



Magnesium: effects on physical and mental performance

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Introduction

Magnesium is a chemical element used by every organ in the body, especially the brain, skeletal muscles and the heart. It functions as a cofactor in approximately 600 enzyme systems that regulate many different biochemical reactions, including aerobic and anaerobic energy production, protein synthesis, muscle and nerve function, blood glucose control, and blood pressure regulation.¹⁻³ Magnesium is instrumental in combating fatigue and energy loss, and is essential for optimal physical and mental performance.

The average person's body contains an estimated 25 grams of magnesium, half of which is in bone. People get magnesium from their diet, but sometimes magnesium supplements are required if magnesium levels are too low for ideal physiological functioning.⁴ Early signs of magnesium deficiency include fatigue, weakness, loss of appetite, nausea and vomiting. This may progress to muscle cramps, seizures, personality changes and cardiac dysfunction. Severe magnesium deficiency may cause low serum calcium and potassium levels because mineral homeostasis is altered.² Magnesium supplementation may modify the effects of chronic stress,⁵ and has shown benefits in athletes, many of whom are magnesium depleted, and in the treatment of chronic fatigue syndrome, pre-eclampsia, migraine, hypertension, diabetes and asthma, amongst others.^{6,7}

How much magnesium is required?

Dietary sources of magnesium include legumes, whole grains, vegetables (especially broccoli, squash, and green leafy vegetables), seeds, and nuts (especially almonds). Other sources include dairy products, meats, chocolate, and coffee. Water with a high mineral content, or "hard" water, is also a source of magnesium. The daily Recommended Dietary Allowances (RDA) for elemental magnesium is outlined in Table I.¹

Causes of magnesium deficiency

Dietary intake of magnesium may be low, particularly among women.⁹ Reports estimate that at least 60 % of Americans do not consume the recommended daily amount of magnesium,^{10,11} while in South Africa the figure is approximately 50 %.¹² Soil used for agriculture is becoming increasingly deficient in essential minerals and the magnesium content in fruit and vegetables has decreased by 20-30 % over the last 60 years.¹⁰ The Western diet contains more refined grains and it is estimated that 80-90 % of magnesium is lost during food processing. As a result, a significant number of people are magnesium deficient, which may increase up to as much as 60 % in critically ill patients.¹³⁻¹⁵

Disturbances of intestinal magnesium uptake and renal excretion are also implicated in magnesium deficiency.¹ For instance, type II diabetes may cause excessive renal losses of magnesium.¹⁶ Older adults are also more at risk of magnesium deficiency because of both reduced gut absorption and increased renal excretion.¹⁷ Strenuous or prolonged endurance exercise increases urinary and sweat losses that may increase magnesium requirements by as much as 10-20 %.³ It is therefore not surprising that many athletes are magnesium deficient, and this may affect their performance.³

Magnesium status is highly associated with stress levels, with both stress and low levels of magnesium potentiating each other's negative effects. Extended periods of physical or

Table I: Daily Recommended Dietary Allowances (RDA) for elemental magnesium

Age	*Recommended Dietary Allowances (RDA)
1-3 years	80 mg
4-8 years	130 mg
9-13 years	240 mg
14-18 years	410 mg (boys) and 360 mg (girls)
19-30 years	400 mg (men) and 310 mg (women)
31 years and older	420 mg (men) and 320 mg (women)
Pregnant women age	*Recommended Dietary Allowances (RDA)
14-18 years	400 mg
19-30 years	350 mg
31-50 years	360 mg
Lactating women age	*Recommended Dietary Allowances (RDA)
14-18 years	360 mg
19-30 years	310 mg
31-50 years	320 mg
Infants less than one year of age	**Adequate intake (AI) levels
birth to 6 months	30 mg
7 to 12 months	75 mg
Miscellaneous	***The daily upper intake level (UL)
1-3 years	65 mg
4-8 years	110 mg
Anyone over 8 years old, including pregnant and breast-feeding women	350 mg

Notes:⁸

*Recommended Dietary Allowance (RDA): the average daily dietary intake level that is sufficient to meet the nutrient requirement of nearly all (97 to 98%) healthy individuals in a group.

**Adequate Intake (AI): a value based on observed or experimentally determined approximations of nutrient intake by a group (or groups) of healthy people—used when an RDA cannot be determined.

***Tolerable Upper Intake Level (UL): the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects to almost all individuals in the general population. As intake increases above the UL, the risk of adverse effects increases.

emotional stress result in progressive magnesium deficits and deleterious consequences for health.¹⁸ Neurotransmitters and hormones released during stress, including catecholamines, cortisol, and corticosteroids, as well as overall hypothalamic-pituitary-adrenal axis dysregulation as seen in stress-related conditions such as fibromyalgia, chronic fatigue syndrome, cold and physical stress, may contribute to magnesium depletion.¹⁹⁻²¹

Magnesium deficiency is also associated with several other important disorders, such as insulin resistance and the metabolic syndrome.²² Other causes of magnesium depletion include vomiting and diarrhoea, alcoholism and drugs such as diuretics, proton pump inhibitors, cisplatin and the antimicrobials, aminoglycosides and amphotericin B.

Symptoms and signs of magnesium deficiency

Magnesium deficiency is determined by measuring total serum concentrations, which range between 0.7 and 1.05 mM in healthy individuals.²³ However, these values reflect only 1% of the total body content, as most is stored in bone, muscle and soft tissues. Sometimes when serum values are within the normal range, the body may be severely magnesium-depleted.

Brain and central nervous system

Low extracellular magnesium levels in the central nervous system contribute to altered nerve conduction, which is mediated by overstimulation of neuro-excitatory NMDA receptors. The corresponding excessive intracellular calcium in the neurons may also lead to the production of toxic reactive oxygen species, and eventually to neuronal cell death.¹ Neuromuscular symptoms of magnesium deficiency therefore include those linked to neuronal hyper-excitability e.g. tremor, muscle spasms and cramps, tetany and convulsions, as well as weakness, apathy, delirium, and coma.¹⁵

Chronic fatigue syndrome is associated with lower red blood cell magnesium levels compared to controls,^{24,25} and approximately 40-50 % of chronic fatigue patients are actually magnesium deficient.²⁶ Not surprisingly, these two clinical entities share similar presentations, and it may therefore be difficult to distinguish between them. Overlapping symptoms include chronic fatigue, weakness, myalgias, paraesthesias, depression, anxiety, sleep disturbances, migraine and tension headaches.¹⁹ Of interest is that these symptoms, in particular loss of energy, may improve significantly with magnesium supplementation.^{19,25}

Other central nervous system disorders linked to magnesium deficiency include depression, migraine, epilepsy, Parkinson's disease, brain injury and stroke.¹ There is evidence that dietary magnesium intake is inversely associated with the risk of stroke, specifically the ischaemic variety.²⁷

Skeletal muscle

In skeletal muscle, magnesium exerts its effects mainly as a calcium antagonist, where it opposes unchecked muscle contraction. Severe or chronic magnesium deficiency therefore causes hyper-contractibility of muscle, which presents as recurrent and prominent muscle cramps and spasms.¹ Magnesium is involved in numerous other processes that affect muscle function including oxygen uptake, energy production and electrolyte balance. As mentioned previously, strenuous exercise may be a cause of magnesium loss. It has also been shown that exercise induces a redistribution of magnesium in the body to accommodate metabolic needs. Athletes participating in weight- or load-bearing sports (e.g. wrestling, weight lifting, gymnastics and running) are especially vulnerable to an inadequate magnesium status. There is also evidence that marginal magnesium deficiency impairs exercise performance and amplifies the negative oxidative stress consequences of strenuous exercise.³ In

otherwise healthy women, magnesium depletion may cause an increase in energy needs and adversely affect cardiovascular performance during submaximal exercise.⁹ It has been shown that magnesium supplementation or increased dietary intake of magnesium has beneficial effects on strength, endurance and exercise performance in magnesium-deficient individuals.³

Heart

Magnesium plays an important role in heart function by influencing myocardial metabolism, calcium homeostasis, vascular tone, peripheral vascular resistance and cardiac output.¹ Importantly, it is required as a co-factor in all reactions that require intracellular energy in the form of adenosine triphosphate (ATP), and it is thus essential for the activity of the sodium-potassium pump, Na⁺-K⁺-ATPase, which keeps extracellular levels of sodium high, and intracellular levels of potassium low.²⁸ In magnesium deficiency, Na⁺-K⁺-ATPase function is impaired, potentially leading to clinically important cardiac arrhythmias. Magnesium has been used in the treatment of the latter as well as in hypertension, coronary artery disease and myocardial infarction.²⁹

Other biochemical abnormalities

Symptomatic magnesium depletion is often associated with multiple biochemical abnormalities such as hypocalcaemia, hypokalaemia and metabolic alkalosis.³⁰ Magnesium plays a critical role in the synthesis and metabolism of parathyroid hormone and vitamin D, and therefore in maintaining bone integrity. Magnesium deficiency is associated with abnormalities of calcium metabolism, including hypocalcaemia, hypo-parathyroidism, parathyroid hormone resistance, and decreased synthesis of calcitriol. Magnesium deficiency may thus be a significant risk factor for osteoporosis.² High intake of total, dietary or supplemental magnesium appears to be associated with significantly reduced risks of vitamin D deficiency.³⁰ Hypokalemia, which occurs in 40 to 60 % of magnesium deficient patients, is relatively refractory to potassium supplementation and requires correction of the magnesium deficit first.³¹

Conclusion

Magnesium is essential for maintaining peak physical and mental functioning, yet dietary intake may be insufficient to meet the body's demands. Magnesium deficiencies are relatively common and may lead to a range of symptoms including loss of energy, fatigue, muscle cramps, metabolic and mineral disturbances. Magnesium supplementation may be required to restore magnesium balance and consequently to improve overall health.

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