



Disponible en ligne sur

ScienceDirect
www.sciencedirect.com

Elsevier Masson France

EM|consulte
www.em-consulte.com



REVIEW

Sport and energy drinks consumption before, during and after training

Utilisation des boissons pour le sport et des boissons énergisantes pendant et après entraînement



V. Simulescu^{a,*}, G. Ilia^{a,b,**}, L. Macarie^a, P. Merghes^c

^a Institute of Chemistry Timisoara of the Romanian Academy, 24 Mihai Viteazul Bvd., 300223 Timisoara, Romania

^b West University of Timisoara, Faculty of Chemistry-Biology-Geography, 4 Bv. Vasile Parvan, 300223 Timisoara, Romania

^c Banat's University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, 119 Calea Aradului, 300645 Timisoara, Romania

Received 12 September 2018; accepted 1st October 2018

Available online 23 December 2018

KEYWORDS

Sport drinks;
Energy drinks;
Carbohydrates;
Caffeine;
Electrolytes

Summary

Aims. – Sports drinks, when used by adult athletes, can have significant performance benefits. Sports drinks provide carbohydrates, electrolytes and fluids to the body, and help the body hydration, before, during, and after physical activity. The carbohydrates supply the muscles with fuel during exercise. The main electrolyte from sport drinks is sodium, which improves the drive to drink and can assist with fluid replacement. One of the main aim of using sport drinks is hydration, without decreasing sodium level in order to prevent hyponatremia. The addition of protein may be beneficial to prevent muscle damage and may improve or maintain subsequent performance over consecutive days. Other active ingredients (as vitamins) may play a role in energy metabolism or in free radical defense, but are usually found in small amounts and it is unclear if they have any direct performance benefits. Caffeine improves reaction time and if consumed few hours before anaerobic/resistance exercise may improve the performance, but has no effect on repeated high-intensity training.

Conclusion. – Sport drinks are useful only for adults athletes involved in endurance training, but are not recommended for children and adolescents. Sport drinks have the proper amounts and concentrations of carbohydrates and electrolytes to help the physical performance, in comparison with energy drinks, caffeinated energy drinks or other beverages.

© 2018 Elsevier Masson SAS. All rights reserved.

* Corresponding author.

** Co-corresponding author.

E-mail address: vsimulescu@gmail.com (V. Simulescu).

MOTS CLÉS

Boissons
énergisantes ;
Caféine ;
Électrolytes

Résumé

Actualités. – Les boissons pour sportifs, lorsqu'elles sont utilisées par des athlètes adultes, peuvent avoir d'importants avantages sur le plan de la performance. Les boissons pour sportifs fournissent des glucides, des électrolytes et des fluides au corps et aident à l'hydratation du corps avant, pendant et après l'activité physique. Les glucides alimentent les muscles en carburant pendant l'exercice. L'électrolyte principal des boissons pour sportifs est le sodium, ce qui améliore la capacité de boire et peut aider à remplacer les liquides. L'un des principaux objectifs de l'utilisation des boissons pour sportifs est l'hydratation, sans diminution du taux de sodium afin de prévenir l'hyponatrémie. L'ajout de protéines peut être bénéfique pour prévenir les dommages musculaires et peut améliorer ou maintenir les performances ultérieures pendant des jours consécutifs. D'autres ingrédients actifs (sous forme de vitamines) peuvent jouer un rôle dans le métabolisme énergétique ou dans la défense des radicaux libres, mais ils se trouvent généralement en petites quantités et il est difficile de savoir s'ils présentent des avantages directs. La caféine améliore le temps de réaction et, si elle est consommée quelques heures avant l'exercice anaérobie/de résistance, elle peut améliorer la performance, mais elle n'a aucun effet sur l'entraînement répété à haute intensité.

Conclusion. – Les boissons pour sportifs ne sont utiles que pour les athlètes adultes impliqués dans l'entraînement en endurance, mais ne sont pas recommandés pour les enfants et les adolescents. Les boissons pour sportifs ont les quantités et les concentrations appropriées de glucides et d'électrolytes pour aider à la performance physique, comparativement aux boissons énergisantes, aux boissons énergisantes contenant de la caféine ou à d'autres boissons.

© 2018 Elsevier Masson SAS. Tous droits réservés.

Ingestion of a sports drink was proved to be helpful for adult athletes who practice intensive exercises for long periods, with high intensity, in the heat environment or at high humidity. The sport drinks contain mainly sugars and electrolytes, but in addition they may also contain sometime compounds as vitamins (in general vitamin C or B vitamins), proteins, lactic acid, low-calorie sweeteners, citric acid, natural or artificial fruit flavours and so on. The carbohydrates from sport drinks are in general glucose, fructose (high-fructose corn syrup), sucrose and maltodextrin, in concentrations ranging from 20 to 56 g/L (Fig. 1). Among the used electrolytes, in sport drinks sodium, potassium and magnesium can be found [1,2].

Citric acid (Fig. 2) is a common food additive and at the same time a mild acid, naturally found in citrus fruits. It is essential for Krebs cycle, for the production of energy. But the amounts found in sports drinks are too low to have any significant effect. Citric acid is added to sport drinks only for flavour. Citric acid has no known significant effects on health. On the other hand, lactic acid (Fig. 2) is produced naturally in our body, more exactly in muscles, during and after an intense physical effort. The aim of adding lactic acid in sports drinks is the acidity regulation. Lactic acid is obtained from natural fermentation and can be found in many foods. As citric acid, it has also no adverse effects. Both, citric acid and lactic acid have also no impact on physical performance.

Sports drinks are designed to provide carbohydrates, electrolytes and fluids to the body, which are absorbed very fast from the small intestine. With other words, the period from ingestion until the carbohydrates, electrolytes and fluids reach the muscles, brain and so on, should be very short. This is the most important advantage of using sport drinks

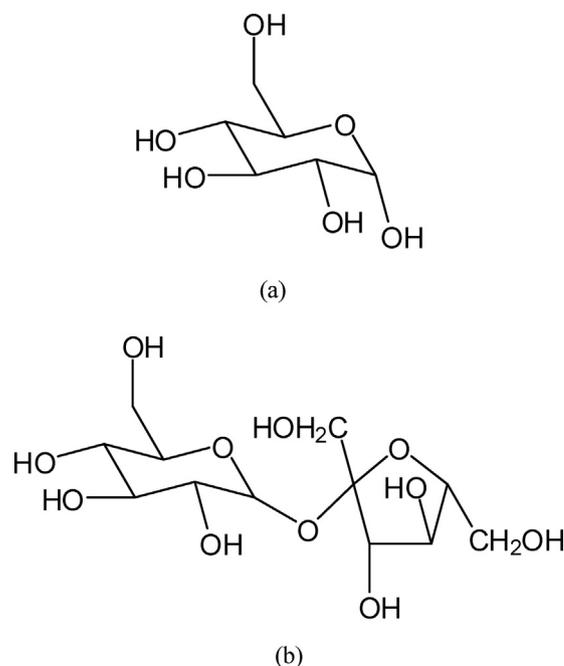


Figure 1 Structures of the glucose (a) and sucrose (b).

by adult athletes, especially when performing endurance training, as long distance running events [1].

On the other hand, the energy drinks contain carbohydrates in much higher concentration (in generally too high for physical activity) and other ingredients as vitamins, taurine, L-tyrosine, citicoline, 5-hydroxy-L-tryptophan (5-HTP), guarana, caffeine, β -alanine, glucuronolactone and

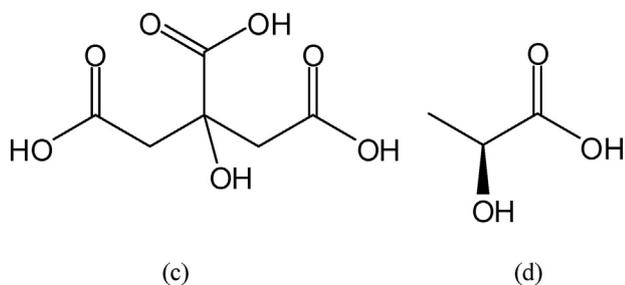


Figure 2 Structures of citric acid (c) and lactic acid (d).

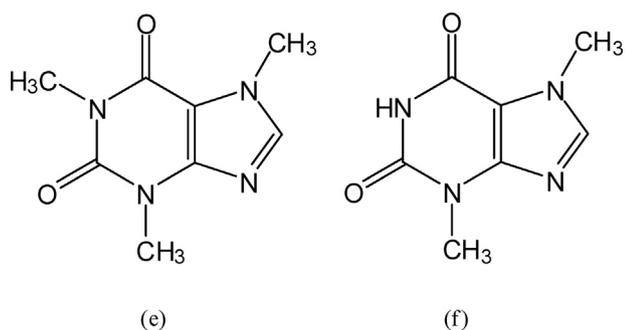


Figure 3 The structures of caffeine (e) and theobromine (f).

so on. The compound 5-HTP is a precursor of serotonin and decreases the appetite. Such energy drinks also became popular, but those were not helpful during training in comparison with sport drinks. Moreover, the energy drinks may cause adverse effects [2] if used by teenagers and young adults, or when mixed with alcohol or medication. Some energy drinks may contain even brominated vegetable oil (BVO) which is used also as flame retardant [3]. Brominated vegetable oil has been banned in Japan and the European Union. Current evidence suggests that these additives have only minimum positive impact on sport performance [1,2,4–7]. But the addition of small to moderate doses of caffeine (75–200 mg) can help to sustain exercise performance. It also reduces the perception of effort [1,4–7]. Caffeine (Fig. 3) is extracted from the fruit of over 60 species of coffee plant and it is also found in guarana, some species of tea, cocoa and yerba mate [8].

Caffeine and theobromine (Fig. 3) are central nervous system stimulants from the class of methylxanthine alkaloids. Theobromine is found in cocoa. Caffeine and theobromine are chemically related to adenine and guanine bases from the structure of DNA and RNA (Fig. 4).

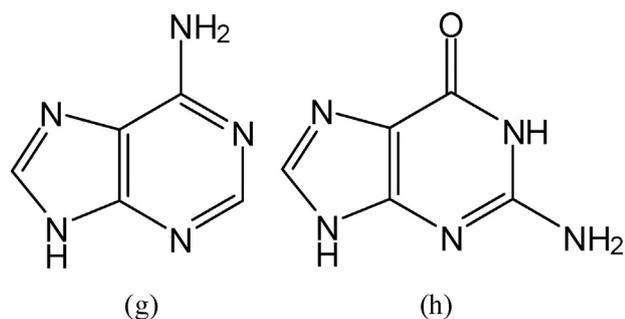


Figure 4 The structures of adenine (g) and guanine (h) bases from DNA and RNA.

The pharmacological effects of caffeine are more significant in comparison with theobromine, and include effects on cardiac and circulatory system, and also central nervous system stimulation [9]. Caffeine can have both positive and negative health effects. If used daily in right doses, caffeine could prevent some diseases, as for instance Parkinson's disease. Caffeine is also known to improve reaction time [10] and if consumed few hours before anaerobic/resistance exercise may improve the performance, but has no effect on repeated high-intensity training [8]. It is the most common stimulant ingredient used in caffeinated energy drinks (CEDs). The allowed concentrations of caffeine in energy drinks beverages may differ (for example 344 mg of caffeine per 473 mL in the USA and 400 mg/L in Canada) [4,11].

Energy drinks and CEDs have the role to bring and deliver energy immediately to the body, but are not so efficient for long-term. On the other hand, sports drinks are designed to replace the lost fluids and electrolytes during training and physical exercises, and to deliver very fast carbohydrates and electrolytes to the body. A good hydration level provides benefits for health and for performances of athletes. Sodium reduces the urine losses before starting the exercise. Sports drinks will allow the athletes to perform longer and at a higher intensity, even in hot environment [4]. Sports drinks will replace the fluids lost in sweat and this will help the thermoregulation process even at high temperatures, and also will give very fast more energy and fuel to the body. The sport drinks have an important role for body recovery, so it is important to use them also after the training. Their use should be combined with foods and other fluids that provide additional carbohydrates, proteins and many other essential nutrients [5].

One main rule when using sport drinks is that they should not be diluted. This would change the concentrations of carbohydrates and sodium. Both will affect the speed at which the drink empties from the stomach, so the entire process of energy and fluids delivery will be delayed. It is very important also to know that the benefits of using sports drinks are proved only for adults involved in intense physical activity, and also for the people doing training at high temperature and humidity, not for children and adolescents. The average children and teenagers are not performing high-intensity physical activity. For them, water and a well established diet are enough and the use of sport drinks, energy drinks or caffeinated energy drinks is not necessary. If used, sports drinks may displace the nutrients necessary for growing at children and adolescents [1–5]. So, while the sports drinks help the athletes during intensive training [6,7], their use is not necessary and strongly not recommended for the children and teenagers. Both, sports drinks and caffeinated energy drinks (CEDs) pose potential risks for the health of youth and may contribute to growing problems and obesity [4]. Sport and energy drinks are not recommended as fluid consumption in schools by children or adolescents [2].

The sport drinks, energy drinks and CEDs should not be mixed with alcohol or with medication. When any medical treatment is used, in general the use of those beverages should be stopped, because their interaction with the medication can be dangerous for the health. Mixing alcohol with caffeinated energy drinks will increase the stimulation, but in the same time will decrease the sedation [12–16].

Frequent consumption of CEDs mixed with alcohol, may also increase the risk of several diseases, especially related to heart, circulatory system and central nervous system [4].

The European Food Safety Authority (EFSA) found that around of 68% children and adolescents used sport drinks and energy drinks at least one time [5,17–19]. Moreover, 12% of the teenagers reported using more than a litre in a single sitting and more than seven litres per month. The first use of those beverages is occurring usually before the age of 12 years old [18]. For children and teenagers, CEDs and alcohol will have a negative impact and influence on collagen and hyaluronic acid biosynthesis and degradation, obesity, serious cardiovascular diseases, type 2 diabetes, grow retardation and so on [19–28]. The research conducted by Costa et al. [29,30] and Gallimberti et al. [31] proved that after using energy drinks, the children and teenagers experienced many symptoms as upset stomach, rapid speech, insomnia, anxiety/agitation, tremors, racing heart, heart palpitations and visual disturbances. Unfortunately, many of the teenagers were mixing energy drinks with alcohol and even cigarettes, causing much more negative effects on their health for long-term [6,11,17,18].

When used by adults athletes, in recommended amounts, the sport drinks beverages increases significantly the physical performances. One of their main target, as mentioned before, is the hydration [4,5]. Before, during and after endurance physical activity, the hydration is a limiting factor in athletic performance. Also, the hydration during intense physical activity is one of the best parameters of athlete's health [32]. Dehydration decreases the athletic performance and also can be a high risk for health, especially under temperature stress [33–35]. The limit of moderate dehydration is maximum 2–3% loss of initial body weight. At this point the physical performance is already affected. The body would try to solve the problem, by increasing the heart rate and by decreasing the blood flow to the skin. The main disadvantage is that the body temperature increases [17,18]. When it reaches 39°C, the physical performance decreases significantly [35]. On the other hand, the body temperature can decrease to 35°C or even lower in an environment with a temperature of 0°C, leading to hypothermia. The extremities are the most affected (especially the fingers, if exposed) due to the peripheral vasoconstriction [34].

Very important is the fact that hyperhydration could be very dangerous also, because it can produce hyponatremia (it is considered very severe when the serum level of sodium decreases below 125 mEq/L) [36–38]. The risks are bigger in high temperature (higher than 30°C) and high humidity (higher than 55%) of the environment [1,5,27]. To help the water absorption during training, additional small amounts of glucose and sodium could be ingested, as isotonic sports drinks (Table 1) [4,32,34].

Table 1 Characteristics of isotonic sport drinks.

	Min.	Max.
Sugars %	6	9
Type of sugars	Glucose (or maltose) with fructose in the ratio 3:1	
Na (g/L)	0.46	1.2
Osmolarity (mOs-m/L)	200	330
Volume (mL/hour of exercise)	500	1000
Temperature (°C)	10	15

In extreme high temperature and humidity of the environment, it is recommended to add ice cubes to the sport drink used. Moreover, in the case of high hydration needs, it is recommended to decrease the sugar content up to 4% and to increase the salt, in order to prevent hyponatremia [5,32,34]. Table 2 shows how the composition of sports drinks should be, before, during and after the physical training [4,5,7,37,38].

Therefore, it is important to control the hydration level not only during exercise, but also before and after the physical activity, as follows:

- hypotonic drinks before training;
- isotonic drinks during exercise;
- slightly hypertonic drinks after the training, combined with food and other fluids that provide additional carbohydrates, proteins and many other essential nutrients [5].

Most of the studies in this area found that during physical activity, a deficit of 0.4–0.6 L/h is common, depending on the environment, temperature, humidity, physical activity and its intensity [39–41]. Dehydration can occur in sports activities during which the water absorption and nutrition are limited, so gastrointestinal issues are expected (especially in ultra-resistance sports competitions as 10 km running, half marathon and marathon) [42–44]. When caffeine is used, in form of CEDs and energy drinks, its diuretic effect should not be negligible [38]. The caffeine's diuretic effect becomes significant only if 2–3 servings of coffee per day are used (200–300 mg caffeine). In the case of caffeine, the literature underlines also some adverse effects, including irritability, anxiety, insomnia, tachycardia, palpitations, vomiting, abdominal pain, hypokalemia (the decrease of potassium level), hallucinations, supraventricular and ventricular tachyarrhythmias and so on [5,27,28,44–46]. All of

Table 2 Characteristics of sport drinks used before, during and after exercise.

	Before training	During training	After training
Type of drinks	Isotonic or slightly hypotonic	Isotonic	Hypertonic
Sugars (%)	4–6	6–9	9–10
Na (g/L)	0.5–0.7	0.5–0.7 (up to 1.2 under heat stress, more than one hour)	1–1.5

these are related only to high amounts of caffeine, as previously mentioned.

As previously shown, the sport drinks are not important only during the event, but also after an intense training in order to improve the body recovery. The aim of another study published in [47] was to evaluate their effects on the physical performance of tennis players. The sport drinks were used before, during and after each tennis match played. It is well known that a prolonged tennis match could induce muscle fatigue [47–49], and this would lead to a decrease in physical performances, even after a few hours of recovery [47]. When sport drinks beverages were used before, during and after each tennis match played, the decrease in effort capacity was much limited and the performance was improved in comparison with the situations where the only fluid used was water [47]. Considering that during tennis tournaments, several matches are played in a limited time, with short recovery periods, it is important to limit fatigue, to help recovery and to increase the performance. This goal was achieved by using sport drinks, but it is important also to control the nutrition influencing the muscle and hepatic glycogen stores [6,17,19,47]. It has been already suggested that the performance of skilled tennis returns to normal relatively quick, even after long matches. For example, recent studies [49–51] showed that after two hours tennis matches, no decrease of physical performance was observed. Only the succession of longer and more intense matches induced a significant decrease in physical performance [20,43–51].

For example a decrease of 9–15% in the plantar flexor muscles was observed immediately after three hours tennis matches [50,51]. Only one study has evaluated the impact of tennis practice on muscle performance using isokinetic measurements by an isokinetic dynamometer, in elite young tennis players [46]. The conclusion was that a 90 minutes practice session induced the decrease with 9–13% of the knee extensors and flexors capacity [46].

In the context of repeated tennis matches with short recovery periods, as it happens in a tennis tournament, it is expected that a decrease in glycogen stocks may contribute to the development of muscle fatigue. The supplementation with carbohydrates before, during and after each match could help also the resynthesis of glycogen stocks between matches. Fluid ingestion is also recommended in order to avoid the hypohydration due to the physical effort, by taking in account of course the individual, environmental and exercise characteristics. Attention should be given not only to the timing and the volume of fluid intake, but also the type and the composition of the fluid to be ingested. Many studies proved that under conditions of sweating, electrolyte loss, hypohydration and glycogen depletion, ingestion of sports drinks may be more advantageous in comparison with water [24]. The sport drinks beverages contain a proper combination of electrolytes and carbohydrates. Such drinks have the purpose of optimizing body hydration, replacement of electrolytes (mainly sodium), and maintaining high rates of carbohydrate oxidation as energy supply. The electrolytes portion of sports drinks may present some variation [7,24]. Usually the drinks used before and during the training contain mainly sugars and electrolytes, and no proteins or magnesium. The caffeine content of the sport drinks is still a

subject in discussion, and many beverages contain no caffeine as well. The drinks used for recovery may contain magnesium. In addition, the use of proteins and honey can help, especially for the recovery [22,40,52]. The sport drinks usually contains mostly monosaccharides and disaccharides ranging from 6 to 9% weight/volume. Hypohydration may occur during high-intensity effort over a period of several hours, if higher amounts of carbohydrates will be used. Short time recovery periods between multiple events would not allow the optimal rehydration in most of the cases, but sport drinks contain the proper amounts of carbohydrates and electrolytes to help the hydration and to prevent hyponatremia. The study published in [31] identified recent cases when the athletes started a new event being already in a state of hypohydration. This was easily proved by urinary markers [31].

To ensure a good hydration level, fluid intake in amounts from 5 to 7 mL per kg of body mass is recommended and necessary with 3–4 hours before an endurance event. Intake of substances that expand plasma volume may interact with the sport drinks effects and can increase the risk of hyponatremia [24]. Hyperhydration would not help performance or thermoregulation, but will also decrease the sodium level even more. When the serum level of sodium decreases below 125 mEq/L, the hyponatremia is considered severe and very dangerous for the health. The symptoms associated with hyponatremia are headache, loss of energy and fatigue, restlessness and irritability, vomiting, confusion, spasms or cramps, muscle weakness, seizures, respiratory failure, cerebral edema or coma [36,37]. This is due to the significant fluid losses from urine and sweat. A sport drink containing sodium (0.3–0.7 g/L) and carbohydrates (to restore glycogen) would help the body recovery and its hydration [43]. These liquids are so-called “recovery” drinks. Body fluids may become disturbed under exercising conditions in which sweat losses are not replaced immediately by fluid intake. Anyway, hypohydration is more often found than hyperhydration.

The cardiovascular and thermoregulatory systems are first affected by hypohydration, especially when exercise is performed in the heat environment or in high humidity conditions. The young and old population is much more affected by hypohydration [24]. In order to avoid the significant hypohydration (more than 2% loss of body weight), fluids should be ingested before and during physical effort. After an event, the body fluids should be restored very fast, especially when the recovery period is short and other sport activities are planned in the next few hours. The water intake is an option for most of the athletes involved in activities lasting less than 60 minutes. For longer or more intense activities, and for the sport activities in heat environment or with high humidity, sports drinks offer much more benefits due to their ideal combination of carbohydrates and electrolytes, in order to obtain a proper and faster hydration and to optimize the body recovery, in a shorter period of time [24].

Disclosure of interest

The authors declare that they have no competing interest.

Acknowledgements

We acknowledge the Research Program 2, Project 2.1 from Institute of Chemistry Timisoara of the Romanian Academy for the financial support.

References

- [1] Rotstein J, Barber J, Strowbridge C, Hayward S, Huang R, Godefroy SB. Energy drinks: an assessment of the potential health risks in the Canadian context. *Int Food Risk Anal J* 2013;3(5):1–29.
- [2] American Academy of Pediatrics, Committee on Nutrition and the Council on Sports Medicine and Fitness. Sports drinks and energy drinks for children and adolescents: are they appropriate? *Pediatrics* 2011;127(6):1182–9.
- [3] Drehe M, Simulescu V, Ilia G. Progress in the development of flame retardants. *Rev Chem Eng* 2008;24(6):263–302.
- [4] Pound CM, Blair B. Energy and sports drinks in children and adolescents. *Paediatr Child Health* 2017;406–10.
- [5] Urdampilleta A, Gómez-Zorita S, Soriano JM, Martínez-Sanz JM, Medina S, Gil-Izquierdo A. Hydration and chemical ingredients in sport drinks: food safety in the European context. *Nutr Hosp* 2015;31(5):1889–99.
- [6] Mosca A, Della Corte C, Sartorelli MR, Ferretti F, Nicita F, Vania A, et al. Beverage consumption and paediatric NAFLD. *Eat Weight Disord* 2016;21:581–8.
- [7] Lasater G, Piernas C, Popkin BM. Beverage patterns and trends among school-aged children in the US, 1989-2008. *Nutr J* 2011;10:103.
- [8] Campbell B, Wilborn C, La Bounty P, Taylor L, Nelson MT, Greenwood M, et al. International Society of Sports Nutrition position stand: energy drinks. *J Int Soc Sports Nutr* 2013;10(1):1–16.
- [9] Kolnes AJ, Ingvaldsen A, Bolling A, Stuenkel JT, Kreft M, Zorec R, et al. Caffeine and theophylline block insulin-stimulated glucose uptake and PKB phosphorylation in rat skeletal muscles. *Acta Physiol (Oxf)* 2010;200(1):65–74.
- [10] Doherty M, Smith PM. Effects of caffeine ingestion on exercise testing: a meta analysis. *Int J Sport Nutr Exerc Metab* 2004;14(6):626–46.
- [11] McCrory C, White CM, Bowman C, Fenton N, Reid JL, Hammond D. Perceptions and knowledge of caffeinated energy drinks: results of focus groups with Canadian youth. *J Nutr Educ Behav* 2017;49:304–11.
- [12] Peacock A, Pennay A, Droste N, Bruno R, Lubman DI. High risk? A systematic review of the acute outcomes of mixing alcohol with energy drinks. *Addiction* 2014;109(10):1612–33.
- [13] Simulescu V, Crasmareanu E, Ilia G. Synthesis, properties and structures of phosphorus-nitrogen heterocycles. *Heterocycles* 2011;83:275–91.
- [14] McKetin R, Coen A, Kaye S. A comprehensive review of the effects of mixing caffeinated energy drinks with alcohol. *Drug Alcohol Depend* 2015;151:15–30.
- [15] Broughton D, Fairchild RM, Morgan ZM. A survey of sports drinks consumption among adolescents. *British Dent J* 2016;220(12):639–43.
- [16] Cohen D. The truth about sports drinks. *BMJ* 2012;345:4737.
- [17] Mosca A, Nobili V, De Vito R, Crudele A, Scorletti E, Villani A, et al. Serum uric acid concentrations and fructose consumption are independently associated with NASH in children and adolescents. *J Hepatol* 2017;66:1031–6.
- [18] Robin S, Buchanan R, Poole R. Energy drinks and adolescents - a hepatic health hazard? *J Hepatol* 2017;68:856–7.
- [19] Zucconi S, Volpato C, Adinolfi F, Gandini E. Gathering consumption data on specific consumer groups of energy drinks. *EFSA Supporting Publications* 2013;10:1–190.
- [20] Westerblad H, Bruton JD, Katz A. Skeletal muscle: energy metabolism, fiber types, fatigue and adaptability. *Exp Cell Res* 2010;316(18):3093–9.
- [21] Hu FB, Malik VS. Sugar-sweetened beverages and risk of obesity and type 2 diabetes: epidemiologic evidence. *Physiol Behav* 2010;100(1):47–54.
- [22] Lagowska K, Podgórski T, Celinska E, Wiertel L, Krysiak J. A comparison of the effectiveness of commercial and natural carbohydrate-electrolyte drinks. *Sci Sports* 2017;32(3):160–4.
- [23] Ilia G, Simulescu V, Mak CA, Crasmareanu EC. The use of transesterification method for obtaining phosphorus containing polymers. *Adv Polym Technol* 2014;33:21437.
- [24] Mondek J, Kalina M, Simulescu V, Pekař M. Thermal degradation of high molar mass hyaluronan in solution and in powder; comparison with BSA. *Pol Degrad Stab* 2015;120:107–13.
- [25] Donejko M, Przyłipiak A, Rysiak E, Głuszuk K, Surażyński A. Influence of caffeine and hyaluronic acid on collagen biosynthesis in human skin fibroblasts. *Drug Design Dev Ther* 2014;8:1923–8.
- [26] Malik VS, Popkin BM, Bray GA, Despres JP, Hu FB. Sugar-sweetened beverages, obesity, type 2 diabetes mellitus, and cardiovascular disease risk. *Circulation* 2010;121(11):1356.
- [27] Meyer F, Volterman KA, Timmons BW, Wilk B. Fluid balance and dehydration in the young athlete: assessment considerations and effects on health and performance. *Am J Lifestyle Med* 2012;6(6):489–501.
- [28] Seifert SM, Schaechter JL, Hershorer ER, Lipshultz SE. Health effects of energy drinks on children, adolescents, and young adults. *Pediatrics* 2011;127(3):511–28.
- [29] Costa BM, Hayley A, Miller P. Adolescent energy drink consumption: an Australian perspective. *Appetite* 2016;105:638–42.
- [30] Costa BM, Hayley A, Miller PG. Young adolescents' perceptions, patterns, and context of energy drink use. A focus group study. *Appetite* 2014;80:183–9.
- [31] Gallimberti L, Buja A, Chindamo S, Vinelli A, Lazzarin G, Ter-raneo A, et al. Energy drink consumption in children and early adolescents. *Eur J Pediatrics* 2013;172:1335–40.
- [32] Noakes TD. Commentary: role of hydration in health and exercise. *BMJ* 2012;345:4171.
- [33] Murray B. Hydration and physical performance. *J Am Coll Nutr* 2007;26(Suppl. 5):542S–8S.
- [34] Kechijian D. Optimizing nutrition for performance at altitude: a literature review. *J Spec Oper Med* 2011;11(1):12–7.
- [35] European Commission. Health and Consumer Protection. Report of the Scientific Committee on Food composition and specification of food intended to meet the expenditure of intense muscular effort, especially for sportsmen. (Adopted by the SCF on 22/6/2000, corrected by the SCF on 28/2/2001).
- [36] Wagner S, Knechtle B, Knechtle P, Rüst CA, Rosemann T. Higher prevalence of exercise-associated hyponatremia in female than in male open-water ultra-endurance swimmers: the 'Marathon-Swim' in Lake Zurich. *Eur J Appl Physiol* 2012;112(3):1095–106.
- [37] Urso C, Brucculeri S, Caimi G. Hyponatremia and physical exercise. *Clin Ter* 2012;163:349–56.
- [38] Maughan RJ, Griffin J. Caffeine ingestion and fluid balance: a review. *J Hum Nutr Diet* 2003;16(6):411–20.
- [39] Williams CA, Blackwell J. Hydration status, fluid intake, and electrolyte losses in youth soccer players. *Int J Sports Physiol Perform* 2012;7(4):367–74.
- [40] Gomes-Neto M, Braga da Silva TLT, Carvalho VO. Whey protein supplementation in association with resistance training on additional muscle strength gain in older adults: a meta-analysis. *Sci sports* 2017;32(4):214–20.
- [41] Jeukendrup AE. Nutrition for endurance sports: marathon, triathlon and road cycling. *J Sports Sci* 2011;29(Suppl. 1):S91–9.

- [42] Pfeiffer B, Stellingwerff T, Hodgson AB, Randell R, Pöttgen K, Res P, et al. Nutritional intake and gastrointestinal problems during competitive endurance events. *Med Sci Sports Exerc* 2012;44(2):344–51.
- [43] Spaccarotella KJ, Andzel WD. Building a beverage for recovery from endurance activity: a review. *J Strength Cond Res* 2011;25(11):3198–204.
- [44] Mendez-Villanueva A, Fernandez-Fernandez J, Bishop D. Exercise-induced homeostatic perturbations provoked by singles tennis match play with reference to development of fatigue. *Br J Sports Med* 2007;41(11):717–22.
- [45] Girard O, Racinais S, Periard JD. Tennis in hot and cool conditions decreases the rapid muscle torque production capacity of the knee extensors but not of the plantar flexors. *Br J Sports Med* 2014;48(Suppl. 1), i52-i58.
- [46] Malliou VJ, Beneka AG, Gioftsidou AF, Malliou PK, Kallistratos E, Pafis GK, et al. Young tennis players and balance performance. *J Strength Cond Res* 2010;24(2):389–93.
- [47] Brink-Elfegoun T, Ratel S, Leprêtre P-M, Metz L, Ennequin G, Doré E, et al. Effects of sports drinks on the maintenance of physical performance during 3 tennis matches: a randomized controlled study. *J Int Soc Sports Nutr* 2014;11:46–55.
- [48] Peltier SL, Lepretre PM, Metz L, Ennequin G, Aubineau N, Les-cuyer JF, et al. Effects of pre-exercise, endurance and recovery designer sports drinks on performance during tennis tournament simulation. *J Strength Cond Res* 2013;27(11):3076–83.
- [49] McRae KA, Galloway SD. Carbohydrate-electrolyte drink ingestion and skill performance during and after 2 hours of indoor tennis match play. *Int J Sport Nutr Exerc Metab* 2012;22(1):38–46.
- [50] Ojala T, Hakkinen K. Effects of the tennis tournament on players' physical performance, hormonal responses, muscle damage and recovery. *J Sports Sci Med* 2013;12(2):240–8.
- [51] Rota S, Morel B, Saboul D, Rogowski I, Hautier C. Influence of fatigue on upper limb muscle activity and performance in tennis. *J Electromyogr Kinesiol* 2014;24(1):90–7.
- [52] Yusof A, Ahmad NS, Hamid AMS, Khong TK. Effects of honey on exercise performance and health components: a systematic review. *Sci Sports* 2018, <http://dx.doi.org/10.1016/j.scispo.2018.02.007>.