Electrolyte Physiology In Physical Exercise

Siti Kaidah[1], Huldani[1], Fauziah[2]

[1]*Department of Physiology, Faculty of Medicine, University of Lambung Mangkurat, Banjarmasin, South Kalimantan*
[2]*Doctor's Professional Education, Faculty of Medicine, Faculty of Medicine, Lambung Mangkurat University, Banjarmasin, South Kalimantan*

Email: [1]siti.kaidah@ulm.ac.i

ABSTRACT
Physical activity causes various changes in the body's regulatory system, these changes are influenced by the type, frequency, duration, and intensity of the exercise. One of the changes is sweating to regulate body temperature. The fluid that comes out through sweat contains water and electrolytes such as sodium and potassium which are important for body metabolism. Electrolyte balance affects fluid balance and cell function. When exercise, increased sodium can occur due to a deficit in body fluids due to water excretion that far exceeds sodium excretion and insufficient water intake. The increase in serum potassium levels occurs due to the transfer of potassium from the intracellular fluid (CIS) to the extracellular fluid (CES), which is then excreted together with sweat as a result of increased body heat. The increase in serum calcium levels after physical activity is caused by the activation of the body's homeostasis mechanism to maintain normal serum calcium levels as an essential substance in the process of muscle contraction. There is also a temporary transfer of magnesium from the extracellular fluid to the skeletal muscle tissue so that the amount of magnesium contained in the skeletal muscle increases while the plasma magnesium concentration decreases. Changes in electrolyte levels due to physical exercise are influenced by the type, duration, and intensity of exercise performed. so that the amount of magnesium contained in skeletal muscle becomes more while the plasma magnesium concentration decreases. Changes in electrolyte levels due to physical exercise are influenced by the type, duration, and intensity of exercise performed. so that the amount of magnesium contained in skeletal muscle becomes more while the plasma magnesium concentration decreases. Changes in electrolyte levels due to physical exercise are influenced by the type, duration, and intensity of exercise.

Key Words: electrolytes, exercise, physiology

1. INTRODUCTION

Physical activity that involves body movements in a planned, structured and repetitive way to increase fitness is the definition of physical exercise. Physical activity can cause various changes in the body's regulatory system, these changes are influenced by the type, frequency, duration, and intensity of exercise (Sjostrom et al., 2009).

Sweating is a biological process that occurs during exercise which functions to regulate body temperature. Increasing the amount of sweat is one of the body's mechanisms to help maintain body temperature during periods of excess heat as a form of compensation for the body to changes due to physical exercise (Sherwood, 2011). When excessive sweating, the body becomes dehydrated due to losing a lot of body fluids and electrolytes. Lots and rate

loss of body fluids through sweat depends on the intensity of exercise, individual factors, environmental conditions, fitness level, and hydration status (Sprenger, 2011).
Loss of body fluids or dehydration of 1-2% of body weight can affect the physiological functions of the body and negatively impact the athlete's performance. Dehydration of more than 3% of body weight can increase the risk of cramps, severe fatigue, and heat stroke (Benardot, 2006). Even can cause weight loss, if it reaches 5-10% it causes someone to fall in serious condition (Guyton, 2008).
Losing body fluids and electrolytes during exercise can cause dehydration which can interfere with the athlete's performance (Wilmore et al., 2008). Loss 2-4% of fluids can reduce the athlete's performance by up to 10% (Adiguna, 2013; Supriyono, 2012).
The fluid that comes out through sweat contains water and electrolytes such as sodium and potassium which are important for body metabolism. Losing fluids and electrolytes for a long time can reduce endurance, cause cognitive impairment, disrupt energy balance, accelerate fatigue, reduce aerobic capacity, and impair cardiovascular function (Cardwell, William, 2006; Supriyono, Putriana, 2012).
Some of the main minerals that make up sweat include sodium, potassium, and chloride. So that the rate of expulsion of sweat is directly proportional to the rate of loss of sodium, potassium, and chloride in the body (Irawan, 2007). If too much sweat is lost, a person can experience a significant decrease in performance.
Electrolytes are compounds contained in a solution that dissociate into positively and negatively charged ions. Electrolytes are important in regulating fluid balance and cell function. In the two compartments of body fluid, there are several cations and anions (electrolytes) which are important in regulating fluid balance and cell function. The real difference between extracellular and intracellular fluid lies in cations (FKUI, 2012).
Electrolyte balance is very important because it affects fluid balance and cell function. There are two important cations, namely sodium and potassium. Both affect the osmotic pressure of the extracellular and intracellular fluid and are directly related to cell function. Minerals and electrolytes in the body can affect muscle contraction. During contraction, muscle cells require energy produced by mitochondria (Barthwal, 2004).
The electrolyte minerals lost through sweat have various functions that support athlete's performance, so these electrolyte losses must be replaced quickly. The function of sodium is to help glucose absorption. Sodium also functions for muscle contraction with potassium. These two minerals also play an important role in maintaining body fluid balance and cardiovascular function (Siregar, 2016).
The mineral potassium together with sodium plays an important role in the mechanism of muscle fatigue, which plays a role in maintaining the depolarization of sarcolemmal and t-tubular membranes. Disturbance in the depolarization of sarcolemma and the t-tubular membrane will cause disruption of intracellular Ca + ion regulation. Ca + ion plays a role in muscle contraction, namely to open the myosin cross-bridge so that it can bind actin.
Movement on the myosin cross-bridge will cause muscle contraction. Changes in electrolytes and disturbances in fluid balance in the body will affect the depolarization of sarcolemma and t-tubular membrane which causes Ca + ion activation and disrupted energy supply so that muscle contraction weakens and causes muscle fatigue. Increased activity of Na +, K +, and ATPase can stabilize Na and K concentrations in the membrane to prevent muscle fatigue (Konopka et al, 2013; Powers et al, 2011; McKenna et al, 2007).

2. DISCUSSION

There are five major groups of sources of fatigue, one of which is metabolic fatigue, associated with homeostatic disorders, including decreased electrolyte levels of body fluids. Another factor is neurological fatigue (fatigue in the muscles due to reduced working capacity of the neuromuscular system); neurological fatigue (reduced working capacity of the central nervous system); psychological exhaustion (related to social, emotional, and cultural conditions); fatigue due to travel and environmental conditions, both temperature and humidity (Hornery et al, 2007). People who do physical exercise in climates with higher temperatures will more often experience fluid and electrolyte loss so they can become dehydrated with a sweat output rate of up to 1-2 liters/hour (Wiarto, 2013).

During physical exercise, there may be changes in the value of sodium levels in the body. A study on football players showed that there was no significant difference in electrolyte levels (Engka et al., 2003). Similar research on handball players shows that there is a decrease in sodium levels after the game, but this value is not significant enough (Koc et al, 2011).

Another study of ice hockey players also showed that there was a significant change in sodium levels after the game and 33% of these players experienced mild dehydration (Sprenger, 2011).

This research is also in line with the research conducted by Wahyudi et al. Most of the respondents in this study experienced an increase in sodium levels. This increase in sodium can occur due to a deficit in body fluids due to sweating due to water excretion that far exceeds sodium excretion and is coupled with less water intake.

In another study of junior high school children, he did a physical exercise test using a treadmill and the results were that some respondents experienced a significant decrease in sodium levels, but the difference was that they only used 10 minutes of exercise time (Wahyudi, 2008).

In the study of Lesar et al, most respondents experienced an increase in sodium levels (Lesar et al, 2016). This increase in sodium can occur due to a deficit in body fluids due to sweat expenditure due to water excretion which far exceeds sodium excretion and is coupled with insufficient water intake (Madjid et al, 2008). People who regularly do physical exercise may experience acclimatization or adaptation in their bodies. People who have acclimatized to hot climates and already sweating frequently can cause reduced salt expenditure through sweat (Wadud, 2012).

Adaptation is a change in the structure or function of the organs of the body which is more sedentary, due to following or as a result of regular physical exercise over some time. Adaptation reactions will only arise if the training load given the intensity is sufficient and lasts long enough (Wiarto, 2013)

Wadud et al in their research on sports education students found an increase in sodium levels after their respondents did the aerobic and anaerobic physical activity. However, statistically, only anaerobic exercise participants experienced a significant increase in sodium, while the aerobic exercise group did not (Wadud, 2012).

Potassium is a chemical element of the alkali metal group with the symbol K + on the periodic table, has an atomic number of 19, and a standard atomic mass of 39,098 (Mulyono, 2009). Potassium is one of the most abundant substances found in intracellular fluid with an amount of 140 mmol / L and 4 mmol / L in extracellular fluid and has an opposite function to sodium (Na^+) (Murray et al, 2006).

Potassium is needed by the human body in small amounts, but if potassium levels in the blood are reduced it can cause several disorders in the body, such as gastrointestinal disorders, cardiovascular system disorders, and metabolic disorders. If the potassium level increases, it can cause several disorders such as muscle weakness, decreased consciousness, and paralysis of the muscles or respiratory system (Grober, 2009).

The value of potassium levels in the blood can change during physical activity. Research by Vollestad et al showed different results, in 10 healthy men found a decrease in blood potassium levels after exercising a bicycle for 10 minutes (Vollestad et al, 1994). Nielsen et al. Conducted a study on six men with the age of ± 25 years and height of ± 185 cm found

that there was a decrease in blood potassium levels 2.2 minutes after pedaling 60 times per minute with a supine position on the ergometer, this study was conducted for 32 training sessions (5 minutes for every session) over 7 weeks (Nielsen et al, 2003).
However, other studies show different results. A study by Hutchinston of 30 healthy adults with an average age of 23-63 years found that 29 out of 30 had increased blood potassium levels after jogging for 30-45 minutes (Hutchinson et al, 1992). Similar to the study by Medbo et al. Of 10 long-distance runners and 10 short-distance runners who found a very significant increase in blood potassium levels while on a treadmill, and after doing a treadmill, blood potassium levels decreased slightly from the values before physical activity (Medbo et al., 1990).
Likewise, the results of AlNawaiseh et al's research on 10 running athletes from Jordan found that there was an increase in potassium levels after doing the treadmill for the first 15 minutes in a room designed to control heat and humidity during exercise (Al-Nawaiseh et al., 2013). Another study by Meludu et al. found that there was an increase in blood potassium levels after exercising an ergometer bicycle for three minutes with a pedal frequency of 90 revolutions per minute (Meluda et al, 2002).
This increase in serum potassium levels can occur when doing physical activity, due to the transfer of potassium from the intracellular fluid (CIS) to the extracellular fluid (CES). This transfer of potassium from intracellular to extracellular occurs because during activity, potassium in the extracellular fluid is released together with sweat as a result of increased body heat, and to maintain potassium levels in the extracellular, the potassium from the intracellular moves to the extracellular (Grober et al., 2009).
Calcium is the most common cation in the human body. Calcium has an important function in the physiology of muscle tissue, nerve tissue, and also in bones where calcium deposition and resorption occurs. When the resorption process that occurs is higher than the deposition process, a disease known as osteoporosis occurs (Goldberg, 2012).
The increase in serum calcium levels that occurs after physical activity can be caused by the activation of the body's homeostasis mechanisms to maintain normal serum calcium levels. During physical exercise, the body requires calcium as an essential substance in the process of muscle contraction (Guyton, 2007).
The increase in calcium levels occurs by increasing the process of calcium reabsorption in the kidneys and the process of taking calcium from the bones together with the excretion of fluids through sweat causing the body fluids to become more concentrated (Lieben et al, 2012; Brouns et al., 1992). Calcium is mostly excreted through urine (20-300 mg/day) and a small part through sweat (35 mg/day) (National Institutes of Health, 2012; Rianon et al, 2003).
A study by Mao showed that 20 mg of calcium was excreted within 1 hour during soccer training in a hot place. The level of total calcium excreted through sweat is almost equal to the daily amount of calcium excreted in the urine, which is a ratio of 0.92. It shows high temperature and minimal ventilation at the study site as a factor that triggers the calcium released through sweat which caused a decrease in serum calcium levels in some respondents (Mao et al, 2001).
Research by Rompas shows a varied picture of changes in calcium levels before and after moderate-intensity physical exercise, but the value is still within normal limits because some respondents experienced changes in serum calcium levels below 2 mg / dL (Rompas et al.,). This is in accordance with Edwards' opinion that serum calcium levels are maintained in a narrow level, namely not exceeding 2 mg / dL (8.5 mg / dL-10.5 mg / L ± 0.5 mg / dL) (Edwards, 2005).
Magnesium is the fourth most abundant cation in the body after sodium, calcium, and potassium. Magnesium is also the most abundant intracellular cation in the body after

potassium. Magnesium has an important role in catalyzing more than 300 enzymatic reactions in the human body (Iriani, 2006).

Magnesium is a versatile mineral that has several major implications concerning physical activity. While doing physical activity, changes can occur on the mineral levels of the body according to the intensity and duration of exercise (Hazar et al., 2013).

Magnesium deficiency can cause weakness, tremors, seizures, cardiac arrhythmias, hypokalemia, and hypocalcemia. The causes of hypomagnesemia include lack of intake, impaired absorption, and increased excretion (drugs, alcohol, diabetes mellitus, kidney tubular disorders, hypercalcemia, hyperthyroidism, aldosteronism, stress) (Elin, 1988).

Getting older can cause a decrease of magnesium levels because magnesium absorption in the intestine decreases and magnesium excretion increases (Bhuto et al, 2005). Hypomagnesemia can occur because the respondent's job includes a heavy-intensity physical activity which makes the body need more magnesium, and coupled with magnesium intake through food that cannot meet the body's nutritional needs (Topf et al., 2003; Hartwig, 2001). The condition of respondents who do heavy work is not balanced with a balanced intake and the habit of consuming alcohol can cause low magnesium levels (Bhuto, 2005).

Research conducted by Hsu et al on the trained and untrained groups showed a significant decrease in serum magnesium levels after exercise (Hsu et al, 2007). Another study was also conducted by Mooren et al, the result showed significant decrease in serum magnesium levels after treadmill exercise. Research conducted by Buchman et al also showed a significant decrease in serum magnesium levels after running a marathon (Buchman et al, 1998). Casoni conducted a study on 11 trained athletes and 30 control groups, there was a decrease in serum magnesium levels after running as far as 25 km (Brilla et al, 1999).

A significant difference is found in the study conducted by Meludu et al, the subjects performed anaerobic exercises after daily activity and the result showed an increase in serum magnesium levels (Meludu et al, 2002).

Research conducted by Rayssiguier et al showed the amount of magnesium contained in skeletal muscle increases while the plasma magnesium concentration decreases. This due to a temporary shift of magnesium from the extracellular fluid to the skeletal muscle tissue. A decrease in plasma magnesium levels can also occur due to a shift in magnesium from plasma to erythrocytes. This reduction in plasma magnesium may be accompanied by an increase or decrease in erythrocyte magnesium depending on adaptation to exercise. Another mechanism is that plasma magnesium decreases when lipolysis increases. When the body requires fatty acids to be used as muscle energy, lipolysis will occur which causes a decrease in plasma magnesium (Rayssiquier et al, 1990).

Magnesium requirements are higher during exercise, especially during vigorous-intensity training. During physical exercise, magnesium is redistributed in the body to accommodate metabolic needs (Geiger et al, 2012).

Physical activity requires energy production to increase muscle work. The energy required for muscle contraction comes from ATP hydrolysis, this reaction requires magnesium. In skeletal muscle, magnesium attaches to ATP before thick-filament myosin ATPase can hydrolyze ATP. Magnesium is also important for calcium-magnesium ATPase enzyme activity which is needed to pump calcium back into the sarcoplasmic reticulum to induce relaxation. The adrenergic outflow which stimulates lipolysis and induces entry of magnesium to adipocytes contributes to the decrease in serum magnesium with exercise (Brilla et al, 1999).

In a study conducted by Meludu et al. in anaerobic exercise every day after intermittent activity, the result is an increase in serum magnesium levels. There was an increase in serum magnesium levels and persisted 12 hours after exercise. This is due to exercise-provoked magnesium shifts in which there is increased intracellular magnesium loss (Meludu et al., 2002).

Electrolyte administration must be adjusted to the number of electrolytes lost through sweat. However, these needs depend on the duration and intensity of training as well as environmental conditions and temperature (Siregar, 2016).

3. CONCLUSION

Changes in electrolyte levels due to physical exercise are influenced by the type, duration, and intensity of the exercise.

REFERENCES

[1]. Sjostrom M, Ekelund U, Ynvge A.Pengkajian aktivitas fisik. In: Gibney MJ, Margetts BM, Kearney JM, Arab L. Jakarta: EGC, 2009; p. 133-42

[2]. Sherwood L. Keseimbangan cairan dan asam-basa. In: Fisiologi manusia dari sel ke sistem (Edisi 6). Pendit BU, alih bahasa. Jakarta: EGC, 2011; p. 605-39.

[3]. Sprenger HML. Fluid balance before and during exercise and the effects of exercise-induced dehydration on physiological responses, substrate oxidation, muscle metabolism, and performance [PhD thesis]. Canada: Guelph University; 2011

[4]. Benardot, D., 2006. Advanced Sport Nutrition. United Graphics. Champaign. 75-100

[5]. Guyton AC, Hall JE. Kompartemen cairan tubuh. In: Buku ajar fisiologi kedokteran (Edisi 11). Irawati, Ramadhani D, Indriyani F, Dany F, Nuryanto I, Rianti S, alih bahasa. Jakarta: EGC, 2008; p. 307-23.

[6]. Wilmore J. H., D. L. Costill, and W. L. Kenney, 2008, Physiology of Sport and Exercise, 4thEds; Human Kinetics, Champaign, 100-248, 328.

[7]. Adiguna, Bara S. 2013.Pengaruh Minuman Suplemen Herbal Berenergi Purica terhadap Peningkatan Stamina Atlet Sepak Bola [skripsi]. Yogyakarta: Universitas Negeri Yogyakarta.

[8]. Supriyono. 2012. Mempersiapkan Makanan Bagi Atlet Sepak Bola. Jakarta: Depkes; Available from: http://gizi.depkes.go.id/

[9]. Cardwell G. 2006. Gold Medal. US: Human Kinetics. p-70

[10]. Supriyono. 2012. Mempersiapkan Makanan Bagi Atlet Sepak Bola. Jakarta: Depkes; Available from: http://gizi.depkes.go.id/

[11]. Irawan MA. Cairan tubuh, elektrolit dan mineral [homepage on the internet]. 2007 [cited 2020] http://www.pssplab.com/journal/01.pdf.

[12]. Unit Pendidikan Kedokteran - Pengembangan Keprofesian Berkelanjutan (UPK-PKB) FKUI. Gangguan Keseimbangan Air-Elektrolit Dan Asam-Basa Fisiologi, Patofisiologi, Diagnosis dan Tatalaksana. EDISI KE-3. Jakarta: FKUI; 2017

[13]. Barthwal MS. Analysis of Arterial Blood Gases — A Comprehensive Approach. Review article. JAPI 2004; 52573–577

[14]. Siregar, N.S. Pengaruh Rehidrasi Setelah Olahraga Dengan Air Kelapa. *Jurnal Ilmu Keolahragaan*. 2016;*15*(2),12-20.

[15]. Konopka AR, Sreekumaran Nair K. Mitochondrial and skeletal muscle health with advancing age. Mol Cell Endocrinol. 2013

[16]. Powers SK, Nelson WB, Hudson MB. Exercise-induced oxidative stress in humans: Cause and consequences. Free Radical Biology and Medicine. 2011.

[17]. McKenna MJ, Bangsbo J, Renaud J-M. Muscle K+, Na+, and Cl disturbances and Na+-K+ pump inactivation: implications for fatigue. J Appl Physiol. 2007

[18]. Hornery, D.J.D.Farrow, I. Mujika, and W. Young (2007). Fatigue in tennis: mechanisms of fatigue and effect on performance. Sport Medicine. 37 (3): 199-212.

[19]. Wiarto G. Fisiologi dan olahraga. Yogyakarta: Graha Ilmu, 2013; p. 153-75.

[20]. Engka, J. N. A., & Soempeno, B. (2003). Pengaruh Penambahan Intensitas Latihan Terhadap Ambilan Oksigen Maksimum. *Sains Kesehatan*, *16*.
[21]. Koc H. The effect of acute exercises on blood electrolyte values in handball players. Afr J Pharm Pharmacol. 2011;4(1):93-97.
[22]. Wahyudi, Ginting S, Siregar C, Yoel C, Pasaribu S, Lubis M. Perubahan Kadar Natrium dan Kalium Serum Akibat Pemberian Glukosa 40% pada Latihan Fisik Akut. Sari Pediatri. 2008;10(2):77-82.
[23]. Lesar, T. S. (2014). Kadar Natrium Serum Pada Latihan Fisik Intensitas Ringan Mahasiswa Fakultas Kedokteran Universitas Sam Ratulangi. *eBiomedik*, *2*(1).
[24]. Madjid AS, Hegar B, Nur BM, Rumende CM, Darwis D, Soewoto H, et al. Fisiologi keseimbangan air dan elektrolit. In: Darwis D, Moenadjat Y, Nur BM, Siregar P, editor. Gangguan keseimbangan air-elektrolit dan asam-basa, fisiologi, patofisiologi, diagnosis dan tatalaksana (Edisi 2). Jakarta: Balai Penerbit FK-UI, 2008; p. 29-114.
[25]. Wadud MA. Pengaruh aktivitas aerobik dan anaerobik terhadap kadar anti diuretik hormon (ADH) dan elektrolit darah. Poltekkes Palembang Journal [serial on the internet]. 2012 [cited 2020]. Available from: http://poltekkespalembang.ac.id/userfiles/files/pengaruh_aktivitas_fisik_aerobik_good.pdf.
[26]. Mulyono. Kamus Kimia. Jakarta: Bumi Angkasa, 2009; p. 207-9
[27]. Murray RK, Granner DK. Biokimia komunikasi ekstrasel dan intrasel. In: Murray RK, Granner DK, Rodwell VW, editors. Biokimia Harper (27th ed). Pendit BU, alih bahasa. Jakarta: EGC, 2006; p. 436, 448-9.
[28]. Grober U. Mikro nutrient: Penyelarasan metabolik, pencegahan dan terapi. Hadinata AH, Nurul A, alih bahasa. Jakarta: EGC, 2009; p. 104-6.
[29]. Vollestad NK, Hallen J, Sejersted OM. Effect of exercise intensity on potassium balance in muscle and blood of man. Ann Intern Med. 1994;2250: 359-88.
[30]. Nielsen JJ, Mohr M, Klarskov C, Kristensen M, Krustrup P, Juel C, et al. Effects of high-intensity intermittent training on potassium kinetics and performance in human skeletal muscle. The Physiological Society. J physiol. 2003;554.3:857-70.
[31]. Hutchinson RG, Barsdale B, Watson RL. The effects of exercise on serum potassium levels. Ann Intern Med. 1992;101:398-400
[32]. Medbo JI, Sejersted OM. Plasma potassium changes with high-intensity exercise. Ann Intern Med. 1990;421:105-22
[33]. Al-Nawaiseh A, Batainefh M, Al Nawayseh AH, Alsuod H. Physiological Responses of Distance Runners During Normal and Warm Condition. Journal of Exercise Physiology online. 2013;16(Pt 2):1-11.
[34]. Meluda SC, Nishimuta M, Yoshitake Y, Toyooka F, Kodama N, Kim CS, et al. Anaerobic exercise induced changes in serum mineral concentrations. African Journal of Biomedical. 2002;5:13-7
[35]. Goldberg D.Calcium, Ionized. Medscape [serial online] 2012. [cited 2020 Dec 15]. Available from: emedicine.medscape.com/article/2087469-overview#showall.
[36]. Guyton A, Hall J.Buku Ajar Fisiologi Kedokteran. 11th ed. Rachman LY, Hartanto H, Novrianti A, Wulandari N, editor bahasa Indonesia.Jakarta: EGC, 2007
[37]. Lieben L, Masuyama R, Torrekens S, Looveren R, Schrooten J, Baatsen P, et al.Normocalcemia is Maintained in Mice Under Condition of Calcium Malabsorption by Vitamin D –induced Inhibition of Bone Mineralization. J Clin Invest. 2012;122(5):1803-15.
[38]. Brouns F, Saris W, Schneider H.Rationale for Upper Limits of ElectrolyteReplacementDuring Exercise. Int J Sport Nutr. 1992;2(3):229-38.

[39]. National Institutes of Health.Dietary Supplement Fact Sheet: Calcium. [serial online]2013. [cited 2020 Dec 15].
[40]. Razzaque I.Urine Calcium. Medscape [serial online] 2012. [cited 2020 Dec 15]. Available from: emedicine.medscape.com/article/2093845-overview#aw2aab6b3.
[41]. Rianon N, Feeback D, Wood R, Driscoll T, Shackelford L, LeBlanc A. MonitoringSweatCalcium Using Skin Patches. Calcif Tissue Int. 2003;72(6):694-7.
[42]. Mao I, Chen M, Ko Y.Electrolyte Loss in Sweat and Iodine Deficiency in a hot environment. Arch EnvironHealth. 2001;56(3):271-7
[43]. Rompas, Q. R. (2014). Kadar Kalsium Serum Pada Latihan Fisik Intensitas Sedang Mahasiswa Fakultas Kedokteran Universitas Sam Ratulang. *eBiomedik*, *2*(1).
[44]. Edwards S. Maintaining Calcium Balance: Physiology and Implications. Nurs Times[serial online].2005 [cited 2020];101(19):58-61.
[45]. Iriani S. The reference range of serum, plasma, and erythrocyte magnesium. Medical Journal of Indonesia. 2006;15:229-30.
[46]. Hazar M, Sever O, Gurkan CA, Er FN, Erol M.Physiologic responses of macro elements to maximal aerobic exercise in male and female footballers. Life Sci J. 2013;10:734-7
[47]. Elin RJ.Magnesium metabolism in health and disease. Dis Mon.1988;4:161-218.
[48]. Bhuto A, Mastoi AA, Memon SA, Qureshi GA, Qureshi AA. Magnesium and Its Essential Role in Health. JUMPS. 2005: p. 33-34.
[49]. Topf JM, Murray PT.Hypomagnesemia and hypermagnesemia. Rev endoc Metab Disord. 2003. p. 195-206.
[50]. Hartwig A.Role of Magnesium in Genomic Stability. Mutat Res. 2001;475(1-2):113-21
[51]. Hsu MH, Wang JM, Lee MS, Lee CP, Cheng FC, et al. Changes in serum magnesium concentration in trained and untrained subjects after exercise. J Biomed Lab Sci. 2007;19:25.
[52]. Buchman AL, Keen C, Commisso J, Killip D, Ou C, Rognerud CL, et al. The effect of a marathon run on a plasma and urine mineral and metal concentrations. J Am Coll Nutr. 1998;17:124-7.
[53]. Brilla LR, Lombordi VP.Magnesium in exercise and sport. In: Driskell JA, Wolinsky I. ed. Macroelements, Water, and Electrolytes in Sport Nutrition. Florida: CRC Press, 1999; p.54-74.
[54]. Meludu SC, Nishimura M, Yoshitake Y, Toyooka F, Kodama N.Anaerobic exercise-induced changes in serum mineral concentrations. Africans Journal of Biomedical Research. 2002;5:13-7.
[55]. Rayssiquier Y. Guezennec CY, Durlach J.New experimental and clinical data on the relationship between magnesium and sport. Magnes Res. 1990;3:93-102.
[56]. Geiger H, Wanner C. Magnesium in disease. Clin Kidney J. 2012;5:25-38.
[57]. Siregar, N. S. Pengaruh Rehidrasi Setelah Olahraga Dengan Air Kelapa. *Jurnal Ilmu Keolahragaan*. 2016;*15*(2), 12-20.