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Minerals in sports nutrition

Apart from the macronutrients fats, carbohydrates and proteins an adequate supply of minerals is essential for the health and performance of athletes. Calcium, Potassium and Magnesium are among the best-known minerals, but also trace elements like Iron and Zinc are of high importance – especially for athletes. These minerals and trace elements ensure optimal functioning of muscles and nerves, besides they are involved in the formation of bones and in the regulation of blood pressure.[1]

Athletes have an increased need for minerals and trace elements due to a higher demand on the metabolism and the loss through perspiration. The most common deficient minerals are Sodium, Calcium, Magnesium, Potassium as well as Iron, Zinc.[2] Depending on the type of sport, the intensity and extent of exercise, and individual factors (e.g. nutritional behaviour, sweat rate and composi-

Element	Nutrient Reference Values[4] (NRV)	Mineral Concentration in Sweat with approx. 60 min of physical exercise [5, 6]	Functions within the Body
Calcium	800 mg	11–36 mg/l	Muscle function – regulation of contraction, energy metabolism
Magnesium	375 mg	0.84–2.36 mg/l	Maintenance of bones, muscle function – counterpart to Calcium, protein synthesis, energy metabolism, decrease of tiredness/fatigue
Potassium	2000 mg	167–236 mg/l	Blood pressure, muscle function
Iron	14 mg	0.56–1.12 mg/l	Formation of red blood cells/haemoglobin, oxygen transport, reduction of tiredness/fatigue
Zinc	10 mg	0.92–1.23 mg/l	Cell protection from oxidative stress, immune system, metabolism of macronutrients, protein synthesis

tion), athletes may be at increased risk of suboptimal supply of some micronutrients.[3] In addition to the daily diet, dietary supplements can help to ensure the supply of all important minerals and trace elements.

The detection of mineral deficiency symptoms is still rather difficult.[1] Usually such symptoms are unspecific, e. g. general indisposition or fatigue. As minerals are fixed with liquid compartments, every loss of water is also a loss of minerals.[1] Especially for athletes the replenishment of mineral losses is of special importance.

Nutrition is an important tool in terms of performance optimisation and regeneration. There is no perfect formula to satisfy every athlete's personal nutritional needs, as every sport has its own specific strain on the human body and every athlete is physically different.[2]

Sports nutrition was a niche sector in the past and has developed into a growth market. At the same time, customers became more diverse. It formerly used to be elite athletes who would focus nutrition, whereas now it can be the office worker commuting by bike, who has an interest in nutrition in order to support a healthy lifestyle.[7]

Endurance athletes

The main goal of an endurance athlete is to hold the highest possible power for a specific period. The need of macronutrients, especially carbohydrates, is high due to of the increased amounts of energy, these athletes transform over a long period.

Besides macronutrients, hydration is an important factor, endurance athletes should focus on. As muscle activity produces heat, the body uses the endothermic effect of the evaporation of the sweat in order to prevent the danger of overheating. Perspiration leads to an increased need for water and minerals, as sweat contains about 2–3 g of mineral salts per litre.[1] However, after long lasting exercises with intensive losses of sweat and thus minerals, it is generally recommended to replenish the lost minerals.[8]

Power sports

The category "power sports" can be divided into three main areas: maximum strength, quickness and strength endurance. The goal of power sports is to set free the highest amount of muscular power possible over a usually short duration.[1]

In addition to the macronutrients, mineral salts are a key factor for successful competition. Training sessions are not as long as in endurance sport, a remineralisation during training is not required.[8] Nevertheless, minerals as important micronutrients ensure that the muscle can be used up to its full potential, supporting muscle contraction, energy metabolism as well as the nervous system.[9]

Popular sports

The category "popular sports" summarises physically active people, exercising to keep a certain level of fitness or as a hobby. The category is nondependent on the type of exercise. As the strains are not as demanding as those of competing athletes, a coordinated nutrition is usually not of high importance. Though, nutritional considerations are not irrelevant for them, as they support the build-up of power and stamina.

As popular sports are physically demanding as well, sweat is lost during performance. Compared to competing athletes, "untrained people" have a different composition of the sweat, due to the fact, that the organism is not as used to intensive strains. The sweat contains more minerals as opposed to trained athletes, who are able to recover some minerals with their sweat glands and whose sweat contains less minerals in general.[1]

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The function of minerals for athletes

Calcium

Calcium is a bivalent metal and corresponds to 1.5 % of the human bodyweight.[1] About 99 % of the amount is bound in bones and teeth. Together with phosphate, it is of high importance for their stability.[10] The body uses the Calcium stores in the bones as a reservoir. Additionally, Calcium plays a key role in regulating various processes in neural transmission, as well as in the haemostasis, the stabilisation of cell membranes and the regulation of metabolism-processes.[9]

Furthermore, Calcium is responsible for all muscle contractions via the transmission of stimuli from the neural system to the muscle cell. A deficiency has an impact on the maximum tension capacity during strength training. Symptoms like a rising excitability of the muscle or cramps can be the consequence.[10]

Magnesium

Since Magnesium is an activator of all reactions involving ATP (Adenosine Triphosphate), it is of high importance to physical performance.[1] The body of a 70 kg adult, contains 20–28 grams of Magnesium. In combination with Calcium, about 60 % of Magnesium is stored in the bones as hydroxyapatite. The remaining Magnesium can be found to 35 % in intracellular and to 5 % in extracellular solution.[10]

The Magnesium is used for growth and stabilization of bones. Additional functions are to be an essential cofactor of more than 300 enzymes in the metabolism, support of muscle contraction, synthesis of proteins and nucleic acids as well as the release of hormones and neurotransmitters. Magnesium is a catalyzer for ATP-dependant enzyme systems and therefore part of the energy-metabolism. Together with Potassium, Calcium and Sodium it is necessary for the transition of chemical into mechanical energy in the muscles. Magnesium is the counterpart of Calcium. While Calcium is responsible for passing on the stimulus to the muscle, Magnesium closes the ion channel again and prevents the continuous tensioning of the muscle.[1]

A deficiency (hypomagnesemia) hampers the appropriate relaxation mechanism of Magnesium and can cause spasms and tensions in muscles. Other signs and symptoms of hypomagnesemia include anything from mild tremors and generalized weakness to vascular spasms of heart and blood vessels and cardiac arrhythmia. Hypomagnesemia can be innate or occur due to reduced resorption, increased excretion or medication but in the most common cases due to insufficient supply.[11] In Germany alone, 26 % of men and 29 % of women do not reach the daily amount of magnesium recommended by the D-A-CH reference values.[11] In addition to a diet low in Magnesium, sporting activity is also a factor that can lead to an undersupply. During intensive sporting activity, a high proportion of Magnesium is lost, especially through sweat.[2] This makes a balanced Magnesium intake vital, especially for athletes.

Potassium

More than 90 % of Potassium in the human organism is located in the intracellular medium.[10] As the most important intracellular cation, Potassium is responsible for the maintenance of the intracellular osmotic pressure and it is involved in many metabolic processes as well.[12]

Symptoms of a Potassium deficiency are diverse. They vary from apathy, to decreased neuromuscular stimulation, cramps, gastrointestinal complaints, tachycardia, kidney damage, decreased glucose tolerance and cardiac dysfunctions.[1, 8, 12, 13, 14]

Athletes can be at risk of Potassium deficiency for multiple reasons. For once Potassium is closely bound to the glycogen metabolism. During the metabolisation of glycogen, Potassium is set free, which is in turn needed for the resynthesis.[1] Moreover, Potassium is lost through increased sweating during long strains.[10,12] Especially endurance athletes prone to heavy perspiration should therefore be advised to consume additional Potassium.[15]

Iron

Iron is the most important trace element in the human organism, with body stores of 3–5 g.[10] Nutritional Iron is available as haem Iron and ionised Iron, respectively Fe (II) and Fe (III).[16]

Iron is a central component of red blood cells. Without Iron, the blood could not transport oxygen and supply the muscles. In the muscle, it is present as the central component of myoglobin in order to transport oxygen into the heart and skeletal muscle tissue. It acts as an antioxidant and is an important component of the electron transport chain for the production of ATP.[17]

Iron deficiency is associated with altered metabolic processes. Physical manifestations of an iron deficiency are e.g. anaemia, fatigue and weakness, pale skin, brittle nails. In the field of sports nutrition, Iron is regarded as one of the most critical micronutrients[18] and counterintuitively iron deficiency is one of the most commonly diag-

nosed mineral deficiencies in sports medicine.[19] The high incidence of Iron depletion among athletes is usually linked to an inadequate energy intake. Factors affecting the Iron status are e.g. vegetarian diet, periods of rapid growth, training at high altitudes, increased Iron losses in sweat, and other body fluids.[19]

Iron is involved in the transport and metabolism of oxygen for aerobic energy production during endurance exercise. Athletes with suboptimal Iron status may experience reduced exercise capacity and impaired sports performance.[20] Once an iron deficiency has developed, the recovering can take months.[21] The Iron supplementation of iron-deficient athletes improves blood bio-chemical measures and iron status on the one hand, on the other hand it also increases work capacity as evidenced by increasing oxygen uptake, reduces the heart rate and decreases the lactate concentration during exercise.[18]

Zinc

Zinc is a trace element with a relatively small storage capacity in the human body, compared to Iron. Hence, large quantities of Zinc cannot be mobilised if higher requirements arise. Therefore, a constant intake of Zinc through food or food supplements is indispensable.[10]

Zinc fulfils catalytic, structural and regulatory functions in the organism and is involved in more than 300 metalloenzymes, as a co-factor or as an integral part. As Zinc-dependent enzymes are present in all metabolic areas. It is also involved in almost all life processes and thus also in antioxidative mechanisms. Moreover, Zinc itself has an antioxidative effect, since it is able to bind to various molecules and to protect them against oxidative damage. A Zinc deficiency manifests in a reduced immunological defence, dermatitis, hair loss, and delayed wound healing.[10]

Zinc plays a particular part in the nutrition of athletes. It is of high importance for physical performance as a part of the muscular enzyme system. Furthermore, Zinc contributes to the protein synthesis and is involved in the adaptation process of training stimuli, process of growth, wound healing and general functions of the immune system.[19] However, a relatively low Zinc status has been observed in many athletes, which is caused by an insufficient intake with food and increased losses through urine and sweat. Continuously high exercise volumes and additional strains induced through the participation in competitions lead to increased Zinc losses. As a result, active athletes generally have higher Zinc requirements. Especially at risk are high endur-ance athletes, athletes using a hypocaloric diet in order to compete in certain weight classes and vegetarian or vegan athletes. If an increased Zinc intake cannot be achieved through an adjusted diet, supplementation is a sensible remedy.[1, 10, 19, 22]

Best performer in sports nutrition

Mineral Salt	Soluble	Insoluble
Calcium	Calcium Bisglycinate Calcium Lactate PLUS	Calcium Citrate Calcium Citrate Malate
Magnesium	Magnesium Bisglycinate Magnesium Citrate Magnesium Citrate Malate* Magnesium Gluconate	Magnesium Carbonate Magnesium Lactate Magnesium Malate* Magnesium Phosphate
Iron	Ferrous Bisglycinate Ferrous Gluconate Ferrous Sulfate	Ferrous Fumarate Ferric Pyrophosphate
Zinc	Zinc Bisglycinate Zinc Ascorbate*	Zinc Citrate Zinc Malate* Zinc Sulfate
Potassium	Potassium Magnesium Citrate Potassium Citrate	-

*Only permitted for food supplements in Europe

How to find the best mineral salt

The choice to the anionic part of a mineral salt is of particular importance. Beside physical and chemical properties like solubility, pH-value and taste, anions have also an important influence on the bioavailability and the compatibility. Organic acids promote the absorption of certain cations, like Magnesium, Calcium, and Iron. Citrate, malate and fumarate are part of the citric acid cycle within the human metabolic pathway and are therefore easy to digest. Fully reacted mineral salts from amino acids like bisglycinates are known for an excellent bioavailability and are well tolerated.

Mineral Salts of Dr. Paul Lohmann® are especially designed for the use in food supplements. They fulfill the purity parameters for ready to use food supplements already in the raw material state. These quality parameters were decreed by the European Commission to ensure the constantly high quality and purity of food supplements. Different techniques of particle size engineering like micronization, granulation or microencapsulation is a strength of Dr. Paul Lohmann®. Tailor-made product developments and product adaptions are carried out in close collaboration with the customers.

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