Int. J. New. Chem., 2023, Vol. 10, Issue 3, pp. 151-161.

International Journal of New Chemistry

Published online 2023 in http://www.ijnc.ir/.

Open Access

Print ISSN: 2645-7237

Online ISSN: 2383-188x

Original Research Article

Metal ions and their Biological Functions in Human Body

Mabrouk M. Salama* and Zahia A. Mohammed

Department of Chemistry, University of Benghazi, Libya

Received: 2023-02-11 *Accepted: 2023-05-11* *Published: 2023-06-01*

ABSTRACT

Metal ions are naturally occurring inorganic substances required in humans in a certain amount by mg/day. They are essential components of biological structures and have an important effect on and play a key role in a variety of the process necessary for life throughout mediating vital biochemical reactions. The role of essential nutrient metal ions as (Na^+, K^+, Ca^{2+}, and Mg^{2+}) often deficient in our food stuffs, its vitally essential in the function of the human body. Excessive levels, a level higher than needed for biological functions, of these elements can be toxic for the body health. Therefore, it has been found that the imbalances in the optimum levels of trace elements may adversely affect biological processes and are associated with many fatal diseases. In the recent study, 15 samples from deferent patients in ages (18-45) and deferent living environments have been taken from Hawari hospital Kidney division, Benghazi, Libya. The samples were treated by separation of serum from the blood without any chemical treatment. The studied values were measured by spectrophotometer as element analysis. The studied values for metal ions (Na^+, K^+, Ca^{2+}, and Mg^{2+}) in serum samples, clearly reflect the lack of healthy food taken by the patients, which have caused some decrease in the normal values, even though still under control. The results showed a satisfactory values comparing with the normal values confirmed by WHO.

Keywords: metal ions, Biological functions, separation of serum, spectrophotometer

Introduction

Metal ions such as Sodium, potassium calcium and magnesium play a crucial role in maintaining body acid-base balance as well as osmotic pressure in body fluids. These processes are the result of synergetic action of all metal ions, and the role of each individual component is difficult to define without knowing and taking into consideration the other metal ions. Metal ions are present in all body tissues and fluids, their presence is necessary for the maintenance of certain

***Corresponding Author: Mabrouk M. Salama**
E-mail: mabrouk.salama@uob.edu.ly

physicochemical processes which are essential to life. Minerals are chemical constituents used by the body in many ways. Metal ions have several important roles in human bodies, some are essential for enzymes reactions where they attract and facilitate conversion of substrate molecules to specific end products. Moreover, some of them donate or accept electrons in redox reactions that are of primary importance in the generation and utilization of metabolic energy. Some of them have structural roles and responsible for the stability of important biological molecules [1]. Every form of living matter requires these inorganic elements or minerals for their normal life processes [1]. Regarding the acid-base balance in blood, supplementation of metal ion (as Na^+) without (Cl^-) in feed lead to an increase in concentration of anions (HCO_3^-) and elevated blood pH, whereas supplementation of anion Cl^- (without Na+) decreases concentration of (HCO_3^-) ions and pH value. Endogenous acid production affects the electrolyte balance. It changes also with the change of protein source in feed, that is, replacement of soybean meal with fish meal results in modification of electrolyte balance from 17.4 to 12.1 mEq/kg feed [1], Anion imbalance can be solved by bicarbonate supplementation in the diet. It is recommended that fishmeal-based poultry diets should be supplemented with sulfates to ensure electrolyte balance. The use of some divalent ions can interfere with electrolyte balance. Thus, supplementation of calcium chloride ($CaCl_2$) in the diet can induce acidosis in poultry, contrary to chloride sources such as NaCl and KCl, which are associated with acidosis to a much minor extent, This is due to the fact that calcium absorption from $CaCl_2$ is lower than that of sodium from NaCl. Calcium bounds to carbonates from $CaCO_3$ using up bicarbonates from blood, and excessive unabsorbed chlorine causes acidosis [2].

Several factors directly or indirectly influence the levels of minerals in plants and hence the amounts available for humans and animals that depend on plants for foods and feeds respectively. The amount of a particular nutrient in the diet may be insufficient to meet the requirements. However, the metabolism of the animal may be deranged by the interaction of dietary, environmental and genetic factors [2-3]. Magnesium is the major intracellular divalent cation and plays an essential physiological role in many functions of the body [3]. Magnesium is essential for the synthesis of nucleic acids and proteins, and is an important cofactor for a wide range of enzymes, transporters. Magnesium has important effects on the cardiovascular system. Intracellular magnesium forms a key complex with ATP and has a key role in many other important biological processes such as protein synthesis, cell replication, and energy metabolism [3].

Calcium

Calcium is the most abundant mineral in the body, there being about 25 mol (1kg) of calcium in a 70 kg man. Its role is in neuromuscular excitability and clotting of the blood. Calcium provides structural support of the body, exerts important influences on cell membrane, support permeability and plays central role in blood coagulation. The action of most protein hormones is inhibited in the absence of calcium [4]. In human diet, the main source of calcium is milk, which contains 85% calcium [5]. Absorption of calcium occurs from the small intestine and considerably influenced by hormonal action. It may be impaired if the diet contains large quantities of inorganic or organic phosphate such as phytate. The calcium excreted in faces is derived partially from diet and partially from intestinal secretions. The efficiency of calcium absorption tends to decrease with age, and increased dietary intakes may be needed in the elderly. The excretion of calcium in the urine varies considerably with the diet and the relationship is not a simple one [6]. Total serum calcium varies with the amount of serum protein. However, factors lowering total serum calcium by lowering protein produces no obvious metabolic disturbances while those lowering ionic calcium have dramatic consequences such as tetany. Parathyroid hormone (PTH) is normally the dominant factor in the maintenance of plasma calcium level. Vitamin D and PTH enhance calcium absorption. Experimentally it was found that high calcium produces goiter in rats [5]. Serum levels of calcium is known to decrease during pregnancy in women, and immediately after delivery [7].

Magnesium

Magnesium is an intracellular cation. Inside the cells, it appears to concentrate in the mitochondria. Although not normally regarded as trace element, magnesium is nevertheless an essential inorganic element for which further research appears to be essential. The adult human body contains approximately 20-25g magnesium. Despite the relatively large amounts present, and the demonstration that magnesium is an essential nutrient for experimental animals, concrete data indicating its role in human nutrition have been presented recently. Magnesium is important in the preservation of integrity of cell-membranes and in the normal activity of excitable tissue [8]. Magnesium is known to be required for the activity of many enzymes, particularly those concerned with oxidative phosphorylation. Magnesium is further involved in protein synthesis. It is also involved in the synthesis and break down of acetylcholine [(4)]. Both vitamin D and PTH promote

magnesium absorption in animal and man. Sodium increases magnesium absorption while potassium decreases it only in vivo (animal experiments). Phosphate decreases magnesium absorption in man. Some workers say that PTH reduces magnesium excretion [9]. The serum concentration of magnesium range is 17-27 mg/l, it has been found to decrease in pregnant women, and it increases after delivery. Nevertheless, that of new born babies is lower than their mothers [8], Magnesium excretion is high in hyperthyroidism and low in hypothyroidism [10]. A state of magnesium deficiency in humans may develop due to lack of intestinal absorption or excessive losses in faces or in other body fluids, also in severe and prolonged dietary restriction. The diagnosis of magnesium is not easy since the blood level of magnesium does not always reflect the state of magnesium ion in the serum. The main clinical manifestation of magnesium depletion includes neuromuscular disturbances and behavioral abnormalities. Coma and death may occur if magnesium deficiency is not treated, Underwood 1980. Hypomagnesaemia may occur in patients with adrenal inefficiency [11]. Excess magnesium appears to block neuromuscular transmission owing to diminution in end plate potential. Respiratory paralysis, narcosis, hypotension and abnormal cardiac conduction may occur as blood levels of magnesium approach 5 mmol/l.

Potassium

Potassium sodium, chloride, together with other inorganic ions are important constituents of body fluids. These elements mainly potassium, sodium and chlorine are major factors in the maintenance of water and acid base balance [12]. In the young adult, the exchangeable potassium content of the body averages 46 mmol/kg or 3200 mmol for a 70/kg man. The muscles provide the main body store of potassium but falls with ages as muscle mass diminish, WHO technical report Geneva, 1996. The healthy adult is in potassium balance, but a positive balance occurs during growth and pregnancy, when new muscle mass is laid down. The potassium intake depends on dietary habits but is usually up to 150 mmol daily. Potassium deficiency is often associated with altered sodium, water, and acid-base balances, all of which may affect the serum potassium result. A serum potassium concentration below 3.6 mmol/l, is associated with varying degree of muscles weakness, increase neuromuscular excitability and disordered myocardial function, arrhythmia, tachycardia. Such effects increase the lower the serum potassium is [12].

Sodium

Sodium is an essential mineral found in extra cellular fluids, within the blood vessels, arteries and veins. Sodium is found in the blood and bones. It is involved in osmotic pressure and acid-base balances, equilibrium, and preservation of normal muscle, cell irritability and cell permeability [13]. It is also important to keep the blood mineral soluble and for hydrochloric acid production in the stomach. Sodium is found in all foods, especially in seafood's, carrots, beets, poultry, and meat. Sodium is excreted in the urine. Absorption of sodium takes place in the upper small intestine and stomach. Deficiency of sodium causes weight loss and vomiting. The conversion of carbohydrate into fat for digestion is impaired when sodium is absent [14]. In this regards as in general, there are many diseases that lead to changes in acid base balance. These conditions are not rare or uncommon in clinical practice, but everyday occurrences on the ward or in critical care [15].

Functions and role of metal ions

Calcium (Ca) – 1.4% of body weight

Atomic Number: 20

About 99% of the body's calcium is found in bones and teeth, where the element is used to build strong structural compounds, such as hydroxyapatite. Although most of the calcium is in bones and teeth, this is not the mineral's most important function. Calcium is an important ion, used in muscle contraction and protein regulation. If any critical function has insufficient calcium, the body will actually pull it out of the bones and teeth. This can lead to osteoporosis and other problems, so it's important to get enough dietary calcium.

Potassium (K) – 0.25% of the body weight

Atomic Number: 19

Electrochemistry in the body depends on ions. Of these, the cation potassium is among the most important metal ions in the human body. Potassium is used in nerve conduction and regulating the heartbeat. All cells in the body require potassium in order to function.

Sodium (Na) – 0.15% of the body weight

Atomic Number: 11

Sodium, like potassium, is an essential cation. This element is important for nerve transmission and muscle function.

Magnesium (Mg) – 0.005% of the body weight

Atomic Number: 12

Magnesium binds to ATP and nucleotides. Its cation is an important cofactor for enzymatic reactions. Magnesium is used to build healthy teeth and bones.

Sources and causes of deficiency of metal ions:

Sodium Ion

The main source of sodium is NaCl salt in cooking in addition to salted foods. The content of sodium is high is Bread Cheese, Clams, Carrots. Cauliflower, Eggs, Milk, Nuts, Spinach. Requirement: 5 to 10 g. of NaCl for adult Na^+ is the major contains of blood. Plasma of vertebrates white K^+ is major cations of the cytoplasm which is present in cells. Sodium ion plays an important role to absorption of glucose, amino acids and glucose. It is associated with chloride and bicarbonate in regulator of acid base balance.

Deficiency of Sodium

Due to high environmental temperature extreme sweating may causes loss of sodium ion. This regard is muscular cramps of the abdomen, headaches. Also high intake of table salt causes high blood pressure.

Potassium

High content of Potassium is present is Chicken, beef liver, bananas. Juice of orange and pine apples and potatoes yams. Intake about 4 g/d. Potassium is principal cation of Intracellular fluid i.e. Cytoplasm of cell. Increase the activity of muscles specially cardiac muscles. Maintain acid base balance and osmotic pressure of body. It increase activity of glycolic enzyme, pyruvate kinase. It also stopped blood coagulation, and regulate heartbeat. It play an important role to synthesis of Ribosomes. Deficiency of potassium*:* Depression and low activeness of cardiac and nervous system. Also Causes muscular weakness (Cramping of muscles)

Calcium

Calcium is present in milk, eggs beans, nuts figs cabbage cauliflower and asparagus, calcium needs about 800 mg dirty of the age of 18th for men and women and below 18th age it require 1 – 1.2 gm/daily

Calcium is a major constituent of bones teeth. About 90% of the body calcium is in the Skelton, where it is maintained as deposits of calcium phosphate is a soft fibrous matrix. Ionized calcium is of great importance in blood coagulation. Calcium also maintains the normal excitability of heart. Deficiency of calcium: Low concentration of calcium causes irritation. Low concentration of calcium also causes weakness of bones in children, and caused Osteoporosis in adults.

Magnesium

Magnesium is present in Cocoa various nuts, soya bean and sea foods. Magnesium also present in beans peas in small quarterly. Magnesium needs few about 300 mg/daily for adult women and 350 mg/daily for adult men. The body contains about 21 mg of magnesium, 70% combined with calcium and phosphorus is complex salt of bones. Magnesium ion is one of essential cation of soft tissue. In muscles and other tissue intra cellular Mg^{2+} ions probably functions as activators of phosphate group transfer enzyme. Deficiency of magnesium: In case of mean lead neuro muscular disfuctioning (Hyper excitability)

Experimental

Materials

All samples were taken from the sampling room, were there is a specialized technician for this purposes. The samples were treated by separation of the serum from the blood without any chemical treatments then directly tested by special test tubes in the photometer machines after calibration by reference were each metal ions has a certain wave length.

Figure 1. Photometer 5010 model used in the sample test

Results

sample	Calcium		Magnesium		Potassium		Sodium	
	Test mg/l	Normal value	Test mg/l	Normal value.	Test mg/l	Normal value	Test mg/l	Normal value.
S 001	9.0	8.0-10.0	0.7	1.8-2.0	4.3	3.6-4.8	136	136-143
S 002	10.0	8.0-10.0	1.0	1.8-2.0	3.6	3.6-4.8	140	136-143
S 003	11.3	8.0-10.0	1.4	1.8-2.0	5.0	3.6-4.8	150	136-143
S 004	8.4	8.0-10.0	1.2	1.8-2.0	4.3	3.6-4.8	136	136-143
S 005	7.6	8.0-10.0	0.4	1.8-2.0	5.1	3.6-4.8	150	136-143
S 006	8.0	8.0-10.0	1.1	1.8-2.0	3.2	3.6-4.8	132	136-143
S 007	8.3	8.0-10.0	0.8	1.8-2.0	3.6	3.6-4.8	138	136-143
S 008	9.1	8.0-10.0	1.2	1.8-2.0	3.8	3.6-4.8	139	136-143
S 009	11.5	8.0-10.0	1.4	1.8-2.0	5.0	3.6-4.8	150	136-143
S 0010	9.0	8.0-10.0	0.7	1.8-2.0	3.8	3.6-4.8	143	136-143
S 0011	10.1	8.0-10.0	1.2	1.8-2.0	4.0	3.6-4.8	140	136-143
S 0012	8.5	8.0-10.0	0.6	1.8-2.0	4.1	3.6-4.8	142	136-143
S 0013	9.5	8.0-10.0	0.8	1.8-2.0	3.9	3.6-4.8	139	136-143
S 0014	12.0	8.0-10.0	1.3	1.8-2.0	5.3	3.6-4.8	150	136-143
S 0015	8.9	8.0-10.0	0.9	1.8-2.0	4.2	3.6-4.8	140	136-143

Table 1. The tested values of Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} as well as the normal values

Discussion

The role of essential nutrient metal ions (Na^{+}, K^{+}, Ca^{2+}, and Mg^{2+}) often deficient in our foodstuffs, although vitally essential in the function of the human organism as well as the different reasons

for these deficiencies in the human body have been studied. 15 samples from deferent patients in ages and living environments have been taken from Hawari hospital Kidney division. The studied samples in table 1, clearly shows the following:

Calcium tests: All samples are in the range of the normal values except 4 samples which have increased values (S003, S009, S0011 and S0014) and only one sample (S005) has decreases value.

Magnesium tests: All samples are in abnormal values and all samples have decreases values comparing with the normal values.

Potassium tests: All samples are in the range of the normal values except 4 samples which have increased values (S003, S005, S009 and S0014) and only one sample (S006) has decreased value.

Sodium tests: All samples are in the range of the normal values except 4 samples which have increased values (S003, S005, S009, and S0014) and only one sample (S006) has decreased value.

On another hand, samples (S003, S009 and S0014) all have increased values, except magnesium values, where sample (S006) has decreased value for all metal ions.

Concussion

Metal ions such as Sodium, potassium, Calcium and Magnesium play a crucial role in maintaining body acid-base balance as well as osmotic pressure in body fluids. These processes are the result of synergetic action of all three elements, and the role of each individual component is difficult to define without knowing and taking into consideration the other metal ions. Based on data presented in this paper the biological role of these metal ions in normal metabolism is essential. Metal ions in general are a relatively nontoxic elements that is required in relatively large amounts to sustain life. However, disturbances in metabolism can result in they being toxic [13-14]. Metal ions such as the studied metal ions play an important role as a cofactor for certain enzymes involved in metabolism and cell growth, most of them involved in the metabolism of proteins, carbohydrates, lipids and energy. They are also necessary for growth ,development, muscle and nerve function, normal cellular functioning, and synthesis of some hormones and connective tissue. The studied values for Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+} metal ions in serum samples, clearly reflect the lack of healthy

food taken by the patients, which have caused some decrease in the normal values, even though still in the range of save values.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

Authors would like to thanks ”Hawari hospital Kidney division, Benghazi, Libya” in general , doctors, and technicians in particular for their help and encouragements.

References

[1] F. S. Al-Fartusie, S. N. Mohssan, *Indian Journal of Advances in Chemical Science*., 5(3) , 127-136 (2017).

[2] R. Aversa, V. Petreascu, A. Aplicella, I. Petrscu, *American Journal of Engineering and Applied Sciences*., 9(4), 1189-1197 (2016).

[3] K. Wongdeee, M. Rodrat, J. Teerapornpuntakit, N. Krishnamra, N. Charoenphandhu, *The Journal of Physiological Sciences.*, 69,683-696. (2019).

[4] J. L. Shaker, M. D, L. Deftos, M. D, *National Library of Medicine*., (2018).

[5] K. Burrow, W. Young, N. Hammer, S. Safavi, M. Scholze, M. Mc Connell, A. Carne, D. Barr, M. Reid, A. El Din Bekhit, *Foods*., 9(8),1070 (2020).

[6] T. Matsuo, H. Ito, K. Mutsunari, K. Ohba, Y. Miyata, *J. of Metabolites*., 12(3), 229. (2022).

[7] H. K. Bhattari, S. Shrestha, K. Rokka, R. Shakya, *J. of Osteoporsis*., (2020).

[8] C. Munteanu, M. Rotariu, M. Turnea, A. M. Ionescu, C. Popescu, A. Spinu, E. V. Ionescu, C. Oprea, R. Elena T, Ucmeanu, L. G. Tătăranu, S. C. Silis, Teanu , G. Onose, *J. of Cells*., 11, 2503 (2022).

[9] J. Wo. Seo, *Electrolyte & blood pressure*., 6, 86-95 (2008).

[10] D. Fiorentini, C. Cappadone, G. Farruggia, Cecilia Prata, *Nutrients*., 13, 1136 (2021).

[11] M. Lin, M. Tsai, J. Leu, Y. Fang, *BMC Endocrine Disorders*., 19, 80 (2019).

[12] WHO technical report Geneva., Report of a WHO Expert Committee (2005).

[13] M. Ž. Baloš, S. Jakšić, S. Knežević, M. Kapetanov, *Arhiv veterinarske medicine*., Vol. 9, No. 1, 31 - 42, 201 (2016).

[14] Er. Hopkins, T. Sanvictores, S. Sharma, *National Library of Medicine*., (2022).

[15] S. L. Edwards, *Intensive and Critical Care Nursing (ICCN)*., 24, 28-40 (2008).

How to Cite This Article

Mabrouk M. Salama, Zahia A. Mohammed, "**Metal ions and their Biological Functions in Human Body**" International Journal of New Chemistry., 10 (3), 151-161 (2023). DOI: 10.22034/ijnc.2023.1999338.1332.