Review article

UDC: 613.2:796.071.2
doi:10.5633/amm.2018.0208

PATHOPHYSIOLOGICAL ASPECTS OF OLIGOELEMENT SUPPLEMENTATION IN ATHLETES

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The precondition for achieving top athletic results is full health and psychophysical readiness. Essential oligoelements are necessary for normal biochemical and physiological processes, utilization of energy and building of tissues, as well as for optimal functioning of the muscles and their harmonious relationship with other systems. Trace elements play an important role in energy metabolism during strenuous physical activity, and in the conditions of increased oxygen demand, free radical production, activity of scavenger enzymes, and antioxidant protection.

Athletes may have iron deficiency due to decreased dietary intake, blood loss or increased needs due to physical activity, however, supplementation is not justified in terms of improving sports performance, and may even be harmful. Copper has particular importance in biological processes of energy metabolism, iron homeostasis and antioxidant protection. Additional amounts of copper of 0.5-3.0 mg per day are recommended to athletes, although high doses do not have ergogenic properties. Moreover, athletes have a greater need for zinc. Additional amounts of zinc supplements are recommended, 15-50 mg per day. The deficiency of manganese occurs most frequently in malnourished people, while the need for selenium in well-trained athletes increase depending on the energy consumption.

Sport activity, especially when it comes to long-term extreme efforts, increases the need for micronutrient substances. Athletes need to ensure a balanced diet and oligoelement supplementation to meet their needs, increased in relation to the recommended daily intake.

Acta Medica Medianae 2018;57(2):45-52.

Key words: *micronutrients, physical activity, iron, copper, zink, recommanded daily intake*

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Introduction

Oligoelements (trace elements) are substances whose concentration does not exceed 250 μg/g of weight and whose decrease below a certain value leads to a reduction of physiologically important functions, because they are part of organic systems which perform vital functions. According to their importance in the diet, as recommended by the experts of the World Health Organization, trace elements can be divided into essential, elements that are likely essential, and elements that are potentially toxic, but can be essential in very small concentrations (1, 2).

Essential trace elements are necessary for normal biochemical, physiological processes in the body, growth, maintenance of health and longevity, and their lack is causing disease, while correcting the deficiency eliminate the disease. This group includes: iron (Fe), cobalt (Co), copper (Cu), zinc (Zn), chromium (Cr), molybdenum (Mo), iodine (I) and selenium (Se). The group of elements that are likely essential comprise: manganese (Mn), silicon (Si), nickel (Ni), bromium (Br), and vanadium (V). Among the elements that are potentially toxic but may be essential in very small concentrations are: fluorine (F), lead (Pb), cadmium (Cd) and mercury (Hg). A pathophysiological division of oligoelements is made according to their biological role in the organism as follows: hematopoietically active (Fe, Cu, Co), active enzyme components (Zn, Mn, Mo, Cr, Se, V), and halogen elements (J, F, Br) (1-4).

A prerequisite for achieving top results in disciplines that require physical strength and stamina is full health and psychophysical fitness of athletes. Full health is necessary for optimal muscle function and harmonious relationship of musculoskeletal, neuroendocrine, immune and other systems.

Clear criteria and recommendations exist on the necessary macronutrient intake and their relation to diet for proper functioning of the body and maximum mental and physical readiness. Although trace elements are measured in micrograms or milligrams, and rarely grams, they are essential for energy utilization, building tissue materials and proper functioning of all the above mentioned systems. This imposes the need for intensive studying of the role and importance of micronutritive materials (vitamins and trace elements).

Experts from the World Health Organization (WHO) and Food and Drug Administration of the United States of America (United States Food and Drug Administration - US FDA) are trying to formulate recognizable standards that determine the daily needs for trace elements, which are defined as the recommended daily allowance (Recommended Daily Intake - RDI). Their efforts are shared by the research teams around the world in order to adopt national and international standards. Despite intense research, there is still a lot of unknown facts when it comes to the impact of vitamins and trace elements to some specific functions related to stamina, physical strength and capability (1, 4).

The body supply with minerals that are present in large quantities, such as Ca, Mg, P, K and C is achieved easily in terms of well-balanced diet, as these substances are present in food in sufficient quantities. Regarding trace elements, the situation is quite different. Some trace elements are present in a small number of foods which can be the cause of their insufficient intake and deficiencies.

Lack of most trace elements in the body is not easily visible and recognizable in part because we still do not know enough about certain elements and possible symptoms of their deficiency, and partly because there are very complex interactions between the individual trace element, that can change and mask the clinical manifestations of deficiency.

Over the long term strenuous physical activity energy transport in skeletal muscle increases by 20 to 100 times compared to the inactive state. There is an increased demand for the substances that provide energy which is accompanied by increased needs for certain macronutrients, vitamins and trace elements. Many trace elements play a key role in energy metabolism during strenuous physical activity (3). Enormous physical activity also increases oxygen consumption, production of free radicals, the activity of the enzyme "cleaners" and the need for antioxidant vitamins (C, E, and beta-carotene) and trace elements (5).

In addition, many trace elements are intensively lost in sweat or urine during physical exertion. It should be mentioned that between certain trace elements there is a strong synergism, meaning that some trace elements are necessary for the proper operation of others. Some trace elements may enter into mutual interaction which should also be taken into account (3, 4, 6, 7).

It is believed that most athletes do not need mineral supplementation as a balanced diet is rich enough and meet the increased needs. However, some groups of athletes are at risk to develop trace element or macronutrient mineral deficiencies. These are the persons involved in sports where low body mass is important for success (gymnasts, ice skaters, jockeys) or sports that require exactly the right body weight due to the category (boxers, weightlifters, wrestlers). Despite intense training, these athletes are very often on reduction diets to achieve the required weight loss to compete. A food intake below 2000 kcal per day can lead to inadequate intake of essential substances such as vitamins and trace elements (1, 4).

The deficiency in trace elements can also occur in the period of rapid growth in adolescents who participate in sports as well as in people who suffer from eating disorders. In athletes, most common eating disorders are borderline forms of bulimia and anorexia. Poor nutrition is the most common cause of deficiencys in athletes. Lack of knowledge about the principles of proper nutrition is a common culprit, as well as the lack of time to prepare quality meals and susceptibility to advertising that favor different supplements and foods of poor quality (1, 8, 9).

The impact of micronutrient deficiency on physical strength and abilities was the subject of numerous studies. Commonly, there is decreased physical fitness and strength associated with the deficiency of a number of oligoelements and vitamins due to prolonged lack of dietary intake, which results in a decrease in their tissue concentrations (1, 8, 10, 11).

The great part of this knowledge was gained in the forties of the twentieth century, until the introduction of the practice of processed foods enrichment with iron and vitamins. In modern conditions, the research of micronutritive substance deficiencies is carried out in experimental conditions in animals or in developing countries where foods enrichment has not been conducted (8, 10, 11).

Today, the generally accepted opinion is that the deficiency of iron, thiamine, riboflavin, vitamin B6, C and E vitamins (individually or combinations) certainly reduces physical strength and fitness. Investigation of the effects of other micronutritive substances on physical strength and fitness give conflicting results (1, 5, 7).

Persons involved in sports, either professional or amateur, are aware of benefits brought about by proper nutrition and optimal health. Lots of information offered by the popular press and media very often are not fully supported by scientific studies and valid evidence. It is wise to consult a physician when making a decision on food supplement use.

Iron (Fe) and the needs of athletes for iron

Iron plays an important role in the body because it participates in oxidation-reduction reactions and allows the transport of oxygen and constitutes a component of metalloenzymes.

In addition to the most known function in transferring oxygen via hemoglobin, the iron allows the running of a number of important functions as a cofactor of many enzymes. Through myoglobin it allows movement, performs modification of collagen and elastin (lysyl and prolyl hydroxylase), supports immune function (myeloperoxidase), detoxify xenobiotics (cytochrome P-450). It is involved in cellular transport of energy: in the production of energy (cytochromes and aconitase), in aerobic metabolism (activities of α-glycerilphosphate dehydrogenase), allows electron transfer (iron-sulfur oxidoreductase), has a role in gluconeogenesis (carboxykinase), exhibits antioxidant activity (catalase) and participates in the synthesis of DNA and RNA (ribonucleotide reductase) (1, 4, 8, 9).

The recommended daily intake (RDI) of iron for adults is 18 mg per recommendation from the 1995 year (1, 2). Iron is abundantly represented in meat, offal, egg yolk, chicken, fish, whole grains, legumes, blueberries, blackberries and leafy vegetables. It is easier to exploit iron from foods of animal origin. In this case, the 25% of the heme Fe is absorbed, compared to only 3-15% of vegetables Fe, as well as supplementation. The iron absorption promotes vitamin C. It is therefore recommended intake of juices and vegetables with meat (6).

The absorption of iron is reduced in the presence of: tea, coffee, calcium carbonate, clay and the reduced acidity of gastric fluid. Iron interacts with zinc and vitamin E. Control mechanisms of absorption and transport of iron are highly specialized and do not allow the spontaneous release of Fe ions in the body (6).

Disorders of iron metabolism may be of a type that lack or deficiencys and excessive intake and intoxication.

Iron deficiency is the most common nutritional disorder. The main risk group for Fe deficiency are females of reproductive age, then children and adolescents (12, 13). The deficiency may occur in the following conditions: pregnancy, malnutrition (anorexia, diet), the elderly, with blood loss (menorrhagia, irregular bleeding, ulcers, hemorrhoids, the use of salicylates, the use of non-steroidal anti-inflammatory drugs, tumors of the digestive tract of various localization, frequent blood donation, thalassemia), gastrectomy, malabsorption syndrome, congenital hemorrhagic syndromes, paroxysmal nocturnal hemoglobinuria and hemolysis in athletes who practice running (6, 8, 10, 11).

Signs and symptoms of iron deficiency are primarily related to the development of sideropenic (microcytic) anemia. These people complain of frequent fatigue and exhaustion, have poor memory, altered peripheral sensitivity (paresthesia), reduced work capacity and tolerance to cold. Their skin is pale, with a pearly white sclera, the hair is frayed and nails are brittle. There may be gastrointestinal discomfort, glossitis, angular stomatitis, dysphagia and edema. Loss of immunity is accompanied by increased propensity to infection and eczema. There is tachycardia and shortness of breath, while in more severe conditions systolic murmur above the ictus cordis can be heard together with electrocardiographic disorders (signs of ischemia). There may be a secondary hormonal disorders, while growth retardation is observed in children (2, 14).

Excessive iron intake usually occurs by the accidental intake of excessive amounts of iron supplements. The first event after oral intake is stomach pain, because iron as a corrosive substance damages gastrointestinal tract epithelium. This is followed by nausea and vomiting, bloody diarrhea and in severe cases of hepatocellular necrosis with hepatic failure (15). Metabolic acidosis can be developed, also depression of cardiac function with a drop in blood pressure and CNS depression to coma (16, 17).

Long-term accumulation of iron in the body (hemochromatosis) as an aquired disorder is usually caused by hematological disorders (thalassemia and anemia). Iron is in these people predominantly deposited and damages the liver, heart and pancreas (18). Excessive iron deposition was observed in athletes involved in professional cycling, because of long-term excessive doses of iron supplementation (19).

Athletes may have iron deficiency due to decreased dietary intake, blood loss or increased needs due to physical activity. Endurance athletes are at greater risk for iron deficiency due to the disproportion between its absorption from foods and exercise-induced loss (12).

Physiological changes during exercise can create a false picture of the reduction of hemoglobin, ferritin and iron. These changes include hemodilution and stimulation of erythropoiesis. The phenomenon of transient decrease in hemoglobin concentration exists at the beginning of training, especially in endurance sports (in runners or swimmers) and is explained by the rapid expansion of plasma volume in relation to the mass of red blood cells, affected by osmosis and hormonal response. In some cases, reticulocytosis and macrocytosis are the consequences of hemolysis. The mechanisms that lead to hemolysis differ depending on type of sport, and the best known cause is the mechanical trauma of peripheral capillaries and consequent fragmentation of erythrocytes, as in runners (13, 20).

It was found that athletes lose iron through bleeding from the gastrointestinal tract, especially the long distance runners. Top athletes have an increased loss of blood through the intestine, but this phenomenon is usually compensated by increased absorption of dietary iron (13). In the study of Stewart et al. (21) 83% of runners had occult blood in the stool after the competition. Of course, athletes who have iron deficiency anemia experienced a significant decline in sport performance, working capacity and VO2max. Their iron supplementation is clearly justified, which is proved by improving athletic performance after treatment (6, 12, 22).

Measurement of ferritin levels is used for a general assessment of the amount of iron in the body, however, the expression of ferritin in the serum is also determined by other factors, for example inflammation. Serum ferritin concentration declines during and after exercise, which was interpreted as a lack of iron after exercise. The level of ferritin in elite athletes is often low, however the iron deficiency is not common (6, 12). Currently the lower limit of ferritin concentration, that would determine the need for iron compensation, has not been standardized yet. According to a study Rodenberg (22) if ferritin is below 35 ng/ml the treatment of iron should be considered (6).

Instead of ferritin, other parameters can be used for assessing of iron reserves in the body. These include serum transferrin receptors (sTfR), for which was found to more accurately shows the need of bone marrow for iron (13, 23).

Athletes are recommended to take iron in an amount of 10 - 25 mg per day depending on their status. A dose above 100 mg per day increases the risk of infection and multiple toxic effects can be expressed (stomach pain, constipation, black stained feces and melena). Mega-doses of iron are certainly anti-ergogenic (10). Supplementation with Fe is not justified in terms of improving sports performance, and may even be harmful (13, 23).

Copper (Cu) and the needs of athletes for copper

The basic role of copper in the body is determined by the activity of two key enzymes that contain this element, and are involved in aerobic metabolism: cytochrome-C-oxidase and superoxide dismutase. Copper has many functions in the body: antioxidant (superoxide dismutase and ceruloplasmin), performs metallothionine (tyrosinase) induction, it is involved in intracellular energy production (cytochrome c oxidase), the formation of disulfide bonds (thiol oxidase), synthesis of collagen (lysyl oxidase), catecholamines, neurotransmitters (monoamine oxidase) and hemoglobin, as well in the process of blood clotting (coagulation factor IV) (1-3, 8, 24).

The current (1995 year) recommended daily intake (RDI) of copper for adults is 2.0 mg (from 0.6 to 0.7 mg/1000 kcal). A dose of 10 mg is toxic (1).

Copper is mostly present in seafoods (mussels, clams, squid), legumes, stone fruits, seeds, cereals, offal (kidney, liver, brain) and potatoes (1-4).

Copper absorption is reduced by excesive intake of calcium, phosphate, iron, zinc, cellulose fibers, fructose and raw meat. The favorable effect on copper absorption have breast milk, histidine and other amino acids (1-3, 24).

A copper deficiency may occur in children, women, the elderly, pregnant women, in long-term total parenteral nutrition, malnutrition, Menke's disease, Wilson's disease and Ehlers-Danlos syndrome, in premature infants (accumulates near the end of pregnancy) (1-4). The signs and symptoms of copper deficiency are hypochromic microcytic anemia (not improving on the administration of iron), growth failure and weight loss, depigmentation (role in melanogenesis), retarded growth, decreased reproductive ability, low immunity, reduced elasticity of blood vessels (blocks the synthesis of elastin causing rigidity of arteries); possible rupture of the aorta, neuropathy, electrocardiographic disorders. The signs of copper deficiency in cattle are decreased appetite, osteoporosis and bone demineralization, hypotonia and hypothermia (1-3, 9).

The causes of copper excess in the body are infections (part of the acute phase proteins), nutritional anemia (pernicious), aplastic anemia (within leukosis), endocrine disorders, liver cirrhosis (inability to store and reduced secretion of the bile) and physiologic (pregnancy), use of contraceptives and estrogen therapy with testosterone and progesterone (2, 24).

Copper has special significance in physical activity in biological processes of energy metabolism, iron homeostasis and antioxidant protection (24).

The sheer physical activity affects copper homeostasis and may interfere with antioxidant activity. Various studies have found that copper concentrations in the blood are high (25) or normal (26). Strenuous exercise leads to an increase in reactive oxygen species and inflammatory reaction with initiation of acute phase response which lead to increased release of ceruloplasmin. On the other hand, intense sweating leads to an immediate reduction of the copper concentration, but not a deficiency. Another proposed possibility is that copper is used for the synthesis of antioxidant enzymes, which is stimulated by long-term physical exercise (24, 27).

Athletes are recommended additional amounts of copper from 0.5-3.0 mg per day. Although it is considered that a daily dose of 10 mg may be toxic, even a single dose of 100 mg has not been found to be toxic in athletes. Large doses of copper do not have ergogenic properties. Because high concentrations of iron and zinc have a negative impact on copper homeostasis, use of supplements that do not take into account this interaction, may undermine the essential elements of its functions related to physical activity, which often occurs in practice (8, 10, 24, 28).

Zinc (Zn) and the needs of athletes for zinc

Zinc is essential for the operation of over 200 enzymes (29). Zinc metalloenzymes have a catalytic, structural and regulatory role. Zink is a component of many enzyme systems: lactate dehydrogenase, carbonic anhydrase, alcohol dehydrogenase, carboxypeptidase, thereby participating in the processes of synthesis and degradation of carbohydrates, proteins, nucleic acids and fats (1, 4).

In addition to these processes, zinc plays a role in cell replication and differentiation (regulates transcription), function of cell membranes, regulation of pH (coal anhydrase), cellular motility and internal transport. It is required for glucose utilization and insulin secretion, cellular immune response (T lymphocytes); acts as an antioxidant (superoxide dismutase) and regulates hormone metabolism (production, deposition and secretion of growth hormone, thyroid, gonadotropins, sex hormones, prolactin and corticosteroids) (1, 4, 30, 31).

Zinc RDI for an adult amounts to 15 mg. The doses above 25 mg can cause anemia and deficiency of copper (1). Zinc is present in the following foods: milk, eggs, red meat, organic meats, wheat germ, seeds, soybeans, brewer’s yeast, stone fruits, beans, spinach, in legumes, potatoes, wine and seafood. Zinc absorption is improved by: red meat, EDTA, citrate, methionine, cysteine, histidine, lysine, and glycine. Foods that decrease zinc absorption are: excessive calcium, iron, copper, oxalates, spinach, phytates, foods rich in cellulose and whole grain products (28, 32).

Primary zinc deficiency has been described in rare hereditary disease Acrodermatitis enteropatica followed by growth retardation and hypogonadism in the presence of gastrointestinal, dermatological and neurological symptoms (1, 9, 33).

The secondary zinc deficiency can develop in various types of malabsorption (ulcer, ulcerative colitis, Crohn's disease, malnutrition in children, pregnant women, the elderly) and increased urinary excretion (2, 4, 9).

The following signs and symptoms of zinc deficiency are identified: growth retardation, delayed bone maturation, delayed sexual maturation, impaired immunity, anorexia, gastrointestinal symptoms and diarrhea, dermatitis, eczema, skin ulcers, acnae, seborrhea, alopecia, hypogeusia (impaired sense of taste), night blindness, impaired reproductive ability, disorders of the musculoskeletal system, slow wound healing, and changes in behavior (1, 34).

It is believed that athletes have a greater need for zinc from people who are not exposed to strenuous physical activity. Increased demand is due to increased production of erythrocytes, caused by increased hemolysis, loss of zinc through the sweat, increased fatty acid metabolism during physical activity, numerous interactions of zinc in the metabolism of iron, as well as the extra testosterone that the athletes needed for muscle development (1- 3, 7-9).

It has been shown that physical activity affects the decrease in the amount of zinc in the body. In the usual diet there are small amounts of zinc. Zinc deficiency usually presents in athletes who are engaged in marathon, running for longer and shorter runs, wrestling, gymnastics and dance (8, 10, 11, 28).

Intense endurance training will increase the plasma concentration of zinc immediately after exercise. It is assumed that the reason is the transition of zinc from the damaged myofibrils of contracting skeletal muscle in the extracellular space. After a short-term increase in the concentration, zinc is eliminated from the blood via urinary excretion, or the re-distribution to the liver under the influence of cytokines (7, 35, 36).

Athletes are recommended to take zinc supplementation of 15-50 mg per day. Zinc exerts toxic effects, which are not disturbing to a dose of 500 mg daily for adults. Large doses of zinc interact with the metabolism of copper and do not have ergogenih effects. The doses above 25 mg can cause anemia and deficiency of copper (8, 10, 11, 28).

Manganese (Mn) and the needs of athletes for manganese

Manganese performs the activation of the following enzymes: glycosyltransferases, manganese -superoxide dismutase, pyruvate carboxylase, phos phoenolpyruvate carboxykinase arginase and glutamine synthetase (1-4). Manganese influences the growth and regeneration of bone, cartilage, and connective tissue through the synthesis of glycosa-minoglycans and proteoglycans. Through the synthesis of glycoproteins it plays a role in the immune system and mucus production, while through the superoxide dismutase it participates in antioxidant protection. It is necessary in the metabolism of carbohydrates (gluconeogenesis) and the production of urea (1-3, 8, 9).

The RDI for manganese is 5.0 mg for adults. It is found in whole grains, black tea, coffee, chocolate, products made of whole grain cereals, seeds, stone fruits, soybeans, liver and fruits. The absorption of manganese is hindered by an excess of calcium, phosphate, iron, zinc, fibers (cellulose, pectin, phytate), oxalate, antacids (alkalinity) and achlorhydria. Manganese absorption enhance vitamin C and hem of meat (1, 9, 37).

Manganese deficiency is most common in underweight people (hospitalized, people on a diet, the elderly), in malabsorption syndrome, Down's syndrome, lupus erythematosus, epilepsy and chronic use of antacids. Signs of manganese deficiency are disorders of skeleton and cartilage (osteoathritis, osteoporosis, fractures) and delayed wound healing (1-4).

Athletes usually take supplementation of 2.0 to 5.0 mg of manganese daily. Ergogenic potential of manganese has not been tested yet, but it probably does not exist. Manganese is considered the least toxic of all of the trace elements, when ingested orally (9, 28, 37).

Selenium (Se) and the needs of athletes for selenium

Selenium is important for the transport of electrons in tissue breathing. As a component of glutathione peroxidase, it participates in the processes of peroxidation. It is important as an antioxidant and replaces the antioxidants vitamin E and C. Selenium is involved in the inactivation of heavy metals and biological transformation of xenobiotics (28). RDI for selenium for adults is 70 mg (1). Foods that contain selenium in lerger amounts are liver, brewer's yeast, broccoli, tomato, onion, tuna, herring, bran, wheat germ and grains (9, 38).

Foods low in selenium causes growth retardation, impaired fetility, degenerative changes in the liver and muscles (38, 39).

Increased intake of selenium causes acute or chronic poisoning. Most often, professional poisonings of workers in the industry of paints and varnishes occur, or with selenium oxide vapor. Poisoning is characterised by respiratory tract irritation and pulmonary edema. Contact dermatitis may occur on the skin. Characteristic symptoms and signs of selenium poisoning are metallic taste and smell of garlic in exhaled air, which is derived from dimethyl selenide, which is produced in the liver (28, 38, 40).

It seems that the need for selenium in well-trained athletes increase depending on the energy consumption, but not in a linear way. In their study, Margaritis et al. (41) have reported that selenium intake in a quarter of men and two thirds of female athletes was inadequate. An additional increase of selenium in the diet is recommended for athletes, in the amounts of 50 to 100 ng (8, 10, 11, 28).

Iodine (J) and the needs of athletes for iodine

Iodine is a component of thyroid hormones and is necessary for the functioning of thyroid hormones (thyroxine and triiodothyronine). RDI for adults is 150 µg. Foods that contain a lot of iodine are sea salt, iodized salt, seafood, onion, vegetables that is grown on soil rich in iodine, and walnuts (1-3).

Iodine deficiency occurs in endemic areas (Jošanica). Symptoms and signs of iodine deficiency are goiter, cretinism (mental retardation, dwarfism), spastic dysplegia, hypothyroidism, myxedema, apathy, fatigue, cardiovascular disease, hypothermia and constipation (1-3, 8, 9).

Athletes needs for iodine are higher than other people's, because lots of iodine is excreted in sweat. The results showed that the loss of iodine in physical activity amounted to 146 ng per day. Athletes are recommended supplementation with 50 to 200 ng of iodine per day. Ergogenic iodine potential is equal to zero (4, 9, 28).

Chromium (Cr) and the needs of athletes for chromium

Chromium improves the utilization of glucose and acts as a factor of glucose tolerance, because of which it potentiates insulin action. RDI is 120 mg for adults. The main source of chromium are whole grains and meats (1-3).

The lack of chromium occurs in: malnutrition, prolonged total parenteral nutrition, pregnancy, trauma, intensive exercise and excessive consumption of simple sugars. Symptoms of chromium deficiency are glucose tolerance disorders, hyperglycemia and hypoglycemia, hyperinsulinemia, hyperlipidemia, fatigue, diabetes mellitus type 2 and cardiovascular diseases (1, 2, 4, 7).

It has been shown that serum concentrations of chromium increase immediately after exercise in runners (after 10km) and remain elevated for up to 2 times after exercise, and are accompanied by an increased secretion of chromium in the urine for 1 day (42).

Although there are several theories and studies about incread muscle mass and strength while reducing body fat as a result of chromium supplementation, there are no reliable results to date (7). Athletes are recommended to consume from 200 to 800 mg of chromium per day. Trivalent chromium, which is located in the food is non-toxic even at levels 100 times greater than the recommended amounts. Hexavalent chromium or chromate is highly toxic and is known to have carcinogenic potential (3, 28, 43).

Conclusion

Trace elements are important substances involved in the metabolism of energy and cellular structural components, and thus directly or indirectly affect the physical strength and fitness of athletes. Optimal presence of micronutrients allows optimal functioning of the body. Playing sports, especially in situations where athletes are exposed to prolonged extreme efforts, increase the need for both macronutrient and micronutrient substances. Supplementation with trace elements should be carried out in athletes when there is a deficiency or boundary deficiency. A balanced diet and trace elements supplementation should be provided to athletes, satisfying their increased demand in relation to the recommended daily intake (RDI). Supplementation with megadoses of trace elements is not recommended because of possible toxic effects. During supplementation, attention has to be taken regarding possible interactions between trace elements.

A balanced diet and professional supplementation with trace elements, when necessary, provide better physical effect and fitness, together with the achievement of top athletic results.

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Revijalni rad **UDC: 613.2:796.071.2**
doi:10.5633/amm.2018.0208

PATOFIZIOLOŠKI ASPEKTI SUPLEMENTACIJE OLIGOELEMENTIMA KOD SPORTISTA

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Preduslov za postizanje vrhunskih sportskih rezultata je puno zdravlje i psihofizička utreniranost. Esencijalni oligoelementi su neophodni za normalno odvijanje biohemijskih i fizioloških procesa, iskorišćavanje energetskih i gradivnih materija i optimalno funkcionisanje samih mišića i njihovu skladnu povezanost sa drugim sistemima. Oligoelementi imaju važnu ulogu u energetskom metabolizmu tokom naporne fizičke aktivnosti, kao i stanjima povećane potrebe za kiseonikom, produkcije slobodnih radikala, aktivnosti skavendžer enzma i antioksidantne zaštite.

Sportisti mogu imati deficit gvožđa zbog smanjenog dijetarnog unusa, gubitka krvi ili povećanih potreba usled fizičke aktivnost, međutim, suplementacija nije opravdana radi samog poboljšanja sportske uspešnosti, čak može biti i štetna. Poseban značaj bakar ima u biološkim procesima energetskog metabolizma, homeostaze gvožđa i antioksidantne zaštite. Sportistima se preporučuju dodatne količine bakra od 0,5 do 3,0 mg dnevno, iako velike doze nemaju ergogena svojstva. Takođe, sportisti imaju veće potrebe za cinkom i preporučuje im se suplementacija dodatnom količinom od 15 do 50 mg dnevno. Deficit mangana se najčešće javlja kod pothranjenih osoba, dok se potrebe za selenom kod dobro utreniranih sportista povećavaju u zavisnosti od energetske potrošnje.

Bavljenje sportom, posebno kada se radi o dugotrajnim ekstremnim naporima, povećava potrebe za mikronutritivnim materijama. Sportistima treba obezbediti izbalansiranu ishranu i suplemantaciju oligoelementima koja će zadovoljiti njihove povećane potrebe u odnosu na preporučeni dnevni unos.

Acta Medica Medianae 2018;57(2):45-52.

Ključne reči: *mikronutrijenti, fizička aktivnost, gvožđe, bakar, cink, preporučeni dnevni unos*