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THE EFFECT OF ELECTROLYTES AND ENERGY DRINKS CONSUMPTION ON ATHLETIC PERFORMANCE – A NARRATIVE REVIEW

Konstantinos D. Tambalis[i]
Department of Nutrition and Dietetics,
School of Health Science & Education,
Harokopio University,
Athens, Greece
Department of Physical Education and Sport Science,
National and Kapodistrian University of Athens,
Greece

Abstract:
The major aim of the current narrative review was to present the current scientific knowledge on the potential effect of electrolytes and energy drink consumption on athletic performance and make recommendations for safe consumption. Athletes appreciate the need to consume fluids before, during, and after exercise as well as the significance of hydration by using drinks or/and energy drinks containing carbohydrates, salts, caffeine, taurine, and other ingredients. Energy drinks are considered by many athletes and/or exercisers to promote, in addition to high levels of energy, important hydration during exercise. The high levels of temperature and humidity in the atmosphere combined with intense exercise of the athlete increases the fluid requirements to avoid a possible risk of thermal disturbances. It is recommended that at least 4 hours before the start of the sports effort, the athlete should consume 5-7 ml of fluids per kilogram of body weight. During exercise that lasts more than 40 minutes, the creation of personalized hydration strategies is proposed. The athlete should try to drink fluids to replace, at least to some extent, enough of the fluid lost through sweat so that the total fluid deficit for a training session or competition is kept at no more than approximately 2% of body mass (an average of 200 ml per 20 min of exercise). During exercise lasting more than 1 hour and causing fatigue, athletes are advised to consume a carbohydrate source that is rapidly converted to blood glucose, while, sodium should be included in fluids consumed during exercise lasting more than 1-2 hours. The main ergogenic nutrients in most energy drinks appear to be carbohydrates and/or caffeine and taurine. The ergogenic value of caffeine on mental and physical performance is well established. Consuming energy drinks 10-60 minutes before exercise can improve focus, alertness,

[i]Correspondence: email dp425603@hua.gr

anaerobic performance, and/or aerobic exercise performance. Higher calorie energy drink intake may promote weight gain if the energy intake from its consumption is not carefully assessed as part of total daily energy intake. Children and adolescents should consider using energy drinks only with parental consent and after considering the number of carbohydrates, caffeine, and other nutrients contained in energy drinks.

Keywords: electrolytes, energy drinks, exercise, athletic performance, health

1. Introduction

In general, athletes appreciate the need to consume fluids before, during, and after exercise as well as the importance of hydration sometimes by using drinks containing additional carbohydrates and salts [1]. Some athletes, however, do not drink enough fluids, while others drink far more [2]. It is therefore important for athletes and sports people to be informed about some practical aspects of hydration, including the following: (a) when it may be useful to drink fluids during exercise; (b) how much to drink, (c) what kind of drinks are best, and (d) what modifications should be made to their hydration when exercising in a hot or cold environment [3]. Just as general competition and training strategies should be tailored to each athlete individually and according to their unique needs and preferences, so should hydration strategies during exercise [4]. Athletes and coaches should refine these recommendations to determine the plan that will help them achieve their athletic goals. The most important functions of water in the human body, in summary, are the following: (a) controls the body's osmotic pressure, and through it maintains the proper balance between fluids and electrolytes, (b) it is the basic component of cytoplasm and blood, (c) it has a main thermoregulatory role since it is the most important component of sweat, (d) it is important for the smooth functioning of the senses and the proper functioning and protection of tissues and organs [5-6]. Therefore, it is understood that the maintenance of the water balance in the human body is necessary and vital for its proper functioning either in conditions of rest or in conditions of exercise [7]. Energy drinks are considered by many athletes to offer, in addition to high levels of energy, important hydration during exercise [8].

Energy drinks, i.e. those sugary drinks that contain caffeine should not be confused with sports drinks designed to hydrate the body during exercise. Energy drinks are not a good choice to consume during exercise (especially in the heat) due to their high sugar content which can interfere with the absorption of fluids consumed [9]. While energy drinks may seem refreshing and hydrating, they should not be consumed before, during, or after exercise when they should replace sweat loss [10-11]. These drinks can also be potentially dangerous if used in excess or in combination with other stimulants or alcohol consumption [12]. Finally, some energy drinks may contain prohibited substances, such as those derived from uncontrolled herbs [13]. Most drinks are not tested for purity and could result in a positive doping test [13]. According to published research, energy drinks are the most popular dietary supplements, except multivitamins, especially among

teenagers and young [11-13]. Energy drinks are also reported as one of the most popular supplements among athletes [11, 13]. More recent evidence claims that energy drinks have ergogenic properties that focus on both psychological support and athletic performance [14]. First of all, it is important to distinguish between energy drinks and sports drinks. Sports drinks are a distinct category within the beverage industry and are marketed to consumers with the primary function of promoting hydration, replacing electrolytes, and maintaining endurance exercise performance [15]. They usually provide a small number of carbohydrates (e.g., 6-8 gr/100 ml) and electrolytes (sodium, potassium, calcium, magnesium) [15]. Energy drinks on the other hand, usually contain higher amounts of carbohydrates, along with nutrients that are said to improve attentional perception and/or mental alertness [16]. There are also low-calorie energy drinks on the market that claim to improve mental alertness, energy metabolism, and athletic performance [14]. As mentioned above, given that energy drinks contain water, carbohydrates, caffeine, and/or nutrients, it is considered that they could affect mental focus, concentration, exercise capacity, and fatigue [13-16].

The purpose of this paper is to review the scientific literature and make recommendations regarding the role that electrolyte and sports drinks may have on athletic performance and/or health and energy expenditure/metabolism, as well as safety issues related to their consumption.

2. Methods

Scientific studies for this narrative paper were found mainly via systematic research of the electronic databases PubMed, MEDLINE, and EMBASE, using title words, terms, and abstract words such as "exercise", "athletes", "health", "athletic performance", "athletic nutrition", "electrolyte", "water", and "energy drinks". Moreover, we assessed previous review articles, as well as references from original research and athletic nutrition books. Health, athletic performance, exercise, electrolyte, and energy drinks were all used as keywords. We desired scientific studies that used the above terms and were published in the English language between January 1985 and June 2022. Studies were taken into consideration if they presented knowledge on electrolyte or energy drinks in athletes and exercisers, evaluated their probable efficiency in terms of health and/or athletic performance, or presented a detailed mechanism of action, administration protocol, safety, and recommendations. Each article's abstract and title were investigated, and the full text was retrieved in circumstances where inclusion was uncertain.

2.1 Dehydration and athletic performance

Maintaining water balance is a very important factor in achieving optimal athletic performance, especially when exercising in a hot environment [17]. The increased loss of fluids from the body due to intense sweating can cause negative consequences in sports performance and some cases even serious complications for the human body, such as heatstroke [18-19]. Dehydration is defined as the condition in which the human body loses

more fluids than it takes in, with the final result being a lack of the necessary amount of water to continue its functions smoothly and without interruption [5-6]. A negative consequence of dehydration during exercise is an increase in core body and muscle temperature. It is thought that a 1% reduction in body weight due to sweating causes a 0.2°C increase in core temperature [5]. Other important negative effects of dehydration on exercise include a reduction in cardiac output due to reduced stroke volume and a reduction in blood pressure, factors that result in a reduced ability to continue high-intensity exercise [20]. In addition, significant dehydration can cause problems in concentration and reflexes and through them possibly also in sports performance in many sports that are affected by the above characteristics [20]. Finally, it is easy to see that when the exercise is carried out in a hot environment the aforementioned negative consequences on sports performance can be more intense, and also if the exercise is particularly prolonged and intense (e.g. marathon, triathlon, etc.) and in a hot environment with coexisting negative water balance, then even heat disturbances (e.g. heat cramps, heat exhaustion, and heatstroke) may occur [20-23].

Dehydration can also occur with cold environmental conditions and in sports where fluids are available such as team sports (e.g. football, basketball) where there are breaks (e.g. half-times, substitutions, etc.). This phenomenon is more widely known as voluntary dehydration [24].

In conclusion, the higher the levels of temperature and humidity in the atmosphere and, at the same time, the more intense the level of exercise of the athlete, the more the fluid requirements increase to avoid a possible risk of thermal disturbances.

2.2 Recommendations for fluid consumption before exercise

The American College of Sports Medicine in collaboration with other scientific bodies issued an official statement regarding fluid consumption before, but also during, and after exercise. In particular, it is recommended that before the start of the exercise, and specifically at least 4 hours before the start of the sports effort, the athlete consumes 5-7 ml of fluids per kilogram of body weight. By implementing the above recommendations, the athlete or athlete is allowed to exercise with optimal levels of hydration as well as to eliminate the possible excess of fluids with urine. Also, it is suggested that the athletes are at their optimal hydration levels in the previous days before the sports test. If in the previous days the exerciser does not urinate or his urine appears dark, then based on the recommendations, the athlete should consume an additional amount of fluids of 3-5 ml per kilogram of body weight, before the start of the exercise [25-27].

2.3 When is it useful to drink fluids during exercise?

Fluids consumed during exercise can play several roles, such as making the athlete more comfortable, helping to replace fluid deficits, and providing a means to consume other nutrients components (e.g. trace elements, and minerals) [25-26]. The importance of each of these roles varies depending on the situation. Athletes need not or rather rarely, drink fluids during exercise lasting less than about 40 minutes [28]. But some of them feel better

after rinsing their mouth with cool drinks, which anyway do not cause any damage to sports performance [28, 29]. During training or competition that lasts more than 40 minutes, there are usually opportunities for fluid intake, a strategy that often brings advantages to athletes or athletes. When athletes can't drink fluids during exercise that causes "heavy sweating" and lasts more than 30 minutes, an alternative is to hydrate well shortly before the start of the session. The athlete should practice fluid intake during the 15 minutes before exercise and find the amount of fluid needed to fill up which will make them feel comfortable at the start of exercise (e.g., 300-800 ml) [25, 26, 30-31]. The characteristics of the exercise (e.g., type, intensity, and duration), the temperature and humidity of the environment, the individual rate of sweating, as well as the possibility of consuming liquids concerning the sport, do not allow the creation of detailed recommendations that to concern all practitioners.

Thus, as mentioned at the beginning of the Chapter, the creation of personalized hydration strategies is proposed, based on the particular conditions and requirements of each sport as well as the personalized needs of each athlete or exerciser.

2.4 How much to drink?

Sweating causes a loss of water and salts from the body, but in addition, water is constantly lost through respiration and the skin, even if these losses are not visible [5]. Small water losses do not affect athletic performance, but severe dehydration is detrimental to performance [5]. There is no clear scientific data on the point at which athletic performance begins to be affected, and this almost certainly varies between individuals, as well as with the type and duration of exercise, environmental conditions, and the body's initial hydration level [32, 33]. Athletes are often advised to drink only when they are thirsty, but this strategy is not always reliable.

In addition, the rules and opportunities for the athlete to drink fluids in many sports may not coincide with the time when the feeling of thirst occurs [34]. A more targeted option is for the athlete to develop a flexible rehydration plan that fits their sport, individual, and other nutritional needs [29]. As a starting point, the athlete should try to drink fluids to replace, at least in part, enough of the fluid lost through sweat so that the total fluid deficit for a training session or competition is kept at no more than approximately 2% of body mass (e.g. 1.0 kg for a 50 kg person, 1.5 kg for a 75 kg person, and 2 kg for a 100 kg person). In particular, the recommended fluid consumption rate amounts to an average of 200 ml per 20 minutes of exercise. It appears that above this threshold (2%), or according to other researchers even with a 1% loss of body mass, there is a risk of developing serious complications such as hyponatremia and heat disturbances [10, 25-26]. Finally, it appears that cool fluids and those close to the exerciser's taste preferences enhance fluid consumption [25, 26].

2.5 Dehydration and exercise in a hot environment

As mentioned above, in hot environments, the needs for training or competition and the restoration of fluids and electrolytes interact with the environment and thus increase the

risk of reduced performance. When sweat loss rates are very high, it is not always practical for the athlete to consume enough fluids to keep the water deficit below target [26, 35]. A more feasible alternative is for the athlete to simply try to minimize dehydration. In some cases, athletes over-hydrate during exercise, meaning they drink more fluids than they lose through sweat. When fluid intake is excessive, it can lead to a serious problem called hyponatremia (dilution of sodium concentrations in the blood) [36]. This problem occurs more often in recreational athletes who may exercise at low intensities but drink large amounts of fluids in the belief that they are doing the right thing [37]. In all these cases, an athlete or sportsperson can help him to replace fluid losses, when he can have an estimate of his usual sweat rates. The guide below provides some ideas on how you can check this.

2.6 When do you need more than just water?

Although hydration is a key goal of nutritional strategies during exercise, fluids consumed during exercise may also contain several nutrients. During exercise lasting more than 1 hour and causing fatigue, athletes are advised to consume a carbohydrate source that is rapidly converted to blood glucose [26]. This generally improves athletic performance - allowing the athlete to maintain pace, skill, and concentration [26]. The aims of carbohydrate intake during exercise vary depending on the athlete's preparation (how well they are carbohydrate-loaded), the energy needs of the exercise (session duration and intensity), and individual tolerance [38]. The use of commercial sports drinks with a carbohydrate content of about 4-8% (4-8 gr/100 ml) allows the simultaneous filling of carbohydrate and fluid needs in most cases [35]. These carbohydrates may come from sugars (i.e., sucrose, fructose, and glucose), maltodextrins, or other rapidly digestible carbohydrates. Athletes should prefer known sports drinks that they are familiar with to avoid gastrointestinal upset or other negative consequences [35]. Some athletes can tolerate more concentrated sports drinks, especially if they contain added sugars. Practicing these drinks in training can help the gut better cope with possible adverse symptoms during the race. Usually, when carbohydrates are consumed during exercise, it is best to consume them in a planned frequent and continuous intake. This will provide constant stimulation of the brain and central nervous system, or when needed, a constant source of additional fuel for the muscle [39]. Sodium should be included in fluids consumed during exercise lasting more than 1-2 hours or by individuals who during exercise and in any case have large sodium losses (i.e., more than 3-4 grams of sodium) [39].

2.7 Hydration after exercise

Replacing water and salts lost through sweat is an essential part of the recovery process. Given that sweat and urine losses continue to occur during recovery, the athlete should drink approximately 1.2-1.5 liters of fluid for every kilogram of body weight lost in training or competition to restore and make up for losses in full [27]. Sodium, the main salt lost in sweat, should also be replaced. Sodium replacement can be achieved through

the intake of fluids containing sodium, such as sports drinks and rehydration solutions [27]. However, a simple meal or snack can also supply the body with the salt it needs. This is because most foods contain salt in high concentrations (e.g. bread, breakfast cereals, cheese, processed meats) or because salt is added in the preparation or serving of the meal. Post-exercise recovery is a part of preparing for the next exercise session, and adequate hydration should be considered an important part of the equation. Thus, the time that elapses until the next exercise session is an important factor that should be taken into account since, if another exercise session does not follow within the same day, the replenishment of fluids and electrolytes may be covered by the consumption of the usual meals and liquids during the rest of the day [35, 40]. However, if the next training session (e.g. dual practices, qualifiers, semi-finals) is on the same day and the intervening time for rehydration is limited, then the fluid consumption strategy mentioned above (1.2-1.5 liters of fluid for each kilogram of body weight loss) [35, 40]. The use of tasty and cool sports drinks seems to significantly help achieve the above goal.

2.8 Special strategies

Athletes who are dehydrated to lose body weight need specific hydration strategies before and during competition to optimize their athletic performance [41]. These athletes will benefit from the advice of qualified and experienced sports nutrition professionals. Athletes who train and compete during a religious fast must practice a hydration strategy that maintains performance and protects their health [4]. The athlete mustn't attempt to try new fluid and energy fuel intake plans during an important race [4].

2.9 Practical ways to assess and manage hydration

Severe dehydration reduces athletic performance and increases the risk of heat illness, but on the other hand, excessive fluid consumption can also be harmful or uncomfortable. Every athlete is different, as they have different sweat losses and different opportunities to drink fluids during training and/or competition. For everyone, a personal hydration plan is needed, and the specialist scientist should play an important role in developing that plan. It should also be taken into account that people do not adapt to dehydration.

Three steps could help your hydration practices:

1) Start your exercise session well hydrated. If you urinate less often than normal, you may be dehydrated. If the colour of your urine is darker than normal for you, then you may not be drinking enough fluids. Check the colour of your urine from the chart. High fluid consumption can have unpleasant consequences, while if it is excessive, it can also have harmful consequences. The goal is to develop daytime hydration practices that keep pace with regular fluid needs and replace specific losses from exercise or a hot, humid environment. As fluid losses vary, so must hydration practices. It is preferable to spread fluid intake throughout the day rather than trying to meet needs at the end of the day. Drinking more than you need at the end of the day can mean interrupted sleep due to pee breaks.

2) Develop a training and race hydration plan that's just right for you. This should be based on many factors, including your typical sweat losses, opportunities to hydrate during your sport, and your feedback about when you feel comfortable and thirsty. Also, the athlete should monitor their sweat losses and the success of their hydration plan during training in different situations. I mean, how did you feel? How was your performance what was your weight loss during the session? This should not go above about 1-2% of body mass. If you've lost more weight than the above percentage, then you're probably not drinking enough fluids, so you should drink more next time. If you've lost less, you may have had too much to drink and you should probably see if that makes you uncomfortable. Consuming so much fluid that you gain body weight during competition is likely a performance inhibitor. The only time you may need to do this is when you are dehydrated at the start of the sporting event.
3) If you have a lot of sweat loss, you may need drinks with more salt and you may also need more salt in your food. To check if you have a lot of sweat loss, wear a black T-shirt in training and look for salt stains (white spots) under the arms and on the chest. High salt losses can also be a contributing factor in some cases of muscle cramps. Sports drinks with higher levels of sodium concentration (e.g. 300-500 mg of sodium per 500 ml of fluid) may help reduce the risks of cramping [10, 12-13, 26, 40].

How to calculate sweat losses and sweat rates:

1) Measure body mass both before and after at least one hour of exercise under race-like conditions or a hard workout.
2) Perform these body mass measurements wearing minimal clothing and barefoot. Wipe immediately after exercise and measure body mass as soon as practicable after exercise (e.g. less than 10 minutes and before eating, drinking, or urinating). Example: Weight before exercise = 74.5 kg–Weight after exercise = 72.8 kg–Fluid deficit = 1.7 kg
3) Calculate the weight of the liquid or food you consumed during the workout. (Example: 800 ml of liquid = 800 g or 0.8 kg).
4) Sweat loss (litres) = body mass before exercise (in kg) - body mass after exercise (kg)+weight of fluids/food consumed (kg). Example: 74.5 kg-72.8 kg=1.7 kg deficit+0.80 kg (800 ml of fluid) = sweat loss of 2.5 kg or 2500 ml. To convert to sweat rate per hour, divide by the exercise time in minutes and multiply by 60.
5) Your weight deficit at the end of your training session provides a guide to how well you are hydrated during exercise, and how much you should hydrate afterward [26, 40].

In conclusion, it is scientifically proven that a negative fluid balance has negative consequences for the proper functioning of the human body as well as for athletic performance. Particularly in sports, it is important to develop realistic and workable individualized hydration strategies.

4. Energy drinks

4.1 Ergonomic evaluations of energy drinks

Nutrient consumption before, during, and/or after exercise can affect exercise performance and/or training adaptations [35]. Energy drinks typically contain water, carbohydrates (e.g., glucose, maltodextrin), vitamins, minerals, and "mixes" of various nutrients that purport to increase energy, alertness, metabolism, and/or athletic performance (e.g., caffeine, taurine, amino acids, Guarana, Ginkgo biloba, Carnitine, Panax ginseng, green tea, Yerba Mate, etc.). Therefore, the consumption of energy drinks before, during, and/or after exercise could have some ergogenic value [43]. Caffeine is the most common ingredient used in energy drinks. Caffeine is extracted from the raw fruit of over sixty different species of coffee plant (Coffea Arabica). In summary, after ingestion, caffeine is rapidly absorbed and increased plasma concentrations are observed between 30 - 60 minutes after ingestion. The difference in absorption time depends on the physicochemical properties of the product dosage formulation. Caffeine is a potent cardiovascular stimulant that increases epinephrine production to a greater extent when ingested via its anhydrous form, compared to an equal amount of caffeinated brewed or instant coffee [44]. Additionally, the half-life of caffeine ranges from approximately 2 to 10 hours with 0.5% - 3.5% of its content excreted unchanged in the urine and select minimal amounts excreted through sweat [44].

Another common ingredient in most energy drinks is some type of carbohydrate (e.g., glucose, sucrose, maltodextrin, etc.). Energy drinks also typically contain glucuronolactone, an ingredient involved in the synthesis of ascorbic acid and metabolized to xylose. Evidence from numerous studies shows that carbohydrate intake during exercise lasting 45 minutes or longer can improve endurance capacity and performance [25]. Glucose, sucrose, maltodextrins, and amylopectin are oxidized at high rates, while fructose, galactose, and amylose are oxidized at lower rates (about 25-50% lower). Consequently, energy drinks that usually contain a mixture of different types of carbohydrates aim to optimize the exogenous oxidation of carbohydrates. Energy drinks contain approximately 25 - 30 g of carbohydrates per 240 mL of content. This amount almost covers the lower value of 30 gr/h recommended during endurance exercise but falls short of the upper carbohydrate intake range of 60 gr/h [45]. To achieve this upper level of 60 g of carbohydrate per hour during endurance exercise, one would need to consume approximately 530 mL of a standard energy drink per hour. While the total carbohydrate content of typical energy drinks is quite high, there is a downside to carbohydrate concentration [46-47]. Specifically, the American College of Sports Medicine (ACSM) and the International Institute of Sports Nutrition (ISSN) recommend carbohydrate intake in a 6 - 8% solution (6 - 8 g per 100 ml of fluid) during endurance exercise [15, 26]. On the other hand, a typical energy drink provides carbohydrates in a higher concentration, usually around 11 - 12% [47]. Ingestion of carbohydrates in liquids with a higher content (>10%) has been reported to delay gastric emptying and increase gastrointestinal discomfort [26]. Consequently, athletes who want to use energy drinks

such as sports drinks may need to dilute the drink and/or alternate the consumption of energy drinks with water during exercise.

4.2 Other nutrients

Tables 1 and 2 present a list of additional nutrients commonly found in energy drinks. Most energy drinks also contain a small number of vitamins (e.g., thiamine, riboflavin, niacin, vitamin B6, vitamin B12, pantothenic acid, vitamin C) and electrolytes (e.g., sodium, potassium, phosphorus, etc.). While the addition of these nutrients may add to the nutrient density of these products, there is limited research evidence to support that intake of these vitamins and minerals in the amounts found in energy drinks could provide any ergogenic benefit by the duration of the exercise in people who are properly fed [47]. Additionally, energy drinks typically contain nutrients that purport to promote cognitive function and mental focus (e.g., taurine, Ginkgo biloba, L-tyrosine, citicoline, 5-hydroxy-L-tryptophan [5-HTP], St. John's wort, etc.), stimulants (e.g., caffeine, Guarana, green tea, Synephrine, Yohimbine, tyramine, vinpocetine, etc.), and/or various purported ergogenic nutrients (e.g., Panax Ginseng, L-carnitine, D-ribose, inositol, citrulline, quercetin, etc.) [12, 13].

Table 1: Potentially ergogenic nutrients contained in energy drinks may affect cognition and/or mental performance

Ingredients	Potential ergogenic action	Scientific support
Taurine	It improves mental focus, and concentration acts as an antioxidant and acts in glucose homeostasis	Some scientific findings in animal models
Gingko Biloba	Improves memory and mental concentration	Some scientific findings on memory (e.g., 120 mg/d). Unknown effect on the doses contained in energy drinks
L-Tyrosine	Prevents catecholamine depletion, and may moderate stress-induced cognitive decline	Some findings on cognitive function (e.g., 2 g/d). No effects on performance were observed. There are no known dosage effects found in energy drinks
Citicoline	Intermediate in the production of phosphatidylcholine from choline. It increases the density of dopamine receptors and delays memory impairment	Some supportive findings with high doses (8.5 g before and during exercise) and in animals. There are no known dosage effects found in energy drinks
5-Hydroxy-L-Tryptophan (5-HTP)	Serotonin precursor. Supposedly anti-depressant, appetite suppressant, and sleep enhancer	Some evidence in the treatment of depression and muscle performance in animals. Its role in athletic performance at doses found in energy drinks is unknown
St. John's Wort	Antidepressant	Some encouraging facts. There are no known dosage effects found in energy drinks

While scientific data is supporting the potential ergogenic value of some of these nutrients on cognitive function and/or exercise capacity, the amounts of these ingredients found in

energy drinks are generally much lower than typical concentrations associated with an ergogenic effect [12-13, 47].

Consequently, it is unclear whether the addition of these nutrients to energy drinks provides a synergistic or additive effect on the carbohydrate and caffeine found in these products. Additionally, adding these nutrients to the caffeine found in energy drinks may alter the adverse effect profile of the final products, which warrants further study.

4.3 Energy drinks and athletic performance

Among the main ingredients of energy drinks are included minerals, vitamins, amino acids, taurine, and mixtures of phytochemicals such as caffeine [48]. Generally, their main impact on athletic performance is attributed to the effects of caffeine and taurine [49]. Several studies have investigated the effects of consuming energy drinks before exercise [48-51]. The types of exercise evaluated include resistance exercise, anaerobic exercise, and aerobic/endurance exercise. Overall, it appears that energy drinks containing about 2 mg/kg body weight (B.W.) of caffeine and consumed 45 to 60 minutes before anaerobic/resistance exercise may improve overall upper and lower body weight lifting volume, but do not affect high-intensity repetitive sprint exercise, or speed and agility [48-54]. Also, energy drinks containing about 2 mg/kg B.W. of caffeine and consumed 10 to 40 minutes before aerobic exercise appear to improve cycling and running performance in both trained cyclists and recreational athletes [48-54].

4.4 Mood / reaction time / alertness

Reaction time, concentration, alertness, and subjective feelings of energy/vitality are important in many competitive activities, such as baseball, tennis, and martial arts. Strategies to improve these characteristics are often the subject of a search by high-level athletes competing in such sports events. Over the past several years, scientific research has carefully investigated the potential effects of energy drink intake on these and other characteristics [48-51, 55]. To date, most studies regarding the effects of energy drinks have reported improvements in mood, reaction time, and/or indices of alertness, even if the relative contribution of the various components is not fully understood. However, it appears that the primary ergogenic value is due to the caffeine and/or carbohydrates contained in these beverages. In conclusion, individuals looking to enhance reaction time, mental alertness, and/or focus may benefit from consuming an energy drink before exercise [48-51, 55]. Regarding the potential effect of taurine consumption, a recent meta-analysis examined the ergogenic effects of energy drinks and revealed a considerable improvement in athletic performance mainly in tests of resistance exercise, muscle strength, and other actions, among energy drinks that contained taurine [56].

4.5 Energy drinks and their role in energy expenditure and weight loss

Consumption of some low-calorie energy drinks has been reported to increase resting energy expenditure and fat metabolism on an immediate basis. Preliminary studies suggest that consuming certain types of energy drinks before exercise during the training

period could promote positive adaptations in body composition [55, 57-60]. However, more research is needed to determine whether daily use of energy drinks will affect energy balance and body composition in the long term.

4.6 Adverse symptoms

People with certain medical conditions (e.g., metabolic syndrome or diabetes mellitus) should avoid consuming high glycemic index beverages and/or foods and therefore should not consume high caloric energy drinks. It would be wise for people with known cardiovascular disease to completely avoid the use of energy drinks or other products with known cardio-stimulating effects [61-64]. While energy drinks containing caffeine and other stimulants may have adverse effects on health and cardiac parameters in individuals with such pre-existing health conditions, the current literature (albeit small) suggests that energy drink consumption is safe in healthy individual populations and similar to the intake of other caffeinated foods and beverages [61-64]. Finally, although it is estimated that only 1% of all adverse reactions to supplements have been reported to the US Food Administration (FDA), considering the number of servings of these products consumed daily, the rate of adverse reactions is estimated to be low in the population. Moreover, the pharmacology of agents included in energy drinks, combined with reports of toxicity, raises concern for potentially serious adverse effects, especially among children and adolescents with high energy drink consumption [64, 65]. Nevertheless, it is recognized that additional short-term and long-term studies are needed to more adequately define all those factors that increase the risk for adverse effects. In addition, since energy drinks often contain many nutrients containing caffeine and/or other stimulants, care should be taken not to consume too much in a short period.

Table 2: Potential ergogenic nutrients contained in energy drinks that may affect athletic performance

Ingredients	Potential ergogenic action	Scientific support
Caffeine	Stimulant. Increases metabolism and lipolysis	Increases alertness, mood, and cognitive function. Increases fat oxidation, improves exercise
Guarana	Natural source of caffeine. Similar properties to caffeine	Similar to the effects of caffeine
Green Tea Extract	It contains high amounts of caffeine and catechin polyphenols. It serves as an antioxidant	Similar effects as caffeine. Some encouraging evidence of increased metabolism. The specific role of dosages found in energy drinks is unknown
Synephrine	Alternative to ephedrine. Naturally derived from Citrus aurantium. Stimulant with less cardiovascular effects than ephedrine. Claims to increase metabolism and promote weight loss	Evidence of a mild tonic effect on metabolism and weight loss. There are no known effects at dosages found in energy drinks
Yerba mate	Contains three xanthines (caffeine, theobromine, theophylline). Similar properties and effect to caffeine.	Similar effect to caffeine. Some encouraging facts. There are no known effects on dosages of energy drinks

Yohimbine	Alkaloid with stimulant and aphrodisiac properties	Similar to the effects of caffeine. Unknown effects on energy drink doses
Tyramine	Monoamine is derived from tyrosine. It acts as a catecholamine releasing agent. Raises blood pressure	Mild cardiovascular stimulant. The dose effects found in energy drinks are unknown
Vinpocetine	Vincamine alkaloid extracted from the myrtle plant (Vinca). Vasodilator properties and memory enhancement	There are no known dosage effects found in energy drinks
Panax Ginseng	It contains substances that are said to have anti-inflammatory, antioxidant, and anti-cancer effects. It is thought to increase endurance and improve nitrogen balance	Well-controlled research does not support ergogenic effects. There are no known effects at dosages found in energy drinks
L-Carnitine	It is involved in the movement of long-chain fatty acids into the mitochondria. Aspired to promote lipolysis	Limited ergogenic value in athletes or weight loss. There are no known effects on dosages of energy drinks
D-Ribose	It participates in the synthesis of ATP. Theoretically, it may increase ATP availability	Limited evidence that high-dose ribose affects exercise capacity. Unknown effects at dosages found in energy drinks
B-Alanine	Increases muscle carnosine levels, and reduces fatigue during high-intensity exercise	Increasing findings of improvement in anaerobic capacity (2-4 g/d). There are no known effects on energy drink dosage
Inositol	Carbohydrates are involved in insulin activation, nerve impulse transmission, and fat oxidation	No known effects at dosages found in energy drinks
Citrulline Malate	Optimizes blood flow. It is thought to reduce fatigue and act as an acidity regulator during exercise	Some evidence that doses (e.g., 6-8 g) may affect exercise capacity and/or anabolism. Unknown effects on beverages
Quercetin	It is reported to have antioxidant, anti-inflammatory, and antiviral effects	Research shows that 1 gr/d for 7 d increases maximal aerobic capacity and time to fatigue.

5. Conclusions and recommendations

- Although energy drinks contain many nutrients that aspire to influence mental and/or physical performance, the primary ergogenic nutrients in most energy drinks appear to be carbohydrates and/or caffeine.
- The ergogenic value of caffeine on mental and physical performance is well established, but the potential additional benefits of other nutrients contained in energy drinks remain to be determined.
- Consuming energy drinks 10-60 minutes before exercise can improve focus, alertness, anaerobic performance, and/or aerobic exercise performance.
- Many energy drinks contain many ingredients. These products need further study to demonstrate their safety and potential effects on physical and mental performance.
- There is some limited evidence that consumption of low-calorie energy drinks during exercise and/or in weight loss programs may provide an ergogenic benefit and/or the loss of a small percentage of fat. However, higher calorie energy drink

intake may promote weight gain if the energy intake from its consumption is not carefully assessed as part of total daily energy intake.

- Athletes should consider the impact of high glycemic load carbohydrate intake on their metabolic health, blood glucose and insulin levels, and the effects of caffeine and other stimulants on athletic performance.
- Children and adolescents should consider using energy drinks only with parental consent and after considering the number of carbohydrates, caffeine, and other nutrients contained in energy drinks as well as an in-depth understanding of potential side effects.
- Uncontrolled and reckless use of energy drinks, especially if more than one serving per day is consumed, can lead to unwanted effects and harmful side effects.
- Diabetics and people with pre-existing cardiovascular, metabolic, liver, and neurological disease taking medications that may be affected by the high glycemic index, caffeine, and/or other stimulants should avoid their use unless approved by their doctor [49-51, 56, 65].

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Conflict of interest statement
The author declares no conflicts of interest.

About the Author(s)
Konstantinos D. Tambalis, (MSc, MSc, PhD) is a Teaching and Research Associate at the Department of Nutrition and Dietetics of the Harokopio University in Greece. His research interests are in the areas of athletic nutrition, Physical Education, and epidemiology of exercise.

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