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Analysis of the pH levels in energy and pre-workout beverages and frequency of consumption: a cross-sectional study

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Abstract

Background Erosive tooth wear is an increasingly common pathology in the youth population. It refers to the chronic, localized, painless loss of dental hard tissues caused by non-bacterial acids, often originating from external sources like acidic beverages. Energy drink consumption is on the rise, frequently preceding physical exercise to enhance perceived energy levels. However, there are other types of beverages that also provide energy, such as pre-workout drinks, classified as sports drinks. The main objective of this research study has been conducted with the purpose of analyzing the pH of energy drinks and pre-workout beverages, and studying the frequency of consumption of such beverages in amateur athletes who practice sports.

Methods A total of 67 beverages were examined, comprising 43 energy drinks and 24 sports supplementation beverages, also known as pre-workout or pre-training beverages. The participants were given a survey to complete. They were asked to respond whether they consumed any type of pre-workout or energy drink, and they were also asked about the timing of consumption.

Results The findings indicated an average pH of 3.3 among the studied beverages, indicating a pH below the critical threshold. Out of the 113 participants, 51% reported taking some form of supplementation.

Conclusions Consequently, it was concluded that most of the analyzed beverages recorded pH values low enough to classify them as erosive, posing a threat to enamel surface. When analyzing the frequency of consumption of energy drinks and pre-workout beverages in amateur athletes, we observed that most participants aged 29 years or younger took supplements 3 to 5 times a week, while the older age groups more frequently took supplements 1 to 2 times a week.

Keywords Tooth erosion, Energy drinks, Sports drinks, Supplement, Pre-workout, Sports, Athletes

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Introduction

Erosive tooth wear is characterized by a pathological, chronic, localized, and painless loss of dental tissues, caused by the chemical action of acids, excluding the involvement of microorganisms [1–3]. The chemical components inherent in solid and liquid foods consumed by individuals play a fundamental role in the development of erosive tooth wear. Evidence supports that the pH of foods is a causal factor in this process, with the critical pH value established at 5.5, below which erosive tooth wear is presumed to initiate [4, 5].

Understanding that after consuming acidic solid or liquid foods, there is a rapid decrease in pH within the first few minutes, followed by an increase that returns to baseline values between 20 and 40 min later, is important. However, the recovery of salivary pH depends on several extrinsic factors such as the pH and buffering capacity of the food, and the duration of exposure, as well as intrinsic factors like salivary flow and composition [1–5].

In recent years, there has been a significant increase in the consumption of energy drinks and pre-workout beverages aimed at improving athletic performance during training sessions and recovery afterward, both among elite and amateur athletes [6, 7]. The substantial increase in the consumption of energy drinks during training sessions among young and adolescent populations has been remarkable, reaching over 5.8 billion liters in 160 countries in 2013, with more than double the consumption occurring between 2016 and 2024. In this context, several studies have reported a high prevalence of oral health issues such as dental caries and erosion associated with increased consumption of energy and sports drinks, particularly among children, adolescents, and athletes [8–11]. Over the past two decades, sports dentistry has emerged as a specialized field within dentistry aimed at preventing and managing oral and facial trauma and associated oral diseases, particularly those affecting athletic performance [12, 13].

Existing research on the erosive potential of energy drinks and pre-workout beverages is limited. Consequently, this research study has been conducted with the purpose of analyzing the pH of energy drinks and pre-workout beverages, and studying the frequency of consumption of such beverages in amateur athletes who practice sports.

Materials and methods

The present study analyzed the pH of 67 commercially available energy drinks and pre-workout beverages. Additionally, a survey was conducted among 113 amateur athletes who completed an anonymous questionnaire to determine their consumption habits regarding different types of beverages during various sports activities.

In-vitro analysis of erosive beverages

An in vitro research study was conducted to analyze the most consumed energy drinks and pre-workout supplementation beverages among athletes.

Before commencing the study, energy drinks from registered brands and various types of pre-workout beverage samples were collected, ensuring they met the inclusion criteria for the study. Subsequently, the beverages were classified according to the registered brand to analyze the pH value based on the brand. Once the samples were obtained, pH measurement commenced in the laboratory.

A total of 67 beverages were examined, comprising 43 energy drinks and 24 sports supplementation beverages, also known as pre-workout or pre-training beverages. All selected beverages belonged to the most commercially available brands currently.

The pH measurement and data collection were carried out at the laboratory facilities of the Universidad Católica de Valencia San Vicente Mártir (Santa Úrsula Campus). A pH meter (SU 051 026) was used for pH measurement, which is widely used in the literature for the study of different beverages [6, 14, 15].

Prior to each measurement, the pH meter underwent calibration using a fluid calibrator set at pH 7.0 and a constant temperature of 25 °C. Calibration involved the use of a buffer solution at 25 °C with a pH of 7.00 ± 0.02. Distilled water was employed for pH meter cleaning between each determination. Concurrently, the weight and mass of each beverage were verified using a scale (SU 006 060) to ensure consistency with the manufacturer's specifications. Powder or suspension samples were diluted according to the manufacturer's recommended liquid quantity using a ml measuring container.

Initially, energy drinks were poured into a container, and pH measurement was conducted. For pre-workout supplementation, a more rigorous procedure was followed. Liquid composition samples were determined similarly to energy drinks. In contrast, powder samples underwent weight verification on the scale before mixing. Then, the powder was mixed with the recommended amount of water by the manufacturer, according to the powder quantity. This mixture was stirred in a closed container for 1–2 min until the required dissolution was achieved, at which point pH measurement of the beverage was carried out.

Analysis of the consumption of energy drinks and pre-workout beverages among amateur athletes

A cross-sectional epidemiological study was conducted, using a descriptive study. The work was approved by the ethics committee of the Universidad Católica de Valencia San Vicente Mártir (UCV/2022–2023/097). All study

participants or their parents or legal guardians signed informed consent to participate in the study.

The study recruited participants who met specific criteria: being 15 years old or older, engaging in regular sports activities for at least 6 months with a minimum weekly frequency, and not being a national or international elite athlete. Those who provided complete and accurate questionnaire responses were included. After confirming eligibility and obtaining informed consent, participants completed a previously validated questionnaire with minor modifications [16]. This questionnaire assessed demographics, sports and energy drink consumption patterns (frequency, timing, brands), and reasons for consumption. It consisted of two sections: Sociodemographic characteristics (age, sex, university affiliation, sports discipline), and energy drink consumption practices (frequency, brands, reasons for consumption).

Participants categorized their sport as strength training (grip strength, bodybuilding, powerlifting, weightlifting, strongman, or strength athletics) or endurance sports (running, jogging, cycling, spinning), or both. They reported pre-workout or energy drink consumption and timing (before, during, or after workout). Consumption frequency for specific supplements was determined using a table listing examples of popular energy drinks and pre-workout supplements alongside frequency options (never, once or twice a week, 3–5 times a week, or 6 or more times a week). This list aimed to standardize results while acknowledging the market's variety. To capture uncommon supplements, a final open-ended question allowed participants to specify any missing product names.

Table 1 Different energy drinks and their corresponding pH values

Energy drinks	pH
Red Bull Energy Drink	3,1
Red Bull (Sugar Free)	3,4
Red Bull Zero	2,6
Red Bull "The Green Edition"	3,2
Red Bull "The Red Edition"	3,2
Red Bull Fig and Apple Flavor	2,9
Red Bull Apricot and Strawberry Flavor	2,8
Red Bull Coconut and Blueberry Flavor	2,9
Contact Energy Drink	3,4
Contact Energy Drink Light	3,7
Monster Energy Green	3,3
Monster Mango Loco	3,0
Monster Energy Ultra White	3,3
Monster Absolutely Zero Sugar	3,7
Monster Energy Ultra Red Zero	3,7
Monster Energy Ultra Fiesta Mango	3,8
Monster Energy Ultra Paradise	3,6
Monster Energy Ultra Watermelom Zero	3,2
Monster Energy Monarch	3,5
Monster Ripper	3,5
Monster Energy Pacific Punch	3,3
Monster Mule (Ginger Brew)	3,7
Monster Super Dry Energy Nitro	3,5
Monster Assault	3,6
Monster Lewis Hamilton	3,9
Monster Ultra Gold Zero	3,5
Monster Energy Zero	3,8
Reign Melon Mania	3,2
Reign Razzle Berry	3,5
Reign Orange Dreamsicle	3,9
Reign Peach Fizz	3,8
Burn Energy Drink Original	2,4
Burn Energy Peach Zero	3,8
Rockstar Original Energy Drink	2,9
Rockstar Energy Original (No sugar)	3,0
Rockstar Guava tropical flavor	2,6
Nocco Caribbean Pineapple (No sugar)	2,8
Nocco Apple BCAA+ (Sugar-free and caffeine-free)	2,8
Nocco Passion Caffeine 180 mg (No sugar). BCAA.	3,0
Nocco Miami Strawberry (No sugar)	3,3
Nocco Blood Orange (No sugar)	3,3
Nocco Mango del sol	3,2
Nocco de limón del sol	3,3

Statistical analysis

After calculating the sample size, a population proportion was estimated from the sample of 111 cases, with a maximum error of 9.3% for p=q=50 (worst-case scenario) and a confidence level of 95%. A reference value of 115 was considered to anticipate possible sample loss throughout the study.

The statistical analysis was conducted using the IBM SPSS Statistics 26.0 software package (IBM Corp, Armonk, NY, USA). Descriptive analysis included the number of subjects (n), mean values, and standard deviation (SD). For inferential analysis, chi-square tests were utilized to study the existence of two nominal variables, and non-parametric tests were applied for dependent samples that did not meet normality criteria. Normality tests were assessed using the Shapiro-Wilk test.

Results

In vitro analysis of erosive beverages

A total of 67 beverages were analyzed in this study, comprising 43 registered brand energy drinks and 24 samples of pre-workout supplementation from various commercial brands. The pH determination of the beverages was conducted using a pH meter.

Tables 1 and 2 display the different types of energy drinks and pre-workout beverages along with their respective pH values.

Table 2 Different pre-workout beverages and their corresponding pH values

Pre-workout drinks	pH
Prozis Big Shot Pre-workout (Orange Spark Flavor)	4,5
Prozis Big Shot Pre-workout (Fiery Raspberry Flavor)	4,5
Prozis Big Shot Pre-workout (Lush Mango Peach Flavor, caffeine free)	4,4
Prozis Powa	4,2
Prozis Energy Charge Pre-workout	5,4
Kyowa Quality L-Glutamine	6,8
My Protein Pre-Workout	4,0
My Protein The Pre-Workout (Blue Raspberry)	4,7
Pre Train 10 Genix Pre Train Green Apple Flavour	4,4
BioTech USA Nitrox Therapy Peach Flavored	4,0
BioTech USA Black Blood	4,0
Star Labs G2T Go2Train Pro Ultraconcentrated Pre-Workout	4,2
FA XTREME Pre-Contest Pumped stimulated free	4,2
FA ICE HYDRO AMINO	4,3
C4 Cellucor Ultimate Pre-Workout Orange Mango	4,0
Iron Nutrition X-PN	4,9
Life Pro Cherry Candy	3,1
Life Pro Pre -Workout	3,3
Scientific Nutrition, SICA+ (Red fruits)	4,5
Moons Truck	5,6
Big Science Real Rip (Really Intense Pre-Workout)	6,8
Amix Nitro Nox (Hardcore Pre-Training Shot)	3,9
Amix Cell up Energy Shot	4,2
Wheyland Mode On (Ultraconcentrated Pre Workout)	4,0

Table 3 Type of beverage and its corresponding average pH

DRINK	AVERAGE pH
Energy drinks	3,3
Pre-workout drinks	4,496
Energy and Pre-workout drinks	3,728

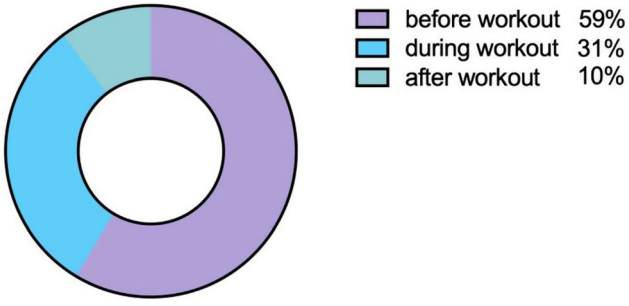

Fig. 1 Distribution of supplementation based on timing of intake

The mean pH of both energy drinks and pre-workout beverages was determined separately and collectively (Table 3).

Analysis of the consumption of energy drinks and pre-workout beverages among amateur athletes

The survey was completed by a total of 117 participants, but when transferring the surveys to the database, 4 surveys were discarded for not meeting the inclusion criteria for participants. The final sample consisted of 113 participants. Of the total participants, as shown in Figs. 1 and 65% (74) were men and 35% (39) were women.

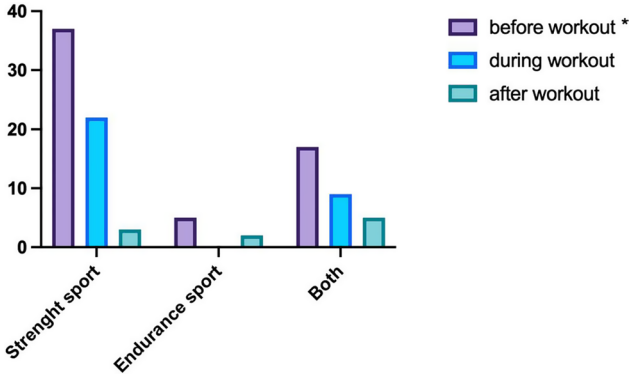

Fig. 2 Distribution of the timing of beverage consumption based on the sport practiced

Regarding the type of sport practiced, 50%, or a total of 57 participants, reported engaging in strength training, 26%, corresponding to 29 participants, stated they practiced endurance exercise, and 24%, totaling 27 participants, selected the option of both types of sports. When analyzing the type of sport by sex, it was observed that men engage in more strength training than women, with these results being statistically significant ($p<0.05$). In contrast, when examining the practice of endurance sports, the number of men and women participating in this activity is similar.

Figure 1 shows when energy drinks and pre-workout beverages were consumed by the study population, with the highest frequency occurring before training sessions.

When comparing data relating the type of exercise practiced and the timing of supplement intake among study participants, it can be observed (Fig. 2) that all athletes consumed the beverages most frequently before training sessions. However, a considerable number of athletes practicing strength training, and a combination of strength and endurance exercises consumed these drinks during training sessions. When analyzing the type of sport practiced by amateur athletes, the timing of intake, and the participants' gender, we can observe that pre-training consumption is higher and statistically significant in both sexes compared to consumption during or after training ($p<0.05$).

After comparing data relating the type of exercise practiced and the timing of supplement intake among the study participants, it can be observed that 37.3% of participants consuming beverages did so 1 to 2 times per week, 40.7% consumed them 3 to 5 times per week, and 22% consumed energy drinks 6 times or more per week. When examining beverage consumption according to the sport practiced (Fig. 3), we find that amateur

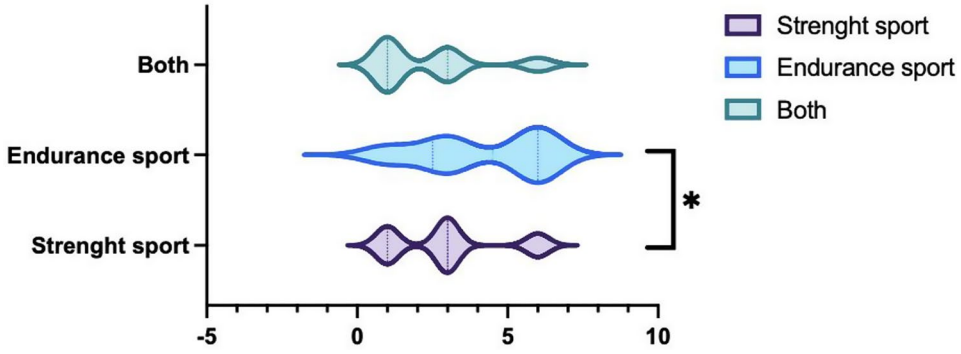

Fig. 3 Distribution of the timing of beverage consumption based on the sport practiced

Table 4 Gender distribution based on type of Sport practiced and timing of Beverage Consumption

		Before training	During training	After training
MEN	Strength	38,65%	27,27%	4,54%
	Endurance	4,54%	0%	0%
	Both	13,63%	9,09%	2,27%
WOMEN	Strength	28,58%	7,14%	0%
	Endurancce	7,14%	0%	7,14%
	Both	28,58%	7,14%	14,28%

athletes engaged in strength training consumed beverages most frequently 3 to 5 times per week. Statistical analysis revealed a significant difference ($p<0.05$) in the frequency of energy and pre-workout beverage consumption among participants based on their training type. Athletes engaged solely in strength training consumed these beverages 1–2 times per week, while those primarily involved in endurance sports reported a significantly higher consumption frequency, exceeding 6 times per week.

Upon analyzing the type of sport practiced in relation to the timing of erosive beverage consumption by gender, it is evident that most men, irrespective of the type of sport, consumed energy drinks or pre-workout beverages prior to training, with the highest consumption observed among those engaging in strength exercises. These men predominantly consumed these beverages before training, followed by during training. Conversely, the analysis of beverage consumption in women, categorized by the sport practiced, reveals that women who participated in strength training and a combination of strength and endurance exercises most frequently consumed these beverages before training. This was followed by women who engaged in both types of exercises, with consumption occurring after training, as illustrated in Table 4.

Figure 4 presents all the data obtained from our study regarding the type of supplementation in relation to the number of participants and the corresponding frequency of consumption for both energy drinks and pre-workout supplements. Monster Energy drink emerged as the most consumed supplement by a larger number of participants, garnering 8 responses for the frequency of 1 to 2 times per week, 7 responses for the frequency of 3 to 5 times per week, and 2 for 6 times or more. The MyProtein

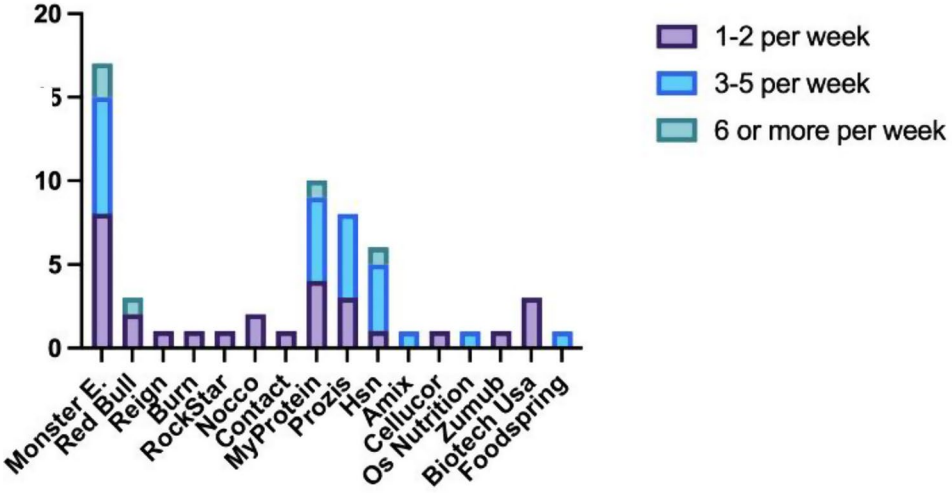

Fig. 4 Participant Distribution Based on Consumption Frequency

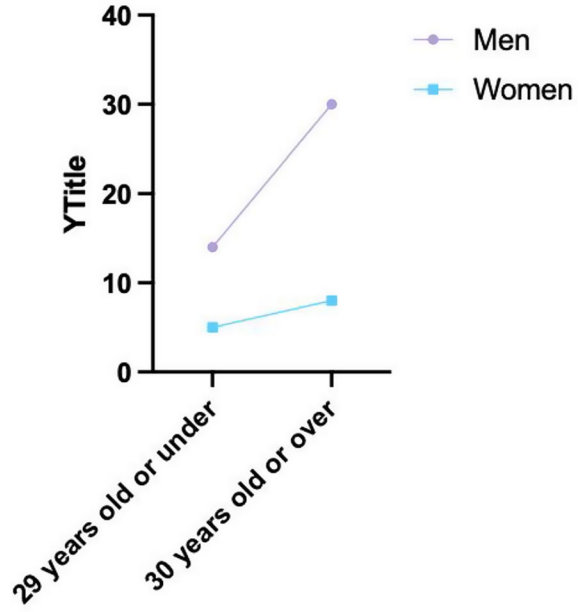

Fig. 5 Distribution of participants taking supplementation based on age and gender

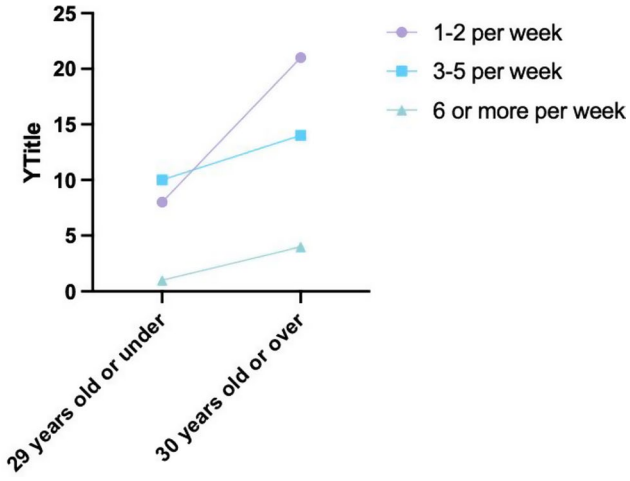

Fig. 6 Distribution of supplementation usage frequency based on age

pre-workout supplement ranked as the second most consumed supplement, accumulating 4 responses for the frequency of 1 to 2 times per week, 5 for the frequency of 3 to 5 times per week, and 1 for the frequency of 6 times or more per week. The third most popular supplement among participants was also another pre-workout, this time from the Prozis brand, with 3 affirmative responses for the frequency of 1 to 2 times per week and 5 for the frequency of 3 to 5 times per week. The fourth most popular supplement among participants was the pre-workout from the HSN brand, with 1 affirmative response for the frequency of 1 to 2 times per week, 4 affirmative responses for the frequency of 3 to 5 times per week, and 1 for the frequency of 6 times or more per week."

The recurrence of supplementation type was analyzed based on gender within our study group, meaning whether men and women who did supplement in our study consumed more energy drinks or pre-workouts. It was found that among male individuals, 21 consumed energy drinks and 23 consumed pre-workout supplements. Among females, it was observed that 5 consumed energy drinks and 9 consumed pre-workout supplements.

Regarding age, participants were divided into 2 broad groups, comprising 29 years or younger and 30 or older. Figure 5 shows that both men and women over the age of 30 consume more energy drinks and pre-workout beverages compared to those under 29 years old, with this trend being more pronounced in men ($P<0.05$).

Figure 6 illustrates the frequency of supplementation consumption based on the aforementioned age ranges without discriminating by the type of supplementation or gender. It can be perceived, that although there is an upward trend in the frequency of consumption among amateur athletes aged 30 years or older, this trend is statistically significant in the increase of 1–2 times per week ($P<0.05$).

When analyzing beverage consumption by participant age group, Fig. 7 demonstrates that participants in both age groups most frequently consumed Monster Energy between 1 and 2 times per week ($P<0.05$). Additionally, participants under 29 years old exhibited a higher frequency of consuming Monster Energy between 3 and 5 times per week and 6 or more times per week, as well as Myprotein. Conversely, participants aged 30 years or older more frequently consumed HSN between 3 and 5 times per week and Monster Energy and Nocco 6 or more times per week.

Discussion

Dental erosion, or erosive wear of the teeth, is a hard tissue disease that negatively impacts individuals' well-being. There is a significant relationship between dental wear and the deterioration of quality of life related to oral health [17, 18].

Consumption of beverages with a pH lower than 5.5 leads to a significant increase in the prevalence of erosive tooth wear [19, 20]. Therefore, it is imperative to evaluate the pH of energy and pre-workout drinks to raise awareness among the population about the risks and effects associated with their consumption [21]. In the context of the present research, an in vitro study was conducted to determine the pH of these beverages, which are consumed by athletes before or during their training sessions. It's important to note that conducting such in vitro analyses offers a significant advantage, as it is carried out in a controlled environment.

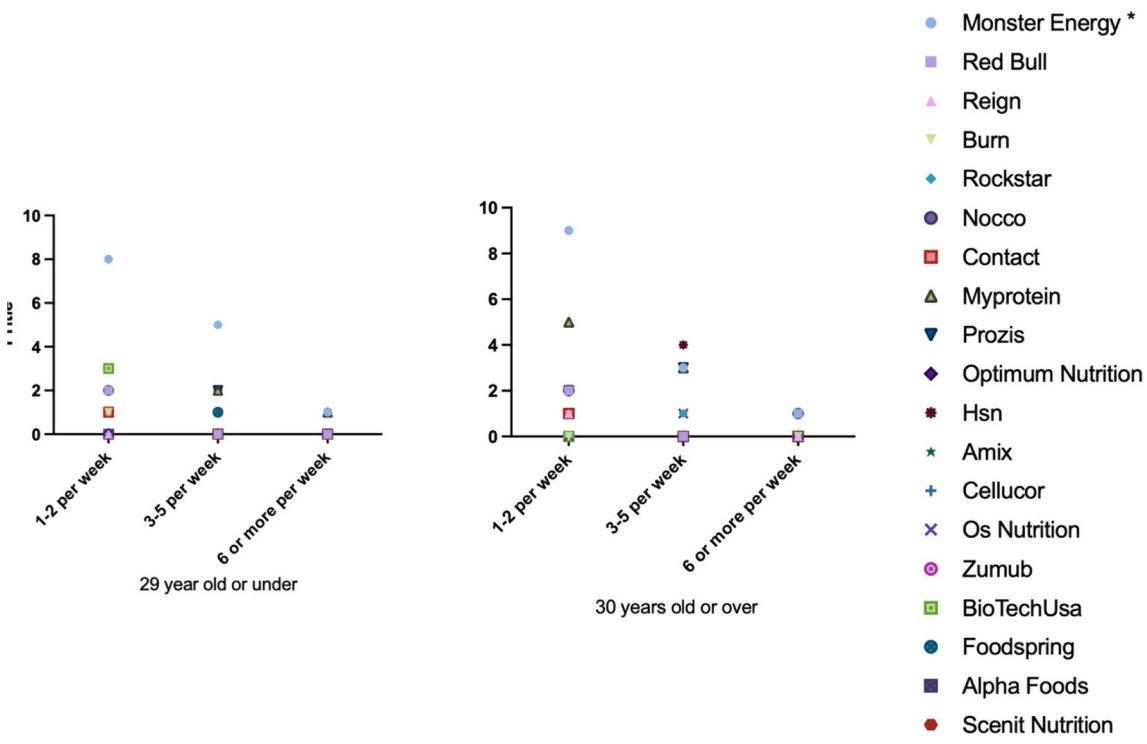

Fig. 7 Distribution of supplementation usage frequency based on age

The study population comprised a total of 67 beverages, of which 43 were energy drinks and 24 were pre-workout sports supplements. All beverages were selected based on inclusion criteria, allowing for the collection and subsequent analysis of samples. Consistent with the objectives established for this study, pH measurements were conducted using a pH meter to determine the corresponding values for each collected beverage.

Upon analyzing the pH of all beverages, it was observed that 100% of the energy drinks recorded a pH of less than or equal to 4.0, and that 87.5% of the pre-workout beverages had a pH below the critical pH threshold, with a pH of less than or equal to 4.5 observed in 75% of cases.

These findings underscore the significant erosive potential of the beverages under study [19, 20, 22, 23].

The findings of this research confirm the variability in acidity levels of energy drinks, as previously documented in related scientific studies [6, 15, 20, 24]. Regarding pre-workout supplementation beverages, their pH can also be classified as low, although compared to energy drinks, these values are more alkaline.

In previous research, various authors have evaluated the erosive capacity of some commonly consumed beverages, using a pH meter, similar to our study, for quantifying these values [6, 15, 21, 25].

Ehlen et al. conducted a study using a pH meter system, in which they evaluated various categories of beverages, including 100% apple juice, regular carbonated drinks, diet carbonated drinks, sports drinks, and energy drinks, observing acidic pH levels and establishing a significant correlation with erosive tooth wear [26].

On the other hand, Pinto et al. conducted research assessing the erosive potential of energy drinks on exposed dentin, demonstrating the possibility of causing lesions and dental hypersensitivity [15].

Kumar and collaborators, in their in vitro study, found that beverages with a pH between 3 and 5 led to a reduction in surface hardness and weight loss of human teeth, classifying these beverages as erosive [27]. Although there are studies analyzing the pH of various types of beverages, including energy drinks [28], no study has analyzed the pH of pre-workout supplements currently used by athletes. In our study, it was observed that both energy drinks and pre-workout beverages exhibited low pH levels, allowing us to categorize both as erosive beverages.

The use of supplements among athletes is a very common practice [29–32]. Erdman et al. [33] concluded in their study that elite athletes took more supplements than non-elite athletes. It was observed that as the level of competition decreased, the prevalence of supplement intake also decreased. Among professional athletes, 93% used supplementation, while among national-level athletes, 83% consumed supplements, and among provincial-level athletes, 76.5% also used them. This seems to be more in line with our study, which revealed that 51% of the participants used supplementation for their training.

The final sample in our study consisted of 65% male participants and 35% female participants, resulting in an unequal distribution of participants by gender, with a ratio of 1.86 male participants for every female participant.

Regarding gender in relation to the prevalence of supplementation, it was noted that men more frequently consumed energy drinks and pre-workout beverages compared to women. This mirrors findings from the study by Goston et al. [34], where the highest supplement intake was in men with 44.6% compared to women with 28.1%. Diehl et al. [35] found that participants in their study took supplementation daily for strength sports, including energy drinks, which were consumed more frequently by men than by women. Other authors, like Sundgot-Borgen et al. [36], did not find differences between sexes regarding the prevalence of supplementation.

Additionally, participants in our study could be classified into 3 major groups based on the timing of supplement intake, and it was observed that the preference trend for the timing of supplementation was before (59%) and during exercise (31%), followed by the group taking supplementation after exercise (10%). This may be because the type of supplements studied functions as energy boosters and are not used as post-exercise recovery aids.

In contrast, Khan et al. [13], while assessing the impact of energy drinks on oral health among elite athletes in Pakistan, observed that the largest group in their sample, comprising 50% of participants, consumed energy and sports drinks after their workouts, followed by a similarly sized but slightly smaller group that consumed them before training, and lastly, the smallest group consisted of participants who consumed them during training. The study also analyzed the frequency of consumption, with the most relevant data indicating that approximately 50% of participants consumed sports and energy drinks once or twice a week, and nearly 25% consumed them once a day.

When comparing it with our own study, where apart from the frequency of energy drink consumption, we also studied the frequency of pre-workout supplement consumption, we observed that the frequency of consumption in our study was 3–5 times per week.

When examining the consumption of energy drinks and pre-workout beverages based on participant gender, we found that men had a higher intake than women. These findings are corroborated by similar studies [4, 37–41].

The study participants were categorized into two distinct age groups based on a pre-established cut-off: under 29 years and over 30 years. This age stratification facilitated the analysis of potential age-related trends in beverage consumption habits. Our findings revealed a positive correlation between age and the consumption of energy and pre-workout beverages, suggesting a potentially age-dependent behavior. These observations align with previous research by Baltazar-Martins et al. [41], who reported a similar trend with a typical supplement user profile of males aged 36–40 years.

The oral environment generated by dietary factors such as acidic beverages can lower the pH, potentially leading to changes in dental structure and negatively affecting its physical properties, thus facilitating the loss of dental hard tissue. This finding is consistent with other studies [4, 24, 42], which evaluated the erosive potential of certain beverages. They found that pH was one of the main parameters related to erosion, as enamel dissolution decreased linearly as pH increased from 2 to 4, with apparent erosion limitation at an approximate pH of 5.

Contrarily, the study mentioned earlier by Khan et al. [13], which examined oral health among elite athletes in Pakistan consuming energy drinks, reported finding erosive tooth wear lesions less frequently than in other studies. These differences could be attributed to the smaller sample size. Erosive tooth wear was evaluated using the Basic Erosive Wear Examination (BEWE), which records the value of the most severely affected dental surface in each sextant on a scale from 1 to 4. The sum of the values from each sextant yields a total numerical value, indicating the presence of erosive tooth wear in 21.2% of the examined athletes.

It is important to highlight that the risk of dental erosion in each patient depends, among many variables, on the consumption of acids of extrinsic origin from solid or liquid foods consumed, as well as certain habits or lifestyles that may lead to a decrease in salivary flow.

The benefits of exercise have been thoroughly proven; however, exercise induces a loss of bodily fluids that can lead to dehydration and a consequent decrease in salivary flow [3, 43]. Mulic et al. conducted a study in 2012 aiming to assess the possible effects of exercise on the salivary flow rate and its correlation with the prevalence of dental erosion. The authors observed that 64% of the individuals who participated in the study showed a decrease in salivary flow after exercising, and of these, 36% presented dental erosion [43]. Other studies, such as the one conducted by Marro et al., also found a high percentage of dental erosion in young athletes with intellectual disabilities [44].

Many athletes, to compensate for fluid loss during exercise, consume energy drinks or pre-workout beverages before, during, and/or after physical activity, as demonstrated in our research and similar studies [9, 45–48], with the aim of improving their performance and recovery [49–53].

This research demonstrates the erosive potential of energy and pre-workout drinks due to their low pH,

which are commonly used by elite and amateur athletes during training sessions, whether before, during, or after exercise.

According to the most recent systematic review, it is essential for healthcare professionals to prioritize dietary factors when evaluating patients at risk of erosive tooth wear. This focus aims to promote preventive measures and prevent both oral and general health problems within the population. The main prevention guidelines should target reducing the intake of acidic beverages, especially during exercise when salivary flow decreases, and increasing the use of fluoride and calcium toothpastes to support remineralization [37].

It would be valuable to explore in future research the impact of pre-workout beverages on the oral cavity. While there are studies examining other types of sports beverages, such as isotonic drinks commonly consumed by athletes to enhance performance and replenish lost fluids and electrolytes during physical exercise, there are still few studies directly linking pre-workout beverage consumption to dental erosion.

Therefore, further research is needed to investigate the relationship between dental erosion and the consumption of erosive beverages in athletes.

Conclusions

The present study demonstrates that all energy drinks and a majority of pre-workout beverages evaluated exhibited a pH below the critical threshold associated with increased erosive tooth wear (ETW) risk. Furthermore, analysis of consumption patterns among amateur athletes revealed a concerning trend of frequent pre-workout consumption, particularly for those engaged in endurance sports (6 or more times per week). These findings suggest a potential link between habitual consumption of acidic beverages and the development of ETW in athletes. Future research is warranted to establish a direct causal relationship between beverage consumption and clinical ETW incidence. Additionally, educational efforts directed towards dental professionals and athletes regarding the oral health risks associated with frequent consumption of acidic beverages are recommended.

Moreover, it is important to establish stringent regulations on the advertising of energy drinks and pre-workout supplements aimed at the youth population, given their potential adverse effects on both oral and overall health following consumption.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12903-024-04843-0.

Supplementary Material 1

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Conceptualization L.M. , E.G. and L.L.; methodology, L.M. , E.G. and L.L.; software, C.B. and JI.; validation, E.G., L.M. and L.L.; investigation L.M. , E.G., C.C. and L.L resources, L.M. , E.G. and L.M.-M.; data curation, L.L; writing—original draft preparation, L.L, C.B, and JI.A.; writing—review and editing, E.G. and L.M.; visualization, L.L, C.B, and JI.A.; supervision, E.G. and L.M; project administration, L.M. All authors have read and agreed to the published version of the manuscript.

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Data availability
Data is provided within the manuscript.

Declarations

Ethics approval and consent to participate
The study was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committee of the Universidad Católica de Valencia San Vicente Mártir (UCV/2022–2023/097). All study participants or their parents or legal guardians signed informed consent to participate in the study.

Consent for publication
Not applicable.

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Competing interests
The authors declare no competing interests.

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