International Journal of Innovative Research and Reviews, 4(1) 32-37

International Journal of Innovative Research and Reviews
ISSN: 2636-8919
Website: www.injirr.com
doi:
Research paper, Short communication, Review, Technical paper

REVIEW ARTICLE

Ergogenic Dietary Supplements: Uses and Evaluation Thereof from a Biochemical Perspective

Esen TAŞĞIN[1*]

[1] *Department of Nutrition and Dietetics, Faculty of Health Sciences, Ataturk University. Erzurum, TURKEY*

**Corresponding author E-mail: esent25@yahoo.com*

HIGHLIGHTS

> Ergogenic dietary supplements are used by athletes to improve performance, endurance and energy efficiency and to support post-workout recovery.
> Ergogenic supplements include amino acids, various minerals and vitamins, and metabolic supplements.
> Nutritional supplements have metabolic importance and effects.

ARTICLE INFO

Received : 06.25.2020
Accepted : 07.12.2020
Published : 07.15.2020

Keywords:
Ergogenic food,
Supplements,
Sports nutrition

ABSTRACT

The studies on the use of ergogenic dietary products, which are often used by both professional and amateur athletes, are quite noteworthy. Athletes often use these products to increase performance, endurance and energy efficiency and to support recovery after exercise. Amino acids, various minerals and vitamins and metabolic supplements are mostly preferred as ergogenic nutritional supplements. While there is no need for supportive products in individuals who are well-balanced and healthy, athletes usually use supportive products according to the type of exercise. In this review, the metabolic importance and effects of ergogenic nutritional supplements, which are thought to increase performance by positively affecting energy metabolism, are focused.

Contents

Cite this article Taşğın E. Ergogenic Dietary Supplements: Uses and Evaluation Thereof from a Biochemical Perspective. *International Journal of Innovative Research and Reviews (INJIRR)* (2020) 4(1) 32-37
Link to this article: http://www.injirr.com/article/view/56

1. Introduction

Nutrition is the most important requirement of life and a balanced and healthy diet is essential for a healthy life. Adequate intake, digestion, absorption and metabolism of all nutrients necessary for life can define nutrition [1]. It is also important preparing foods as when, how and how much food should be taken in the healthy diet process as. One of the actions that is important for a healthy life is physical activity. A healthy and dynamic life can be maintained with daily enough physical activity. Physical activity is voluntary muscle movements that help daily energy expenditure. But, exercise is to repeat the planned movement processes regularly and within a program. Especially amateur or professional athletes working with any branch of sports should exercise regularly to maintain and increase their performance. Individuals who exercise or sport should be fed with a nutrition program suitable for their physical activities. However, many individuals or athletes tend to take supplements to get higher performance in addition to their nutrition programs and to be more durable in heavy exercises. With such products, they believe that their performance will increase very much and they will reach the desired goal in a shorter time [2]. Support products that help increase performance during exercise are known as ergogenic foods. It is used that metabolic supports such as many vitamins and trace minerals, essential fatty acids, amino acids, proteins, herbs as ergogenic nutrition aids [3, 4]. These products are generally consumed as powder, tablet or liquid drinks [5, 6]. The main reasons for using these products are improving performance and endurance, improving body muscles, increasing protein synthesis and preventing amino acid breakdown. It is also preferred for maintaining fitness after exercise or sports [6–8]. However, it has been stated in the studies that micro and macronutrients taken with an adequate and balanced nutrition program can meet the daily needs of individuals doing sports, and when support is provided to athletes without deficiency, it will not be needed ergogenic supports for performance [9]. Accordingly, if a good diet program is prepared according to the type of sports activity, nutrients to be taken before and after sports, body fat mass balance, muscle volume, fluid balance will be preserved, and recovery after sports will also be accelerated [10]. However, athletes and exercisers turn to such products to avoid stress and get quick results in a short time. Ergogenic aid products may increase performance, but it is important to use the right product at the right time and in the right amounts [7]. Because some of these products also have side effects and harm. For this reason, individuals need to get professional help to get healthy support from the products used and to avoid unwanted health problems while using them [7, 10]. Athletes and individuals who exercise often resort to ergogenic supplements. The use of ergogenic food supplements is increasing day by day among professional and amateur athletes and exercisers. Yarar et al. (2011) showed that the majority of professional athletes working in many branches use ergogenic supplements. Performance increase (40.3%) and muscle mass (28.5%) enhance are among the main purposes use of participating athletes, and in addition have been reported it that use for fitness, immunity, relaxation and slimming [8]. Again in this study, protein powders and amino acids have been identified as the most preferred products as nutritional supplements. The vast majority of athletes said that they learned their nutritional support products from their coaches and some of them from their dietitians [8]. Actually, it is advised that ergogenic supplements prepared in different forms should be used at appropriate under the supervision of specialists such as a dietician or physician [11].

Considering the Australian Sports Institute (AIS) information, ergogenic food supplements are divided into groups according to their effectiveness and safety [12]. The most used nutritional supplements in these groups are; proteins, different amino acids, branched-chain amino acids, herbal products, minerals, vitamins, creatine, caffeine, ginseng, conjugated linoleic acid (CLA), l-carnitine, coenzyme Q10, bicarbonate, pollen and plant flavonoids, HMB, energy drinks [5–7]. Table 1 shows the most frequently used ergogenic supports according to their intended use [5].

Table 1 Ergogenic nutrients supports according to their aims use

Muscle Builder	Performance Enhancer	Weight Reducing
Protein	Protein	Low energy products
Creatine	BCAA	Caffeine
Essential amino acids	Medium chain fatty acids	Herbal Food Supplements
BCAA	Calcium	Calcium
	HMB	CLA
	Carbohydrate	Green tea
	Essential amino acids	L-Carnitine
	Sodium bicarbonate	Phosphates
	Sodium phosphate	Diuretics
	Water and sports drinks	Pyruvate
	Caffeine	

2. Ergogenic Dietary Supplements

2.1. Protein Supplements

The most common group of the ergogenic support products used is protein originated products with constitutes 60%. Ergogenic products that fall into this category are protein and different products, casein, branched chain amino acids, glutamine and arginine [13]. Protein supports have been advised to athletes to increase muscle mass, prevent post-exercise protein degradation and nitrogen loss [14]. And also, the use of protein after training appears to be beneficial in repairing and reconstructing muscles. As excessive use of everything is harmful to the body, excessive use of protein has also been found to disrupt the functions of the liver and kidney, and to remove calcium from the body [15].

2.1.1. Whey Protein

Approximately 20% of milk proteins consist of whey protein, the rest being casein [16]. Whey proteins mostly includes lactoglobulin, lactalbumin, glycoacropeptide, immunoglobulins. It also consists of serum insulin, lactoferrin, glutamine, lactoperoxidase and other small proteins such as insulin-like growth factors and globulins. Whey proteins are also an important source of BCAA which is effective in muscle strength and muscle increase [17]. The evaluation of the studies showed us that whey proteins have a lowering effect on cholesterol, LDL and triaacil glycerol, blood sugar and insulin [16].

2.1.2. Branched Chain Amino Acids-BCAA

Branched-chain amino acids contain valine leucine isoleucine, which prevents muscle breakdown in training and is taken from the outside as it is not produced by the body. The catabolism of BCAAs does not occur in the liver because of the low activity of branched chain amino-acid aminotransferase (BCAT) in the liver. After digestion, BCAA proteins are transported to extrahepatic tissues, especially muscle and brain, and metabolized there [18]. BCAAs are oxidized by muscle cells and converted into ATP, a form of energy at the cellular level. Since leucine, isoleucine, and valine are metabolized in muscle tissue, they act as a rapid source of energy needed during muscle contraction. Although BCAAs function as a food signal, they are important N donors for many amino acids. Apart from these, they also undertake many important critical tasks in metabolism [19]. It has been stated that BCAAs, which are used primarily used as exogenous nutritional supplements by athletes, especially enhance muscle proteins, increase fitness and accelerate recovery after exercise [18]. However, there have been reports showing that high levels of ammonia, which are formed by BCAA metabolism, can negatively affect muscle performance [20].

2.1.3. β-Alanine

β-alanine increases the content of carnosine in the muscle. It is a dipeptide molecule that is formed by the binding of carnosine histidine and beta-alanine and is in high amounts in muscle [21]. As a result of medium and high intensity exercise, hydrogen ions increase and pH begins to decrease. It also occurs in lactic acid as a result of insufficient oxygen and causes the pH to drop further and fatigue occurs. As a result of the studies, beta-alanine supplement increases the production of carnosine, acts as a buffering agent, prevents pH drop and delays the fatigue period [22]. With the use of daily supplements containing alanine for more than 2 weeks, better performance was achieved during exercise [12].

2.1.4. Glutamine

Glutamine is considered an important nitrogen source, as it acts as a nitrogen carrier between the organs that provide synthesis and degradation. Thus, it is plenty in body. Glutamine, which is among the ergogenic nutritional supplements, has been reported to increase the amount of protein in the muscles and also has an effect on the immunity and glucose balance [14]. Although researches have stated that glutamine can improve the immunological function, there are also studies indicating that it has no effect on immune functions [14, 23]. Some studies have reported lower rates of infection in athletes who consume glutamine supplements after intensive training [24]. It has been said that being taken additional glutamine increases the amount of glutamine in the blood and protects skeletal muscles, thereby reducing muscle catabolism. The constant change in the body’s protein stores and the increase in BCAA / Leucine oxidation caused by training suggests that the body needs a high level of leucine. Otherwise it cannot fully assist muscle growth. At this point, it has been expressed that BCAAs should be supported with glutamine supplements [19].

2.1.5. Arginine

Arginine is an important intermediate metabolite of the urea cycle. While arginine synthesized in the liver participates in the urea cycle, it provides both urea formation and on the other hand, it plays a role as a substrate in NO synthesis. NO is a powerful endogenous vasodilator that regulates blood flow and benefits vascular endurance [14]. Arginine also increases performance by stimulating muscle protein synthesis in athletes and delays the fatigue period by reducing the level of lactic acid in muscles [25].

2.2. Vitamin Supplements

Vitamins known as regulatory molecules for metabolism play important roles in the functioning of many systems. They are often preferred by athletes especially since they support energy production and affect muscle development significantly. Athletes can use a variety of important vitamins to increase strength, speed, endurance and performance [26]. Vitamins B, vitamin C, vitamins A, D, E and K have act in energy and carbohydrate metabolism with many different functions (Table 2) [27].

There is no vitamin deficiency in adequate and balanced nutrition, so there is no need for additional vitamin supplements. However, it has been shown that vitamins commonly used by many athletes as dietary supplements [26]. The result of a research, it has been determined that the most vitamin supplements taken are vitamin C (86.1%), vitamin A (54.0%) and 49.6% vitamin D [3]. Among the vitamins, the antioxidant properties of beta-carotene and vitamin C, E have been suggested to be high factors in improving performance or prevent fatigue [26]. Vitamin E has been shown to increase oxygen use in activities at high altitudes by Simon-Schnass and Pabst [28]. It has been reported that the risk of knee osteoarthritis increases especially in athletes if vitamin K, which is effective in blood clotting, is insufficient [29].

Table 2 Ergogenic nutrition supplements –Vitamins

Vitamin Supplement	Ergogenic Values	Reference
Vitamin A	It acts as an antioxidant. Takes part in exercise-induced muscle damage and lipid peroxidation, improves exercise performance, increases night vision.	[26, 27]
Vitamin D	Vitamin D supplements cannot be planted in exercise performance, but prevent bone loss. Prevents to against infections.	[27, 30, 31]
Vitamin E	It has no effect on working performance, but as an antioxidant, it prevents oxygen radicals and damages from exercise.	[27, 28]
Vitamin K	It takes part in blood clotting. There is evidence that it will affect bone metabolism in postmenopausal women, its the absence increases risk of knee osteoarthritis increases.	[27, 29]
Vitamin B groups (B1, B2, B3, B6)	They play a role in energy metabolism as a coenzyme, increases energy availability in the oxidative metabolic process.	[27, 32]
Folic acid, B12	Enables red blood cell (RBC) development, Folic acid and B12 have a vital important in cell growth and development.	[33, 34]
Vitamin C	Roles place in many metabolic events, acts to epinephrine synthesis, iron intake, improves performance, increases immunity, it is an antioxidant.	[35, 36]

2.3. Mineral Supplements

Minerals are inorganic elements necessary for a wide range of metabolic and physiological processes in the human body. They act as nerve impulses forwarder, oxygen and electron carrier and enzyme cofactors. In addition, it has been stated that minerals are required for muscle contraction, normal heart rhythm, immunity, antioxidant activity, bone health and electrolyte balance in metabolism [37]. Therefore, many metabolic processes can will be interrupted in case of minerals deficiency.

It is important to have enough minerals in the body as the metabolic rate will increase during sports or exercise. Otherwise, performance may decrease. It was found that performance was increased when a mineral supplement with a diet was added to an athlete with a mineral deficiency [27]. The importance of mineral supplements in sports has been shown in many studies (Table 3). For this reason, taking these supplements in favorable conditions will help maintain body balance during and after the exercise period. The studies shown that sodium and potassium deficiency, which maintain fluid and electrolyte balance in the body, can cause muscle cramps in athletes [27, 38]. Studies have shown that iron and calcium are the lowest minerals in dietary nutrients [39, 40], so, it has been reported that iron supplement increases exercise capacity in athletes prone to iron deficiency [41]. As similarly, sodium phosphate supplementation has been stated to increase oxygen uptake and endurance for athletes who experience major fluid and electrolyte loss after intense exercise [42].

Although zinc has many metabolic roles, it is a known cofactor for some enzymes. For this reason, it has been reported that a decrease in the level of zinc may decrease the strength in the muscles and intense and continuous exercise also may decrease the level of zinc. For example, runners have been reported to have lower plasma zinc levels compared to the controls [27].

Table 3 Ergogenic nutrition supplements – Minerals

Vitamin Supplement	Ergogenic Values	Reference
Calcium	Necessary for the preservation of bone mass, coagulation and nerve conduction, no effect on performance.	[27]
Chromium	Chromium intake helps to increasing muscle mass and reducing body fat.	[43]
Iron	It is a carrier of oxygen, improving aerobic performance.	[41, 42]
Phosphorus	Important for metabolism due to its many biochemical functions (ATP, thiamin pyrophosphate, 2,3-diphosphoglycerate ect., expecially due to 2,3- diphosphoglycerate, which facilitates oxygen release from hemoglobin).	[39]
Selenium	Se is radical remover and reduces oxidant stress due to exercise.	[27, 44]
Sodium, Potassium	They are responsible electrolytes from the acid-base balance and nerve transmitting.	[40, 45]
Zinc	Supports immunity, enhances exercise performance, increases endurance.	[27, 39]
Magnesium	Improves energy metabolism.	[27]

With studies, in zinc deficiency, it is determined that collagen synthesis is decreased and wound healing is delayed. The researchers have stated that the lack of zinc observed after excessive exercise and fatigue can reduce immunity [46]. Magnesium is a cofactor for many enzymes involved in regulating muscle contraction, oxygen delivery, and protein synthesis [39]. It regulates nervous system messages, so in its deficiency, muscle contractions are observed.

2.4. Liquid and Electrolyte Supplements

Recovery of fluid and electrolytes lost after intense exercise is very important. Thus, both it contributes to the development of physical performance and increases endurance and prevents dehydration [47]. Products used for this purpose include carbohydrates, caffeine and minerals. The most widely used energy drinks in this group. While the main components of energy drinks are caffeine, carbohydrates (glucose, fructose sucrose glucuronolactone and inositol), they also contain substances such as B vitamin groups, taurine, plant and herbs (ginseng, green tea extract). Caffeine is known increasing performance and alertness. In recent years, the fact that energy drinks are consumed frequently by the youth, apart from athletes, has caused many controversies due to its high caffeine content and many side effects. Therefore, it is emphasized that its consumption should to be controlled [48]. Because these drinks increase concentration and endurance, they can also lead to disruptions in sleep patterns, increased consumption and other health problems (heart disease, obesity etc.) [49].

Electrolytes are also frequently used supplements. After intense sports, the rate of acid (H^+) and carbon dioxide (CO_2) in the body increases, especially in the muscle and blood, acidity increases. They are removed by buffering with acidity and CO_2 bicarbonate ions. Researches have observed that bicarbonate supplementation significantly increases performance capacity in exercises such as swimming and running [27]. Also, sodium phosphate supplement is used especially for weight loss. Therefore, it has an ergogenic value. The results of the researches have showed that sodium phosphate can be quite effective in increasing endurance during performing [50, 51].

2.5. Other Supplements

In addition to the basic supplements, creatine, l-carnitine, CoQ10, CLA, HMB and energy drinks are also among the frequently used ergogenic dietary supplements (Table 4).

2.5.1. Creatine

Creatine is one of the important ergogenic dietary supplements that are frequently used by athletes to increase muscle strength recently [52]. Creatine consists of glycine, methionine and arginine amino acids. 95% of creatine is stored as a ready energy source in the muscles as phosphocreatine. Phosphocreatine is important a phosphate source to produce energy in muscles. It is required in transformation to adenosine triphosphate (ATP) from adenosine diphosphate (ADP).

$$ATP \rightarrow ADP + Pi$$

$$ADP + CP \rightarrow ATP + C$$

Creatine provides strength and endurance in instant and high-intensity muscle movements [53].

2.5.2. L-Carnitine

L-carnitine helps in the production of ATP by transporting long chain fatty acids to mitochondria in fatty acid metabolism. Therefore, many athletes use it as an ergogenic supplement nowadays. Studies have shown that l-carnitine supplementation can reduce the harmful effects of hypoxic training. In addition, and it has been expressed that L-carnitine supplementation speeds recovery and improves performance by removing negative effects after exercise and sports [54, 55]. In another study with 90 wistar rats supplemented with carnitine supplements in different concentrations, rats showed significant ergogenic effects. In the same study, carnitine supplementation increased the amounts of ATP, muscle glycogen, reduced glutation, plasma triglyceride and glucose and enzymatic antioxidant enzymes (superoxide dismutase, catalase and glutathione peroxidase), resulting in increased energy levels [56].

2.5.3. Coenzyme Q10

Coenzyme Q10 is an important metabolic antioxidant molecule that plays role as an electron carrier in the electron transport chain and is providing the energy needed by the cells. Therefore, it is found in the cell mitochondria. Its density in the heart cells is higher. For this reason, it has been recommended as a complementary treatment for many diseases, especially chronic heart failure. In addition, it protects the cells from free oxygen radicals that may occur during intense exercise [39]. It has been reported that athletes may experience CoQ10 deficiency as metabolic stress and free radical formation increase during intensive training periods. For this reason, it has been stated that there is a suitable supplement among active athletes [57]. However, in some studies with athletes, it was suggested that CoQ has no effect on performance, and it has been interpreted as this is due to the low bioavailability of CoQ, which is a large molecule [58].

Table 4 Functions of some ergogenic supports

Vitamin Supplement	Ergogenic Values	Reference
Beta-hydroxy-betamethylbutyrate (HMB)	It is a metabolite of leucine amino acid, important for wound closure and healing, increases the accumulation of collagen, increases muscle.	[59, 60]
Creatine	An energy substrate for skeletal muscle contraction, increases endurance and effectiveness.	[53]
Coenzyme Q10	It is a mitochondrial electron carrier, with its antioxidant and anti-inflammatory effects, it reduces negative results from exercise, prevents muscle damage, increases exercise performance.	[57, 61]
Conjugated Linoleic Acids (CLA)	Reduces body fat, increases muscle and bone mass, increases immunity.	[27]
L-Carnitine	Carries fatty acids to mitochondria, accelerates the conversion of fats into energy.	[55, 56]

3. Conclusion

Ergogenic food supplements are forms of nutrients taken with daily nutrition, prepared in forms such as liquid, powder, tablet. Athletes generally use this kind of products when they are inadequate in their natural and daily nutrition. These products meet their needs effectively and quickly. However, studies show that it would be more appropriate to turn to natural nutrition when was seen to usage limitations, side effects and psychological effects of such supplements. Because, it is very important not to use ergogenic supplements that have not been proven effective. Especially young people and adolescents should be informed about such products and be directed towards the establishment of metabolic balance with natural foods.

References

[1] Alphan Tüfekçi ME. *Hastalıklarda Beslenme Tedavisi [Nutrition Therapy in Diseases]*. Ankara: Hatiboğlu (2018).

[2] Dziedzic CE, Higham D. Performance Nutrition Guidelines for International Rugby Sevens Tournaments. *International Journal of Sport Nutrition and Exercise Metabolism* (2014) **24**:305–314.

[3] Güler D, Gökdemir K, Günay M. The Level of Use and Information of the Footballers Participating in Interuniversity Sports Games about the Ergogenic Aids in Turkey. *Gazi Journal of Physical Education and Sports Sciences* (2008) **9**(3):37–48.

[4] Schnohr C, Pedersen JM, Alcón MCG, Curtis T, Bjerregaard P. Trends in the Dietary Patterns and Prevalence of Obesity Among Greenlandic School Children. *International Journal of Circumpolar Health* (2004) **63**(2):261–264.

[5] Kharazi P. *Farklı Ülkelerin Beden Eğitimi ve Spor Yüksekokul Öğrencilerinin Beslenme Alışkanlık ve Ergojenik Yardım Kullanma Düzeylerinin İncelenmesi [Examination of Nutrition Habits and Ergogenic Use Levels of Physical Education and Sports College Students of Different Countries]*. PhD Thesis. Gazi University (2017).

[6] Babal AF. *Investigation of Nutritional Status and Supplement Use in Individuals who Exercise*. Master Thesis. Halic University (2015).

[7] Karakuş M. Ergogenic Support in Athletes. *Journal of Sports Medicine* (2014) **49**:155–167.

[8] Yarar H, Gökdemir K, Özdemir G. Elit Sporcularda Beslenme Destek Ürünü Kullanımı ve Bilincinin Değerlendirilmesi [Evaluation of the Use of Dietary Supplements and the Level of Awareness of Elite Athletes]. *Atatürk Üniversitesi Beden Eğitimi ve Spor Bilimleri Dergisi* (2011) **13**(3):1–11.

[9] Kerksick CM, Wilborn CD, Roberts MD, Smith-Ryan A, Kleiner SM, Jäger R, et al. ISSN Exercise & Sports Nutrition Review Update: Research & Recommendations. *Journal of the International Society of Sports Nutrition* (2018) **38**. doi:10.1186/s12970-018-0242-y.

[10] Kulağsız C, Turgal E, Derici MK. Çorum İlinde Spor Merkezlerinde Spor Yapan Bireylerin Besin Destek Ürünleri Kullanımının ve Bilgi Düzeylerinin Değerlendirilmesi [The Evaluation of Knowledge and Usage Levels of Nutritional Support Products Among Sports Individuals in Fitness Centers in Çorum City]. *Anadolu Güncel Tıp Dergisi* (2019) **1**(4):85–91.

[11] CodexCAC/GL. *Alimentarus Draft Guidelines for Vitamin and Mineral Food Supplements* (2005). 1-5.

[12] Ulaş, AG. *ADÜ Beden Eğitimi ve Spor Yüksekokulu Öğrencilerinin Sporcu Beslenmesi ile İlgili Farkındalıkları [The Awareness of the Students of ADU School of Physical Education and Sports on Sports Nutrition]*. Master Thesis. Aydın Adnan Menderes University (2018).

[13] Ercen Ş. *Determination of Knowledge Level and Attitudes About Ergogenic Support Products and Expression of Nutritional Habits of 18-40 Age Group Healthy Male Athletes Concerning Fitness and Bodybuilding Sports in TRNC*. Master Thesis. Eastern Mediterranean University (2016).

[14] Williams M. Dietary Supplements and Sports Performance: Amino Acids. *Journal of the International Society of Sports Nutrition* (2005)(2):63–67.

[15] Yeşilkaya B, Mut E. Ergogenic Supports Used in Athletes. *International Refereed Journal of Nutrition Research* (2018) **52**(75):13–18.

[16] Graf S, Egerta S, Heerb M. Effects of Whey Protein Supplements on Metabolism: Evidence from Human Intervention Studies. *Functional Foods* (2011) **14(6)**(569):1363–1950.

[17] Marshall K. Therapeutic Applications of Whey Protein. *Alternative Medicine Review* (2004) **9**:136–156.

[18] Holecek M. Branched-chain Amino Acids in Health and Disease: Metabolism, Alterations in Blood Plasma, and as Supplements. *Nutrition and Metabolism* (2018) **15**(33).

[19] Nie C, He T, Zhang W, Zhang G, Ma X. Branched Chain Amino Acids: Beyond Nutrition Metabolism. *International Journal of Molecular Sciences* (2018) **19**:954.

[20] Falavigna G, Araújo AJ de, Rogero MM, Pires IS, Pedrosa RG, Martins E. Effects of Diets Supplemented with Branched-Chain Amino Acids on the Performance and Fatigue Mechanisms of Rats Submitted to Prolonged Physical Exercise. *Nutrients* (2012) **4**:1767–1780.

[21] Sale C, Saunders B, Harris RC. Effect of Beta-alanine Supplementation on Muscle Carnosine Concentrations and Exercise Performance. *Amino Acids* (2010) **39**(2):321–333.

[22] Blancquaert L, Everaert I, Derave W. Beta-alanine Supplementation, Muscle Carnosine and Exercise Performance. *Current Opinion in Clinical Nutrition & Metabolic Care* (2015) **18**(1):63–70.

[23] Antonio J, Street C. Glutamine: A Potentially Useful Supplement for Athletes. *Canadian Journal of Applied Physiology* (1999) **24**(1):1–14.

[24] Castell, LM., Newsholme EA., Poortmans JR. Does Glutamine Have a Role in Reducing Infections in Athletes. *European Journal of Applied Physiology* (1996) **73**:488–490.

[25] Mor A, Atan T, Ağaoglu SA, Ayyıldız M. Effect of Arginine Supplementation on Footballers' Anaerobic Performance and Recovery. *Progress in Nutrition* (2018) **20**(1):104–112.

[26] Williams M. Vitamin Supplementation and Athletic Performance. *International Journal of Vitammine Nutrition Resesearch Supplemant* (1989) **30**:163–191.

[27] Kreider RB, corresponding author Colin D Wilborn, Taylor L, Campbell B, Almada AL, Collins R, et al. ISSN Exercise & Sport Nutrition Review: Research & Recommendations. *Journal of the International Society of Sports Nutrition* (2010) **7**(1):7.

[28] Simon-Schnass I, Pabst H. Influence of Vitamin E on Physical Performance. *International Journal for Vitamin and Nutrition Research* (1988) **58**(1):49–54.

[29] Sousa M, Fernandes MJ, Carvalho P, Soares J, Moreira P, Teixeira V. Nutritional Supplements Use in High-Performance Athletes is Related with Lower Nutritional Inadequacy from Food. *Journal of Sport and Health Science* (2016) **5**.

[30] Owens DJ, Allison R, Graeme L. Vitamin D and the Athlete: Current Perspectives and New Challenges. *Sports Medical* (2018) **48**(1):3–16.

[31] Cameron F, Gunville CF, Mourani P, Ginde A. The Role of Vitamin D in Prevention and Treatment of Infection. *Inflammation & Allergy - Drug Targets* (2013) **12**(4):239–245.

[32] Woolf K, Manore M. B-Vitamins and Exercise: Does Exercise Alter Requirements? *International Journal of Sport Nutrition and Exercise Metabolism* (2006)(16):453–484.

[33] Molina-López J, José M, Molina J, Luís J, Chirosa LJ, Daniela I, et al. Effect of Folic Acid Supplementation on Homocysteine Concentration and Association with Training in Handball Players. *Journal of the International Society of Sports Nutrition* (2013)(10):10.

[34] Mahmood L. The Metabolic Processes of Folic Acid and Vitamin B12 Deficiency. *Journal of Health Research and Reviews* (2014) **1**(1):5–9.

[35] Hemilä H, Kaprio J. Vitamin E Supplementation and Pneumonia Risk in Males who Initiated Smoking at an Early Age: Effect Modification by Body Weight and Vitamin C. *Nutritional Journal* (2008) **7**:33.

[36] Hemilä H. Vitamin C and Infections. *Nutrients* (2017) **9**:4.

[37] Speich M, Pineau A, Ballereau F. Minerals, Trace Elements and Related Biological Variables in Athletes and During Physical Activity. *Clinica Chimica Acta* (2001) **312**(1-2):1–11.

[38] Sawka MN, Montain S. Fluid and Electrolyte Supplementation for Exercise Heat Stress. *American Journal Clinical Nutrition* (2000) **72**(56):4S-72S.

[39] Williams M. Dietary Supplements and Sports Performance: Introduction and Vitamins. *Journal of the International Society of Sports Nutrition* (2004) **1**(2):1–6.

[40] Alaunyte L, Stojceska V, Plunkett A. Iron and the Female Athlete: A Review of Dietary Treatment Methods for Improving Iron Status and Exercise Performance. *Journal of the International Society of Sports Nutrition* (2015) **12**:38.

[41] Eichner E, Randy MD. Anemia in Athletes, News on Iron Therapy and Community Care During Marathons. *Current Sports Medicine Reports* (2018) **17**(1):2–3.

[42] Shirreffs SM, Sawka M. Fluid and Electrolyte Needs for Training, Competition, and Recovery. *Journal of Sports Science* (2011) **29**(1):39–46.

[43] Ghosh D, Bhattacharya B, Mukherjee B, Manna B, Sinha M, Chowdhury J, et al. Role of Chromium Supplementation in Indians with Type 2 Diabetes Mellitus. *The Journal of Nutritional Biochemistry* (2002) **13**(11):690–697.

[44] Louise, A, La Savory, Kerr CJ, Whiting P, Finer N, et al. Selenium Supplementation and Exercise: Effect on Oxidant Stress in Overweight Adults. *Obesity* (2012) **20**(4):794–801.

[45] Lemuel, WT. *Nutritional Guidelines for Athletic Performance: The Training Table*. USA: CRP (2012). 167 p.

[46] Cordova A, Alvarez-Moni M. Behaviour of Zinc in Physical Exercise: A Special Reference to Immunity and Fatigue. *Neuroscience and Biobehavioral Reviews* (1995) **19**(3):439–445.

[47] Al-Fares MN, Alsunni AA, Majeed F, Badar A. Effect of Energy Drink Intake Before Exercise on Indices of Physical Performance in Untrained Females. *Saudi Med Journal* (2015) **36**(5):580–586.

[48] Georgios AE, Alfonso M, Karen L, Hirsch-Erns I. Risk Assessment of Energy Drinks with Focus on Cardiovascular Parametersand Energy Drink Consumption in Europe. *Food and Chemical Toxicology* (2019) **130**:109–121.

[49] Steinke L, de Lanfear, Dhanapal V, Kalus J. Effect of "Energy Drink" Consumption on Hemodynamic and Electrocardiographic Parameters in Healthy Young Adults. *Annals of Pharmacotherapy* (2009) **43**(4):596–602.

[50] Folland JP, Stern R, Brickley G. Sodium Phosphate Loading Improveslaboratory Cycling Time-trial Performance in Trained Cyclists. *Journal of Science and Medicine in Sport* (2008) **11**(5):464–468.

[51] Brewer C. *Effect of Sodium Phosphate Loading on Exercise Performance in Well-Trained Cyclists*. PhD Thesis. The University of Western Australia (2015). 13-16.

[52] Jagim AR, Stecker RA, Harty PS, Erickson JL, Kerksick C. Safety of Creatine Supplementation in Active Adolescents and Youth: A Brief Review. *Frontiers in Nutrition* (2018) **5**:115.

[53] Butts J, Jacobs B, Silvis M. Creatine Use in Sports. *Sports Health* (2018) **10**(1):31–34.

[54] Karlic H, Lohninger A. Supplementation of l-carnitine in Athletes: Does It Make Sense? *Nutrition* (2004) **20**(7–8):709–715.

[55] Cha YS, Kim HY, Daily J. Exercise-Trained but not Untrained Rat Manitain Free Carnitine Reserves During Acute Exercise. *Asia Pacific Journal of Clinical Nutrition* (2003) **12**:120–126.

[56] Pandareesh MD, Anand T. Ergogenic Effect of Dietary L-carnitine and Fat Supplementation Against Exercise Induced Physical Fatigue in Wistar Rats. *Journal of Physiology and Biochemistry* (2013) **69**(4):799–809.

[57] Cooke M, Losia L, Buford T, Shelmadine B. Effects of Acute and 14-day Coenzyme Q10 Supplementation on Exercise Performance in Both Trained and Untrained Individuals. *Journal of International Society of Sports Nutrition* (2008) **5**:8.

[58] Joshi SS, Sawant SV, Shedge A, Halpner A. Comparative Bioavailability of Two Novel Coenzyme Q10 Preparations in Humans. *International Journal of Clinical Pharmacology and Therapeutics* (2003) **41**(1):42–48.

[59] Holeček M. Beta-hydroxy - beta-methylbutyrate Supplementation and Skeletal Muscle in Healthy and Muscle-wasting Conditions. *Journal of Cachexia Sarcopenia Muscle* (2017) **8**(4):529–541.

[60] Wilson GJ, Wilson JM, Manninen AH. Effects of Beta-hydroxy - Beta-methylbutyrate (HMB) on Exercise Performance and Body Composition across Varying Levels of Age, Sex, and Training Experience: A review. *Nutrition & Metabolism* (2008) **3**(5):1.

[61] Armanfar, M, Jafari A, Dehghan GR, Abdizadeh L. Effect of Coenzyme Q10 Supplementation on Exercise-Induced Response of Inflammatory Indicators and Blood Lactate in Male Runners. *Medical Journal of Islamic Republic of Iran* (2015) **29**:202.