a mere 3.3 (Martínez et al., 2024). This means that contact between the liquid and the tooth surface introduces a massive acid load into the oral environment. Analyses confirm that the acidity of most commercial energy drinks remains at a consistently extremely low level (often below 3.5), unquestionably classifying them as highly erosive (Silva et al., 2021). Furthermore, as rightly noted by Kawałko et al., energy drinks drastically affect the pH of the oral cavity by increasing its acidity, which directly promotes demineralization, and the sucrose present in many of them provides an additional medium for cariogenic bacteria (Kawałko et al., 2022). It is estimated that approximately 50% of consumers of these beverages are children, adolescents, and young adults up to 25 years of age (Kawałko et al., 2022). However, the initial pH value is not the only indicator of risk. Equally important parameters are titratable acidity (TA) and buffer capacity, which determine how long the acid remains active and how much base (in natural conditions - saliva) is needed to neutralize it. Laboratory studies show that while classic cola-type carbonated beverages may sometimes have a lower initial pH, it is energy drinks (such as Red Bull) that have the highest titratable acidity

(AlHelal et al., 2025). This is due to the presence of strong organic acids, primarily citric acid. It not only has the ability to acidify the environment but also exhibits chelating properties - it strongly binds calcium ions from the hydroxyapatite structure, which accelerates the process of enamel destruction with double the force.

Particular attention should also be paid to a widespread, dangerous myth regarding “Zero” or “Light” (sugar-free) beverages. The absence of sucrose absolves these products of responsibility for directly causing classic bacterial tooth decay, which leads many patients to consider them “safe for teeth.” However, studies show that their erosive potential remains extremely high (Hamza et al., 2021). Furthermore, advanced analyses using spectroscopy (FTIR) have revealed a striking paradox: sugar-free versions of energy drinks often exhibit even more aggressive erosive effects than their sweetened counterparts. They rapidly leach the mineral phase of the enamel, leading to drastic exposure of the organic matrix (AlHelal et al., 2025). From a clinical standpoint, replacing a traditional energy drink with a “Zero” version does not protect against erosion but merely reinforces a false sense of security in patients.

3.2. Mechanisms and ultrastructural changes in dental tissues

The damaging effect of energy drinks on hard dental tissues occurs at an extremely rapid pace. Advanced *in vitro* studies using spectroscopy show that a measurable increase in surface roughness and aggressive leaching of the mineral phase occur after just 5 minutes of enamel exposure to the liquid (AlHelal et al., 2025). The demineralization process directly results in a drastic decrease in the surface microhardness of the tissues (Jácome et al., 2025). This picture of the changes is further highlighted by observations made under an atomic force microscope (AFM). The phenomenon of acid erosion enlarges the natural microcracks in the enamel, transforming its previously flat topography into uneven undulations, referred to by researchers as “desert dunes” (Iosif et al., 2022).

However, the impact of low-pH beverages is not limited solely to the mineralized crown enamel. Studies using scanning electron microscopy (SEM) demonstrate that repeated exposure to energy drinks leads to rapid degradation of the sensitive cemento-enamel junction (CEJ) area. The dissolution of a thin layer of root cementum in the cervical region results in the rapid exposure of dentinal tubules. This creates ideal conditions for the development of acute, difficult-to-treat dentin hypersensitivity, which patients often complain about in the dental office (Mitic et al., 2020).

The issue of erosion becomes particularly critical in patients undergoing orthodontic treatment. The complex topography of brackets and archwires creates a mechanical barrier to the natural flow of saliva, hindering the buffering of acids introduced from outside. It has been demonstrated that adolescents wearing fixed orthodontic appliances and regularly consuming energy drinks are nearly four times more likely to develop a rapid onset of white demineralization spots (WSL) on the labial surfaces of their teeth, often covering entire quadrants of the dentition (von Bremen et al., 2025). Furthermore, microscopic damage to the enamel caused during the debonding procedure becomes an open gateway for acids from energy drinks, which drastically accelerates the formation of deep erosive craters (Iosif et al., 2022).

Chemical destruction of tissues is further exacerbated by the phenomenon of post-erosive abrasion. The outer layer of enamel, softened by acids, becomes extremely susceptible to mechanical damage. Brushing your teeth immediately after consuming an acidic beverage (e.g., after a workout) prevents saliva from carrying out its natural remineralization process. The use of toothpaste, especially those with a high abrasion index (RDA), such as popular whitening toothpastes, acts on the softened enamel like an abrasive, leading to irreversible tissue loss and the formation of wedge-shaped cervical cavities (Gálvez-Bravo et al., 2025; Khan et al., 2022).

3.3. Specificity of the physically active patient – risk co-factors

The susceptibility of hard dental tissues to erosion increases dramatically during intense physical exertion, making athletes a high-risk group. The main contributing factor is the physiological activity of the salivary glands during training. During physical activity, the body’s sympathetic nervous system is strongly stimulated at the expense of the parasympathetic nervous system. This results in a sharp decrease in the volume of saliva secreted (hyposalivation) and a change in its composition to a thicker, water-poor consistency. Studies conducted on elite swimmers and triathletes unequivocally demonstrate that during intense exercise, both salivary flow and its buffering capacity drop drastically (Grzesiak-Gasek & Dębska-Łasut, 2026; Lind et al., 2025). As a result, the oral cavity loses its primary natural defense mechanism, responsible for neutralizing acids and remineralizing enamel damage. The situation is exacerbated by the fact that both extreme physical

exertion and high doses of caffeine from energy drinks lead to chronic stimulation of the nervous system and can intensify anxiety symptoms (Lisik et al., 2026; Małajewicz et al., 2026). From a dental perspective, this continuous state of sympathetic nervous system arousal (the "fight or flight" response) additionally and persistently blocks resting saliva secretion, drastically potentiating erosion. This mechanism is further exacerbated in the absence of adequate recovery, as Dziarnowska et al. have shown that sleep deprivation leads to autonomic nervous system dysfunction and a shift in its balance toward even higher sympathetic activity (Dziarnowska et al., 2026). Thus, a patient relying on energy drinks falls into a vicious cycle where permanent physiological stress completely abolishes the protective function of the salivary glands.

The introduction of liquids with high erosive potential at this critical moment creates an environment that is highly destructive to the teeth. As behavioral analyses indicate, amateur athletes and physically active individuals most often consume pre-workout supplements and classic energy drinks in the immediate vicinity of a training session just before or during exercise (Martínez et al., 2024). This means that a powerful acid attack hits the tissues precisely at the moment when saliva is unable to provide them with any physiological protection.

Another extremely important risk factor is harmful consumption patterns, which are common among both gym-goers and young people who spend their time in front of screens (e.g., esports players). Instead of quickly consuming a portion of liquid, the dominant habit is slow, repeated sipping of an energy drink from a can or water bottle over several dozen minutes, and often several hours (Tanner et al., 2020). This drinking behavior constantly replenishes the supply of acids to the mouth, preventing the pH from returning above the safe threshold of 5.5. The combination of repeated, prolonged drops in pH, the absence of saliva's buffering role due to physical exertion, and the high citric acid content in beverages is key to understanding the pathomechanism of rapid tooth tissue loss in this patient group.

4. Discussion

The findings of this review highlight the severe erosive impact of energy and pre-workout drinks on hard dental tissues, aligning with broader epidemiological trends that indicate heightened vulnerability among physically active individuals and adolescents. In light of the growing consumption of these beverages, the role of the dental team must evolve from restorative treatment toward proactive prevention. Effective management of patients at risk for acid erosion requires the implementation of a multifaceted protocol, including behavioral education, appropriate clinical procedures, and the use of modern protective agents.

From a behavioral perspective, changing oral hygiene habits is an absolute priority. The dentist should strongly advise patients against brushing their teeth immediately after consuming an acidic beverage or following intense exercise. Softened enamel needs time to restore its ionic balance thanks to the buffering properties of saliva; mechanical brushing during this time window leads to irreversible post-erosive abrasion (Khan et al., 2022). It is recommended to delay brushing for at least 30–60 minutes. To immediately neutralize the environment, patients should rinse their mouths with clean water or chew sugar-free gum, which stimulates saliva secretion. It is also recommended to change drinking habits—avoiding prolonged “sipping” of beverages and using straws to minimize direct contact between acids and the tooth surface.

In a dental office setting, proper tissue management following iatrogenic procedures is crucial. Studies using AFM microscopy clearly indicate the need for extremely rigorous enamel polishing after the removal of fixed braces (debonding). Inadequate polishing of the surface leaves micro-cracks that act as gateways for acids from energy drinks, leading to drastically faster tissue destruction than in the case of smooth, healthy enamel (Iosif et al., 2022). Furthermore, to strengthen tissue resistance, professional application of remineralizing agents (e.g., calcium-, fluoride-, and phosphate-based) is recommended, as these effectively inhibit the decline in microhardness of enamel subjected to acid attacks (Jácome et al., 2025).

An extremely promising approach to prevention, one that does not require direct involvement on the part of the patient, is modifying the composition of the beverages themselves during production (so-called prevention at the source). Systematic reviews including *in situ* studies confirm that fortifying energy drinks with calcium compounds or xanthan gum significantly reduces their erosive potential, protecting the enamel structure under oral conditions (Jácome et al., 2024). The addition of green tea extract exhibits similar, highly protective properties. The polyphenols contained in this extract, due to their antioxidant and surface tension-modifying effects, effectively reduce mineral dissolution and decrease the roughness of enamel exposed to acid erosion (Blatter et al., 2023; Hamza et al., 2021). A practical summary of the most important behavioral and clinical recommendations for patients in high-risk groups is presented in Table 1.

Table 1. Clinical and behavioral guidelines for physically active patients who consume low-pH beverages

Area / Risk Factor	Don'ts	Do's
Post-Workout Hygiene	Brushing your teeth immediately after a workout or drinking an energy drink (especially with whitening toothpaste).	Postpone brushing for at least 30–60 minutes to avoid post-erosive abrasion.
Neutralization of acids	Replacing plain water with various isotonic beverages to quench thirst.	Rinsing your mouth with plain water after exercise, chewing gum with xylitol to stimulate saliva production.
Timing	Slowly “sipping” a drink from a can over many hours, which steadily lowers the pH.	Drink the beverage quickly, preferably through a straw (to avoid contact with the surfaces of the teeth near the lips).
Orthodontic Treatment	Leaving the enamel incompletely polished after removing the braces (debonding).	Rigorous, highly precise polishing of the enamel to seal micro-cracks that are susceptible to acid attacks.
Clinical Support in the Office	Relying solely on the patient's personal hygiene at home for high-risk individuals.	Regular application of professional varnishes and remineralizing treatments (e.g., containing calcium and phosphates).

5. Conclusions

An analysis of the current literature allows us to draw the following clinical conclusions regarding the impact of energy drinks and pre-workout supplements on the oral health of adolescents and athletes:

1. Extremely high erosive potential: Energy drinks and liquid pre-workout supplements are characterized by critically low pH and high titratable acidity. This leads to rapid demineralization, a decrease in enamel microhardness, and an increase in surface roughness after just a few minutes of exposure.

2. The false safety of “Zero” variants: The elimination of sugar in “Zero” and “Light” drinks protects against classic bacterial demineralization (tooth decay), but does not reduce the risk of acid erosion. These beverages have a destructive effect on the mineral phase and organic matrix of tissues, often exceeding the effects of sweetened variants.

3. Critical accumulation of cofactors in athletes: Hyposalivation and a decrease in the buffering capacity of saliva caused by intense physical exertion, combined with the intake of environmentally aggressive supplements immediately before or after training, completely deprive the oral cavity of its natural protective mechanisms.

4. Risks in Orthodontics: Patients treated with fixed braces are at increased risk of rapid demineralization (WSL). Furthermore, microdamage to the enamel caused during the removal of brackets requires meticulous polishing; otherwise, it creates an opening for rapid erosive degradation.

5. The Need for Proactive Prevention: Protecting teeth requires behavioral education for patients (including avoiding brushing immediately after consuming acidic liquids or after exercise to prevent post-erosive abrasion) and the implementation of professional remineralization procedures. There is also great hope in the technological modification of beverages through the addition of calcium compounds, xanthan gum, or green tea extracts, which effectively reduces their destructive potential at the source.

A detailed summary of the most important scientific studies and review articles forming the foundation of this work is presented in Table 2.

Table 2. Summary of selected studies evaluating the impact of energy and pre-workout drinks on hard dental tissues and risk factors.

Author and year of publication	Type of study	Test Sample / Material	Key Clinical Findings
(Martínez et al., 2024)	In vitro study	67 sports drinks on the market	The average pH of the tested liquids is 3.3, which classifies them as highly corrosive.
(AlHelal et al., 2025)	In vitro (FTIR Spectroscopy)	Isolated enamel samples	A decrease in the mineral phase and exposure of the organic matrix are visible after just 5 minutes.
(Hamza et al., 2021)	In vitro study	Sweetened Beverages vs. “Zero” Varieties	The absence of sugar does not protect against erosion; “Zero” versions are just as chemically aggressive.
(Iosif et al., 2022)	In vitro (AFM Microscopy)	Enamel after the braces are removed	The acid from energy drinks creates deep craters with a topography resembling des
(Mitic et al., 2020)	In vitro (SEM Microscopy)	The area around the enamel-cement junction	Rapid degradation of root cementum and exposure of dentin tubules.
(Melbye et al., 2020)	Survey	High school students in Norway	A significant lack of knowledge about erosion. Boys constitute the main group with elevated consumption.
(Grzesiak-Gasek & Dębska-Łasut, 2026; Lind et al., 2025)	Clinical trial	Elite swimmers and triathletes	Intense physical exertion drastically reduces saliva flow and buffering capacity.
(von Bremen et al., 2025)	Clinical trial	Teens with braces	Drinking energy drinks increases the risk of developing white spots fourfold.

Author and year of publication	Type of study	Test Sample / Material	Key Clinical Findings
(Gálvez-Bravo et al., 2025; Grzesiak-Gasek & Dębska-Łasut, 2026)	In vitro study	Enamel exposed to acids	Brushing with toothpaste that has a high RDA immediately after an acid attack causes irreversible abrasion.
(Jácome et al., 2024)	Systematic Review	Changes to the composition of beverages	The addition of calcium, xanthan gum, or green tea significantly reduces the erosive potential.
(Kawałko et al., 2022)	Literature Review	Health effects of energy drinks on children, adolescents, and young adults.	Energy drinks drastically lower the oral pH, directly promoting demineralization. Additionally, the sucrose present in them acts as a medium for cariogenic bacteria.
(Lisik et al., 2026)	Literature Review	Systemic effects of energy drink consumption (the role of caffeine and taurine).	Caffeine in energy drinks increases noradrenaline release, which at higher doses overstimulates the nervous system and promotes chronic sympathetic arousal.
(Dziarnowska et al., 2026; Małajewicz et al., 2026)	Literature Review	The effect of different forms of physical activity on anxiety symptoms in adults.	Although moderate physical activity is beneficial, extremely intensive exercise can paradoxically exacerbate anxiety symptoms by amplifying physiological stress.
(Dziarnowska et al., 2026)	Literature Review	The consequences of sleep deprivation and lack of recovery on body functioning.	Sleep deprivation leads to autonomic nervous system dysfunction, resulting in a shift of the autonomic balance toward pathologically elevated sympathetic activity.

Author Contribution:

Conceptualization G.P. and A.C.; methodology, A.C; software, M.Z.; validation, G.P., Z.K., and M.B.; formal analysis, G.P.; investigation, J.S.; resources, A.C.; data curation, G.P.; writing original draft preparation, M.Z.; writing review and editing, Z.K. and M.B.; visualization, J.S.; supervision, G.P.; project administration, Z.K; All authors have read and agreed to the published version of the manuscript.

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