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Magnesium in Pediatric and Adult Health: Physiological Significance, Clinical Implications, and Therapeutic Applications: A Comprehensive Review

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Abstract

Magnesium is the fourth most abundant cation in the human body and a critical intracellular ion involved in over 300 enzymatic reactions. It plays essential roles in energy metabolism, neuromuscular transmission, cardiovascular stability, bone mineralization, immune modulation, and genomic integrity. Despite its physiological importance, magnesium deficiency remains under-recognized across pediatric and adult populations. Subclinical deficiency is associated with asthma, migraine, neurodevelopmental disorders, insulin resistance, hypertension, arrhythmias, metabolic syndrome, and increased inflammatory burden. In pediatrics, magnesium is particularly vital during periods of rapid growth, neurodevelopment, and critical illness. In adults, deficiency contributes to chronic disease progression. This review comprehensively discusses magnesium physiology, homeostasis, mechanisms of action, clinical manifestations of deficiency, diagnostic challenges, pediatric and adult therapeutic applications, safety considerations, and emerging research. Recognizing magnesium as a modifiable risk factor in several disease states may significantly improve preventive and therapeutic strategies in clinical practice.

Keywords: Magnesium, Hypomagnesemia, Pediatric health, Asthma, Cardiovascular disease, Electrolytes, Micronutrients, Insulin resistance

1. Introduction

Magnesium (Mg^{2+}) is an essential divalent cation required for cellular survival. Approximately 50–60% of total body magnesium is stored in bone, 39–49% in soft tissues, and less than 1% in extracellular fluid. Because serum magnesium represents a very small proportion of total body stores, deficiency often remains undetected.

Modern dietary patterns characterized by refined grains, low vegetable intake, soil mineral depletion, chronic gastrointestinal disorders, diabetes mellitus, and proton pump inhibitor use contribute to widespread magnesium insufficiency. Epidemiological data suggest that up to 40–60% of individuals may not meet recommended dietary intake levels.

Magnesium is particularly important in pediatric populations due to its role in cellular growth, synaptic plasticity, and electrolyte regulation. In adults, deficiency contributes to chronic cardiometabolic and inflammatory disorders.

2. Magnesium Physiology and Homeostasis

Magnesium absorption occurs predominantly in the small intestine via passive paracellular diffusion and active transcellular transport mediated by transient receptor potential melastatin (TRPM6 and TRPM7) channels. Absorption efficiency increases during states of deficiency.

Renal handling is critical in maintaining magnesium balance. Approximately 60–70% of filtered magnesium is reabsorbed in the thick ascending limb of the loop of Henle, while 5–10% is fine-regulated in the distal convoluted tubule. Renal magnesium wasting may result from diuretic therapy, tubular disorders, diabetes mellitus and nephrotoxic medications.

3. Schematic Representation of Magnesium Distribution

Total Body Magnesium
↓
Bone (50–60%)
↓
Muscle & Soft Tissue (39–49%)
↓
Extracellular Fluid (<1%)

Serum magnesium reference range is typically 1.7–2.2 mg/dL; however, this does not necessarily reflect intracellular status.

4. Biological Functions of Magnesium

Magnesium is indispensable in cellular energy metabolism. Adenosine triphosphate (ATP) exists primarily as Mg-ATP complex, which stabilizes phosphate bonds and facilitates phosphorylation reactions. More than 300 enzymes involved in glycolysis, oxidative phosphorylation, DNA replication and protein synthesis require magnesium as a cofactor.

In neuromuscular physiology, magnesium regulates calcium influx through voltage-gated channels and modulates N-methyl-D-aspartate (NMDA) receptors, thereby preventing neuronal hyperexcitability. This mechanism underlies its anticonvulsant and migraine-preventive properties.

Cardiovascularly, magnesium functions as a natural calcium antagonist, stabilizes myocardial membranes and reduces arrhythmogenic potential. It also improves endothelial function and modulates vascular tone, influencing blood pressure regulation.

Magnesium is structurally incorporated into bone matrix and is essential for parathyroid hormone secretion and vitamin D activation. Immunologically, magnesium deficiency has been associated with increased inflammatory cytokine production and oxidative stress.

5. Magnesium in Pediatric Health

Growth and Neurodevelopment

During childhood, magnesium plays a critical role in neuronal maturation, synaptic plasticity and myelination. Experimental and clinical studies suggest associations between low magnesium status and behavioural disorders, attention-deficit/hyperactivity disorder and pediatric migraine. Adequate magnesium intake supports cognitive development and neurobehavioral stability.

Pediatric Asthma

Intravenous magnesium sulfate is recommended in moderate to severe asthma exacerbations unresponsive

to initial bronchodilator therapy. Magnesium inhibits calcium-mediated smooth muscle contraction, leading to bronchodilation.

Calcium Influx → Bronchial Constriction

Magnesium blocks Ca^{2+} channels

↓

Smooth Muscle Relaxation

↓

Bronchodilation

Meta-analyses demonstrate reduced hospitalization rates when magnesium sulfate is used adjunctively in severe pediatric asthma.

Neonatal Applications

Maternal magnesium sulfate administration during preterm labour provides fetal neuroprotection and reduces the risk of cerebral palsy. In neonates, magnesium is used in hypomagnesemic seizures and certain cases of persistent pulmonary hypertension.

Electrolyte Interactions

Magnesium deficiency frequently results in refractory hypokalemia and hypocalcemia. Correction of magnesium levels is essential before potassium normalization can occur, underscoring its importance in pediatric critical care.

6. Magnesium in Adult Health

Magnesium deficiency is strongly associated with cardiovascular disease. Observational studies demonstrate inverse relationships between dietary magnesium intake and risk of hypertension, atrial fibrillation and sudden cardiac death. Magnesium stabilizes myocardial excitability and is the treatment of choice for torsades de pointes.

In type 2 diabetes mellitus, hypomagnesemia correlates with insulin resistance and impaired glucose control. Magnesium influences insulin receptor phosphorylation and intracellular signaling pathways. Meta-analyses suggest improved glycemic parameters with supplementation in deficient individuals.

Magnesium also plays a role in metabolic syndrome, where low intake correlates with obesity, dyslipidemia and systemic inflammation. Emerging evidence links magnesium status with depression, anxiety and migraine prophylaxis.

In obstetric practice, magnesium sulfate remains the gold standard for prevention and treatment of eclampsia.

7. Hypomagnesemia: Clinical Manifestations and Causes

Hypomagnesemia may arise from inadequate intake, chronic diarrheal illness, malabsorption syndromes, alcoholism, diabetes mellitus, diuretic therapy and prolonged proton pump inhibitor use.

Clinical manifestations range from neuromuscular irritability, tremors and muscle cramps to seizures and cardiac arrhythmias. Severe deficiency may precipitate torsades de pointes or cardiac arrest.

8.Diagnosis and Monitoring

Serum magnesium measurement remains the most widely used diagnostic tool, although it may not accurately reflect intracellular stores. In selected cases, red blood cell magnesium or urinary magnesium assessment may provide additional information. Clinical context remains critical for diagnosis.

9. Therapeutic Supplementation

Oral magnesium supplementation in children typically ranges from 5–10 mg/kg/day of elemental magnesium in mild deficiency. In acute severe cases, intravenous magnesium sulfate (25–50 mg/kg) is administered under monitoring.

In adults, oral supplementation of 200–400 mg/day elemental magnesium is commonly used. Intravenous magnesium is indicated in arrhythmias, severe deficiency and obstetric emergencies.

Hypermagnesemia is uncommon and usually associated with renal impairment or excessive intravenous administration. Clinical features include hypotension, bradycardia, loss of deep tendon reflexes and respiratory depression. Intravenous calcium gluconate serves as the antidote.

10.Dietary Requirements

Recommended daily allowances vary by age. Children aged 1–3 years require approximately 80 mg/day, increasing to 240 mg/day by early adolescence. Adult males require 400–420 mg/day and adult females 310–320 mg/day. Green leafy vegetables, nuts, seeds, whole grains and legumes remain primary dietary sources.

11. Emerging Evidence

Recent research has highlighted magnesium's role in immune modulation, chronic inflammatory states and potential implications in long COVID and metabolic disorders. Subclinical magnesium deficiency may represent a modifiable contributor to chronic disease burden worldwide. Further randomized controlled trials are warranted to establish preventive benefits.

12. Conclusion

Magnesium is a fundamental micronutrient essential for metabolic stability, neuromuscular regulation, cardiovascular integrity and skeletal health across the lifespan. Deficiency remains underrecognized yet contributes significantly to pediatric growth disorders, asthma severity, insulin resistance and cardiovascular disease. Routine dietary assessment and clinical vigilance are necessary to identify and correct deficiency. Recognizing magnesium as a modifiable risk factor may enhance preventive and therapeutic strategies in modern medical practice.

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