NIH Office of Dietary Supplements

Magnesium

Fact Sheet for Health Professionals

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Introduction

Magnesium, an abundant mineral in the body, is naturally present in many foods, added to other food products, available as a dietary supplement, and present in some medicines (such as antacids and laxatives). Magnesium is a cofactor in more than 300 enzyme systems that regulate diverse biochemical reactions in the body, including protein synthesis, muscle and nerve function, blood glucose control, and blood pressure regulation [1-3]. Magnesium is required for energy production, oxidative phosphorylation, and glycolysis. It contributes to the structural development of bone and is required for the synthesis of DNA, RNA, and the antioxidant glutathione. Magnesium also plays a role in the active transport of calcium and potassium ions across cell membranes, a process that is important to nerve impulse conduction, muscle contraction, and normal heart rhythm [3].

An adult body contains approximately 25 g magnesium, with 50% to 60% present in the bones and most of the rest in soft tissues [4]. Less than 1% of total magnesium is in blood serum, and these levels are kept under tight control. Normal serum magnesium concentrations range between 0.75 and 0.95 millimoles (mmol)/L [1,5]. Hypomagnesemia is defined as a serum magnesium level less than 0.75 mmol/L [6]. Magnesium homeostasis is largely controlled by the kidney, which typically excretes about 120 mg magnesium into the urine each day [2]. Urinary excretion is reduced when magnesium status is low [1].

Assessing magnesium status is difficult because most magnesium is inside cells or in bone [3]. The most commonly used and readily available method for assessing magnesium status is measurement of serum magnesium concentration, even though serum levels have little correlation with total body magnesium levels or concentrations in specific tissues [6]. Other methods for assessing magnesium status include measuring magnesium concentrations in erythrocytes, saliva, and urine; measuring ionized magnesium concentrations in blood, plasma, or serum; and conducting a magnesium-loading (or “tolerance”) test. No single method is considered satisfactory [7]. Some experts [4] but not others [3] consider the tolerance test (in which urinary magnesium is measured after parenteral infusion of a dose of magnesium) to be the best method to assess magnesium status in adults. To comprehensively evaluate magnesium status, both laboratory tests and a clinical assessment might be required [6].

Recommended Intakes

Intake recommendations for magnesium and other nutrients are provided in the Dietary Reference Intakes (DRIs) developed by the Food and Nutrition Board (FNB) at the Institute of Medicine of the National Academies (formerly National Academy of Sciences) [1]. DRI is the general term for a set of reference values used to plan and assess nutrient intakes of healthy people. These values, which vary by age and sex, include:

- Recommended Dietary Allowance (RDA): average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%–98%) healthy individuals.
- Adequate Intake (AI): established when evidence is insufficient to develop an RDA and is set at a level assumed to ensure nutritional adequacy.
- Estimated Average Requirement (EAR): average daily level of intake estimated to meet the requirements of 50% of healthy individuals. It is usually used to assess the adequacy of nutrient intakes in population groups but not individuals.
- Tolerable Upper Intake Level (UL): maximum daily intake unlikely to cause adverse health effects.

Table 1 lists the current RDAs for magnesium [1]. For infants from birth to 12 months, the FNB established an AI for magnesium that is equivalent to the mean intake of magnesium in healthy, breastfed infants, with added solid foods for ages 7–12 months.

Table 1: Recommended Dietary Allowances (RDAs) for Magnesium [1]

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	30 mg*	30 mg*		
7–12 months	75 mg*	75 mg*		
1–3 years	80 mg	80 mg		
4–8 years	130 mg	130 mg		
9–13 years	240 mg	240 mg		
14–18 years	410 mg	360 mg	400 mg	360 mg
19–30 years	400 mg	310 mg	350 mg	310 mg
31–50 years	420 mg	320 mg	360 mg	320 mg
51+ years	420 mg	320 mg		

*Adequate Intake (AI)

Sources of Magnesium

Food

Magnesium is widely distributed in plant and animal foods and in beverages. Green leafy vegetables, such as spinach, legumes, nuts, seeds, and whole grains, are good sources [1,3]. In general, foods containing dietary fiber provide magnesium. Magnesium is also added to some breakfast cereals and other fortified foods. Some types of food processing, such as refining grains in ways that remove the nutrient-rich germ and bran, lower magnesium content substantially [1]. Selected food sources of magnesium are listed in Table 2.

Tap, mineral, and bottled waters can also be sources of magnesium, but the amount of magnesium in water varies by source and brand (ranging from 1 mg/L to more than 120 mg/L) [8].

Approximately 30% to 40% of the dietary magnesium consumed is typically absorbed by the body [2,9].

Table 2: Selected Food Sources of Magnesium [10]

Food	Milligrams (mg) per serving	Percent DV*
Almonds, dry roasted, 1 ounce	80	20
Spinach, boiled, ½ cup	78	20
Cashews, dry roasted, 1 ounce	74	19
Peanuts, oil roasted, ¼ cup	63	16
Cereal, shredded wheat, 2 large biscuits	61	15
Soymilk, plain or vanilla, 1 cup	61	15
Black beans, cooked, ½ cup	60	15
Edamame, shelled, cooked, ½ cup	50	13
Peanut butter, smooth, 2 tablespoons	49	12
Bread, whole wheat, 2 slices	46	12
Avocado, cubed, 1 cup	44	11
Potato, baked with skin, 3.5 ounces	43	11
Rice, brown, cooked, ½ cup	42	11
Yogurt, plain, low fat, 8 ounces	42	11
Breakfast cereals, fortified with 10% of the DV for magnesium	40	10
Oatmeal, instant, 1 packet	36	9
Kidney beans, canned, ½ cup	35	9
Banana, 1 medium	32	8
Salmon, Atlantic, farmed, cooked, 3 ounces	26	7

Food	Milligrams (mg) per serving	Percent DV*
Milk, 1 cup	24–27	6–7
Halibut, cooked, 3 ounces	24	6
Raisins, ½ cup	23	6
Chicken breast, roasted, 3 ounces	22	6
Beef, ground, 90% lean, pan broiled, 3 ounces	20	5
Broccoli, chopped and cooked, ½ cup	12	3
Rice, white, cooked, ½ cup	10	3
Apple, 1 medium	9	2
Carrot, raw, 1 medium	7	2

*DV = Daily Value. DVs were developed by the U.S. Food and Drug Administration (FDA) to help consumers compare the nutrient contents of products within the context of a total diet. The DV for magnesium is 400 mg for adults and children aged 4 and older. However, the FDA does not require food labels to list magnesium content unless a food has been fortified with this nutrient. Foods providing 20% or more of the DV are considered to be high sources of a nutrient.

The U.S. Department of Agriculture's (USDA's) Nutrient Database Web site [10] lists the nutrient content of many foods and provides comprehensive list of foods containing magnesium arranged by nutrient content and by food name.

Dietary supplements

Magnesium supplements are available in a variety of forms, including magnesium oxide, citrate, and chloride [2,3]. The Supplement Facts panel on a dietary supplement label declares the amount of *elemental* magnesium in the product, not the weight of the entire magnesium-containing compound.

Absorption of magnesium from different kinds of magnesium supplements varies. Forms of magnesium that dissolve well in liquid are more completely absorbed in the gut than less soluble forms [2,11]. Small studies have found that magnesium in the aspartate, citrate, lactate, and chloride forms is absorbed more completely and is more bioavailable than magnesium oxide and magnesium sulfate [11-15]. One study found that very high doses of zinc from supplements (142 mg/day) can interfere with magnesium absorption and disrupt the magnesium balance in the body [16].

Medicines

Magnesium is a primary ingredient in some laxatives [17]. Phillips' Milk of Magnesia®, for example, provides 500 mg elemental magnesium (as magnesium hydroxide) per tablespoon; the directions advise taking up to 4 tablespoons/day for adolescents and adults [18]. (Although such a dose of magnesium is well above the safe upper level, some of the magnesium is not absorbed because of the medication's laxative effect.) Magnesium is also included in some remedies for heartburn and upset stomach due to acid indigestion [17]. Extra-strength Rolaids®, for example, provides 55 mg elemental magnesium (as magnesium hydroxide) per tablet [19], although Tums® is magnesium free [20].

Magnesium Intakes and Status

Dietary surveys of people in the United States consistently show that intakes of magnesium are lower than recommended amounts. An analysis of data from the National Health and Nutrition Examination Survey (NHANES) of 2005–2006 found that a majority of Americans of all ages ingest less magnesium from food than their respective EARs; adult men aged 71 years and older and adolescent females are most likely to have low intakes [21]. In a study using data from NHANES 2003–2006 to assess mineral intakes among adults, average intakes of magnesium from food alone were higher among users of dietary supplements (350 mg for men and 267 mg for women, equal to or slightly exceeding their respective EARs) than among nonusers (268 mg for men and 234 for women) [22]. When supplements were included, average total intakes of magnesium were 449 mg for men and 387 mg for women, well above EAR levels.

No current data on magnesium status in the United States are available. Determining dietary intake of magnesium is the usual proxy for assessing magnesium status. NHANES has not determined serum magnesium levels in its participants since 1974 [23], and magnesium is not evaluated in routine electrolyte testing in hospitals and clinics [2].

Magnesium Deficiency

Symptomatic magnesium deficiency due to low dietary intake in otherwise-healthy people is uncommon because the kidneys limit urinary excretion of this mineral [3]. However, habitually low intakes or excessive losses of magnesium due to certain health conditions, chronic alcoholism, and/or the use of certain medications can lead to magnesium deficiency.

Early signs of magnesium deficiency include loss of appetite, nausea, vomiting, fatigue, and weakness. As magnesium deficiency worsens, numbness, tingling, muscle contractions and cramps, seizures, personality changes, abnormal heart rhythms, and coronary spasms can occur [1,2]. Severe magnesium deficiency can result in hypocalcemia or hypokalemia (low serum calcium or potassium levels, respectively) because mineral homeostasis is disrupted [2].

Groups at Risk of Magnesium Inadequacy

Magnesium inadequacy can occur when intakes fall below the RDA but are above the amount required to prevent overt deficiency. The following groups are more likely than others to be at risk of magnesium inadequacy because they typically consume insufficient amounts or they have medical conditions (or take medications) that reduce magnesium absorption from the gut or increase losses from the body.

People with gastrointestinal diseases

The chronic diarrhea and fat malabsorption resulting from Crohn's disease, gluten-sensitive enteropathy (celiac disease), and regional enteritis can lead to magnesium depletion over time [2]. Resection or bypass of the small intestine, especially the ileum, typically leads to malabsorption and magnesium loss [2].

People with type 2 diabetes

Magnesium deficits and increased urinary magnesium excretion can occur in people with insulin resistance and/or type 2 diabetes [24,25]. The magnesium loss appears to be secondary to higher concentrations of glucose in the kidney that increase urine output [2].

People with alcohol dependence

Magnesium deficiency is common in people with chronic alcoholism [2]. In these individuals, poor dietary intake and nutritional status; gastrointestinal problems, including vomiting, diarrhea, and steatorrhea (fatty stools) resulting from pancreatitis; renal dysfunction with excess excretion of magnesium into the urine; phosphate depletion; vitamin D deficiency; acute alcoholic ketoacidosis; and hyperaldosteronism secondary to liver disease can all contribute to decreased magnesium status [2,26].

Older adults

Older adults have lower dietary intakes of magnesium than younger adults [20,27]. In addition, magnesium absorption from the gut decreases and renal magnesium excretion increases with age [28]. Older adults are also more likely to have chronic diseases or take medications that alter magnesium status, which can increase their risk of magnesium depletion [1,29].

Magnesium and Health

Habitually low intakes of magnesium induce changes in biochemical pathways that can increase the risk of illness over time. This section focuses on four diseases and disorders in which magnesium might be involved: hypertension and cardiovascular disease, type 2 diabetes, osteoporosis, and migraine headaches.

Hypertension and cardiovascular disease

Hypertension is a major risk factor for heart disease and stroke. Studies to date, however, have found that magnesium supplementation lowers blood pressure, at best, to only a small extent. A meta-analysis of 12 clinical trials found that magnesium supplementation for 8–26 weeks in 545 hypertensive participants resulted in only a small reduction (2.2 mmHg) in diastolic blood pressure [30]. The dose of magnesium ranged from approximately 243 to 973 mg/day. The authors of another meta-analysis of 22 studies with 1,173 normotensive and hypertensive adults concluded that magnesium supplementation for 3–24 weeks decreased systolic blood pressure by 3–4 mmHg and diastolic blood pressure by 2–3 mmHg [31]. The effects were somewhat larger when supplemental magnesium intakes of the participants in the nine crossover-design trials exceeded 370 mg/day. A diet containing more magnesium because of added fruits and vegetables, more low-fat or non-fat dairy products, and less fat overall was shown to lower systolic and diastolic blood pressure by an average of 5.5 and 3.0 mmHg, respectively [32]. However, this Dietary Approaches to Stop Hypertension (DASH) diet also increases intakes of other nutrients, such as potassium and calcium, that are associated with reductions in blood pressure, so any independent contribution of magnesium cannot be determined.

Several prospective studies have examined associations between magnesium intakes and heart disease. The Atherosclerosis Risk in Communities study assessed heart disease risk factors and levels of serum magnesium in a cohort of 14,232 white and African-American men and women aged 45 to 64 years at baseline [33]. Over an average of 12 years of follow-up, individuals in the highest quartile of the normal physiologic range of serum magnesium (at least 0.88 mmol/L) had a 38% reduced risk of sudden cardiac death compared with individuals in the lowest quartile (0.75 mmol/L or less). However, dietary magnesium intakes had no association with risk of sudden cardiac death. Another prospective study tracked 88,375 female nurses in the United States to determine whether serum magnesium levels measured early in the study and magnesium intakes from food and supplements assessed every 2 to 4 years were associated with sudden cardiac death over 26 years of follow-up [34]. Women in the highest compared with the lowest quartile of ingested and plasma magnesium concentrations had a 34% and 77% lower risk of sudden cardiac death, respectively. Another prospective population study of 7,664 adults aged 20 to 75 years in the Netherlands who did not have cardiovascular disease found that low urinary magnesium excretion levels (a marker for low dietary magnesium intake) were associated with a higher risk of ischemic heart disease over a median follow-up period of 10.5 years. Plasma magnesium concentrations were not associated with risk of ischemic heart disease [35]. A systematic review and meta-analysis of prospective studies found that higher serum levels of magnesium were significantly associated with a lower risk of cardiovascular disease, and higher dietary magnesium intakes (up to approximately 250 mg/day) were associated with a significantly lower risk of ischemic heart disease caused by a reduced blood supply to the heart muscle [36].

Higher magnesium intakes might reduce the risk of stroke. In a meta-analysis of 7 prospective trials with a total of 241,378 participants, an additional 100 mg/day magnesium in the diet was associated with an 8% decreased risk of total stroke, especially ischemic rather than hemorrhagic stroke [37]. One limitation of such observational studies, however, is the possibility of confounding with other nutrients or dietary components that could also affect the risk of stroke.

A large, well-designed clinical trial is needed to better understand the contributions of magnesium from food and dietary supplements to heart health and the primary prevention of cardiovascular disease [38].

Type 2 diabetes

Diets with higher amounts of magnesium are associated with a significantly lower risk of diabetes, possibly because of the important role of magnesium in glucose metabolism [39,40]. Hypomagnesemia might worsen insulin resistance, a condition that often precedes diabetes, or it might be a consequence of insulin resistance [41]. Diabetes leads to increased urinary losses of magnesium, and the subsequent magnesium inadequacy might impair insulin secretion and action, thereby worsening diabetes control [3].

Most investigations of magnesium intake and risk of type 2 diabetes have been prospective cohort studies. A meta-analysis of 7 of these studies, which included 286,668 patients and 10,912 cases of diabetes over 6 to 17 years of follow-up, found that a 100 mg/day increase in total magnesium intake decreased the risk of diabetes by a statistically significant 15% [39]. Another meta-analysis of 8 prospective cohort studies that followed 271,869 men and women over 4 to 18 years found a significant inverse association between magnesium intake from food and risk of type 2 diabetes; the relative risk reduction was 23% when the highest to lowest intakes were compared [42].

A 2011 meta-analysis of prospective cohort studies of the association between magnesium intake and risk of type 2 diabetes included 13 studies with a total of 536,318 participants and 24,516 cases of diabetes [43]. The mean length of follow-up ranged from 4 to 20 years. Investigators found an inverse association between magnesium intake and risk of type 2 diabetes in a dose-responsive fashion, but this association achieved statistical significance only in overweight (body mass index [BMI] 25 or higher) but not normal-weight individuals (BMI less than 25). Again, a limitation of these observational studies is the possibility of confounding with other dietary components or lifestyle or environmental variables that are correlated with magnesium intake.

Only a few small, short-term clinical trials have examined the potential effects of supplemental magnesium on control of type 2 diabetes and the results are conflicting [40,44]. For example, 128 patients with poorly controlled diabetes in a Brazilian clinical trial received a placebo or a supplement containing either 500 mg/day or 1,000 mg/day magnesium oxide (providing 300 or 600 mg elemental magnesium, respectively) [45]. After 30 days of supplementation, plasma, cellular, and urine magnesium levels increased in participants receiving the larger dose of the supplement, and their glycemic control improved. In another small trial in Mexico, participants with type 2 diabetes and hypomagnesemia who received a liquid supplement of magnesium chloride (providing 300 mg/day elemental magnesium) for 16 weeks showed significant reductions in fasting glucose and glycosylated hemoglobin concentrations compared with participants receiving a placebo, and their serum magnesium levels became normal [46]. In contrast, neither a supplement of magnesium aspartate (providing 369 mg/day elemental magnesium) nor a placebo taken for 3 months had any effect on glycemic control in 50 patients with type 2 diabetes who were taking insulin [47].

The American Diabetes Association states that there is insufficient evidence to support the routine use of magnesium to improve glycemic control in people with diabetes [44]. It further notes that there is no clear scientific evidence that vitamin and mineral supplementation benefits people with diabetes who do not have underlying nutritional deficiencies.

Osteoporosis

Magnesium is involved in bone formation and influences the activities of osteoblasts and osteoclasts [48]. Magnesium also affects the concentrations of both parathyroid hormone and the active form of vitamin D, which are major regulators of bone homeostasis. Several population-based studies have found positive associations between magnesium intake and bone mineral density in both men and women [49]. Other research has found that women with osteoporosis have lower serum magnesium levels than women with osteopenia and those who do not have osteoporosis or osteopenia [50]. These and other findings indicate that magnesium deficiency might be a risk factor for osteoporosis [48].

Although limited in number, studies suggest that increasing magnesium intakes from food or supplements might increase bone mineral density in postmenopausal and elderly women [1]. For example, one short-term study found that 290 mg/day elemental magnesium (as magnesium citrate) for 30 days in 20 postmenopausal women with osteoporosis suppressed bone turnover compared with placebo, suggesting that bone loss decreased [51].

Diets that provide recommended levels of magnesium enhance bone health, but further research is needed to elucidate the role of magnesium in the prevention and management of osteoporosis.

Migraine headaches

Magnesium deficiency is related to factors that promote headaches, including neurotransmitter release and vasoconstriction [52]. People who experience migraine headaches have lower levels of serum and tissue magnesium than those who do not.

However, research on the use of magnesium supplements to prevent or reduce symptoms of migraine headaches is limited. Three of four small, short-term, placebo-controlled trials found modest reductions in the frequency of migraines in patients given up to 600 mg/day magnesium [52]. The authors of a review on migraine prophylaxis suggested that taking 300 mg magnesium twice a day, either alone or in combination with medication, can prevent migraines [53].

In their evidence-based guideline update, the American Academy of Neurology and the American Headache Society concluded that magnesium therapy is “probably effective” for migraine prevention [54]. Because the typical dose of magnesium used for migraine prevention exceeds the UL, this treatment should be used only under the direction and supervision of a healthcare provider.

Health Risks from Excessive Magnesium

Too much magnesium from food does not pose a health risk in healthy individuals because the kidneys eliminate excess amounts in the urine [28]. However, high doses of magnesium from dietary supplements or medications often result in diarrhea that can be accompanied by nausea and abdominal cramping [1]. Forms of magnesium most commonly reported to cause diarrhea include magnesium carbonate, chloride, gluconate, and oxide [11]. The diarrhea and laxative effects of magnesium salts are due to the osmotic activity of unabsorbed salts in the intestine and colon and the stimulation of gastric motility [55].

Very large doses of magnesium-containing laxatives and antacids (typically providing more than 5,000 mg/day magnesium) have been associated with magnesium toxicity [56], including fatal hypermagnesemia in a 28-month-old boy [57] and an elderly man [58]. Symptoms of magnesium toxicity, which usually develop after serum concentrations exceed 1.74–2.61 mmol/L, can include hypotension, nausea, vomiting, facial flushing, retention of urine, ileus, depression, and lethargy before progressing to muscle weakness, difficulty breathing, extreme hypotension, irregular heartbeat, and cardiac arrest [28]. The risk of magnesium toxicity increases with impaired renal function or kidney failure because the ability to remove excess magnesium is reduced or lost [1,28].

The FNB has established ULs for magnesium that apply *only to supplemental* magnesium for healthy infants, children, and adults (see Table 3) [1].

Table 3: Tolerable Upper Intake Levels (ULs) for Supplemental Magnesium [1]

Age	Male	Female	Pregnant	Lactating
Birth to 12 months	None established	None established		
1–3 years	65 mg	65 mg		
4–8 years	110 mg	110 mg		
9–18 years	350 mg	350 mg	350 mg	350 mg
19+ years	350 mg	350 mg	350 mg	350 mg

Interactions with Medications

Several types of medications have the potential to interact with magnesium supplements or affect magnesium status. A few examples are provided below. People taking these and other medications on a regular basis should discuss their magnesium intakes with their healthcare providers.

Bisphosphonates

Magnesium-rich supplements or medications can decrease the absorption of oral bisphosphonates, such as alendronate (Fosamax®), used to treat osteoporosis [59]. Use of magnesium-rich supplements or medications and oral bisphosphonates should be separated by at least 2 hours [55].

Antibiotics

Magnesium can form insoluble complexes with tetracyclines, such as demeclocycline (Declomycin®) and doxycycline (Vibramycin®), as well as quinolone antibiotics, such as ciprofloxacin (Cipro®) and levofloxacin (Levaquin®). These antibiotics should be taken at least 2 hours before or 4–6 hours after a magnesium-containing supplement [55,60].

Diuretics

Chronic treatment with loop diuretics, such as furosemide (Lasix®) and bumetanide (Bumex®), and thiazide diuretics, such as hydrochlorothiazide (Aquazide H®) and ethacrynic acid (Edecrin®), can increase the loss of magnesium in urine and lead to magnesium depletion [61]. In contrast, potassium-sparing diuretics, such as amiloride (Midamor®) and spironolactone (Aldactone®), reduce magnesium excretion [61].

Proton pump inhibitors

Prescription proton pump inhibitor (PPI) drugs, such as esomeprazole magnesium (Nexium®) and lansoprazole (Prevacid®), when taken for prolonged periods (typically more than a year) can cause hypomagnesemia [62]. In cases that FDA reviewed, magnesium supplements often raised the low serum magnesium levels caused by PPIs. However, in 25% of the cases, supplements did not raise magnesium levels and the patients had to discontinue the PPI. FDA advises healthcare professionals to consider measuring patients' serum magnesium levels prior to initiating long-term PPI treatment and to check magnesium levels in these patients periodically [62].

Magnesium and Healthful Diets

The federal government's 2015-2020 *Dietary Guidelines for Americans* notes that "Nutritional needs should be met primarily from foods. … Foods in nutrient-dense forms contain essential vitamins and minerals and also dietary fiber and other naturally occurring substances that may have positive health effects. In some cases, fortified foods and dietary supplements may be useful in providing one or more nutrients that otherwise may be consumed in less-than-recommended amounts."

For more information about building a healthy diet, refer to the *Dietary Guidelines for Americans* and the U.S. Department of Agriculture's MyPlate.

The *Dietary Guidelines for Americans* describes a healthy eating pattern as one that:

- Includes a variety of vegetables, fruits, whole grains, fat-free or low-fat milk and milk products, and oils.
    Whole grains and dark-green, leafy vegetables are good sources of magnesium. Low-fat milk and yogurt contain magnesium as well. Some ready-to-eat breakfast cereals are fortified with magnesium.
- Includes a variety of protein foods, including seafood, lean meats and poultry, eggs, legumes (beans and peas), nuts, seeds, and soy products.
    Dried beans and legumes (such as soybeans, baked beans, lentils, and peanuts) and nuts (such as almonds and cashews) provide magnesium.
- Limits saturated and *trans* fats, added sugars, and sodium.
- Stays within your daily calorie needs.

References

1. Institute of Medicine (IOM). Food and Nutrition Board. Dietary Reference Intakes: Calcium, Phosphorus, Magnesium, Vitamin D and Fluoride. Washington, DC: National Academy Press, 1997.
2. Rude RK. Magnesium. In: Coates PM, Betz JM, Blackman MR, Cragg GM, Levine M, Moss J, White JD, eds. Encyclopedia of Dietary Supplements. 2nd ed. New York, NY: Informa Healthcare; 2010:527-37.
3. Rude RK. Magnesium. In: Ross AC, Caballero B, Cousins RJ, Tucker KL, Ziegler TR, eds. Modern Nutrition in Health and Disease. 11th ed. Baltimore, Mass: Lippincott Williams & Wilkins; 2012:159-75.
4. Volpe SL. Magnesium. In: Erdman JW, Macdonald IA, Zeisel SH, eds. Present Knowledge in Nutrition. 10th ed. Ames, Iowa; John Wiley & Sons, 2012:459-74.
5. Elin RJ. Assessment of magnesium status for diagnosis and therapy. Magnes Res 2010;23:1-5. [PubMed abstract]
6. Gibson, RS. Principles of Nutritional Assessment, 2nd ed. New York, NY: Oxford University Press, 2005.
7. Witkowski M, Hubert J, Mazur A. Methods of assessment of magnesium status in humans: a systematic review. Magnesium Res 2011;24:163-80. [PubMed abstract]
8. Azoulay A, Garzon P, Eisenberg MJ. Comparison of the mineral content of tap water and bottled waters. J Gen Intern Med 2001;16:168-75. [PubMed abstract]

9. Fine KD, Santa Ana CA, Porter JL, Fordtran JS. Intestinal absorption of magnesium from food and supplements. J Clin Invest 1991;88:396-402. [PubMed abstract]
10. U.S. Department of Agriculture, Agricultural Research Service. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory Home Page, 2012.
11. Ranade VV, Somberg JC. Bioavailability and pharmacokinetics of magnesium after administration of magnesium salts to humans. Am J Ther 2001;8:345-57. [PubMed abstract]
12. Firoz M, Graber M. Bioavailability of US commercial magnesium preparations. Magnes Res 2001;14:257-62. [PubMed abstract]
13. Mühlbauer B, Schwenk M, Coram WM, Antonin KH, Etienne P, Bieck PR, Douglas FL. Magnesium-L-aspartate-HCl and magnesium-oxide: bioavailability in healthy volunteers. Eur J Clin Pharmacol 1991;40:437-8. [PubMed abstract]
14. Lindberg JS, Zobitz MM, Poindexter JR, Pak CY. Magnesium bioavailability from magnesium citrate and magnesium oxide. J Am Coll Nutr 1990;9:48-55. [PubMed abstract]
15. Walker AF, Marakis G, Christie S, Byng M. Mg citrate found more bioavailable than other Mg preparations in a randomized, double-blind study. Mag Res 2003;16:183-91. [PubMed abstract]
16. Spencer H, Norris C, Williams D. Inhibitory effects of zinc on magnesium balance and magnesium absorption in man. J Am Coll Nutr 1994;13:479-84. [PubMed abstract]
17. Guerrera MP, Volpe SL, Mao JJ. Therapeutic uses of magnesium. Am Fam Physician 2009;80:157-62. [PubMed abstract]
18. Phillips'®. Phillips' Milk of Magnesia. 2012.
19. Rolaids®. 2012.
20. Tums®. 2012.
21. Moshfegh A, Goldman J, Ahuja J, Rhodes D, LaComb R. 2009. What We Eat in America, NHANES 2005-2006: Usual Nutrient Intakes from Food and Water Compared to 1997 Dietary Reference Intakes for Vitamin D, Calcium, Phosphorus, and Magnesium. U.S. Department of Agriculture, Agricultural Research Service.
22. Bailey RL, Fulgoni III VL, Keast DR, Dwyer JD. Dietary supplement use is associated with high intakes of minerals from food sources. Am J Clin Nutr 2011;94:1376-81. [PubMed abstract]
23. Rosanoff A, Weaver CM, Rude RK. Suboptimal magnesium status in the United States: are the health consequences underestimated? Nutr Rev 2012;70:153-64. [PubMed abstract]
24. Chaudhary DP, Sharma R, Bansal DD. Implications of magnesium deficiency in type 2 diabetes: a review. Biol Trace Elem Res 2010;134:119–29. [PubMed abstract]
25. Tosiello L. Hypomagnesemia and diabetes mellitus. A review of clinical implications. Arch Intern Med 1996;156:1143-8. [PubMed abstract]
26. Rivlin RS. Magnesium deficiency and alcohol intake: mechanisms, clinical significance and possible relation to cancer development (a review). J Am Coll Nutr 1994;13:416–23. [PubMed abstract]
27. Ford ES, Mokdad AH. Dietary magnesium intake in a national sample of U.S. adults. J Nutr 2003;133:2879-82. [PubMed abstract]
28. Musso CG Magnesium metabolism in health and disease. Int Urol Nephrol 2009;41:357-62. [PubMed abstract]
29. Barbagallo M, Belvedere M, Dominguez LJ. Magnesium homeostasis and aging. Magnes Res 2009;22:235-46. [PubMed abstract]
30. Dickinson HO, Nicolson D, Campbell F, Cook JV, Beyer FR, Ford GA, Mason J. Magnesium supplementation for the management of primary hypertension in adults. Cochrane Database of Systematic Reviews 2006: CD004640. [PubMed abstract]
31. Kass L, Weekes J, Carpenter L. Effect of magnesium supplementation on blood pressure: a meta-analysis. Eur J Clin Nutr 2012;66:411-8. [PubMed abstract]
32. Champagne CM. Dietary interventions on blood pressure: the Dietary Approaches to Stop Hypertension (DASH) trials. Nutr Rev 2006;64:S53-6. [PubMed abstract]
33. Peacock JM, Ohira T, Post W, Sotoodehnia N, Rosamond W, Folsom AR. Serum magnesium and risk of sudden cardiac death in the Atherosclerosis Risk in Communities (ARIC) study. Am Heart J 2010;160:464-70. [PubMed abstract]
34. Chiuve SE, Korngold EC, Januzzi Jr JL, Gantzer ML, Albert CM. Plasma and dietary magnesium and risk of sudden cardiac death in women. Am J Clin Nutr 2011;93:253-60. [PubMed abstract]
35. Joosten MM, Gansevoort RT, Mukamal KJ, van der Harst P, Geleijnse JM, Feskens EJM, Navis G, Bakker SJL. Urinary and plasma magnesium and risk of ischemic heart disease. Am J Clin Nutr 2013;97:1299-306. [PubMed abstract]
36. Del Gobbo LC, Imamura F, Wu JHY, Otto MCdO, Chiuve SE, Mozaffarian D. Circulating and dietary magnesium and risk of cardiovascular disease: a systematic review and meta-analysis of prospective studies. Am J Clin Nutr 2013;98:160-73. [PubMed abstract]
37. Larsson SC, Orsini N, Wolk A. Dietary magnesium intake and risk of stroke: a meta-analysis of prospective studies. Am J Clin Nutr 2012;95:362-6. [PubMed abstract]

38. Song Y, Liu S. Magnesium for cardiovascular health: time for intervention. Am J Clin Nutr 2012;95:269-70. [PubMed abstract]
39. Larsson SC, Wolk A. Magnesium intake and risk of type 2 diabetes: a meta-analysis. J Intern Med 2007;262:208-14. [PubMed abstract]
40. Rodriguez-Moran M, Simental Mendia LE, Zambrano Galvan G, Guerrero-Romero F. The role of magnesium in type 2 diabetes: a brief based-clinical review. Magnes Res 2011;24:156-62. [PubMed abstract]
41. Simmons D, Joshi S, Shaw J. Hypomagnesaemia is associated with diabetes: not pre-diabetes, obesity or the metabolic syndrome. Diabetes Res Clin Pract 2010;87:261-6. [PubMed abstract]
42. Schulze MB, Schulz M, Heidemann C, Schienkiewitz A, Hoffmann K, Boeing H. Fiber and magnesium intake and incidence of type 2 diabetes: a prospective study and meta-analysis. Arch Intern Med 2007;167:956–65. [PubMed abstract]
43. Dong J-Y, Xun P, He K, Qin L-Q. Magnesium intake and risk of type 2 diabetes: meta-analysis of prospective cohort studies. Diabetes Care 2011;34:2116-22. [PubMed abstract]
44. Evert AB, Boucher JL, Cypress M, Dunbar SA, Franz MJ, Mayer-Davis EJ, Neumiller JJ, Nwankwo R, Verdi CL, Urbanski P, Yancy WS Jr. Nutrition therapy recommendations for the management of adults with diabetes. Diabetes Care 2013;36:3821-42. [PubMed abstract]
45. Lima MDL, Cruz T, Pousada JC, Rodrigues LE, Barbosa K, Canguco V. The effect of magnesium supplementation in increasing doses on the control of type 2 diabetes. Diabetes Care 1998;21:682-6. [PubMed abstract]
46. Rodriquez-Moran M, Guerrero-Romero F. Oral magnesium supplementation improves insulin sensitivity and metabolic control in type 2 diabetic subjects: a randomized double-blind controlled trial. Diabetes Care 2003;26:1147-52. [PubMed abstract]
47. de Valk HW, Verkaaik R, van Rijn HJ, Geerdink RA, Struyvenberg A. Oral magnesium supplementation in insulin-requiring Type 2 diabetic patients. Diabet Med 1998;15:503-7 [PubMed abstract]
48. Rude RK, Singer FR, Gruber HE. Skeletal and hormonal effects of magnesium deficiency. J Am Coll Nutr 2009;28:131–41. [PubMed abstract]
49. Tucker KL. Osteoporosis prevention and nutrition. Curr Osteoporos Rep 2009;7:111-7. [PubMed abstract]
50. Mutlu M, Argun M, Kilic E, Saraymen R, Yazar S. Magnesium, zinc and copper status in osteoporotic, osteopenic and normal post-menopausal women. J Int Med Res 2007;35:692-5. [PubMed abstract]
51. Aydin H, Deyneli O, Yavuz D, Gözü H, Mutlu N, Kaygusuz I, Akalin S. Short-term oral magnesium supplementation suppresses bone turnover in postmenopausal osteoporotic women. Biol Trace Elem Res 2010;133:136-43. [PubMed abstract]
52. Sun-Edelstein C, Mauskop A. Role of magnesium in the pathogenesis and treatment of migraine. Expert Rev Neurother 2009;9:369–79 [PubMed abstract]
53. Schürks M, Diener H-C, Goadsby P. Update on the prophylaxis of migraine. Cur Treat Options Neurol 2008;10:20–9. [PubMed abstract]
54. Holland S, Silberstein SD, Freitag F, Dodick DW, Argoff C, Ashman E. Evidence-based guideline update: NSAIDs and other complementary treatments for episodic migraine prevention in adults. Neurology 2012;78:1346-53. [PubMed abstract]
55. Natural Medicines Comprehensive Database. Magnesium. 2013.
56. Kutsal E, Aydemir C, Eldes N, Demirel F, Polat R, Taspnar O, Kulah E. Severe hypermagnesemia as a result of excessive cathartic ingestion in a child without renal failure. Pediatr Emerg Care 2007;23:570-2. [PubMed abstract]
57. McGuire JK, Kulkarni MS, Baden HP. Fatal hypermagnesemia in a child treated with megavitamin/megamineral therapy. Pediatrics 2000;105:E18. [PubMed abstract]
58. Onishi S, Yoshino S. Cathartic-induced fatal hypermagnesemia in the elderly. Intern Med 2006;45:207-10. [PubMed abstract]
59. Dunn CJ, Goa KL. Risedronate: A review of its pharmacological properties and clinical use in resorptive bone disease. Drugs 2001;61:685-712. [PubMed abstract]
60. Arayne MS, Sultana N, Hussain F. Interactions between ciprofloxacin and antacids–dissolution and adsorption studies. Drug Metabol Drug Interact 2005;21:117-29. [PubMed abstract]
61. Sarafidis PA, Georgianos PI, Lasaridis AN. Diuretics in clinical practice. Part II: electrolyte and acid-base disorders complicating diuretic therapy. Expert Opin Drug Saf 2010;9:259-73. [PubMed abstract]
62. U.S. Food and Drug Administration. Proton Pump Inhibitor Drugs (Ppis): Drug Safety Communication—Low Magnesium Levels Can Be Associated With Long-Term Use. March 2, 2011.

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Updated: February 11, 2016