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Energy drinks: is there anything to be concerned about? A review of the literature with attention to the value of drinks among athletes.

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ABSTRACT

Introduction:
Popular energy drinks containing caffeine, taurine or guarana are currently generating a lot of interest. Their supply is an increasingly popular method of boosting the body. Therefore, it is important to know the effects of such drinks on health.

Objective:
A review of the literature on the health effects of energy drinks with a focus on the value of their consumption in athletes.

Current Knowledge:
Many studies have been made and numerous medical cases have been analyzed to assess the health effects of energy drinks. The most commonly described complications are those involving the cardiovascular and neurological systems, but there are also cases of gastrointestinal, kidney, gynecological or skin diseases. The severity of these complications depends on the amount of energy drinks consumed and the time interval in which they were drunk. Nowadays, athletes are increasingly turning to energy drinks to boost their performance. It is also noticeable that children and adolescents who should not consume caffeine or sugar in excess consume this type of drink.

Conclusions:
The growing popularity of energy drinks, including among professional athletes as well as children and adolescents, is leading to an increasing number of complications due to their excessive consumption. Therefore, further research on their health effects and harmfulness is needed to determine their safe use.

Keywords: energy drink, health, athelets, healthcare workers, caffeine, guarana, ginseng, alcohol

Introduction:

Energy drinks are growing in popularity. Attractive marketing, taste and stimulating properties motivate patients to reach for this type of product. The composition of an energy drink varies depending on the manufacturer. The most common ingredients are caffeine, taurine, guarana, vitamin B, herbs and a high sugar content [1]. The composition is supplemented by water, carbon dioxide, acidity regulators and colours. The most important aspects of the ingredients of energy drinks are listed in Table 1.

TABLE 1 Common Ingredients, Therapeutic Uses, and Adverse Effects of Energy Drink Ingredients [1]

Ingredient	Description	Therapeutic Uses	Purported Effect From Energy Drinks	Adverse Effects (due to Idiosyncratic Reaction or Excessive Dosage)
Caffeine	An adenosine receptor antagonist: a central nervous system stimulant	As caffeine citrate, used to treat apnea and bronchopulmonary dysplasia in premature infants	Increases exercise endurance and improves cognition and mood when fatigued or sleep-deprived	Nervousness, irritability, anxiety, insomnia, tachycardia, palpitations, upset stomach, vomiting, abdominal pain, rigidity, hypokalemia, altered consciousness, paralysis, hallucinations, increased intracranial pressure, cerebral edema, seizures, rhabdomyolysis, supraventricular and ventricular tachyarrhythmias
Guarana	A South American plant that contains large amounts of caffeine, theobromine, and theophylline (a chronotrope and an inotrope) and tannins	None known	Stimulant, mainly through the effects of caffeine, and weight loss	Generally considered safe by the FDA Center for Food Safety and Applied Nutrition

Taurine	An abundant amino acid in the central nervous system; acts in neural growth and protection, cell metabolism, osmoregulation, antioxidation, and glycolysis; estimated daily intake is 400 mg/d	Infant formula has been supplemented with taurine since the 1980s because of evidence that it promotes healthy development; used to treat alcohol withdrawal, congestive heart failure, cystic fibrosis, palpitations/dysrhythmias, hypertension, diabetes, seizure disorders, hepatitis	Marketed to promote eye and biliary health and to prevent congestive heart failure by lowering blood pressure while improving cardiac contractility	Generally considered safe by the FDA

Methodology

Various scientific sources describing the effects of energy drinks on the health of the general population with a focus on athletes were analyzed.

Health effects of abusing energy drinks

In a review aimed at investigating the reported effects of acute or chronic abuse of energy drinks on human health (Costantino et al., 2023), researchers evaluated a total of 86 cases (96 studies). Most patients were young (median age 30 years; range 8 to 62 years). The analyzed studies were divided into seven groups based on the effects they presented: cardiovascular (35 studies), neurological (18 studies), gastrointestinal (12 studies), renal (7), gynecological (2 studies), autoimmune and skin (2 studies). [2]

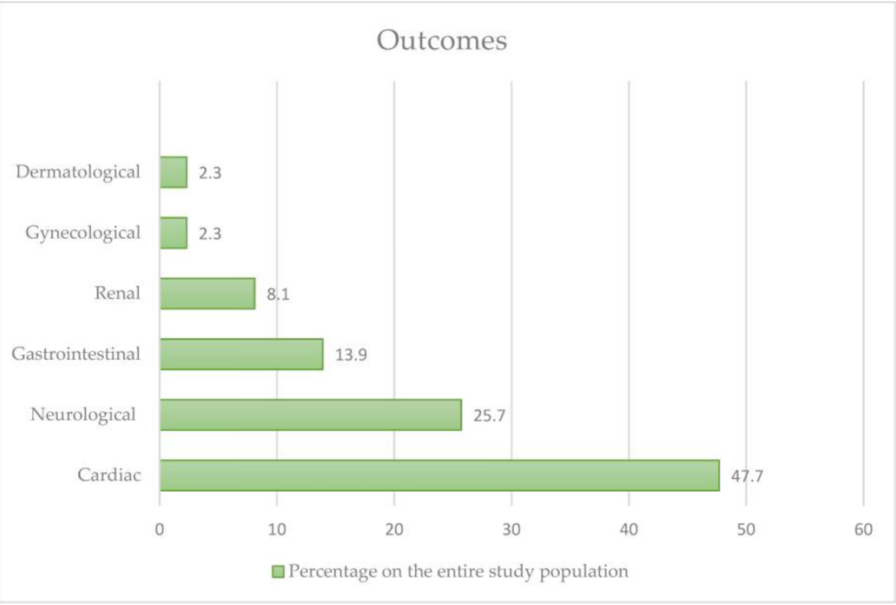

Figure 1. Percentage distribution of the study population according to the developed complication of energy drink consumption [2]

The impact of energy drinks on the cardiovascular system is one of the most frequently studied due to the potentially fatal outcomes of these complications. [2] High consumption of energy drinks reduces insulin sensitivity, thus increasing glucose [3] and noradrenaline [4] levels, and consequently causing a state of hemodynamic and adrenergic arousal [5]. The European Cardiac Arrhythmia Society (ECAS) reviewed reported data on cardiovascular events, including life-threatening arrhythmias with or without cardiac arrest, and other cardiovascular events. It highlights the dangers of consuming energy drinks and emphasizes the need for further well-designed studies to develop safe usage standards and preventive measures [4].

In the report (Costantino et al., 2023), the following adverse cardiovascular events were described along with their frequency: 17 cases (41.5%) of arrhythmias, 6 (14.7%) of cardiac arrest after resuscitation, 5 (12.2%) of arterial dissections (aortic or coronary), 5 (12.2%) of acute coronary syndrome, 3 (7.3%) deaths, 2 (4.9%) cardiomyopathies, 1 (2.4%) case of hypertension, 1 (2.4%) aneurysm, and 1 (2.4%) case of syncope. The median age of patients who exhibited adverse cardiovascular effects from abusing energy drinks was 27.7 years. Cardiovascular complications were observed in only 21.9% of women. These complications were observed after consuming varying amounts of energy drinks; for example, atrial fibrillation was triggered by drinking two cans of the drink [2][6], whereas a fatal heart attack was reported in a patient who drank 20 cans the previous night [2][7]. In another comparative analysis evaluating the impact of energy drinks on the cardiovascular system (C. Ajibo et al., 2024), it was shown that excessive consumption results in an increased number of supraventricular contractions and a decrease in heart rate [8][9], as well as increased arterial stiffness [8,10] and elevated systolic and diastolic blood pressure [8][11].

Studies indicate an overall improvement in information processing performance after caffeine consumption. EEG study results confirm the belief that caffeine is a stimulant, increasing transmission through D2 dopamine receptors by inhibiting A2A adenosine receptors [12]. It is believed that caffeine doses of less than 500 mg result in increased alertness, faster speech and thought, and reduced fatigue and need for sleep [2]. However, higher doses can cause anxiety, restlessness, insomnia, and even tremors or seizures unresponsive to antiepileptic drugs [2][13].

The most commonly reported neurological complications described in the study (Costantino et al., 2023) are: experiencing a psychotic episode (40.9%), clonic seizures (27.3%), as well as retinopathy, ischemic stroke, subarachnoid hemorrhage, and the presence of agitation and anxiety. Similar to cardiovascular complications, neurological effects varied depending on the amount of the drink consumed and the time in which it was consumed. Mania episodes were observed in a patient who consumed seven times the recommended dose of ginseng daily for several months [14], and in a man who drank 20 cans of the drink within 24 hours [15]. [2]

Studies show that excessive consumption of energy drinks, in addition to cardiovascular and neurological complications, which are the most frequently described, can also generate gastrointestinal problems (e.g., hepatitis and pancreatitis)[16][17], kidney diseases (e.g., acute kidney failure)[18], gynecological complications (e.g., severe menstrual bleeding)[20], and skin issues (e.g., erythema)[20]. [2]

As with cardiovascular events, neurological and gastrointestinal complications were more common in men than in women.[2]

The impact of energy drink consumption on athletic performance

Energy drinks contain numerous substances that may affect athletic performance by enhancing exercise efficiency, endurance, and cognitive abilities. One of the primary ingredients responsible for these effects is caffeine. Energy drinks feature caffeine sourced from coffee beans, as well as a form derived from seeds of a plant native to the Amazon basin, commonly known as guarana, which contains caffeine at concentrations approximately 4 times higher than coffee beans. Aside from its higher caffeine content (ranging from 2 to 4.5%), caffeine from guarana is released more slowly in the body compared to caffeine from coffee, leading to a longer and more stable stimulating effect.

Caffeine was listed as a prohibited substance by the World Anti-Doping Agency (WADA) until 2004, with a permissible urine concentration limit of 12 μg/mL [21]. This regulation was particularly significant for athletes using alternate forms of caffeine, as compliance would have been challenging through isolated consumption of beverages containing caffeine. Assuming an average caffeine content of approximately 80 mg per 250 ml can of energy drink, with a volume of distribution of 0.7 L/kg body weight, a half-life of approximately 5 hours, and 1-3% of unchanged caffeine excreted in urine, an athlete would need to consume around 11-12 cans to risk disqualification. Currently, due to the absence of restrictions on caffeine supplementation, it has become a noteworthy substance for enhancing athletic performance and has been the subject of extensive research. A correlation between the application of an appropriate caffeine dose and the performance of study participants has been observed in disciplines requiring high endurance, such as cycling and strength sports-cyclists who ingested at least 5 mg of caffeine per kilogram of body weight achieved better times than the placebo group [22][23], and similarly, participants in resistance training who ingested 3 mg or more per kilogram of body weight recorded a higher number of exercise repetitions [24]. This trend extends beyond endurance sports to high-intensity disciplines like swimming, rowing, running [27], and sports involving intermittent effort such as team sports or racquet sports [25][26]. Genetics play a significant role in determining the optimal dose for achieving desired athletic outcomes, specifically the polymorphism of cytochrome P450 1A2, which affects caffeine metabolism in the liver. From a pharmacological standpoint, consuming more than 6 mg of caffeine per kilogram of body weight does not yield stronger effects [28, 29]. For a male weighing 70 kg consuming energy drinks containing 80 mg of caffeine per 250 ml can, this equates to approximately 5 cans.

Another key ingredient in energy drinks is taurine—a naturally occurring amino acid responsible for supporting neurological and muscular functions. While taurine does not exhibit stimulating properties on its own, its addition to caffeine-containing energy drinks brings about beneficial athletic effects through several mechanisms. Taurine modulates calcium homeostasis in muscle cells, optimizing muscle contraction and enhancing muscular endurance during intense physical exertion. Furthermore, as an antioxidant, it reduces oxidative stress induced by caffeine, protecting cells from damage. Consequently, the combination of taurine and caffeine can lead to improved physical performance, faster muscle recovery, and reduced risk of excessive nervous system stimulation.

Studies confirm enhanced athletic performance among athletes using such beverages compared to placebos in disciplines such as cycling [30], soccer [31], volleyball [32], rugby [32], racquet sports [33], and strength sports [34, 35]. Some studies also indicate superiority of energy drinks combining caffeine with taurine over those containing caffeine alone [36].
While energy drinks may enhance athletic performance, their consumption is also associated with potential side effects and health risks.

Consumption of energy drinks among children, adolescents, and young adults:
According to surveys, energy drinks are consumed by 30% to 50% of teenagers and young adults, which is a highly worrying statistic. One study found that 28% of 12- to 14-year-olds, 31% of 12- to 17-year-olds, and 34% of 18- to 24-year-olds reported regularly consuming energy drinks. [1] Regular consumption of energy drinks risks exceeding safe doses for caffeine and causing toxic effects among children and adolescent. According to the European Food Safety Authority (EFSA), the safe dose of caffeine for children is 2.5 mg per kilogram of body weight per day, i.e. for example: for a 13-year-old weighing 40 kg, the safe dose of caffeine is 100 mg/day. A 500 ml can of energy drink can contain up to 160 mg of caffeine. This poses a real risk of exceeding safe doses and caffeine intoxication, which can cause strong psychomotor agitation, weakness, nausea and vomiting, and in extreme cases cardiac arrhythmia or paralysis of the nervous system. High energy drink consumption has also been linked to more frequent sleep disturbances among adolescents [37]. It is extremely important that paediatricians make patients and their carers aware of the dangers of regularly consuming energy drinks. Attention should also be paid to the amount of sugar in these products, which contribute to overweight and obesity, but also caries.

Consumption of energy drinks among healthcare workers:
Medical workers are vulnerable to sleep disorders due to their shift work. Caffeine increases cortisol secretion in people under psychological stress, disrupting the neuroendocrine response, circadian rhythm and thus affecting cognitive function and performance, body weight and diet quality. Furthermore, the combination of stress and caffeine causes an additional increase in blood pressure. Recommendations in this group include avoiding high intake of coffee and energy drinks to eliminate the anxiogenic effect and possible sleep disturbances. [38] It has been shown that nurses who consume energy drinks have significantly poorer sleep quality and fewer hours of sleep than caffeine-only and non-caffeine consuming nurses, and higher perceived stress levels compared to non-caffeine consuming nurses. [39]

Energy drinks combined with alcohol:
Consuming energy drinks with alcohol is a common practice and contributes to alcohol abuse. [40] Among students, the use of such a connection is estimated at 37%. [41] Some of the chemicals found in energy drinks may improve ethanol's reinforcing characteristics. [42] Problems also include more frequent drunkenness, younger drinking age, alcohol poisoning, more negative side effects, as well as engaging in risky sexual behaviour and using illicit substances [43].

Conclusions:

The growing popularity of energy drinks, including among professional athletes as well as children and adolescents, is leading to an increasing number of complications associated with their excessive consumption. Energy drinks can enhance athletic performance through their content of caffeine and taurine, which increase endurance and exercise efficiency. Despite these benefits, the consumption of energy drinks may involve health risks and side effects. Further research into their health effects and harms is therefore needed to determine their safe use. The existing safe dosage of caffeine should not be forgotten, as well as added sugars or sweeteners, which should not be a dietary basis.

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Authors contribution:

Conceptualization Karolina Błaszczak, Maria Witkowska, Mateusz Sawicki ; Methodology Maria Witkowska, Joanna Skotnicka; Software: Karolina Błaszczak, Joanna Skotnicka; Formal analysis Joanna Skotnicka, Monika Turek, Katarzyna Jastrzębska; Investigation Karolina Błaszczak, Monika Turek, Adrian Borkowski; Resources: Maria Witkowska, Monika Turek, Mateusz Sawicki ; Data curation: Aleksandra Jaroń, Katarzyna Jastrzębska, Adrian Borkowski; Writing - rough preparation Aleksandra Jaroń, Katarzyna Jastrzębska, Mateusz Sawicki ; Writing -review and editing Klara Wojciechowska, Adrian Borkowski; Supervision: Klara Wojciechowska, Aleksandra Jaroń; Project administration: Karolina Błaszczak, Klara Wojciechowska

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