Minerals Calcium, Phosphorous and Magnesium as important ingredients for sports performance

Dr.S.Srividhya

Dr.S.Srividhya M.Sc,M.Phil, Ph.D
Junior Scientific Assistant
Department of Biochemistry
SAI, NSSC,
Gnanabharathi campus,
Bangalore-560056.
Email: vidhybiochemistry@gmail.com
Phone: 8892923811
Fax: 080-23215214
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Abstract:

Minerals calcium, phosphorous and magnesium play key roles in many biological processes. Calcium involves in many functions of our body which includes muscle contraction, energy metabolism, and conduction of nerve impulse. Calcium released from endoplasmic reticulum is essential for mitochondrial activity which involves in energy generation that in turn helps for sports performance. Phosphorous is essential for bone and teeth formation, energy metabolism (Adenosine Triphosphate) and a building block of deoxyribonucleic acid which helps in cell metabolism and also used for recovery process of tissue turn over in athletes. Magnesium regulates nerve and muscle function, it acts as a cofactor for many enzymes which involves in several biochemical reactions of the body like regulation of hormones, nervous system, protein production. Marginal deficiency states of these minerals also have a negative impact with exercise performance. Regular exercise training in athletes may result in increase in demand of these minerals as there may be increase in degradation rates or increase in losses from the body. Adequate intake of these micronutrients may facilitate in enhancing the athletic performance.

Keywords: Minerals, Athletic performance, calcium, phosphorous, Magnesium.
Introduction:

The ultimate target of all athletes is to get their best performance. The best performance can be achieved by proper training program and nutrition. Nutrients are compounds found in food which is required to make energy, for the growth and development. Nutrients are of two types, Macronutrients which are consumed relatively in large amounts that include carbohydrate, Protein and Fat, Micronutrients which are consumed relatively in small amounts that include vitamins and Minerals. Macronutrients provide energy and micronutrients support the metabolism to provide energy (1). In sports, during strenuous physical activity, the energy turn over in skeletal muscle may be increased upto 20-100 times the resting state (Maughan, 1999). Effective regulation of all metabolic processes requires a blending of micronutrients in the watery medium of the cell (William D. McArdle, Frank I.Katch, 2013). Micronutrients are vitamins and minerals, they are also called as essential nutrients as human body cannot synthesize and has to obtain from food. Minerals are inorganic substances found naturally in a variety of foods. The two major classes of minerals are the macrominerals and trace elements (Melvin H.WilliamsSpeich, 2005). About 4% of the human body weight is composed of minerals. There are seven major minerals also called as macrominerals and the requirement in amounts is more than 100 mg daily, the macrominerals are calcium, phosphorous, magnesium, sodium, chloride, potassium and sulphur. Minerals required in smaller quantities which is less than 100 mg daily is called trace minerals, they are iron, manganese, copper, zinc, iodine, fluoride and selenium.

Studies show that strenuous exercise increases the need for minerals. Researchers have found that exercise can increase the physiological and metabolic
demand for certain minerals due to an increased rate of mineral loss through urine and sweat. Many studies proved that inadequate mineral intake by active people could negatively impact performance and recovery. All nutritionally essential minerals can have impact on sports performance. In athletic performance, minerals play important roles in muscle contraction, normal heart rhythm, nerve conduction, oxygen transport, oxidative phosphorylation, enzyme activation, antioxidant activity, bone health, immune function and acid base balance. Many of these processes are accelerated during athletic performance, so an adequate amount of these minerals is necessary for optimal performance (Melvin H. Williams, Speich, 2005).

CALCIUM

Calcium accounts for 1 to 2 percent of body weight. Almost 99 percent of total body calcium is found in bones and teeth. Calcium is a micronutrient with great importance to many cellular events in different tissues in the body, as well as forming the major structural component of bone. Calcium is the most abundant mineral in the body and is essential for the development and maintenance of bones and teeth, intracellular signaling to enable the integration and regulation of metabolic processes, impulse conduction in nervous system, muscle contraction and blood clotting. Foods rich in calcium include dairy products such as milk, cheese, yogurt, green leafy vegetables like spinach, legumes and dried fruit.

Calcium has been reported to inhibit the absorption of iron from the food and it is therefore suggested that these two nutrients should not be taken together in large amounts (Gleerup, Rossander-Hulthen, Gramatkovski, & Hallberg, 1995). When both iron status and calcium status are precarious, special attention must be paid to the initiation of any supplementation regimen. This may be particularly relevant to female
athletes, who may suffer from anaemia due to both low energy intake and loss of iron through the menses. Increased physical activity, and in particular running, has been shown to be associated with an increased bone density (Lane et al. 1986), and it seems clear that the physical stress imposed on the bone is an important factor (Lanyon 1992; Wolman 1994). Recommended Dietary Allowance of calcium in male and female adults is 1000 mg/day.

Whole body net calcium balance reflects the relationship between the dietary calcium intake and all routes of calcium loss. Positive calcium balance is essential for bone growth and peak bone mass. Negative calcium balance will result in decreased bone mass and bone density. Bone loss is calcium related and exercise is positively related to bone mineral content provided that calcium intake is sufficient to offset dermal loss. It was found that dermal calcium loss averaged 247 mg per training session in a basketball team players (Klesges et al., 1996).

Calcium status is maintained by balancing calcium absorption from the gut, excretion via the kidneys, mobilisation and deposition in the bone. These sites are regulated by feedback mechanisms controlled by several hormones including parathyroid hormone and the activated form of vitamin D. Plasma levels of calcium only become abnormal if there is a breakdown of this homeostatic mechanism, and not usually as a result of differences in dietary calcium intake. The body invests this effort because small variations in plasma calcium concentrations may have serious consequences to the functioning of vital organs and to health in general. Reference interval of calcium in adults is 8.2-10.4 mg/dl (Rubin et al., 2011). Low blood calcium that is less than 8.2 mg/dl is called hypocalcaemia and high blood calcium that is above 10.4 mg/dl is called hypercalcaemia. Calcium supplements helps to prevent the
calcium loss, supplements taken before the exercise induce reduced sweat calcium loss (Haakonsen et al., 2015). Caffeine intake before the exercise will help in release of calcium from sarcoplasmic reticulum and extends the fatigue in athletes (Allen, Lamb, & Westerblad, 2008). Till date, it is not clearly mentioned that increase in calcium supplementation reduces body weight. However, after considering age, sex, BMI, and length of calcium supplementation, the effects of calcium intake on weight loss were evident. Increasing calcium supplements can reduce body weight in subjects with normal BMI or in children, adolescents, adult men, and either premenopausal or old women (Li, Fan, Lu, & Qi, 2016).

**PHOSPHOROUS**

Phosphorous has many important functions in our body that includes the phosphate in ATP (Adenosine triphosphate) to produce energy, synthesis of protein, muscle growth, helps in muscle contraction, repairs muscle damage, delay fatigue and exhaustion. Phosphorous also functions as a backbone component for DNA (Deoxyribonucleic acid), RNA (Ribonucleic acid) and phospholipids. Phosphorus makes up about 0.65 to 1.1 percent of the adult body weight (Novkovic, 1997). Phosphorus supplementation over an extended period of time can result in lowered blood calcium, however, some studies have shown that acute 'phosphate loading' will enhance performance (Clarkson, 1991). Reference interval of serum phosphorous level is 2.5-4.5 mg/dl (Michigami, 2009). Serum phosphorous level below 2.5 mg/dl is defined as hypophosphatemia and the level more than 4.5 mg/dl is defined as hyperphosphatemia (Malliaropoulos et al., 2013). Recommended Dietary Allowance of phosphorous in male and female adults is 700 mg/day. Foods that are rich in phosphorous are fish, meats, egg and dairy products (Melvin H.WilliamsSpeich, 2005).
Due to muscle contraction, acids are produced and end up with fatigue, hindering the performance of an athlete. To neutralize the produced acid, phosphate supplements can be used to enhance athletic performance. In a study, 3-5 g/day of sodium phosphate was given as supplements for 6 days and there is increased aerobic capacity, increased peak power output, increased anaerobic threshold and improved cardiovascular response to exercise (Buck, Wallman, Dawson, & Guelfi, 2013). Phosphate salt supplementation has an effect on 2,3-Diphosphoglycerate (Clarkson, 1991). Increased levels of 2,3-DPG could facilitate release of oxygen from hemoglobin in the red blood cell and possibly enhance aerobic endurance exercise performance (Melvin H. Williams Speich, 2005). Hence, more oxygen being delivered to muscle tissue through the blood, the athlete can produce more ATP for the generation of energy for muscle contraction, thereby can perform better by extending the time to exhaustion (Fukuda, Smith, Kendall, & Stout, 2010). Most studies have used the supplements as sodium phosphate, potassium phosphate or calcium phosphate but the sodium phosphate had shown the most consistent positive results, it is used as an ergogenic aid for enhancing performance. The recommended phosphate loading dosage consists of 1 g of sodium phosphate salt 4 times daily for 3-5 days (Kerksick et al., 2018). Shahsavar & Pourvaghar, 2010 found that an exhausting and intense aerobic exercise can change the serum phosphorous even at the level of nanogram per microliter and the research also showed that the serum phosphorous can return to its early state after 24 hours of rest.

**MAGNESIUM**

Magnesium is a ubiquitous element that plays a fundamental role in many cellular reactions and it acts as a co-factor for many enzymes like kinases. Magnesium is also required for the glycolysis and oxidative phosphorylation for the generation of
ATP (Shahsavar & Pourvaghar, 2010). It is also required for muscle contraction, nerve function and protein synthesis. Magnesium also has a strong relation with the immune system in both non specific and specific immune responses and magnesium deficit has been shown to be related to impaired cellular and humoral immune function (Laires & Monteiro, 2008). Our human body contains about 25g of magnesium, with 50 to 60 % present in the bones and in soft tissues (National Institute of Health & Supplements, 2016). Reference interval of Magnesium is 1.5-2.5 mg/dl. Hypermagnesemia occurs when serum magnesium is more than 2.5 mg/dl and hypomagnesemia occurs when serum magnesium level is less than 1.5 mg/dl (Malliaropoulos et al., 2013). Recommended dietary allowance of magnesium is 410 mg/day (14-18years), 400 mg/day (19-30years), 420 mg/day (>31 years) for male and 360 mg/day (14-18years), 310 mg/day (19-30years), 320 mg/day (>31 years) for female. Food sources of magnesium are nuts such as almonds, green leafy vegetables such as spinach, bread, fish, meat and dairy products. Magnesium supplements helps in increasing the strength and cardiovascular adaptation in athletes and in turn improves the performance of an athlete. Adequate magnesium content in our body is essential for the physical activity. Magnesium depletion can be caused by inadequate food intake that contains magnesium, excessive alcohol intake and increased sweating rates during exercise (Mariño et al., 2020). There are studies concluded that there is no effect of magnesium supplementation on performance of an athlete (Newhouse & Finstad, 2000). Study also shows that marginal deficiency of magnesium could impair exercise performance and may get severe due to intense exercise too (McDonald & Keen, 1988). Marino et al., 2020 found that there are low concentrations of erythrocyte iron, magnesium and phosphorous in moderate level training group and high level training group compared
to control group. Physical exercise produce a decrease in concentration of erythrocyte iron, magnesium and phosphorous. Intense exercise leads to increased sweat and urinary magnesium losses and there is a increased requirement by 10-20% of these athletes (Volpe, 2012). Magnesium supplementation 350mg/day for 4 weeks was given to 25 volleyball players and this improved the alactic anaerobic metabolism, even though the players were not magnesium-deficient (Setaro et al., 2014). Magnesium deficiency is associated with bone disorders. In a study, it was observed that bone mass is correlated with magnesium intake and also found significant association between bone mineral density and lean soft tissue (Matias et al., 2012). Malliaropoulos et al., 2013 found that 47% athletes detected with higher phosphate concentrations and 46% of athletes with higher magnesium concentrations, the reference interval for the athlete population should be framed to avoid misinterpretation of results.
Table 1:

<table>
<thead>
<tr>
<th>Minerals</th>
<th>Reference Interval</th>
<th>Percentage of mineral in Human Body weight (%)</th>
<th>Recommended Dietary Allowance</th>
<th>Function</th>
<th>Food Sources (Olza et al., 2017)</th>
<th>Ergogenic aid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Female</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>8.2-10.4 mg/dl</td>
<td>8.2-10.4 mg/dl</td>
<td>1 to 2</td>
<td>1000 mg/day</td>
<td>Muscle contraction, formation of bone and teeth, energy metabolism, second messenger for signal transduction pathway, hormone regulation (Brini, Ottolini, Calì, &amp; Carafoli, 2013).</td>
<td>Milk, cheese, yogurt, green leafy vegetables like spinach, legumes and dried fruit. Calcium supplement in well nourished athletes does not improve performance. (Melvin H. WilliamsSpeich, 2005)</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>2.5-4.5 mg/dl</td>
<td>2.5-4.5 mg/dl</td>
<td>0.65 to 1.1</td>
<td>700 mg/day</td>
<td>Component of DNA, RNA &amp; ATP, component of bone &amp; teeth, Energy metabolism, regulate gene transcription, maintenance of blood pH (Calvo &amp; Lamberg-Allardt, 2015).</td>
<td>Fish, meats, egg and dairy products. The recommended phosphate loading dosage consists of 1 g of sodium phosphate salt 4 times daily for 3-5 days (Kerksick et al., 2018).</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1.5-2.5 mg/dl</td>
<td>1.5-2.5 mg/dl</td>
<td>0.1</td>
<td>Male: 410 mg/day (14-18 years), 400 mg/day (19-30 years), 420 mg/day (&gt;31 years). Female: 360 mg/day (14-18 years), 310 mg/day (19-30 years), 320 mg/day (&gt;31 years).</td>
<td>Regulation of muscle contraction, acts as a cofactor for many enzymes involved in synthesis of DNA, RNA &amp; protein, nerve transmission (Kirkland, Sarlo, &amp; Holton, 2018).</td>
<td>Spinach, bread, fish, meat and dairy products. Magnesium supplementation 350mg/day for 4 weeks was given to 25 volleyball players and this improved the alactic anaerobic metabolism, even though the players were not magnesium-deficient (Setaro et al., 2014).</td>
</tr>
</tbody>
</table>
Conclusions:

Minerals play an important role in various biochemical reactions for the support of generation of ATP, the marginal deficiencies of these minerals calcium, phosphorous and magnesium for long term hinder the athletic performance. Hence, monitoring of these minerals is essential for the athletes. Meta-analysis of the study also reveals that there is a need for framing reference interval of these minerals for the athletic population.

References:


Author Biography:

Dr. S. Srividhya M.Sc., M.Phil., Ph.D
Junior Scientific Assistant
Department of Biochemistry
SAI, NSSC,
Gnanabharathi campus,
Bangalore-560056.
Email: vidhyaiochemistry@gmail.com
Phone: 8892923811
Fax: 080-23215214

Dr. S. Srividhya is working with SAI since 2008 and has more than 10 years of experience in the field of sports Biochemistry. Research focused on framing reference interval of biochemical profile for sports population and biochemical monitoring of athletes to enhance the performance of an athlete.