Magnesium — distribution and basic metabolism

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Summary

Magnesium is extensively distributed in soil, water and plants. It is essential for enzymatic reactions requiring adenosine triphosphate, and the recommended dietary allowance in man is 5 - 10 mg/kg/d. About 50% of magnesium in man is stored in bone, where it is regulated by parathyroid hormone and $1,25(OH)_2$-D_3. Most of the remaining magnesium pool is intracellular, plasma magnesium accounting for less than 0,5% of the total.

S Afr Med J 1983; **63**: 319-320.

The importance of electrolyte and fluid balance in man is generally understood by practising clinicians, particularly where losses of water, sodium, chloride and potassium are concerned. However, it has become apparent of late that changes in the homeostasis of elements such as magnesium may also be of considerable practical importance. Magnesium should be of particular interest to clinicians in view of the numerous enzymatic reactions which require this cation as a co-factor.

Magnesium (Mg^{2+}) is found within the earth's cortex, accounting for 2% of its total mass.[1] It is widely distributed, principally as silicates, magnesite (magnesium carbonate) and dolomite (calcium and magnesium carbonate), although only 10% of the element in soil is soluble and can be utilized by plants. In animals, magnesium is essential for enzymatic reactions requiring adenosine triphosphate (ATP) and is therefore of importance in DNA transcription, RNA aggregation, protein synthesis and various cell membrane functions.[2] The recommended dietary allowance of magnesium varies from 5 mg/kg/d in healthy adult males to 6 mg/kg/d in children or during pregnancy or lactation, although an intake as high as 7 - 10 mg/kg/d has been recommended in the latter circumstances.[3,4] Somatic depletion of the ion and clinical manifestations of magnesium deficiency, including neuromuscular and cardiac symptoms and signs, may develop when inadequate intake is coupled with changes in the absorption or excretion of or physiopathological demand for magnesium.[1,4,5]

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Date received: 13 October 1982.

Magnesium in water

Magnesium is present in both fresh and salt water. Water for human consumption varies in its solute content and is described as 'hard', when calcium and magnesium levels are high, or 'soft', when the concentrations of these ions are low. In most regions a litre of drinking water contains 5 - 30 mg magnesium, and healthy adults usually obtain 3 - 60 mg from this source daily.

Magnesium in food

The magnesium concentration in common foods is low. Fruit, flour, vegetables, dairy products, meat and sugar usually contain less than 30 mg/100 g. Refinement of products such as sugar and flour always leads to a major loss of magnesium content.[1] However, bananas are an excellent source of the ion, 3-4 containing sufficient magnesium to provide an adult with the recommended daily allowance of the cation.

Absorption

In conditions of magnesium balance, 50-60% of the ingested mineral passes through the gastro-intestinal tract unabsorbed. The percentage absorbed increases in conditions of relative magnesium deficiency. Magnesium absorption from the gut is affected by nonspecific factors such as vomiting, diarrhoea,

alterations in the total gut absorptive surface, interactions with other substances within the intestinal lumen, and systemic pathological conditions.[6] Intestinal absorption of the ion is favoured by the presence of protein and decreased by intraluminal fat.

Glucose depresses magnesium absorption whereas lactose and vitamin D increase it. None of the known hormones appears to affect magnesium absorption to a significant extent.

Plasma transport

The measurement of magnesium in biological fluids is complicated by technical problems,[7] although experimental error can be minimized by the use of atomic absorption spectrophotometry.[8-11] Normal plasma magnesium levels range from 0,75 to 1,05 mmol/l (1,5 - 2,1 mEq/l) in the adult but are normally maintained within narrow limits in the individual. It is conventionally accepted that a plasma magnesium level below 0,75 mmol/l is diagnostic of magnesium deficiency, although somatic depletion of magnesium may exist in the presence of normal plasma levels.

Distribution

Magnesium and potassium are the most important intracellular cations and share a similar distribution within the body. In an adult magnesium accounts for approximately 0,36 g of every kilogram body weight. Only about 0,04% of this is in the plasma, whereas 50-55% is in bone, approximately 46% intracellular and 1,0% transcellular; 1,0% is contained in lymph and interstitial tissues and 0,04% in dense connective tissue and cartilage. Magnesium turnover is slow in comparison with that of potassium[9] and is altered by parathormone and $1,25(OH)_2$-D_3.

Bone magnesium is either incorporated in the thin lamella or forms part of the superficial mineral sheet. These superficial stores account for 30% of bone magnesium, correlate well with plasma magnesium levels and serve as a source of magnesium interchange for the maintenance of normal plasma magnesium concentrations.[12] No correlation exists between striated muscle magnesium and magnesium in plasma, bone or erythrocytes; the content of magnesium in erythrocytes largely depends upon the concentration in extracellular fluid during haematopoiesis. As a result erythrocyte magnesium levels do not correlate with plasma magnesium levels and fall slowly when magnesium deficiency develops. In cells of electrically excitable tissues such as the myocardium, the concentration of magnesium reaches 6 - 9 mmol/kg wet weight and most of the ion is found in the microsomes and mitochondria. Intracellular magnesium reaches a concentration of 1 mmol/l, but its cytosolic concentration is not uniform, since it accumulates at the inner surface of the polyionic macromolecules, attracted by their electronegativity.

Renal excretion

Renal excretion of magnesium usually ranges between 4 and 8 mmol/d (100-400 mg/d). Between 80% and 95% of filtered magnesium is reabsorbed, 20-30% in the proximal convoluted tubule, 50-60% in the thick limb of Henle's loop and 1-5% in the distal convoluted tubule. Parathyroid hormone positively affects reabsorption of magnesium in the thick limb of Henle's loop and possibly also in the distal convoluted tubule.[13] No other factor seems to be of importance in the regulation of renal magnesium excretion.[14-16] Detailed accounts of the renal regulation of magnesium excretion have been published elsewhere.[11,17-19]

Intracellular functions

Magnesium acts as a co-factor for various enzymes, thereby regulating the excitability of heart[20-24] and skeletal muscle,[19] neuromuscular junctions and, to a lesser extent, the central nervous system[25,26] and smooth muscle. Magnesium modulates the production of energy within the cells[12,17] and also the cellular response to various hormones.[22,27,28]

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