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Sports and energy drinks

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Abstract: Presently, sports and energy drinks are widely spread not only among athletes, but also among ordinary people of different ages. The purpose of these beverages is to effectively compensate for the loss of water, energy and electrolytes in the human body before or after some exhausting activities. A questionnaire survey on energy drinks conducted in all eight federal districts of the Russian Federation shows that the younger groups of the Russian population (aged 12–17 and 18–30) drink tonic beverages more often than the older groups (aged 31–45 and 45–60). Further, a recent rise in unreasonable consumption of sports and energy drinks among teenagers may lead to various diseases: obesity, type 2 diabetes, heart disease and tooth enamel erosion. Finally, the authors analyse the composition of energy beverages and thoroughly describe each of their main components (L-carnitine, creatine, caffeine, taurine, and juice-containing products). These components are used by athletes due to their effects: L-carnitine helps reduce the signs of physical and mental overstrain, and stimulates working capacity; creatine improves endurance and anaerobic activity; caffeine raises aerobic endurance by increasing the oxidation of fats, thereby helping preserve glycogen in the muscles; taurine plays an important role as an antioxidant protector in the regulation of Ca++ transport, and as a regulator of osmotic pressure in the tissues.

Keywords: Energy drinks, sports nutrition, creatine, caffeine, taurine, L-carnitine

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INTRODUCTION

Among specialised food products, sports drinks, as well as energy drinks, have become very popular in the last few decades. Despite an overall decrease in daily consumption of sports drinks, sugar sweetened sports drinks remain popular among the majority of young people, especially high school students. From 2010 to 2015, there was a statistically significant increase in the proportion of teenagers who reported consuming sports drinks in the past 7 days; however, that increase was small (from 56% to 57.6%) [1]. A survey by Cardiff University School of Dentistry [2] showed a large proportion of 12- to 14-year-olds regularly consuming high sugar sports drinks unnecessarily. In particular, it was found that:

– 89% of school children consumed sports drinks, with 68% drinking them regularly (1–7 times per week);
– half of the respondents drank sports drinks for social reasons;
– high sugar content and low pH of sports drinks increased the risk of obesity, type 2 diabetes, heart disease, and tooth enamel erosion; and
– most sports drinks ware purchased by children in local shops at value prices.

Of 160 respondents (87% response rate), 89.4% (143) claimed to drink sports drinks, with 50% drinking them at least twice a week. The main reason for consuming sports drinks was their ‘nice taste’ (90%, 129/143). Most respondents purchased drinks from local shops (80.4%, 115) or supermarkets (54.5%, 78). More boys claimed to drink sports drinks during physical activity (77.9% *versus* 48.6% girls, $P < 0.001$), whereas more girls claimed to drink them socially (51.4% *versus* 48.5% boys, NS).

Water plays a vital role in the diet of athletes. It contributes to the accumulation of glycogen in the muscles (composed of 3–4 parts of water per part of glycogen); in addition, water is involved in the regulation of body temperature. Optimal hydration of the body is of vital importance to human health. Depending on age, temperature, climate, health status and physical activity, the athlete’s daily need for free fluid can vary from 1.5–2 to 5–6 litres per day (in some cases). Drinking regimen in a balanced, healthy diet of athletes cannot be organic, since its deficiency not only contributes to a decrease in the performance, but it can also lead to serious violations of the urinary system [3].

To avoid the risk of dehydration and reduce physical disturbances, athletes are advised to use sports drinks that provide compensation for fluid, electrolyte and carbohydrate losses. In some cases, thirst does not always appear in the early stages of dehydration. At the same time, there are data on dehydration developing in the first 10–15 minutes during, for example, a marathon race.

To quench thirst, it is permissible to use mineral water, fruit and vegetable juices and drinks, fruit drinks, tea, tonic drinks, or fresh fruit. The most widely used are specialised sports drinks.

There are three main types of sports drinks that contain different amounts of water, electrolytes, and carbohydrates:

(1) isotonic drinks, containing water, carbohydrates, and 4–8% electrolytes;

(2) hypotonics, containing 6% electrolytes, 2% carbohydrates, and 92% water; and

(3) hypertensive drinks, containing 32% carbohydrates, 4% electrolytes (not all drinks), and water.

For intensive physical training, it is recommended to take isotonic, and for extremely intensive training, hypertensive drinks that contain a high amount of easily digestible carbohydrates and are designed to quickly restore energy reserves.

Rehydration after physical activity is an important part of the recovery process. Biochemical and physiological recovery of the body begins in the first minutes after the end of endurance exercises. To compensate for losses, it is recommended to use a volume of fluid that is at least 50% greater than its amount lost with sweat [4]. In order to quickly restore the resources, dilute solutions of glucose with the addition of sodium chloride are used, since these hypotonic solutions are most effective in reducing the delay in the stomach and absorption in the intestine.

Replenishment of fluid losses in the body of athletes requires regular compliance with the drinking regime. It is shown that the loss of 9–12% of water is an emergency situation for the body which can lead to death. Losing 2% of weight due to water reduces the work ability by 3–7%, while with the loss of 40% of protein, fat and carbohydrates, a person can stay alive for a long time. In severe physical activity, it is necessary to monitor the state of the water balance and continuously replenish the fluid loss. Water comes in when consuming liquids, with food, and as a result of metabolic processes. The first way accounts for about 60% of total water consumption, the second one – 30%, and the third – about 10%. There are also different ways of water loss from the body: 50–60% of water is daily discharged with urine, about 20% with exhaled air, 15–20% with sweat (depending on the load intensity), and less than 5% with faeces. The average person needs about two litres of water per day to make up for the losses. With intensive loads, water intake reaches 3–4 litres per day. It is proved that when the volume of fluid in the body decreases by 2%, the athlete's result may deteriorate by 15%.

It should be noted that the most effective way to compensate for the loss of large amounts of water and salts is to consume weakly acidic and slightly sweet mineralized drinks, of which the hypo- and isotonic solutions of carbohydrate-mineral complexes are the most physiological.

At present, however, there are no sufficient studies to reveal the psycho-physiological effects of various combinations of tonic beverage ingredients on the organism. Therefore, the state needs to control the release, sales and consumption of tonic beverages. According to the Russian Federation Law 'On Protection of Consumer Rights', the product must be safe for the consumer's life and health.

It is now established that inadequate water intake or moderate dehydration may be associated with a risk of developing chronic diseases [5–7]. Hypohydration is a common condition for 16–28% of the population, depending on the age [8], and dehydration among the elderly is often associated with the presence of chronic diseases [9,10].

Sources of water are liquids or drinks (including drinking water, tea, wine, soft drinks) and water contained in food. All products contain water, although the amount of water in food will vary between their individual species. The European Food Safety Authority (EFSA) found that 20–30% of total daily water consumption in Europe came from food [11]. However, the total percentage of water in food varies vary between countries and depends on the types of foods and diets. For example, in Ireland, the amount of water in foods is on average 33% [12], and in China, where people consume more liquid products, such as soups and broths, it is 40% [13].

The human body has a system for monitoring the volume of fluid by hormonal regulation, carried out through osmoreceptors controlling the osmolarity of blood serum and volume receptors that are responsible for the volume of extracellular fluid. The concentration of sodium in serum is the main parameter of osmolarity. Since perspiration is hypotonic, prolonged exercise increases the osmolality of blood serum.

Active athletes can lose up to 2.5 litres of sweat per hour. Sweat contains electrolytes (mainly sodium chloride, but also potassium, calcium, and magnesium) with a sodium concentration of 20–80 mMol/l. Dehydration occurs when more fluid is lost than consumed. It disrupts the fluid and electrolyte balance in muscle cells, the activity of the cardiovascular system and temperature regulation, reducing the athlete's performance.

The most physiological are drinks containing carbohydrates and minerals. They not only rehydrate the body, but also retain the electrolyte balance and energy status (glycogen stores).

Tonic and energy drinks in sports. In recent years, there has been an increase in the consumption of tonic beverages in the Russian Federation [14]. More than 40% of the population periodically use toning beverages, and 30–50% of them are young people aged 12–24, for whom these drinks are contraindicated because of their negative impact on health [15–17]. Today, there is an increased number of tonic drinks in the market of the Russian Federation. Nevertheless, our survey of 11,850 people of different ages (12–60) and sex in all eight federal districts of Russia showed a fairly low frequency of consumption and no significant differences in the consumption of sweet carbonated drinks between various districts. The survey revealed that the carbohydrate component of sweet carbonated beverages in various districts of Russia, even when consumed frequently (5–6 times a week), did not exceed 3.71% of the total calorie content of the diet or 7.1% of the caloric value of carbohydrates in the diet energy supply [18].

The same survey demonstrated a low frequency of energy drinks consumption. The study showed that individuals aged 46–60 hardly ever used these drinks. Only a small number of individuals aged 31–45 (from 1.25% to 0.32%) consumed energy drinks, but not more than 2–4 times a week. In the 12–17 and 18–30 age groups, there was a slight increase in the number of people consuming energy drinks (Table 1).

Table 1. Energy drinks consumption in various federal districts of the Russian Federation

Federal District	Age groups							
	12–17		18–30		31–45		46–60	
	2–4/week	1/day	2–4/week	1/day	2–4/week	1/day	2–4/week	1/day
Central	1.96	0	2.71	0.19	1.25	0	0	0
North-western	0.99	0	0.90	0.41	0	0	0	0
Ural	0	0	0.30	0	0	0	0	0
North Caucasian	0.33	0	0.21	0.30	0.32	0	0	0
Volga	1.01	0	0.61	0	0	0	0	0
Southern	0	0	5.10	0.60	0	0	0	0
Siberian	0.66	0	2.37	0	0.32	0	0	0
Far Eastern	0	0	1.82	0	0	0	0	0

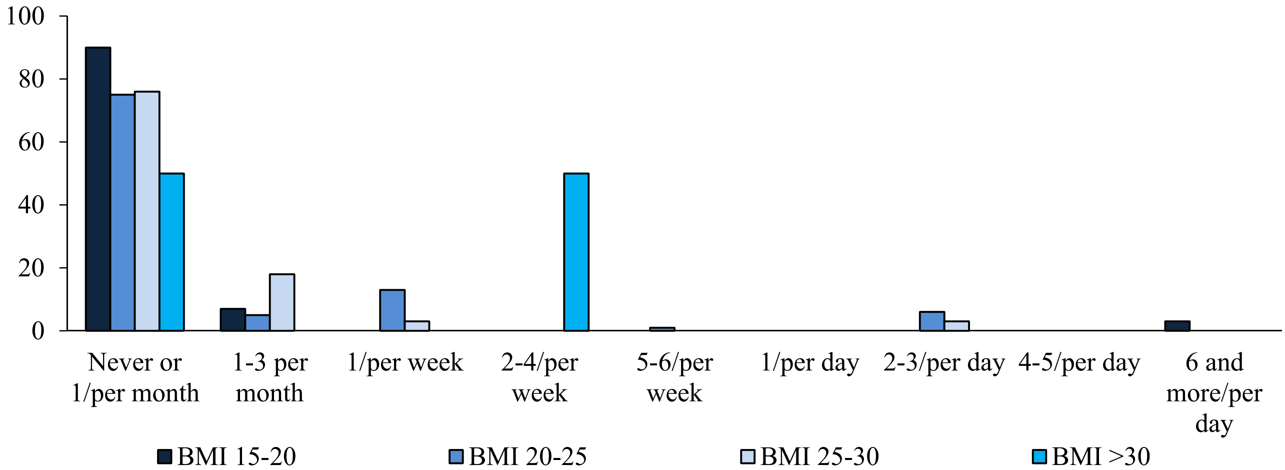

Fig. 1. Non-alcoholic energy drinks (Burn, Red Bull, Adrenaline Rush) consumption by males aged 12–17.

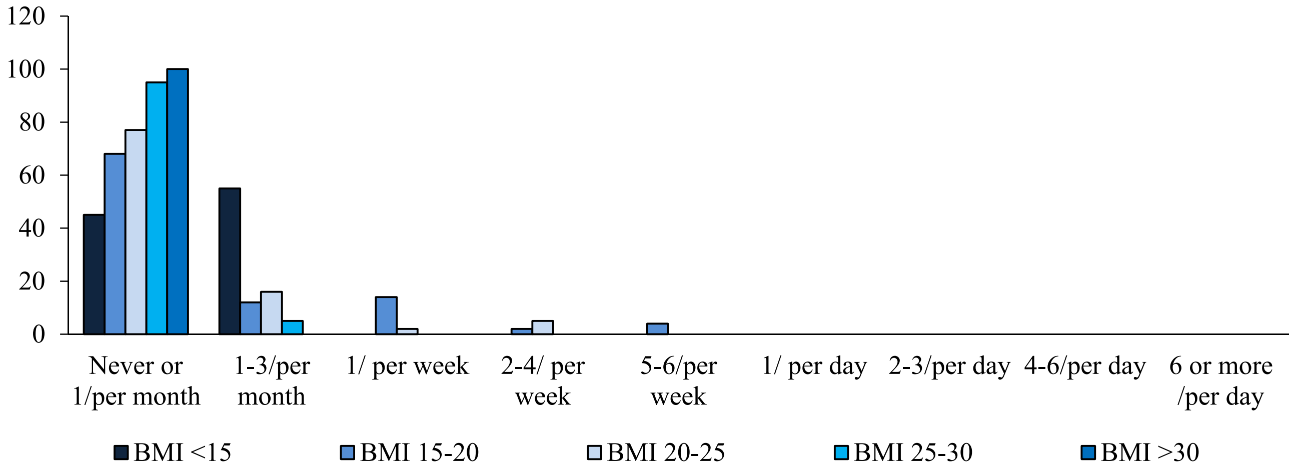

Fig. 2. Non-alcoholic energy drinks (Burn, Red Bull, Adrenaline Rush) consumption by females aged 12–17.

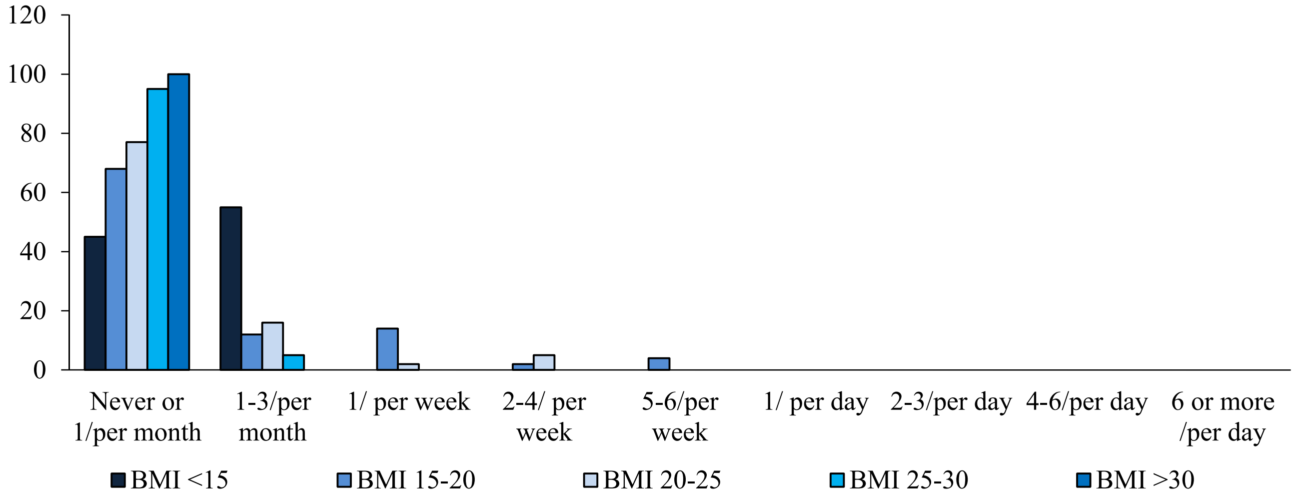

Fig. 3. Non-alcoholic energy drinks (Burn, Red Bull, Adrenaline Rush) consumption by males aged 18–30.

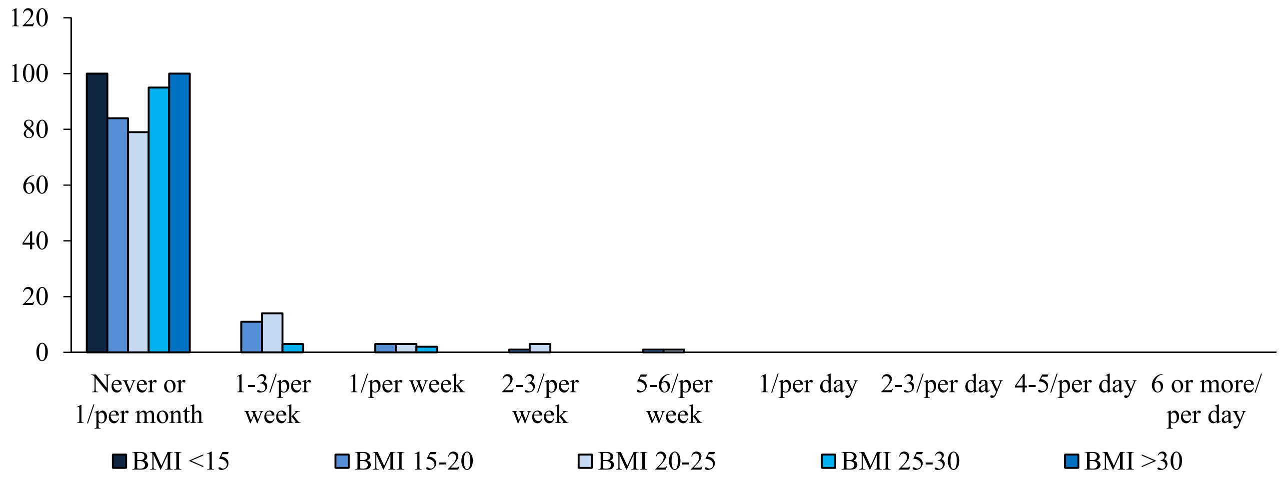

Fig. 4. Non-alcoholic energy drinks (Burn, Red Bull, Adrenaline Rush) consumption by females aged 18–30.

We demonstrated that there was no correlation between the body mass index (BMI) and the frequency of energy drinks consumption (Figs. 1–4) in the main consumer groups (aged 18–30 and 12–17).

The discovery of tonic (energy) drinks in Europe is associated with the Austrian entrepreneur Dieter Mateschitz. In 1984, after studying Asian energy drinks, he modified them to suit European tastes. In 1987, the European market saw the first non-alcoholic energy drink named 'Red Bull Energy Drink,' carbonated and with a lower sugar content than its Asian prototype. Currently, there are over 500 energy drinks consumed in different parts of the world [20]. Energy drinks most often contain a combination of caffeine, taurine, and D-glucurono-lactone among other ingredients, such as synephrine, for example [21].

Synephrine is a biogenic amine of the phenylethanolamine/phenylpropanolamine group. The protoalkaloid p-synephrine is present in the bitter orange (*Citrus aurantium L.*) and other fruits of citrus cultures. The presence of p-synephrine or m-synephrine in food additives containing extracts of *C. aurantium*, indicates adulteration. Only p-synephrine, a natural compound from *C. aurantium* extracts present in food additives, is considered in [21]. The formulation of drinks, however, also includes with the main components such as tonic compounds, amino acids, B group vitamins, and carbohydrates. Among the most important components of energy drinks are also the methyl-xanthine alkaloid Caffeine and the sulphur-containing amino acid Taurine. Energy drinks are becoming more popular among athletes and individuals engaged in fitness and physical exercise. Unfortunately, scientific literature rarely provides evidence of the ergogenic role of energy drinks in sports. Existing evidence suggests that caffeine in doses contained in energy drinks is probably an insufficient factor for increasing muscle activity.

Along with these components (caffeine, taurine, etc.), tonic and energy drinks contain complex carbohydrates. Complex carbohydrates and water, of course, are significant nutrients for athletes, playing an important role in preventing and inhibiting fatigue during long, intensive training. Nevertheless, to analyse the effectiveness and safety of tonic (energy) beverages in sports, it is necessary to analyse the properties of not only carbohydrates, but also all the biologically active ingredients that make up this type of beverage. This is significant, given the multi-component nature of energy drinks. For example, one of the most popular drinks (Red Bull) contains 4 g of taurine, 2.4 g of glucuronolactone, 320 mg of caffeine, 108 g of carbohydrates, and 140 mg of B group vitamins in one litre (4 cans). The concentration of carbohydrates in this drink is 11%, with an osmolality of 601 mOsmol/kg H_2O. By contrast, a well-known sports drink (for example, Gatorade Orange) has a lower concentration of carbohydrates (6%) and an osmolality of 297 mOsmol/kg H_2O. Carbohydrates are basic macronutrients in drinks that determine their caloric value. The calorie content of the drink affects the rate of gastric emptying at rest [22] and its intake in the body during exercise [23]. Emptying the stomach is important for ensuring the bioavailability of the drink. For example, ingesting a drink with a carbohydrate concentration of 8% or higher may result in delays in the blood flow and decrease the availability of ingredients to the muscles. In addition, an increase in osmolality of up to 414 mOsmol/kg H_2O reduces fluid absorption from 82% to 68%, compared to water [24]. The combination of high osmolality and carbohydrate concentration (601 mOsmol/kg H_2O and 11%, respectively) probably reduces its absorption compared to a commercial sports drink. It should be noted that the available data allow us to speak not only of the effectiveness of specialised sports drinks components, but also of their safety. The existing fears associated with the risk of undesirable health effects of caffeine intake from all sources, including tonic beverages, are not justified. A thorough analysis conducted by the European Food Safety Agency (EFSA), and, in particular, the EFSA Scientific Committee's report on food allow us to conclude that an intake of up to 300 mg of caffeine per day is a safe amount [25]. This report is based on the study of caffeine content in the diet of pregnant women. Pure caffeine, as well as caffeine consumed as an extract of green tea, or a combination of the main antioxidant components of tea, epigallocatechin gallate, quercetin and caffeine in amounts equal to their content in the tea extract, is not only safe, but it also improves the antioxidant activity of blood plasma and liver and increases the stability of microsome and lysosome membranes [26]. However, in the context of conflicting opinions among experts on the effectiveness of tonic drinks for athletes and concerns about their safety, it seems worthwhile to mention one of the most comprehensive studies into the safety of energy drinks commissioned by the Ministry of Health of the Russian Federation and conducted by the National Medical Research Centre for Psychiatry and Narcology [27]. It was found that giving rats 30–60 mg of energy beverage per day did not affect the dynamics of their body weight growth; nor did it lead to increased alcohol consumption in adulthood, compared to the control animals. The average daily motor activity of those animals which consumed the drink increased, compared to the control animals, and correlated with the volume of consumed beverage, while remaining at a constant level throughout the experiment. Thus, the analysis of research data and the properties of the main biologically active components of energy drinks suggests that both caffeine and taurine, as well as their combinations in concentrations contained in energy drinks and taken in recommended doses, do not have an adverse effect on the body [28]. Today, there is little information confirming the extensive use of tonic (energy) drinks in sports. There are arguments 'for' and 'against' such practice, so there is a clear need for further experimental and clinical studies into the issue. The safety of energy drinks in the Russian Federation, including in sports, is regulated by the legislative documents. For example, the technical regulations TR CU 021/2011 of the Customs Union stipulate that the amount of caffeine in soft drinks should not exceed 150 mg/l, and in specialised tonic drinks – 400 mg/l. According to Article 4 of the technical regulations TR CU 022/2011 of the Customs Union, soft drinks containing more than 150 mg of caffeine per litre and/or medicinal plants and their extracts in an amount sufficient to provide a tonic effect on the human body should have an inscription 'not recommended for children under the age of 18, pregnant and lactating women, as well as people suffering from increased nervous excitability, insomnia, and hypertension.'

The main biologically active components of specialised sports and energy/tonic drinks. L-Carnitine. L-carnitine is a choline-like quaternary amine discovered by two Russian researchers, V.S. Gulevich and R. Krinberg in 1905. L-carnitine plays an important role in suppressing inflammatory reactions, oxidative stress and apoptosis [29], and ischemic heart disease [30, 31]. Deficiency of acetyl-L-carnitine (ALC) seems to contribute to the risk of developing depression, indicating a dysregulation of fatty acid transport across the inner membrane of mitochondria [32]. L-carnitine is an amino acid derivative that plays an essential role in the cellular metabolism by acylation of its β-hydroxyl group. Carnitine (b-hydroxy-c-trimethylaminobutyrate), a high polar zwitterionic compound, facilitates the transport of long-chain fatty acid across the inner mitochondrial membrane for subsequent b-oxidation [33]. L-carnitine enters the body with food, especially of animal origin, and accumulates mainly in muscle tissue **(**up to 95% of all carnitine consumed); therefore, its deficiency primarily affects muscular activity [34]. Biologically active is the natural L-stereoisomer of carnitine; thus, only L-carnitine should be used as a food supplement or drug [35, 36]. It should be noted that the antioxidant activity of L-carnitine helps to prevent muscle disorders caused primarily by high physical loads [37]. However, the role of L-carnitine is not limited to participation in the energy metabolism of muscles. In fact, it produces a high pharmacotherapeutic effect on damaged muscle tissue [38, 39]. In humans and animals, L-carnitine is synthesised primarily in the liver and kidneys by the transformation of lysine and methionine with the participation of vitamins C, B3 and B6, folic acid, iron, and a number of amino acids and enzymes [31]. Its main function is to transfer long chain fatty acids from the cytosol into the mitochondrial matrix, where their beta-oxidation occurs, to acetyl-CoA, which is a substrate for the formation of ATP in the Krebs cycle. [40–43]. Fatty acids with a short and medium chain length (from 4 to 12 carbon atoms) can penetrate into the mitochondrial matrix by diffusion. Fatty acids with a long chain that predominate in the human body (12 to 20 carbon atoms) are activated by acyl-CoA synthetase located on the outer membrane of mitochondria, with the participation of magnesium ions and ATP [44].

These enzymes catalyse a reaction during which a thioether bond occurs between the carboxyl group of the fatty acid and the thiol group of coenzyme A, i.e. CoA, and a fatty acid derivative is formed. At the same time, ATP is split into AMP and inorganic phosphate. The long-chain acyl-CoA is catalysed by the enzyme carnitine acyltransferase I on the outer surface of the inner membrane with a formation of acylcarnitine, which is transported through the internal mitochondrial membrane with the transport protein-carnitine-acyl-translocase [44]. On the inner surface of the mitochondrial membrane, the enzyme carnitine acyltransferase II catalyses the transfer of acyl to intramitochondrial CoA with a formation of acyl CoA, which during the β-oxidation is converted to acetyl-CoA, participating in the Krebs cycle [44]. Free carnitine returns to the outside of the inner membrane of the mitochondria with the same translocase. Fatty acids with a long hydrocarbon radical are transferred through mitochondrial membranes [44]. It is believed that this pathway receives predominantly long-chain fatty acids in the mitochondria. In addition to being a carrier of fatty acids, carnitine also modulates the ratio of acyl-CoA / CoAsSH and supports the free pool (CoA), which is necessary for the functioning of pyruvate dehydrogenase and ketoglutarate dehydrogenase [45] and, therefore, for the operation of the Krebs cycle. A decrease in the intake of carnitine causes a decrease in the CoA content in the matrix and a concomitant increase in the ratio of acyl-CoA/CoAsSH, which inhibits the enzymatic activity of the aforementioned dehydrogenases. Consequently, not only the oxidation of fatty acids is weakened, but also the utilisation of carbohydrates, the catabolism of some amino acids, the detoxification of cytotoxic organic acids and xenobiotics [45]. Also, L-carnitine improves the integrity of membranes, stabilises the immune system, promotes a more economical use of glycogen and glucose stores during prolonged intensive training [29], participates in the exchange of ketones and cholines, and suppresses the formation of lactate and processes of apoptosis [45]. The main source of L-carnitine is meat and dairy products. It should be noted that endogenous synthesis accounts for only 10–25% of the human body's need for carnitine. Therefore, it is extremely important for athletes to take L-carnitine exogenously. Excess accumulation of acyl-CoAs in the mitochondria during increased physical activity inhibits the rate of enzyme-dependent oxidative metabolic processes in various tissues of the body. Carnitine is able to take acyl groups for conversion to acetyl-carnitine, effectively reducing the level of acyl-CoA and increasing the possibility of continuing high intensity exercise [45]. This process is limited by the level of L-carnitine in the muscles, which gradually decreases with the continuation of intensive exercise. Thus, L-carnitine levels in the muscles are associated with the ability to maintain a high level of aerobic oxidation at low levels of lactic acid production [29, 40, 43, 45]. Therefore, the use of L-carnitine in sports can reduce anaerobic lactic energy production and increase more effective aerobic energy production, improving the activity of the respiratory chain in muscles and working capacity during intense physical exertion. It helps athletes reduce the signs of physical and mental overstrain, stimulates their working capacity, increases their appetite, produces cardio-, hepato- and neuroprotective effects, and, at the same time, possesses immunostimulating properties.

Creatine. Creatine monohydrate is one of the most effective products of sports nutrition that increases physical activity and muscle mass during training. Numerous studies show that creatine increases body weight and/or muscle mass during exercise [46]. The increase in muscle mass during 4–12 weeks of training with the use of creatine, compared to the control group, is usually around 900 to 2,250 grams [47], which appears to be the result of an improved ability to perform high intensity exercises allowing the athlete to faster adapt to the load and muscle hypertrophy [48, 49]. The only clinically significant side effect of creatine monohydrate is its ability to increase athletes' body weight [47, 50, 51]. Although there are some studies on possible side effects of creatine, the recent long-term safety studies suggest no obvious side effects [51, 52]. In addition, creatine monohydrate helps reduce the incidence of injury during training [53–55]. Thus, creatine monohydrate and creatine in various formulations are a safe and effective product for increasing muscle mass. The analysis carried out by the International Society of Sports Nutrition (ISSN) allowed the following conclusions to be drawn [56]: 'Creatine monohydrate is the most effective ergogenic food additive currently available to athletes, in terms of increased physical activity of high intensity and muscle mass during training.' There is no conclusive scientific evidence that the short-term or long-term use of creatine monohydrate has a side effect for healthy individuals. It is not only safe, but possibly effective in preventing injuries. With proper control and precautions taken, the use of creatine by young athletes is acceptable and can provide an alternative to potentially dangerous anabolic drugs. Monohydrate is the most widely studied and clinically effective form of creatine to be used in nutritional supplements in terms of its accumulation in muscles and the ability to increase tolerance to high-intensity exercise. Although the combined use of carbohydrates or carbohydrates and proteins in sports creatine-containing supplements also contributes to the accumulation of creatine in the muscles, the effect of such a combined use is not higher than that of using monocomponent creatine monohydrate. The fastest method for increasing muscle creatine is its consumption in the amount of 0.3~g/kg/day for at least 3 days, followed by 3–5 g/day as a maintenance dose. Consuming smaller amounts of creatine monohydrate (2–3 g/day) leads to an increase in muscle creatine content for 3–4 weeks; however, the effectiveness of this supplementation method is little proven. Along with increasing muscle mass and muscle strength, creatine improves tolerability of physical activity in different conditions [47]. This is especially true when performing loads of high intensity, intermittent exercises, such as several approaches to the bar, repeated sprints and/or physical exercises, including long-distance running and jogging (for example, football) [47]. Creatine is also effective in intermittent high intensity training. It is stated that in addition to these effects, creatine improves the 'critical power' of the athlete [57]. Endurance athletes can also theoretically improve their sports power in various ways. For example, increasing creatine supplies before applying carbohydrate loading (i.e. increasing the dietary intake of carbohydrates before competition in an attempt to maximise carbohydrate stores) improves carbohydrate safety [58–59]. A study [60] showed that taking 20 grams of creatine for 5 days improved endurance and anaerobic activity in elite rowers. Most highly skilled athletes also performed intermittent drills (sprint or speed activity) in an attempt to improve their anaerobic threshold. Since creatine has been reported to increase sprint performance, its use during the training process can improve adaptation to exercise in endurance athletes [61].

Caffeine. Caffeine is the most commonly used pharmacologically active purine compound. In natural sources, caffeine is mainly found in coffee (*Coffea arabica*) and tea (*Camellia cinensis*). The content of caffeine in raw materials and different products varies within fairly wide limits. Coffee beans contain up to 1.5% of caffeine. Even higher is its content in tea leaves – up to 5%. However, caffeine is found not only in coffee and tea, but also in guarana berries and cola nuts. Along with this, caffeine is an ingredient added to a variety of foods, such as baked goods, ice cream, soft caramel, cola drinks and others. Caffeine is also an ingredient in so-called 'energy drinks' and it is present, in combination with synephrine, in certain dietary supplements designed to reduce body weight (increase weight loss) and improve athletic performance. Energy drinks most often contain a combination of caffeine, taurine D-glucurono-lactone and other ingredients. It should be noted that the data obtained in a Russian study [62] on the magnitude of caffeine intake differ from those of foreign researchers [63]. The level of caffeine consumption in Russia significantly exceeds the maximum level of safe daily intake of caffeine (150 mg) established in Russia, although it is lower than the safe level (400 mg/day) established abroad. The content of caffeine in one average consumer package of coffee or tea exceeds its content in one package of energy drinks (12 brands studied). A study of the actual level of caffeine consumption in Russia, which involved 3,600 people (1,600 adults and 2,000 adolescents), showed the following average daily levels of caffeine intake: 344.9 mg by adults (aged 18–44), 225.8 mg by younger adolescents (aged 12–14), and 256.6 mg by older adolescents (aged 15–17) [63]. The FDA (USA) recognises caffeine, the most physiologically active component of energy drinks, as a safe ingredient to use in beverages. Guarana containing caffeine, along with a small amount of theophylline, theobromine and tannins, is also safe, according to the FDA. The content of ginseng root extract in energy drinks is lower than in dietary supplements, which ensures their safety [62]. The pharmacokinetics of pure caffeine and caffeine in various 'dietary' compositions (drinks, dietary supplements, food products, etc.) may vary. The time of caffeine absorption and elimination, as well as peak plasma concentration rates, differ significantly between dietary and pure caffeine. The slower absorption of dietary caffeine can prolong lipolytic, metabolic, psycho-stimulating, and other effects of caffeine [21]. Recent studies show that caffeine taken as part of dietary supplements before exercise improves aerobic endurance by increasing the oxidation of fats, thereby helping preserve glycogen in the muscles. They also demonstrate that caffeine contained in food additives and beverages contributes to ergogenic effects in anaerobic conditions, and when taken in combination with various other ingredients (e.g. taurine), it produces an enhanced effect [64].

Taurine. Taurine is one of the main components of tonics and sports food products. It is a sulphur-containing amino acid which is not important for protein synthesis, but is the most common amino acid found free in many mammalian tissues. Taurine, first discovered in 1827, has multiple properties that can be effectively used in sports nutrition. There is a considerable number of publications about its important physiological functions that manifest themselves in different tissues of the body, ranging from its classical role as a conjugating agent for bile acids to its functions as an important regulator of osmotic pressure, a modulator of calcium homeostasis and its signalling pathways, and a recently found role as an endogenous antioxidant and anti-inflammatory compound. The classic studies of Huxtable R. J. [65] postulated that taurine was humans is involved in many metabolic functions; in particular, it played an important role as an antioxidant protector in the regulation of Ca++ transport and as a regulator of osmotic pressure in the tissues. Along with this, taurine has an anti-inflammatory effect [66]. Taurine is widely used not only as a medicinal product, but also is a part of many specialised products for sports nutrition and energy drinks. The average dose of taurine in energy drinks is 200–400 mg 100 g.

It should be noted that taurine is a synergist of caffeine. A study published in 2008 [cit. 67] showed that the amount of taurine used in various beverages did not cause any side effects. The interest in taurine significantly increased after it was found that exercise reduced its content in skeletal muscles [67]. Subsequent studies showed that taking 6 g of taurine per day for 7 days could increase exercise tolerance, possibly due to its antioxidant effects [68]. However, there are also conflicting opinions on the effectiveness of taurine in sports practice. For example, it is shown that taking 5 g of taurine per day for 7 days as a dietary supplement does not change its content in the muscle tissue and has no influence on the metabolism in the muscles during exercise [68]. However, there is evidence that the normal level of taurine is important for skeletal muscle function. Taurine appears to play an important role in regulating the release of Ca+ from the sarcoplasmic reticulum and helps maintain the sensitivity of the contractile elements to Ca+ [69], which is extremely important in sports. Studies offer conflicting data on the effect of taurine on muscle strength, the time of muscle fatigue development and the rate of its recovery. For example, experimental studies in mice demonstrate the absence of such effects in taurine [70]. At the same time, other studies suggest that supplementing the diet with taurine, or adding it to drinking water, leads to the accumulation of taurine in muscle tissue [71]. It was shown that the concentration of taurine introduced in dietary supplements during two weeks increased the content of taurine in rat muscles by almost 40%, which improved muscle contraction [71]. Intensive physical exercises decrease the concentration of taurine in the muscles and have a negative effect on contractility [72]. Another study showed that simultaneous administration of taurine and caffeine during a two-week period increased the running time of the mice and led to a decrease in lactate accumulation in the muscles [73].

Juices and juice-containing products. There is an annual increase in the consumption of juices and juice-containing products in the world. Juices are good for human health, because vegetables and fruits, and, consequently, juices obtained from them, have protective functions [74]. Fruit and vegetable juices supply the body with food ingredients that reduce the risk of cardiovascular and oncological diseases. Flavonoids contained in citrus juices have an anticarcinogenic, antioxidant, and antimutagenic effect [75, 76]. Consumption of juice drinks in Europe and Russia is continuously increasing due to both the marketing activities of producers and a high utility of juices. Blending juices with plant extracts of medicinal, spicy and aromatic raw materials enriches the drinks with vitamins, minerals and other biologically active substances. Such beverages are classified as functional.

Recommendations for health promotion and disease prevention include the need for a person to consume a variety of fruits and vegetables every day [77, 78]. The available data indicate a direct relationship between a diet rich in fruits and vegetables and an improvement in people's health, as well as a reduction in the risk of developing major chronic diseases [80]. In addition, ongoing research shows that biologically active substances contained in plant food sources have a significant effect on metabolism [81]. Despite the fact that consumption of fruits and vegetables is an essential component of a healthy diet, there is no consensus on the effects of freshly squeezed juices on the body [80, 82]. Freshly squeezed juices have a lower fibre content and a higher calorie content per serving.

It is well-known that fruit and vegetable juices contain biologically active substances that have an antioxidant effect. The imbalance between the generation of active oxygen species and the body's antioxidant defence system is an important factor in the development of chronic diseases, such as cardiovascular and oncological diseases, diabetes, and a number of others [82]. The effects of consuming 100% fruit juices on the mechanisms of antioxidant protection have been thoroughly studied [83–89]. The consumption of natural juices increases the antioxidant activity of blood serum and the effect can persist for several hours depending on the volume and type of juice, and on the individual's subjective characteristics. Apple, orange and grape juice made from homogenised fruit 150 ml had the maximum antioxidant effect within 30 minutes after administration in 10 healthy men (aged 24 ± 1 year) [83]. A significant decrease in the indices of oxidative stress in plasma persisted for 90 minutes (apple and orange juice) and 2 hours (grape juice) after intake [83]. A number of studies reveal a positive effect of fruit and vegetable juices on the state of the endothelium, the inflammatory reaction, and the proliferation of cells involved in the pathogenesis of atherosclerosis and cardiovascular diseases [83]. As is known, a change in lipid metabolism is a risk factor for the development of cardiovascular diseases [87]. A number of studies confirm the positive effect of 100% juices on blood lipid markers [87–92]. There is evidence of a positive effect of diets with a high content of fruits and vegetables, including juices, in the treatment of certain types of cancer [94]. However, it should be noted that fruit juices, as well as drinks with sugar and sugar substitutes, can be risk factors in the development of obesity and type 2 diabetes [95–102].

CONCLUSION

Specialised food products, sports drinks, as well as energy drinks, have become very popular in the last few decades. It is now established that inadequate water intake or moderate dehydration may be associated with a risk of developing chronic diseases. Hypohydration is a common condition in different types of sport activity. Despite an overall decrease in daily consumption of sports drinks, sugar sweetened sports drinks remain popular among the majority of young people, especially high school students. Among the main compounds in sports and energy drinks, Caffeine, Taurine and L-Carnitine are the most commonly used pharmacologically active agents inducing multiple activities. L-carnitine plays an important role in suppressing inflammatory reactions, oxidative stress and apoptosis, and ischemic heart disease. The antioxidant activity of L-carnitine helps to prevent muscle disorders caused primarily by high physical loads. Taurine is one of the main components of tonics and sports food products that is important for skeletal muscle function. The studies published during the last two decades demonstrate the usefulness of sports drinks. Furthermore, multiple international studies also show the safety of sports and energy drinks containing well-known biologically active substances, when taken in recommended doses.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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