Dietary Minerals

Goals and Objectives

Course Description
“Dietary Minerals” is an online continuing education course for physical therapists and physical therapist assistants. This course presents current information about essential dietary minerals including sections on recommended dietary guidelines, food sources, effects of deficiencies, supplementation, up-to-date published research findings, and toxicity.

Course Rationale
The purpose of this course is to present therapists and assistants with current information about many of the essential dietary minerals and the roles they play in disease, health maintenance, and prophylaxis. Both therapists and assistants will find this information pertinent and useful when providing care for individuals, who have, or are at risk for having, a compromised nutritional status.

Course Goals and Objectives
Upon completion of this course, the therapist or assistant will be able to
1. recognize the specific physiologic function of each of the common dietary minerals
2. identify several food sources that provide high levels of each of the discussed dietary minerals
3. recognize the health risks, conditions, and symptomology associated with mineral deficiencies
4. differentiate the various supplemental forms of each of the dietary minerals
5. recognize the role dietary minerals play in human disease process, health maintenance, and prophylaxis.
6. identify and review current research data and information about essential dietary minerals.
7. identify health risks, conditions, and symptomology associated with mineral toxicity

Course Provider – Innovative Educational Services

Course Instructor - Michael Niss, DPT

Target Audience – Physical therapists and physical therapist assistants

Course Educational Level - This course is applicable for introductory learners.

Course Prerequisites – None

Method of Instruction/Availability – Online text-based course available continuously.

Criteria for issuance of CE Credits - A score of 70% or greater on the course post-test.

Continuing Education Credits - Five (5) hours of continuing education credit
## Dietary Minerals

### Course Outline

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Calcium

Overview

Calcium, the most abundant mineral in the body, is found in some foods, added to others, available as a dietary supplement, and present in some medicines (such as antacids). Calcium is required for vascular contraction and vasodilation, muscle function, nerve transmission, intracellular signaling and hormonal secretion, though less than 1% of total body calcium is needed to support these critical metabolic functions. Serum calcium is very tightly regulated and does not fluctuate with changes in dietary intakes; the body uses bone tissue as a reservoir for, and source of calcium, to maintain constant concentrations of calcium in blood, muscle, and intercellular fluids.

The remaining 99% of the body’s calcium supply is stored in the bones and teeth where it supports their structure and function. Bone itself undergoes continuous remodeling, with constant resorption and deposition of calcium into new bone. The balance between bone resorption and deposition changes with age. Bone formation exceeds resorption in periods of growth in children and adolescents, whereas in early and middle adulthood both processes are relatively equal. In aging adults, particularly among postmenopausal women, bone breakdown exceeds formation, resulting in bone loss that increases the risk of osteoporosis over time.

Recommended Intakes

Intake recommendations for calcium 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). DRI is the general term for a set of reference values used for planning and assessing the nutrient intakes of healthy people. These values, which vary by age and gender, 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.
- Tolerable Upper Intake Level (UL): maximum daily intake unlikely to cause adverse health effects.

The FNB established RDAs for the amounts of calcium required for bone health and to maintain adequate rates of calcium retention in healthy people.
**DIETARY MINERALS**

<table>
<thead>
<tr>
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<th>Female</th>
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<th>Lactating</th>
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<tr>
<td>0–6 months*</td>
<td>200 mg</td>
<td>200 mg</td>
<td></td>
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<tr>
<td>7–12 months*</td>
<td>260 mg</td>
<td>260 mg</td>
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<tr>
<td>1–3 years</td>
<td>700 mg</td>
<td>700 mg</td>
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<tr>
<td>4–8 years</td>
<td>1,000 mg</td>
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<tr>
<td>9–13 years</td>
<td>1,300 mg</td>
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<tr>
<td>14–18 years</td>
<td>1,300 mg</td>
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<tr>
<td>19–50 years</td>
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<tr>
<td>51–70 years</td>
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<tr>
<td>71+ years</td>
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* Adequate Intake (AI)

**Sources of Calcium**

**Food**
Milk, yogurt, and cheese are rich natural sources of calcium and are the major food contributors of this nutrient to people in the United States. Nondairy sources include vegetables, such as Chinese cabbage, kale, and broccoli. Spinach provides calcium, but its bioavailability is poor. Most grains do not have high amounts of calcium unless they are fortified; however, they contribute calcium to the diet because they contain small amounts of calcium and people consume them frequently. Foods fortified with calcium include many fruit juices and drinks, tofu, and cereals.

In its food guidance system, MyPlate, the U.S. Department of Agriculture recommends that persons aged 9 years and older eat 3 cups of foods from the milk group per day. A cup is equal to 1 cup (8 ounces) of milk, 1 cup of yogurt, 1.5 ounces of natural cheese (such as Cheddar), or 2 ounces of processed cheese (such as American).

**Dietary Supplements**
The two main forms of calcium in supplements are carbonate and citrate. Calcium carbonate is more commonly available and is both inexpensive and convenient. Due to its dependence on stomach acid for absorption, calcium carbonate is absorbed most efficiently when taken with food, whereas calcium citrate is absorbed equally well when taken with or without food. Calcium citrate is also useful for people with achlorhydria, inflammatory bowel disease, or absorption disorders. Other calcium forms in supplements or fortified foods include gluconate, lactate, and phosphate. Calcium citrate malate is a well-absorbed form of calcium found in some fortified juices.

Innovative Educational Services
To take the post-test for CE credit, go to: WWW.CHEAPCEUS.COM
Calcium supplements contain varying amounts of elemental calcium. For example, calcium carbonate is 40% calcium by weight, whereas calcium citrate is 21% calcium. Fortunately, elemental calcium is listed in the Supplement Facts panel, so consumers do not need to calculate the amount of calcium supplied by various forms of calcium supplements.

The percentage of calcium absorbed depends on the total amount of elemental calcium consumed at one time; as the amount increases, the percentage absorption decreases. Absorption is highest in doses ≤500 mg. So, for example, one who takes 1,000 mg/day of calcium from supplements might split the dose and take 500 mg at two separate times during the day.

Some individuals who take calcium supplements might experience gastrointestinal side effects including gas, bloating, constipation, or a combination of these symptoms. Calcium carbonate appears to cause more of these side effects than calcium citrate, so consideration of the form of calcium supplement is warranted if these side effects are reported. Other strategies to alleviate symptoms include spreading out the calcium dose throughout the day and/or taking the supplement with meals.

**Medicines**

Because of its ability to neutralize stomach acid, calcium carbonate is found in some over-the-counter antacid products, such as Tums® and Rolaids®. Depending on its strength, each chewable pill or softchew provides 200 to 400 mg of elemental calcium. As noted above, calcium carbonate is an acceptable form of supplemental calcium, especially for individuals who have normal levels of stomach acid.

**Calcium Intake**

In the United States, estimated calcium intakes from both food and dietary supplements are provided by the National Health and Nutrition Examination Survey (NHANES). Mean calcium intake levels for males ranged from 871 to 1,266 mg/day depending on life stage group; for females the range was 748 to 968 mg/day. Groups falling below desirable intakes include girls aged 9–13 years and 14–18 years, women aged 51–70 years, and both men and women older than 70 years. Overall, females are less likely than males to get recommended intakes of calcium from food.

About 43% of the U.S. population (including almost 70% of older women) use dietary supplements containing calcium, increasing calcium intakes by about 330 mg/day among supplement users. According to NHANES data, mean total calcium intakes from foods and supplements range from 918 to 1,296 mg/day for people aged 1 year and older. When considering total calcium intakes, only adolescent girls still fall short of achieving recommended intakes, and some older women likely exceed the UL.
Not all calcium consumed is actually absorbed in the gut. Humans absorb about 30% of the calcium in foods, but this varies depending upon the type of food consumed. Other factors also affect calcium absorption including the following:

- **Amount consumed:** the efficiency of absorption decreases as calcium intake increases.
- **Age and life stage:** net calcium absorption is as high as 60% in infants and young children, who need substantial amounts of the mineral to build bone. Absorption decreases to 15%–20% in adulthood (though it is increased during pregnancy) and continues to decrease as people age; compared with younger adults, recommended calcium intakes are higher for females older than 50 years and for both males and females older than 70 years.
- **Vitamin D intake:** this nutrient, obtained from food and produced by skin when exposed to sunlight of sufficient intensity, improves calcium absorption.
- **Other components in food:** phytic acid and oxalic acid, found naturally in some plants, bind to calcium and can inhibit its absorption. Foods with high levels of oxalic acid include spinach, collard greens, sweet potatoes, rhubarb, and beans. Among the foods high in phytic acid are fiber-containing whole-grain products and wheat bran, beans, seeds, nuts, and soy isolates. The extent to which these compounds affect calcium absorption varies. Research shows, for example, that eating spinach and milk at the same time reduces absorption of the calcium in milk. In contrast, wheat products (with the exception of wheat bran) do not appear to lower calcium absorption. For people who eat a variety of foods, these interactions probably have little or no nutritional consequence and, furthermore, are accounted for in the overall calcium DRIs, which factor in differences in absorption of calcium in mixed diets.

Some absorbed calcium is eliminated from the body in urine, feces, and sweat. This amount is affected by such factors as the following:

- **Sodium and protein intakes:** high sodium intake increases urinary calcium excretion. High protein intake also increases calcium excretion and was therefore thought to negatively affect calcium status. However, more recent research suggests that high protein intake also increases intestinal calcium absorption, effectively offsetting its effect on calcium excretion, so whole body calcium retention remains unchanged.
- **Caffeine intake:** this stimulant in coffee and tea can modestly increase calcium excretion and reduce absorption. One cup of regular brewed coffee, for example, causes a loss of only 2–3 mg of calcium. Moderate caffeine consumption (1 cup of coffee or 2 cups of tea per day) in young women has no negative effects on bone.
• Alcohol intake: alcohol intake can affect calcium status by reducing its absorption and by inhibiting enzymes in the liver that help convert vitamin D to its active form. However, the amount of alcohol required to affect calcium status and whether moderate alcohol consumption is helpful or harmful to bone is unknown.

• Phosphorus intake: the effect of this mineral on calcium excretion is minimal. Several observational studies suggest that consumption of carbonated soft drinks with high levels of phosphate is associated with reduced bone mass and increased fracture risk. However, the effect is probably due to replacing milk with soda rather than the phosphorus itself.

• Fruit and vegetable intakes: metabolic acids produced by diets high in protein and cereal grains increase calcium excretion. Fruits and vegetables, when metabolized, shift the acid/base balance of the body towards the alkaline by producing bicarbonate, which reduces calcium excretion. However, it is unclear if consuming more fruits and vegetables affects bone mineral density. These foods, in addition to reducing calcium excretion, could possibly reduce calcium absorption from the gut and therefore have no net effect on calcium balance.

Calcium Deficiency

Inadequate intakes of dietary calcium from food and supplements produce no obvious symptoms in the short term. Circulating blood levels of calcium are tightly regulated. Hypocalcemia results primarily from medical problems or treatments, including renal failure, surgical removal of the stomach, and use of certain medications (such as diuretics). Symptoms of hypocalcemia include numbness and tingling in the fingers, muscle cramps, convulsions, lethargy, poor appetite, and abnormal heart rhythms. If left untreated, calcium deficiency leads to death.

Over the long term, inadequate calcium intake causes osteopenia which if untreated can lead to osteoporosis. The risk of bone fractures also increases, especially in older individuals. Calcium deficiency can also cause rickets, though it is more commonly associated with vitamin D deficiency.

Groups at Risk

Although frank calcium deficiency is uncommon, dietary intakes of the nutrient below recommended levels might have negative health consequences over the long term. The following groups are among those most likely to need extra calcium.

Postmenopausal women
Menopause leads to bone loss because decreases in estrogen production both increase bone resorption and decrease calcium absorption. Annual decreases in bone mass of 3%–5% per year frequently occur in the first years of menopause,
but the decreases are typically less than 1% per year after age. Increased calcium intakes during menopause do not completely offset this bone loss. Hormone replacement therapy (HRT) with estrogen and progesterone helps increase calcium levels and prevent osteoporosis and fractures. Estrogen therapy restores postmenopausal bone remodeling to the same levels as at premenopause, leading to lower rates of bone loss, perhaps in part by increasing calcium absorption in the gut. However, because of the potential health risks associated with HRT use, several medical groups and professional societies recommend that postmenopausal women consider using medications, such as bisphosphonates, instead of HRT to prevent or treat osteoporosis. In addition, consuming adequate amounts of calcium in the diet might help slow the rate of bone loss in all women.

**Amenorrheic Women and the Female Athlete Triad**

Amenorrhea, the condition in which menstrual periods stop or fail to initiate in women of childbearing age, results from reduced circulating estrogen levels that, in turn, have a negative effect on calcium balance. Amenorrheic women with anorexia nervosa have decreased calcium absorption and higher urinary calcium excretion rates, as well as a lower rate of bone formation than healthy women.

The "female athlete triad" refers to the combination of disordered eating, amenorrhea, and osteoporosis. Exercise-induced amenorrhea generally results in decreased bone mass. In female athletes and active women in the military, low bone-mineral density, menstrual irregularities, certain dietary patterns, and a history of prior stress fractures are associated with an increased risk of future stress fractures. Such women should be advised to consume adequate amounts of calcium and vitamin D. Supplements of these nutrients have been shown to reduce the risk of stress fractures in female Navy recruits during basic training.

**Individuals with Lactose Intolerance**

Lactose intolerance refers to symptoms (such as bloating, flatulence, and diarrhea) that occur when one consumes more lactose, the naturally occurring sugar in milk, than the enzyme lactase produced by the small intestine can hydrolyze into its component monosaccharides, glucose and galactose. The symptoms vary, depending on the amount of lactose consumed, history of consumption of lactose-containing foods, and type of meal. Although the prevalence of lactose intolerance is difficult to discern, some reports suggest that approximately 25% of U.S. adults have a limited ability to digest lactose, including 85% of Asians, 50% of African Americans, and 10% of Caucasians.

Lactose-intolerant individuals are at risk of calcium inadequacy if they avoid dairy products. Research suggests that most people with lactose intolerance can consume up to 12 grams of lactose, such as that present in 8 ounces of milk, with minimal or no symptoms, especially if consumed with other foods; larger amounts can frequently be consumed if spread over the day and eaten with other foods. Other options to reduce symptoms include eating low-lactose dairy
products including aged cheeses (such as Cheddar and Swiss), yogurt, or lactose-reduced or lactose-free milk. Some studies have examined whether it is possible to induce adaptation by consuming incremental lactose loads over a period of time, but the evidence in support of this strategy is inconsistent.

Cow's milk allergy is less common than lactose intolerance, affecting 0.6% to 0.9% of the population. People with this condition are unable to consume any products containing cow's milk proteins and are therefore at higher risk of obtaining insufficient calcium.

To ensure adequate calcium intakes, lactose-intolerant individuals and those with cow's milk allergy can choose nondairy food sources of the nutrient (such as kale, bok choy, Chinese cabbage, broccoli, collards and fortified foods) or take a calcium supplement.

Vegetarians
Vegetarians might absorb less calcium than omnivores because they consume more plant products containing oxalic and phytic acids. Lacto-ovo vegetarians (who consume eggs and dairy) and nonvegetarians have similar calcium intakes. However, vegans, who eat no animal products and ovo-vegetarians (who eat eggs but no dairy products), might not obtain sufficient calcium because of their avoidance of dairy foods. In the Oxford cohort of the European Prospective Investigation into Cancer and Nutrition, bone fracture risk was similar in meat eaters, fish eaters and vegetarians, but higher in vegans, likely due to their lower mean calcium intake. It is difficult to assess the impact of vegetarian diets on calcium status because of the wide variety of eating practices and thus should be considered on a case by case basis.

Calcium and Health

Many claims are made about calcium's potential benefits in health promotion and disease prevention and treatment. Several areas in which calcium is or might be involved: bone health and osteoporosis; cardiovascular disease; blood pressure regulation and hypertension; cancers of the colon, rectum, and prostate; kidney stones; and weight management.

Bone Health and Osteoporosis
Bones increase in size and mass during periods of growth in childhood and adolescence, reaching peak bone mass around age 30. The greater the peak bone mass, the longer one can delay serious bone loss with increasing age. Everyone should therefore consume adequate amounts of calcium and vitamin D throughout childhood, adolescence, and early adulthood. Osteoporosis, a disorder characterized by porous and fragile bones, is a serious public health problem for more than 10 million U.S. adults, 80% of whom are women. (Another 34 million have osteopenia, or low bone mass, which precedes osteoporosis.) Osteoporosis is most associated with fractures of the hip, vertebrae, wrist, pelvis,
ribs, and other bones. An estimated 1.5 million fractures occur each year in the United States due to osteoporosis. Supplementation with calcium plus vitamin D has been shown to be effective in reducing fractures and falls (which can cause fractures) in institutionalized older adults.

When calcium intake is low or ingested calcium is poorly absorbed, bone breakdown occurs as the body uses its stored calcium to maintain normal biological functions. Bone loss also occurs as part of the normal aging process, particularly in postmenopausal women due to decreased amounts of estrogen. Many factors increase the risk of developing osteoporosis, including being female, thin, inactive, or of advanced age; smoking cigarettes; drinking excessive amounts of alcohol; and having a family history of osteoporosis.

Various bone mineral density (BMD) tests are available. The T-score from these tests compares an individual's BMD to an optimal BMD (that of a healthy 30-year old adult). A T-score of -1.0 or above indicates normal bone density, -1.0 to -2.5 indicates low bone mass (osteopenia), and lower than -2.5 indicates osteoporosis. Although osteoporosis affects individuals of all races, ethnicities, and both genders, women are at highest risk because their skeletons are smaller than those of men and because of the accelerated bone loss that accompanies menopause. Regular exercise and adequate intakes of calcium and vitamin D are critical to the development and maintenance of healthy bones throughout the life cycle. Both weight-bearing exercises (such as walking, running, and activities where one's feet leave and hit the ground and work against gravity) and resistance exercises (such as calisthenics and that involve weights) support bone health.

In 1993, the U.S. Food and Drug Administration authorized a health claim related to calcium and osteoporosis for foods and supplements. In January 2010, this health claim was expanded to include vitamin D. Model health claims include the following: "Adequate calcium throughout life, as part of a well-balanced diet, may reduce the risk of osteoporosis" and "Adequate calcium and vitamin D as part of a healthful diet, along with physical activity, may reduce the risk of osteoporosis in later life".

**Cardiovascular Disease**

Calcium has been proposed to help reduce cardiovascular disease risk by decreasing intestinal absorption of lipids, increasing lipid excretion, lowering cholesterol levels in the blood, and promoting calcium influx into cells. In the Iowa Women's Health Study, higher calcium intake was associated with reduced ischemic heart disease mortality in postmenopausal women. But results from other prospective studies have shown no significant associations between calcium intake and cardiac events or cardiovascular mortality. Data for stroke are mixed, with some studies linking higher calcium intakes with lower risk of stroke, while others have found no associations or trends in the opposite direction. A 2010 systematic review of 17 prospective studies and randomized trials found no
increased risk of cardiovascular disease from calcium supplements with or without vitamin D among adults.

A controversial 2010 meta-analysis and a subsequent reanalysis of data from the Women's Health Initiative (WHI) raised questions about the safety of calcium supplements with respect to cardiovascular disease. In the 2010 meta-analysis, the authors pooled the results from 11 studies involving close to 12,000 women and found that women taking calcium supplements (about 1,000 mg/day in most of the studies) had a 27% increased risk of myocardial infarction. However, the findings from this analysis were criticized within the scientific community for several reasons: the analysis considered only studies involving calcium supplements, not calcium plus vitamin D, which is a more common regimen; none of the studies were designed primarily to examine cardiovascular disease; and the analysis found no significant increase in stroke or death—seemingly contradictory findings that raise questions about the conclusions of the analysis.

In their reanalysis of the WHI data, Bolland and colleagues reported that calcium supplements, taken with or without vitamin D, increased the risk of cardiovascular events in women who were not taking calcium supplements when they entered the study. This effect was masked in the original publication of WHI data, which combined data from women who were and were not taking calcium supplements at enrollment. When Bolland and colleagues pooled the WHI results with data from other trials comprising a total of almost 29,000 subjects, they found the same relationship—an increased risk of cardiovascular events, especially myocardial infarction, from calcium supplementation with or without vitamin D. They hypothesize that abrupt changes in plasma calcium concentrations after starting calcium supplementation might cause the adverse effects.

The recent suggestions of potential harm from calcium supplements to the cardiovascular system have generated debate within the scientific community. Further investigation is needed, but overall, the totality of evidence to date does not support a link between calcium and cardiovascular disease risk.

**Blood Pressure and Hypertension**

Several clinical trials have demonstrated a relationship between increased calcium intakes and both lower blood pressure and risk of hypertension, although the reductions are inconsistent. In the Women's Health Study, calcium intake was inversely associated with risk of hypertension in middle-aged and older women. However, other studies have found no association between calcium intake and incidence of hypertension. The authors of a systematic review of the effects of calcium supplements for hypertension found any link to be weak at best, largely due to the poor quality of most studies and differences in methodologies. Calcium's effects on blood pressure might depend upon the population being studied. In hypertensive subjects, calcium supplementation appears to lower systolic blood pressure by 2–4 mmHg, whereas in normotensive subjects,
calcium appears to have no significant effect on systolic or diastolic blood pressure.

Other observational and experimental studies suggest that individuals who eat a vegetarian diet high in minerals (such as calcium, magnesium, and potassium) and fiber and low in fat tend to have lower blood pressure. The Dietary Approaches to Stop Hypertension (DASH) study was conducted to test the effects of three different eating patterns on blood pressure: a control "typical" American diet; one high in fruits and vegetables; and a third diet high in fruits, vegetables, and low-fat dairy products. The diet containing dairy products resulted in the greatest decrease in blood pressure, although the contribution of calcium to this effect was not evaluated. Additional information and sample DASH menu plans are available on the National Heart, Lung, and Blood Institute Web site.

**Cancer of the Colon and Rectum**

Data from observational and experimental studies on the potential role of calcium in preventing colorectal cancer, though somewhat inconsistent, are highly suggestive of a protective effect. Several studies have found that higher intakes of calcium from foods (low-fat dairy sources) and/or supplements are associated with a decreased risk of colon cancer. In a follow-up study to the Calcium Polyp Prevention Study, supplementation with calcium carbonate led to reductions in the risk of adenoma (a nonmalignant tumor) in the colon, a precursor to cancer, even as long as 5 years after the subjects stopped taking the supplement. In two large prospective epidemiological trials, men and women who consumed 700–800 mg per day of calcium had a 40%–50% lower risk of developing left-side colon cancer. But other observational studies have found the associations to be inconclusive.

In the Women's Health Initiative, a clinical trial involving 36,282 postmenopausal women, daily supplementation with 1,000 mg of calcium and 400 IU of vitamin D₃ for 7 years produced no significant differences in the risk of invasive colorectal cancer compared to placebo. The authors of a Cochrane systematic review concluded that calcium supplementation might moderately help prevent colorectal adenomas, but there is not enough evidence to recommend routine use of calcium supplements to prevent colorectal cancer. Given the long latency period for colon cancer development, long-term studies are needed to fully understand whether calcium intakes affect colorectal cancer risk.

**Cancer of the Prostate**

Several epidemiological studies have found an association between high intakes of calcium, dairy foods or both and an increased risk of developing prostate cancer. However, others have found only a weak relationship, no relationship, or a negative association between calcium intake and prostate cancer risk. The authors of a meta-analysis of prospective studies concluded that high intakes of dairy products and calcium might slightly increase prostate cancer risk.
Interpretation of the available evidence is complicated by the difficulty in separating the effects of dairy products from that of calcium. But overall, results from observational studies suggest that total calcium intakes >1,500 mg/day or >2,000 mg/day may be associated with increased prostate cancer risk (particularly advanced and metastatic cancer) compared with lower amounts of calcium (500–1,000 mg/day. Additional research is needed to clarify the effects of calcium and/or dairy products on prostate cancer risk and elucidate potential biological mechanisms.

Kidney Stones
Kidney stones in the urinary tract are most commonly composed of calcium oxalate. Some, but not all, studies suggest a positive association between supplemental calcium intake and the risk of kidney stones, and these findings were used as the basis for setting the calcium UL in adults. In the Women's Health Initiative, postmenopausal women who consumed 1,000 mg of supplemental calcium and 400 IU of vitamin D per day for 7 years had a 17% higher risk of kidney stones than subjects taking a placebo. The Nurses' Health Study also showed a positive association between supplemental calcium intake and kidney stone formation. High intakes of dietary calcium, on the other hand, do not appear to cause kidney stones and may actually protect against developing them. For most individuals, other risk factors for kidney stones, such as high intakes of oxalates from food and low intakes of fluid, probably play a bigger role than calcium intake.

Weight Management
Several studies have linked higher calcium intakes to lower body weight or less weight gain over time. Two explanations have been proposed. First, high calcium intakes might reduce calcium concentrations in fat cells by decreasing the production of two hormones (parathyroid hormone and an active form of vitamin D) that increase fat breakdown in these cells and discourage fat accumulation. Secondly, calcium from food or supplements might bind to small amounts of dietary fat in the digestive tract and prevent its absorption. Dairy products, in particular, might contain additional components that have even greater effects on body weight than their calcium content alone would suggest.

Despite these findings, the results from clinical trials have been largely negative. For example, a meta-analysis of 13 randomized controlled trials concluded that neither calcium supplementation nor increased dairy product consumption has a statistically significant effect on weight reduction. A more recent clinical trial found dietary supplementation with 1,500 mg/day of calcium (from calcium carbonate) for 2 years to have no clinically significant effects on weight in overweight and obese adults as compared with placebo. An evidence report from the Agency for Healthcare Research and Quality (AHRQ) concluded that overall, clinical trial results do not support an effect of calcium supplementation on body weight loss. Any apparent effects of calcium and dairy products on weight...
regulation and body composition are complex, inconsistent, and not well understood.

**Excessive Calcium**

Excessively high levels of calcium in the blood known as hypercalcemia can cause renal insufficiency, vascular and soft tissue calcification, hypercalciuria (high levels of calcium in the urine) and kidney stones. However, hypercalcemia rarely results from dietary or supplemental calcium intake; it is most commonly associated with primary hyperparathyroidism or malignancy.

High calcium intake can cause constipation. It might also interfere with the absorption of iron and zinc, though this effect is not well established. High intake of calcium from supplements, but not foods, has been associated with increased risk of kidney stones. Some evidence links higher calcium intake with increased risk of prostate cancer, but this effect is not well understood, in part because it is challenging to separate the potential effect of dairy products from that of calcium.

The Tolerable Upper Intake Levels (ULs) for calcium established by the Food and Nutrition Board are listed in milligrams (mg) per day. Getting too much calcium from foods is rare; excess intakes are more likely to be caused by the use of calcium supplements. NHANES data from 2003–2006 indicate that approximately 5% of women older than 50 years have estimated total calcium intakes (from foods and supplements) that exceed the UL by about 300–365 mg.

**Tolerable Upper Intake Levels (ULs) for Calcium:**

<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
<th>Pregnant</th>
<th>Lactating</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–6 months</td>
<td>1,000 mg</td>
<td>1,000 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7–12 months</td>
<td>1,500 mg</td>
<td>1,500 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–8 years</td>
<td>2,500 mg</td>
<td>2,500 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9–18 years</td>
<td>3,000 mg</td>
<td>3,000 mg</td>
<td>3,000 mg</td>
<td>3,000 mg</td>
</tr>
<tr>
<td>19–50 years</td>
<td>2,500 mg</td>
<td>2,500 mg</td>
<td>2,500 mg</td>
<td>2,500 mg</td>
</tr>
<tr>
<td>51+ years</td>
<td>2,000 mg</td>
<td>2,000 mg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Interactions with Medications**

Calcium supplements have the potential to interact with several types of medications. This section provides a few examples. Individuals taking these medications on a regular basis should discuss their calcium intake with their healthcare providers.

Calcium can decrease absorption of the following drugs when taken together: biphosphonates (to treat osteoporosis), the fluoroquinolone and tetracycline.
classes of antibiotics, levothyroxine, phenytoin (an anticonvulsant), and tiludronate disodium (to treat Paget's disease).

Thiazide-type diuretics can interact with calcium carbonate and vitamin D supplements, increasing the risks of hypercalcemia and hypercalciuria. Both aluminum- and magnesium-containing antacids increase urinary calcium excretion. Mineral oil and stimulant laxatives decrease calcium absorption. Glucocorticoids, such as prednisone, can cause calcium depletion and eventually osteoporosis when they are used for months.

**Iron**

**Overview**

Iron, one of the most abundant metals on Earth, is essential to most life forms and to normal human physiology. Iron is an integral part of many proteins and enzymes that maintain good health. In humans, iron is an essential component of proteins involved in oxygen transport. It is also essential for the regulation of cell growth and differentiation. A deficiency of iron limits oxygen delivery to cells, resulting in fatigue, poor work performance, and decreased immunity. On the other hand, excess amounts of iron can result in toxicity and even death.

Almost two-thirds of iron in the body is found in hemoglobin, the protein in red blood cells that carries oxygen to tissues. Smaller amounts of iron are found in myoglobin, a protein that helps supply oxygen to muscle, and in enzymes that assist biochemical reactions. Iron is also found in proteins that store iron for future needs and that transport iron in blood. Iron stores are regulated by intestinal iron absorption.

**Iron in Foods**

There are two forms of dietary iron: heme and nonheme. Heme iron is derived from hemoglobin, the protein in red blood cells that delivers oxygen to cells. Heme iron is found in animal foods that originally contained hemoglobin, such as red meats, fish, and poultry. Iron in plant foods such as lentils and beans is arranged in a chemical structure called nonheme iron. This is the form of iron added to iron-enriched and iron-fortified foods. Heme iron is absorbed better than nonheme iron, but most dietary iron is nonheme iron.

**Iron Absorption**

Iron absorption refers to the amount of dietary iron that the body obtains and uses from food. Healthy adults absorb about 10% to 15% of dietary iron, but individual absorption is influenced by several factors.
Storage levels of iron have the greatest influence on iron absorption. Iron absorption increases when body stores are low. When iron stores are high, absorption decreases to help protect against toxic effects of iron overload. Iron absorption is also influenced by the type of dietary iron consumed. Absorption of heme iron from meat proteins is efficient. Absorption of heme iron ranges from 15% to 35%, and is not significantly affected by diet. In contrast, 2% to 20% of nonheme iron in plant foods such as rice, maize, black beans, soybeans and wheat is absorbed. Nonheme iron absorption is significantly influenced by various food components.

Meat proteins and vitamin C will improve the absorption of nonheme iron. Tannins (found in tea), calcium, polyphenols, and phytates (found in legumes and whole grains) can decrease absorption of nonheme iron. Some proteins found in soybeans also inhibit nonheme iron absorption. It is most important to include foods that enhance nonheme iron absorption when daily iron intake is less than recommended, when iron losses are high (which may occur with heavy menstrual losses), when iron requirements are high (as in pregnancy), and when only vegetarian nonheme sources of iron are consumed.

**Recommended Iron Intake**

Recommendations for iron are provided in the Dietary Reference Intakes (DRIs) developed by the Institute of Medicine of the National Academy of Sciences. Dietary Reference Intakes is the general term for a set of reference values used for planning and assessing nutrient intake for healthy people. Three important types of reference values included in the DRIs are Recommended Dietary Allowances (RDA), Adequate Intakes (AI), and Tolerable Upper Intake Levels (UL). The RDA recommends the average daily intake that is sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in each age and gender group. An AI is set when there is insufficient scientific data available to establish a RDA. AIs meet or exceed the amount needed to maintain a nutritional state of adequacy in nearly all members of a specific age and gender group. The UL, on the other hand, is the maximum daily intake unlikely to result in adverse health effects.
Recommended Dietary Allowances for iron:

<table>
<thead>
<tr>
<th>Age</th>
<th>Males (mg/day)</th>
<th>Females (mg/day)</th>
<th>Pregnancy (mg/day)</th>
<th>Lactation (mg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 to 12 months</td>
<td>11</td>
<td>11</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>1 to 3 years</td>
<td>7</td>
<td>7</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>4 to 8 years</td>
<td>10</td>
<td>10</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>9 to 13 years</td>
<td>8</td>
<td>8</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>14 to 18 years</td>
<td>11</td>
<td>15</td>
<td>27</td>
<td>10</td>
</tr>
<tr>
<td>19 to 50 years</td>
<td>8</td>
<td>18</td>
<td>27</td>
<td>9</td>
</tr>
<tr>
<td>51+ years</td>
<td>8</td>
<td>8</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Healthy full term infants are born with a supply of iron that lasts for 4 to 6 months. There is not enough evidence available to establish a RDA for iron for infants from birth through 6 months of age. Recommended iron intake for this age group is based on an Adequate Intake (AI) that reflects the average iron intake of healthy infants fed breast milk.

Adequate Intake for Iron for Infants (0 to 6 months):

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>Males and Females (mg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 6</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Iron in human breast milk is well absorbed by infants. It is estimated that infants can use greater than 50% of the iron in breast milk as compared to less than 12% of the iron in infant formula. The amount of iron in cow's milk is low, and infants poorly absorb it. Feeding cow's milk to infants also may result in gastrointestinal bleeding. For these reasons, cow's milk should not be fed to infants until they are at least 1 year old. The American Academy of Pediatrics (AAP) recommends that infants be exclusively breast fed for the first six months of life. Gradual introduction of iron-enriched solid foods should complement breast milk from 7 to 12 months of age. Infants weaned from breast milk before 12 months of age should receive iron-fortified infant formula. Infant formulas that contain from 4 to 12 milligrams of iron per liter are considered iron-fortified.

Data from the National Health and Nutrition Examination Survey (NHANES) describe dietary intake of Americans 2 months of age and older. NHANES data suggest that males of all racial and ethnic groups consume recommended amounts of iron. However, iron intakes are generally low in females of childbearing age and young children.
Researchers also examine specific groups within the NHANES population. For example, researchers have compared dietary intakes of adults who consider themselves to be food insufficient to those who are food sufficient. Older adults from food insufficient families had significantly lower intakes of iron than older adults who are food sufficient. In one survey, twenty percent of adults age 20 to 59 and 13.6% of adults age 60 and older from food insufficient families consumed less than 50% of the RDA for iron, as compared to 13% of adults age 20 to 50 and 2.5% of adults age 60 and older from food sufficient families.

Iron intake is negatively influenced by low nutrient density foods, which are high in calories but low in vitamins and minerals. Sugar sweetened sodas and most desserts are examples of low nutrient density foods, as are snack foods such as potato chips. Among almost 5,000 children and adolescents between the ages of 8 and 18 who were surveyed, low nutrient density foods contributed almost 30% of daily caloric intake, with sweeteners and desserts jointly accounting for almost 25% of caloric intake. Those children and adolescents who consumed fewer "low nutrient density" foods were more likely to consume recommended amounts of iron.

Data from The Continuing Survey of Food Intakes by Individuals was used to examine the effect of major food and beverage sources of added sugars on micronutrient intake of U.S. children aged 6 to 17 years. Researchers found that consumption of presweetened cereals, which are fortified with iron, increased the likelihood of meeting recommendations for iron intake. On the other hand, as intake of sugar-sweetened beverages, sugars, sweets, and sweetened grains increased, children were less likely to consume recommended amounts of iron.

**Iron Deficiency**

The World Health Organization considers iron deficiency the number one nutritional disorder in the world. As many as 80% of the world's population may be iron deficient, while 30% may have iron deficiency anemia.

Iron deficiency develops gradually and usually begins with a negative iron balance, when iron intake does not meet the daily need for dietary iron. This negative balance initially depletes the storage form of iron while the blood hemoglobin level, a marker of iron status, remains normal. Iron deficiency anemia is an advanced stage of iron depletion. It occurs when storage sites of iron are deficient and blood levels of iron cannot meet daily needs. Blood hemoglobin levels are below normal with iron deficiency anemia.

Iron deficiency anemia can be associated with low dietary intake of iron, inadequate absorption of iron, or excessive blood loss. Women of childbearing age, pregnant women, preterm and low birth weight infants, older infants and toddlers, and teenage girls are at greatest risk of developing iron deficiency anemia because they have the greatest need for iron. Women with heavy menstrual losses can lose a significant amount of iron and are at considerable
risk for iron deficiency. Adult men and post-menopausal women lose very little iron, and have a low risk of iron deficiency.

Individuals with kidney failure, especially those being treated with dialysis, are at high risk for developing iron deficiency anemia. This is because their kidneys cannot create enough erythropoietin, a hormone needed to make red blood cells. Both iron and erythropoietin can be lost during kidney dialysis. Individuals who receive routine dialysis treatments usually need extra iron and synthetic erythropoietin to prevent iron deficiency.

Vitamin A helps mobilize iron from its storage sites, so a deficiency of vitamin A limits the body's ability to use stored iron. This results in an "apparent" iron deficiency because hemoglobin levels are low even though the body can maintain normal amounts of stored iron. While uncommon in the U.S., this problem is seen in developing countries where vitamin A deficiency often occurs. Chronic malabsorption can contribute to iron depletion and deficiency by limiting dietary iron absorption or by contributing to intestinal blood loss. Most iron is absorbed in the small intestines. Gastrointestinal disorders that result in inflammation of the small intestine may result in diarrhea, poor absorption of dietary iron, and iron depletion.

Signs of iron deficiency anemia include:
- feeling tired and weak
- decreased work and school performance
- slow cognitive and social development during childhood
- difficulty maintaining body temperature
- decreased immune function, which increases susceptibility to infection
- glossitis (an inflamed tongue)

Eating nonnutritive substances such as dirt and clay, often referred to as pica or geophagia, is sometimes seen in persons with iron deficiency. There is disagreement about the cause of this association. Some researchers believe that these eating abnormalities may result in an iron deficiency. Other researchers believe that iron deficiency may somehow increase the likelihood of these eating problems.

People with chronic infectious, inflammatory, or malignant disorders such as arthritis and cancer may become anemic. However, the anemia that occurs with inflammatory disorders differs from iron deficiency anemia and may not respond to iron supplements. Research suggests that inflammation may over-activate a protein involved in iron metabolism. This protein may inhibit iron absorption and reduce the amount of iron circulating in blood, resulting in anemia.
Iron Supplementation

Three groups of people are most likely to benefit from iron supplements: people with a greater need for iron, individuals who tend to lose more iron, and people who do not absorb iron normally. These individuals include:

- pregnant women
- preterm and low birth weight infants
- older infants and toddlers
- teenage girls
- women of childbearing age, especially those with heavy menstrual losses
- people with renal failure, especially those undergoing routine dialysis
- people with gastrointestinal disorders who do not absorb iron normally

Celiac Disease and Crohn’s Syndrome are associated with gastrointestinal malabsorption and may impair iron absorption. Iron supplementation may be needed if these conditions result in iron deficiency anemia.

Women taking oral contraceptives may experience less bleeding during their periods and have a lower risk of developing an iron deficiency. Women who use an intrauterine device (IUD) to prevent pregnancy may experience more bleeding and have a greater risk of developing an iron deficiency. If laboratory tests indicate iron deficiency anemia, iron supplements may be recommended.

Total dietary iron intake in vegetarian diets may meet recommended levels; however that iron is less available for absorption than in diets that include meat. Vegetarians who exclude all animal products from their diet may need almost twice as much dietary iron each day as non-vegetarians because of the lower intestinal absorption of nonheme iron in plant foods. Vegetarians should consider consuming nonheme iron sources together with a good source of vitamin C, such as citrus fruits, to improve the absorption of nonheme iron.

Iron Requirements During Pregnancy

Nutrient requirements increase during pregnancy to support fetal growth and maternal health. Iron requirements of pregnant women are approximately double that of non-pregnant women because of increased blood volume during pregnancy, increased needs of the fetus, and blood losses that occur during delivery. If iron intake does not meet increased requirements, iron deficiency anemia can occur. Iron deficiency anemia of pregnancy is responsible for significant morbidity, such as premature deliveries and giving birth to infants with low birth weight.

Low levels of hemoglobin and hematocrit may indicate iron deficiency. Hemoglobin is the protein in red blood cells that carries oxygen to tissues. Hematocrit is the proportion of whole blood that is made up of red blood cells. Nutritionists estimate that over half of pregnant women in the world may have...
hemoglobin levels consistent with iron deficiency. In the U.S., the Centers for Disease Control (CDC) estimates that 12% of all women age 12 to 49 years are iron deficient. When broken down by groups, 10% of non-Hispanic white women, 22% of Mexican-American women, and 19% of non-Hispanic black women were iron deficient. Prevalence of iron deficiency anemia among lower income pregnant women has remained the same, at about 30%, since the 1980s.

The RDA for iron for pregnant women increases to 27 mg per day. Unfortunately, data suggests that the median iron intake among pregnant women is approximately 15 mg per day. When median iron intake is less than the RDA, more than half of the group consumes less iron than is recommended each day.

Several major health organizations recommend iron supplementation during pregnancy to help pregnant women meet their iron requirements. The CDC recommends routine low-dose iron supplementation (30 mg/day) for all pregnant women, beginning at the first prenatal visit. When a low hemoglobin or hematocrit is confirmed by repeat testing, the CDC recommends larger doses of supplemental iron. The Institute of Medicine of the National Academy of Sciences also supports iron supplementation during pregnancy.

**Iron Supplementation**

Iron supplementation is indicated when diet alone cannot restore deficient iron levels to normal within an acceptable timeframe. Supplements are especially important when an individual is experiencing clinical symptoms of iron deficiency anemia. The goals of providing oral iron supplements are to supply sufficient iron to restore normal storage levels of iron and to replenish hemoglobin deficits. When hemoglobin levels are below normal, physicians often measure serum ferritin, the storage form of iron. A serum ferritin level less than or equal to 15 micrograms per liter confirms iron deficiency anemia in women, and suggests a possible need for iron supplementation.

Supplemental iron is available in two forms: ferrous and ferric. Ferrous iron salts (ferrous fumarate, ferrous sulfate, and ferrous gluconate) are the best absorbed forms of iron supplements. Elemental iron is the amount of iron in a supplement that is available for absorption. The graph below shows the percent elemental iron in these supplements.
Percent Elemental Iron in Iron Supplements:

The amount of iron absorbed decreases with increasing doses. For this reason, it is recommended that most people take their prescribed daily iron supplement in two or three equally spaced doses. For adults who are not pregnant, the CDC recommends taking 50 mg to 60 mg of oral elemental iron (the approximate amount of elemental iron in one 300 mg tablet of ferrous sulfate) twice daily for three months for the therapeutic treatment of iron deficiency anemia.

Therapeutic doses of iron supplements, which are prescribed for iron deficiency anemia, may cause gastrointestinal side effects such as nausea, vomiting, constipation, diarrhea, dark colored stools, and/or abdominal distress. Starting with half the recommended dose and gradually increasing to the full dose will help minimize these side effects. Taking the supplement in divided doses and with food also may help limit these symptoms. Iron from enteric coated or delayed-release preparations may have fewer side effects, but is not as well absorbed and not usually recommended.

Physicians monitor the effectiveness of iron supplements by measuring laboratory indices, including reticulocyte count (levels of newly formed red blood cells), hemoglobin levels, and ferritin levels. In the presence of anemia, reticulocyte counts will begin to rise after a few days of supplementation. Hemoglobin usually increases within 2 to 3 weeks of starting iron supplementation.

In rare situations parenteral iron (provided by injection or I.V.) is required. Doctors should carefully manage the administration of parenteral iron.
Precautions

Iron deficiency is uncommon among adult men and postmenopausal women. These individuals should only take iron supplements when prescribed by a physician because of their greater risk of iron overload.

Iron overload is a condition in which excess iron is found in the blood and stored in organs such as the liver and heart. Iron overload is associated with several genetic diseases including hemochromatosis, which affects approximately 1 in 250 individuals of northern European descent. Individuals with hemochromatosis absorb iron very efficiently, which can result in a build up of excess iron and can cause organ damage such as cirrhosis of the liver and heart failure.

Hemochromatosis is often not diagnosed until excess iron stores have damaged an organ. Iron supplementation may accelerate the effects of hemochromatosis, an important reason why adult men and postmenopausal women who are not iron deficient should avoid iron supplements. Individuals with blood disorders that require frequent blood transfusions are also at risk of iron overload and are usually advised to avoid iron supplements.

Iron and Health Issues

Iron and Heart Disease
Because known risk factors cannot explain all cases of heart disease, researchers continue to look for new causes. Some evidence suggests that iron can stimulate the activity of free radicals. Free radicals are natural by-products of oxygen metabolism that are associated with chronic diseases, including cardiovascular disease. Free radicals may inflame and damage coronary arteries, the blood vessels that supply the heart muscle. This inflammation may contribute to the development of atherosclerosis, a condition characterized by partial or complete blockage of one or more coronary arteries. Other researchers suggest that iron may contribute to the oxidation of LDL (“bad”) cholesterol, changing it to a form that is more damaging to coronary arteries.

As far back as the 1980s, some researchers suggested that the regular menstrual loss of iron, rather than a protective effect from estrogen, could better explain the lower incidence of heart disease seen in pre-menopausal women. After menopause, a woman’s risk of developing coronary heart disease increases along with her iron stores. Researchers have also observed lower rates of heart disease in populations with lower iron stores, such as those in developing countries. In those geographic areas, lower iron stores are attributed to low meat (and iron) intake, high fiber diets that inhibit iron absorption, and gastrointestinal (GI) blood (and iron) loss due to parasitic infections.

Past research has linked high iron stores with increased risk of heart attacks in men. However, more recent studies have not supported such an association.
One way of testing an association between iron stores and coronary heart disease is to compare levels of ferritin, the storage form of iron, to the degree of atherosclerosis in coronary arteries. In one study, researchers examined the relationship between ferritin levels and atherosclerosis in 100 men and women referred for cardiac examination. In this population, higher ferritin levels were not associated with an increased degree of atherosclerosis, as measured by angiography. In a different study, researchers found that ferritin levels were higher in male patients diagnosed with coronary artery disease. They did not find any association between ferritin levels and risk of coronary disease in women.

A second way to test this association is to examine rates of coronary disease in people who frequently donate blood. If excess iron stores contribute to heart disease, frequent blood donation could potentially lower heart disease rates because of the iron loss associated with blood donation. Over 2,000 men over age 39 and women over age 50 who donated blood were surveyed 10 years later to compare rates of cardiac events to frequency of blood donation. Cardiac events were defined as (1) occurrence of an acute myocardial infarction (heart attack), (2) undergoing angioplasty, a medical procedure that opens a blocked coronary artery; or (3) undergoing bypass grafting, a surgical procedure that replaces blocked coronary arteries with healthy blood vessels. Researchers found that frequent donors, who donated more than 1 unit of whole blood each year, were less likely to experience cardiac events than casual donors (those who only donated a single unit in that 3-year period). Researchers concluded that frequent and long-term blood donation may decrease the risk of cardiac events.

Conflicting results, and different methods to measure iron stores, make it difficult to reach a final conclusion on this issue. However, researchers know that it is feasible to decrease iron stores in healthy individual through phlebotomy (blood letting or donation).

**Iron and Intense Exercise**

Many men and women who engage in regular, intense exercise such as jogging, competitive swimming, and cycling have marginal or inadequate iron status. Possible explanations include increased gastrointestinal blood loss after running and a greater turnover of red blood cells. Also, red blood cells within the foot can rupture while running. For these reasons, the need for iron may be 30% greater in those who engage in regular intense exercise.

Three groups of athletes may be at greatest risk of iron depletion and deficiency: female athletes, distance runners, and vegetarian athletes. It is particularly important for members of these groups to consume recommended amounts of iron and to pay attention to dietary factors that enhance iron absorption. If appropriate nutrition intervention does not promote normal iron status, iron supplementation may be indicated. In one study of female swimmers, researchers found that supplementation with 125 milligrams (mg) of ferrous
sulfate per day prevented iron depletion. These swimmers maintained adequate iron stores, and did not experience the gastrointestinal side effects often seen with higher doses of iron supplementation.

**Iron and Mineral Interactions**

Some researchers have raised concerns about interactions between iron, zinc, and calcium. When iron and zinc supplements are given together in a water solution and without food, greater doses of iron may decrease zinc absorption. However, the effect of supplemental iron on zinc absorption does not appear to be significant when supplements are consumed with food. There is evidence that calcium from supplements and dairy foods may inhibit iron absorption, but it has been very difficult to distinguish between the effects of calcium on iron absorption versus other inhibitory factors such as phytate.

**Toxicity**

There is considerable potential for iron toxicity because very little iron is excreted from the body. Thus, iron can accumulate in body tissues and organs when normal storage sites are full. For example, people with hemachromatosis are at risk of developing iron toxicity because of their high iron stores.

In children, death has occurred from ingesting 200 mg of iron. It is important to keep iron supplements tightly capped and away from children's reach.

The Institute of Medicine of the National Academy of Sciences has set a tolerable upper intake level (UL) for iron for healthy people. There may be times when a physician prescribes an intake higher than the upper limit, such as when individuals with iron deficiency anemia need higher doses to replenish their iron stores.

**Tolerable upper intake levels for iron:**

<table>
<thead>
<tr>
<th>Age</th>
<th>Males (mg/day)</th>
<th>Females (mg/day)</th>
<th>Pregnancy (mg/day)</th>
<th>Lactation (mg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 to 12 months</td>
<td>40</td>
<td>40</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>1 to 13 years</td>
<td>40</td>
<td>40</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>14 to 18 years</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>19 + years</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
</tbody>
</table>
Magnesium

Overview

Magnesium is the fourth most abundant mineral in the body and is essential to good health. Approximately 50% of total body magnesium is found in bone. The other half is found predominantly inside cells of body tissues and organs. Only 1% of magnesium is found in blood, but the body works very hard to keep blood levels of magnesium constant.

Magnesium is needed for more than 300 biochemical reactions in the body. It helps maintain normal muscle and nerve function, keeps heart rhythm steady, supports a healthy immune system, and keeps bones strong. Magnesium also helps regulate blood sugar levels, promotes normal blood pressure, and is known to be involved in energy metabolism and protein synthesis. There is an increased interest in the role of magnesium in preventing and managing disorders such as hypertension, cardiovascular disease, and diabetes. Dietary magnesium is absorbed in the small intestines. Magnesium is excreted through the kidneys.

Magnesium in Food

Green vegetables such as spinach are good sources of magnesium because the center of the chlorophyll molecule contains magnesium. Some legumes (beans and peas), nuts and seeds, and whole, unrefined grains are also good sources of magnesium. Refined grains are generally low in magnesium. When white flour is refined and processed, the magnesium-rich germ and bran are removed. Bread made from whole grain wheat flour provides more magnesium than bread made from white refined flour. Tap water can be a source of magnesium, but the amount varies according to the water supply. Water that naturally contains more minerals is described as "hard". "Hard" water contains more magnesium than "soft" water.

Recommended Dietary Intake of Magnesium

Recommendations for magnesium are provided in the Dietary Reference Intakes (DRIs) developed by the Institute of Medicine of the National Academy of Sciences. Dietary Reference Intakes is the general term for a set of reference values used for planning and assessing nutrient intake for healthy people. Three important types of reference values included in the DRIs are Recommended Dietary Allowances (RDA), Adequate Intakes (AI), and Tolerable Upper Intake Levels (UL). The RDA recommends the average daily intake that is sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in each age and gender group. An AI is set when there is insufficient scientific data available to establish a RDA for specific age/gender groups. Als meet or exceed the amount needed to maintain a nutritional state of adequacy in nearly all
members of a specific age and gender group. The UL, on the other hand, is the maximum daily intake unlikely to result in adverse health effects.

**RDA for magnesium for children and adults:**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Male (mg/day)</th>
<th>Female (mg/day)</th>
<th>Pregnancy (mg/day)</th>
<th>Lactation (mg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>80</td>
<td>80</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>4-8</td>
<td>130</td>
<td>130</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>9-13</td>
<td>240</td>
<td>240</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>14-18</td>
<td>410</td>
<td>360</td>
<td>400</td>
<td>360</td>
</tr>
<tr>
<td>19-30</td>
<td>400</td>
<td>310</td>
<td>350</td>
<td>310</td>
</tr>
<tr>
<td>31+</td>
<td>420</td>
<td>320</td>
<td>360</td>
<td>320</td>
</tr>
</tbody>
</table>

There is insufficient information on magnesium to establish a RDA for infants. For infants 0 to 12 months, the DRI is in the form of an Adequate Intake (AI), which is the mean intake of magnesium in healthy, breastfed infants.

**AIs for infants in milligrams (mg):**

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>Males and Females (mg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 6</td>
<td>30</td>
</tr>
<tr>
<td>7 to 12</td>
<td>75</td>
</tr>
</tbody>
</table>

Data from the National Health and Nutrition Examination Survey suggest that substantial numbers of adults in the United States (US) fail to consume recommended amounts of magnesium. Among adult men and women, Caucasians consume significantly more magnesium than African-Americans. Magnesium intake is lower among older adults in every racial and ethnic group. African-American men and Caucasian men and women who take dietary supplements consume significantly more magnesium than those who do not.

**Magnesium Deficiency**

Even though dietary surveys suggest that many Americans do not consume recommended amounts of magnesium, symptoms of magnesium deficiency are rarely seen in the US. However, there is concern about the prevalence of sub-optimal magnesium stores in the body. For many people, dietary intake may not be high enough to promote an optimal magnesium status, which may be protective against disorders such as cardiovascular disease and immune dysfunction.

The health status of the digestive system and the kidneys significantly influence
magnesium status. Magnesium is absorbed in the intestines and then transported through the blood to cells and tissues. Approximately one-third to one-half of dietary magnesium is absorbed into the body. Gastrointestinal disorders that impair absorption such as Crohn's disease can limit the body's ability to absorb magnesium. These disorders can deplete the body's stores of magnesium and in extreme cases may result in magnesium deficiency. Chronic or excessive vomiting and diarrhea may also result in magnesium depletion.

Healthy kidneys are able to limit urinary excretion of magnesium to compensate for low dietary intake. However, excessive loss of magnesium in urine can be a side effect of some medications and can also occur in cases of poorly-controlled diabetes and alcohol abuse.

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. Severe magnesium deficiency can result in low levels of calcium in the blood (hypocalcemia). Magnesium deficiency is also associated with low levels of potassium in the blood (hypokalemia).

**Indications for Supplementation**

Magnesium supplementation may be indicated when a specific health problem or condition causes an excessive loss of magnesium or limits magnesium absorption.

- Some medicines may result in magnesium deficiency, including certain diuretics, antibiotics, and medications used to treat cancer (anti-neoplastic medication). Examples of these medications are:
  - Diuretics: Lasix, Bumex, Edecrin, and hydrochlorothiazide
  - Antibiotics: Gentamicin, Amphotericin, and Cyclosporin
  - Anti-neoplastic medication: Cisplatin
- Individuals with poorly-controlled diabetes may benefit from magnesium supplements because of increased magnesium loss in urine associated with hyperglycemia.
- Magnesium supplementation may be indicated for persons with alcoholism. Low blood levels of magnesium occur in 30% to 60% of alcoholics, and in nearly 90% of patients experiencing alcohol withdrawal. Anyone who substitutes alcohol for food will usually have significantly lower magnesium intakes.
- Individuals with chronic malabsorptive problems such as Crohn's disease, gluten sensitive enteropathy, regional enteritis, and intestinal surgery may lose magnesium through diarrhea and fat malabsorption. Individuals with these conditions may need supplemental magnesium.
DIETARY MINERALS

- Individuals with chronically low blood levels of potassium and calcium may have an underlying problem with magnesium deficiency. Magnesium supplements may help correct the potassium and calcium deficiencies.
- Older adults are at increased risk for magnesium deficiency. The National Health and Nutrition Examination Surveys suggest that older adults have lower dietary intakes of magnesium than younger adults. In addition, magnesium absorption decreases and renal excretion of magnesium increases in older adults. Seniors are also more likely to be taking drugs that interact with magnesium. This combination of factors places older adults at risk for magnesium deficiency. It is very important for older adults to consume recommended amounts of dietary magnesium.

The table below describes some important interactions between certain drugs and magnesium. These interactions may result in higher or lower levels of magnesium, or may influence absorption of the medication.

<table>
<thead>
<tr>
<th>Drug</th>
<th>Potential Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop and thiazide diuretics (e.g. lasix, bumex, edecrin, and hydrochlorothiazide) Anti-neoplastic drugs (e.g. cisplatin) Antibiotics (e.g. gentamicin, amphotericin, and cyclosporine)</td>
<td>These drugs may increase the loss of magnesium in urine. Thus, taking these medications for long periods of time may contribute to magnesium depletion.</td>
</tr>
<tr>
<td>Tetracycline antibiotics</td>
<td>Magnesium binds tetracycline in the gut and decreases the absorption of tetracycline.</td>
</tr>
<tr>
<td>Magnesium-containing antacids and laxatives</td>
<td>Many antacids and laxatives contain magnesium. When frequently taken in large doses, these drugs can inadvertently lead to excessive magnesium consumption and hypermagnesemia, which refers to elevated levels of magnesium in blood.</td>
</tr>
</tbody>
</table>

Types of Magnesium Supplementation

When blood levels of magnesium are very low, intravenous (i.e. by IV) magnesium replacement is usually recommended. Magnesium tablets also may be prescribed, although some forms can cause diarrhea. Because people with kidney disease may not be able to excrete excess amounts of magnesium, they should not consume magnesium supplements unless prescribed by a physician.

Oral magnesium supplements combine magnesium with another substance such as a salt. Examples of magnesium supplements include magnesium oxide, magnesium sulfate, and magnesium carbonate. Elemental magnesium refers to the amount of magnesium in each compound. The amount of elemental magnesium in a compound and its bioavailability influence the effectiveness of the magnesium supplement. Bioavailability refers to the amount of magnesium in food, medications, and supplements that is absorbed in the intestines and ultimately available for biological activity in your cells and tissues. Enteric coating of a magnesium compound can decrease bioavailability. In a study that
compared four forms of magnesium preparations, results suggested lower bioavailability of magnesium oxide, with significantly higher and equal absorption and bioavailability of magnesium chloride and magnesium lactate. This supports the belief that both the magnesium content of a dietary supplement and its bioavailability contribute to its ability to replete deficient levels of magnesium.

**Magnesium and Health Issues**

**Blood Pressure**
Epidemiologic evidence suggests that magnesium may play an important role in regulating blood pressure. Diets that provide plenty of fruits and vegetables, which are good sources of potassium and magnesium, are consistently associated with lower blood pressure. The DASH study (Dietary Approaches to Stop Hypertension), a human clinical trial, suggested that high blood pressure could be significantly lowered by a diet that emphasizes fruits, vegetables, and low fat dairy foods. Such a diet will be high in magnesium, potassium, and calcium, and low in sodium and fat.

An observational study examined the effect of various nutritional factors on incidence of high blood pressure in over 30,000 US male health professionals. After four years of follow-up, it was found that a lower risk of hypertension was associated with dietary patterns that provided more magnesium, potassium, and dietary fiber. For 6 years, the Atherosclerosis Risk in Communities (ARIC) Study followed approximately 8,000 men and women who were initially free of hypertension. In this study, the risk of developing hypertension decreased as dietary magnesium intake increased in women, but not in men.

Foods high in magnesium are frequently high in potassium and dietary fiber. This makes it difficult to evaluate the independent effect of magnesium on blood pressure. However, newer scientific evidence from DASH clinical trials is strong enough that the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure states that diets that provide plenty of magnesium are positive lifestyle modifications for individuals with hypertension.

**Diabetes**
Magnesium plays an important role in carbohydrate metabolism. It may influence the release and activity of insulin. Low blood levels of magnesium (hypomagnesemia) are frequently seen in individuals with type 2 diabetes. Hypomagnesemia may worsen insulin resistance, a condition that often precedes diabetes, or may be a consequence of insulin resistance. Individuals with insulin resistance do not use insulin efficiently and require greater amounts of insulin to maintain blood sugar within normal levels. The kidneys possibly lose their ability to retain magnesium during periods of severe hyperglycemia (significantly elevated blood glucose). The increased loss of magnesium in urine may then result in lower blood levels of magnesium. In older adults, correcting magnesium depletion may improve insulin response and action.
The Nurses' Health Study (NHS) and the Health Professionals' Follow-up Study (HFS) follow more than 170,000 health professionals through biennial questionnaires. Diet was first evaluated in 1980 in the NHS and in 1986 in the HFS, and dietary assessments have been completed every 2 to 4 years since. Information on the use of dietary supplements, including multivitamins, is also collected. As part of these studies, over 127,000 research subjects (85,060 women and 42,872 men) with no history of diabetes, cardiovascular disease, or cancer at baseline were followed to examine risk factors for developing type 2 diabetes. Women were followed for 18 years; men were followed for 12 years. Over time, the risk for developing type 2 diabetes was greater in men and women with a lower magnesium intake. This study supports the dietary recommendation to increase consumption of major food sources of magnesium, such as whole grains, nuts, and green leafy vegetables.

The Iowa Women's Health Study has followed a group of older women since 1986. Researchers from this study examined the association between women's risk of developing type 2 diabetes and intake of carbohydrates, dietary fiber, and dietary magnesium. Dietary intake was estimated by a food frequency questionnaire, and incidence of diabetes throughout 6 years of follow-up was determined by asking participants if they had been diagnosed by a doctor as having diabetes. Based on baseline dietary intake assessment only, researchers' findings suggested that a greater intake of whole grains, dietary fiber, and magnesium decreased the risk of developing diabetes in older women.

The Women's Health Study was originally designed to evaluate the benefits versus risks of low-dose aspirin and vitamin E supplementation in the primary prevention of cardiovascular disease and cancer in women 45 years of age and older. In an examination of almost 40,000 women participating in this study, researchers also examined the association between magnesium intake and incidence of type 2 diabetes over an average of 6 years. Among women who were overweight, the risk of developing type 2 diabetes was significantly greater among those with lower magnesium intake.

On the other hand, the Atherosclerosis Risk in Communities (ARIC) study did not find any association between dietary magnesium intake and the risk for type 2 diabetes. During 6 years of follow-up, ARIC researchers examined the risk for type 2 diabetes in over 12,000 middle-aged adults without diabetes at baseline examination. In this study, there was no statistical association between dietary magnesium intake and incidence of type 2 diabetes in either black or white research subjects.

Several clinical studies have examined the potential benefit of supplemental magnesium on metabolic control of type 2 diabetes. In one such study, 63 subjects with below normal serum magnesium levels received either 2.5 grams of oral magnesium chloride daily "in liquid form" (providing 300 mg elemental
magnesium per day) or a placebo. At the end of the 16-week study period, those who received the magnesium supplement had higher blood levels of magnesium and improved metabolic control of diabetes, as suggested by lower Hemoglobin A1C levels, than those who received a placebo. Hemoglobin A1C is a test that measures overall control of blood glucose over the previous 2 to 3 months, and is considered by many doctors to be the single most important blood test for diabetics.

In another study, 128 patients with poorly controlled type 2 diabetes were randomized to receive a placebo or a supplement with either 500 mg or 1000 mg of magnesium oxide (MgO) for 30 days. All patients were also treated with diet or diet plus oral medication to control blood glucose levels. Magnesium levels increased in the group receiving 1000 mg magnesium oxide per day (equal to 600 mg elemental magnesium per day) but did not significantly change in the placebo group or the group receiving 500 mg of magnesium oxide per day (equal to 300 mg elemental magnesium per day). However, neither level of magnesium supplementation significantly improved blood glucose control.

These studies provide intriguing results but also suggest that additional research is needed to better explain the association between blood magnesium levels, dietary magnesium intake, and type 2 diabetes. The American Diabetes Association (ADA) has issued nutrition recommendations for diabetics stating that "...routine evaluation of blood magnesium level is recommended only in patients at high risk for magnesium deficiency. Levels of magnesium should be repleted (replaced) only if hypomagnesemia can be demonstrated".

**Cardiovascular Disease**

Magnesium metabolism is very important to insulin sensitivity and blood pressure regulation, and magnesium deficiency is common in individuals with diabetes. The observed associations between magnesium metabolism, diabetes, and high blood pressure increase the likelihood that magnesium metabolism may influence cardiovascular disease.

Some observational surveys have associated higher blood levels of magnesium with lower risk of coronary heart disease. In addition, some dietary surveys have suggested that a higher magnesium intake may reduce the risk of having a stroke. There is also evidence that low body stores of magnesium increase the risk of abnormal heart rhythms, which may increase the risk of complications after a heart attack. These studies suggest that consuming recommended amounts of magnesium may be beneficial to the cardiovascular system. They have also prompted interest in clinical trials to determine the effect of magnesium supplements on cardiovascular disease.

Several small studies suggest that magnesium supplementation may improve clinical outcomes in individuals with coronary disease. In one of these studies, the effect of magnesium supplementation on exercise tolerance, exercise-
induced chest pain, and quality of life was examined in 187 patients. Patients received either a placebo or a supplement providing 365 milligrams of magnesium citrate twice daily for 6 months. At the end of the study period researchers found that magnesium therapy significantly increased magnesium levels. Patients receiving magnesium had a 14 percent improvement in exercise duration as compared to no change in the placebo group. Those receiving magnesium were also less likely to experience exercise-induced chest pain.

In another study, 50 men and women with stable coronary disease were randomized to receive either a placebo or a magnesium supplement that provided 342 mg magnesium oxide twice daily. After 6 months, those who received the oral magnesium supplement were found to have improved exercise tolerance.

In a third study, researchers examined whether magnesium supplementation would add to the anti-thrombotic (anti-clotting) effects of aspirin in 42 coronary patients. For three months, each patient received either a placebo or a supplement with 400 mg of magnesium oxide two to three times daily. After a four-week break without any treatment, treatment groups were reversed so that each person in the study then received the alternate treatment for three months. Researchers found that supplemental magnesium did provide an additional anti-thrombotic effect.

These studies are encouraging, but involved small numbers. Additional studies are needed to better understand the complex relationships between magnesium intake, indicators of magnesium status, and heart disease.

**Osteoporosis**
Bone health is supported by many factors, most notably calcium and vitamin D. However, some evidence suggests that magnesium deficiency may be an additional risk factor for postmenopausal osteoporosis. This may be due to the fact that magnesium deficiency alters calcium metabolism and the hormones that regulate calcium. Several human studies have suggested that magnesium supplementation may improve bone mineral density. In a study of older adults, a greater magnesium intake maintained bone mineral density to a greater degree than a lower magnesium intake. Diets that provide recommended levels of magnesium are beneficial for bone health, but further investigation on the role of magnesium in bone metabolism and osteoporosis is needed.

**Magnesium Toxicity**
Dietary magnesium does not pose a health risk, however pharmacologic doses of magnesium in supplements can promote adverse effects such as diarrhea and abdominal cramping. Risk of magnesium toxicity increases with kidney failure, when the kidney loses the ability to remove excess magnesium. Very large doses of magnesium-containing laxatives and antacids also have been associated with
magnesium toxicity. For example, a case of hypermagnesemia after unsupervised intake of aluminum magnesia oral suspension occurred after a 16 year old girl decided to take the antacid every two hours rather than four times per day, as prescribed. Three days later, she became unresponsive and demonstrated loss of deep tendon reflex. Doctors were unable to determine her exact magnesium intake, but the young lady presented with blood levels of magnesium five times higher than normal. Therefore, it is important for medical professionals to be aware of the use of any magnesium-containing laxatives or antacids. Signs of excess magnesium can be similar to magnesium deficiency and include changes in mental status, nausea, diarrhea, appetite loss, muscle weakness, difficulty breathing, extremely low blood pressure, and irregular heartbeat.

The table below lists the ULs for supplemental magnesium for healthy infants, children, and adults in milligrams (mg). Physicians may prescribe magnesium in higher doses for specific medical problems. There is no UL for dietary intake of magnesium; only for magnesium supplements.

**Tolerable Upper Intake Levels for supplemental magnesium:**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Male (mg/day)</th>
<th>Female (mg/day)</th>
<th>Pregnancy (mg/day)</th>
<th>Lactation (mg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants</td>
<td>Undetermined</td>
<td>Undetermined</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>1-3</td>
<td>65</td>
<td>65</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>4 - 8</td>
<td>110</td>
<td>110</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>9 - 18</td>
<td>350</td>
<td>350</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>19+</td>
<td>350</td>
<td>350</td>
<td>350</td>
<td>350</td>
</tr>
</tbody>
</table>

**Selenium**

**Overview**

Selenium is a trace mineral that is essential to good health but required only in small amounts. Selenium is incorporated into proteins to make selenoproteins, which are important antioxidant enzymes. The antioxidant properties of selenoproteins help prevent cellular damage from free radicals. Free radicals are natural by-products of oxygen metabolism that may contribute to the development of chronic diseases such as cancer and heart disease. Other selenoproteins help regulate thyroid function and play a role in the immune system.
Selenium in Food

Plant foods are the major dietary sources of selenium in most countries throughout the world. The content of selenium in food depends on the selenium content of the soil where plants are grown or animals are raised. For example, researchers know that soils in the high plains of northern Nebraska and the Dakotas have very high levels of selenium. People living in those regions generally have the highest selenium intakes in the United States. In the U.S., food distribution patterns across the country help prevent people living in low-selenium geographic areas from having low dietary selenium intakes. Soils in some parts of China and Russia have very low amounts of selenium. Selenium deficiency is often reported in those regions because most food in those areas is grown and eaten locally.

Selenium also can be found in some meats and seafood. Animals that eat grains or plants that were grown in selenium-rich soil have higher levels of selenium in their muscle. In the U.S., meats and bread are common sources of dietary selenium. Some nuts are also sources of selenium.

Selenium content of foods can vary. For example, Brazil nuts may contain as much as 544 micrograms of selenium per ounce. They also may contain far less selenium. It is wise to eat Brazil nuts only occasionally because of their unusually high intake of selenium.

Recommended Dietary Intake for Selenium

Recommendations for selenium are provided in the Dietary Reference Intakes developed by the Institute of Medicine. Dietary Reference Intakes (DRIs) is the general term for a set of reference values used for planning and assessing nutrient intake for healthy people. Three important types of reference values included in the DRIs are Recommended Dietary Allowances (RDA), Adequate Intakes (AI), and Tolerable Upper Intake Levels (UL). The RDA recommends the average daily dietary intake level that is sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in each age and gender group. An AI is set when there is insufficient scientific data available to establish a RDA. Als meet or exceed the amount needed to maintain a nutritional state of adequacy in nearly all members of a specific age and gender group. The UL, on the other hand, is the maximum daily intake unlikely to result in adverse health effects. The table below lists the RDAs for selenium, in micrograms (µg) per day, for children and adults.
**DIETARY MINERALS**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Males and Females</th>
<th>Pregnancy</th>
<th>Lactation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3 y</td>
<td>20</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>4-8 y</td>
<td>30</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>9-13 y</td>
<td>40</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>14-18 y</td>
<td>55</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>19 y +</td>
<td>55</td>
<td>60</td>
<td>70</td>
</tr>
</tbody>
</table>

There is insufficient information on selenium to establish a RDA for infants. An Adequate Intake (AI) has been established that is based on the amount of selenium consumed by healthy infants who are fed breast milk. The table below lists the AIs for selenium, in micrograms (µg) per day, for infants.

**Adequate Intake for selenium for infants:**

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>Males and Females (µg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6 months</td>
<td>15</td>
</tr>
<tr>
<td>7-12 months</td>
<td>20</td>
</tr>
</tbody>
</table>

Results of the National Health and Nutrition Examination Survey (NHANES III) indicated that diets of most Americans provide recommended amounts of selenium. The INTERMAP study examined nutrient intakes of almost 5,000 middle-aged men and women in four countries, including the U.S. The primary aim of the study was to evaluate the effect of dietary micronutrients on blood pressure. Each study participant completed four, 24-hour dietary recalls, during which they were asked to record everything consumed (food, beverages, and dietary supplements) over the previous 24 hours. Selenium intake was lowest among residents of China, the country with the highest known rate of selenium deficiency. Mean dietary intake of selenium of U.S. participants was 153 µg for men and 109 µg for women. Both values exceed the recommended selenium intake for adults and are further evidence of adequate selenium intakes in the U.S.

**Selenium Deficiency**

Human selenium deficiency is rare in the U.S. but is seen in other countries, most notably China, where soil concentration of selenium is low. There is evidence that selenium deficiency may contribute to development of a form of heart disease, hypothyroidism, and a weakened immune system. There is also evidence that selenium deficiency does not usually cause illness by itself. Rather, it can make the body more susceptible to illnesses caused by other nutritional,
biochemical or infectious stresses.

Three specific diseases have been associated with selenium deficiency:
- Keshan Disease, which results in an enlarged heart and poor heart function, occurs in selenium deficient children.
- Kashin-Beck Disease, which results in osteoarthropathy
- Myxedematous Endemic Cretinism, which results in mental retardation

Keshan disease was first described in the early 1930s in China, and is still seen in large areas of the Chinese countryside with selenium poor soil. Dietary intake in these areas is less than 19 micrograms per day for men and less than 13 micrograms per day for women, significantly lower than the current RDA for selenium. Researchers believe that selenium deficient people infected with a specific virus are most likely to develop Keshan disease.

Selenium deficiency has also been seen in people who rely on total parenteral nutrition (TPN) as their sole source of nutrition. TPN is a method of feeding nutrients through an intravenous (IV) line to people whose digestive systems do not function. Forms of nutrients that do not require digestion are dissolved in liquid and infused through the IV line. It is important for TPN solutions to provide selenium in order to prevent a deficiency.

Severe gastrointestinal disorders may decrease the absorption of selenium, resulting in selenium depletion or deficiency. Gastrointestinal problems that impair selenium absorption usually affect absorption of other nutrients as well, and require routine monitoring of nutritional status so that appropriate medical and nutritional treatment can be provided.

**Selenium Supplementation**

In the U.S., most cases of selenium depletion or deficiency are associated with severe gastrointestinal problems, such as Crohn’s disease, or with surgical removal of part of the stomach. These and other gastrointestinal disorders can impair selenium absorption. People with acute severe illness who develop inflammation and widespread infection often have decreased levels of selenium in their blood.

People with iodine deficiency may also benefit from selenium supplementation. Iodine deficiency is rare in the U.S., but is still common in developing countries where access to iodine is limited. Researchers believe that selenium deficiency may worsen the effects of iodine deficiency on thyroid function, and that adequate selenium nutritional status may help protect against some of the neurological effects of iodine deficiency. Researchers involved in the Supplementation en Vitamines et Minéraux Antioxydants (SU.VI.MAX) study in France, which was designed to assess the effect of vitamin and mineral supplements on chronic disease risk, evaluated the relationship between goiter
and selenium in a subset of this research population. Their findings suggest that selenium supplements may be protective against goiter.

As noted above, selenium supplementation during TPN administration is now routine. While specific medical problems such as those described above indicate a need for selenium supplementation, evidence is lacking for recommending selenium supplements for healthy children and adults.

Selenium occurs in staple foods such as corn, wheat, and soybean as selenomethionine, the organic selenium analogue of the amino acid methionine. Selenomethionine can be incorporated into body proteins in place of methionine, and serves as a vehicle for selenium storage in organs and tissues. Selenium supplements may also contain sodium selenite and sodium selenate, two inorganic forms of selenium. Selenomethionine is generally considered to be the best absorbed and utilized form of selenium.

Selenium is also available in 'high selenium yeasts', which may contain as much as 1,000 to 2,000 micrograms of selenium per gram. Most of the selenium in these yeasts is in the form of selenomethionine. This form of selenium was used in a large scale cancer prevention trial, which demonstrated that taking a daily supplement containing 200 micrograms of selenium per day could lower the risk of developing prostate, lung, and colorectal cancer. However, some yeasts may contain inorganic forms of selenium, which are not utilized as well as selenomethionine.

A study suggested that the organic forms of selenium increased blood selenium concentration to a greater extent than inorganic forms. However, it did not significantly improve the activity of the selenium-dependent enzyme, glutathione peroxidase. Researchers are continuing to examine the effects of different chemical forms of selenium, but the organic form currently appears to be the best choice.

**Selenium and Health Issues**

**Selenium and Cancer**

Observational studies indicate that death from cancer, including lung, colorectal, and prostate cancers, is lower among people with higher blood levels or intake of selenium. In addition, the incidence of nonmelanoma skin cancer is significantly higher in areas of the United States with low soil selenium content. The effect of selenium supplementation on the recurrence of different types of skin cancers was studied in seven dermatology clinics in the U.S. from 1983 through the early 1990s. Taking a daily supplement containing 200 μg of selenium did not affect recurrence of skin cancer, but significantly reduced the occurrence and death from total cancers. The incidence of prostate cancer, colorectal cancer, and lung cancer was notably lower in the group given selenium supplements.
Research suggests that selenium affects cancer risk in two ways. As an antioxidant, selenium can help protect the body from damaging effects of free radicals. Selenium may also prevent or slow tumor growth. Certain breakdown products of selenium are believed to prevent tumor growth by enhancing immune cell activity and suppressing development of blood vessels to the tumor.

However, not all studies have shown a relationship between selenium status and cancer. Over 60,000 participants of the Nurse's Health Study with no history of cancer submitted toenail clippings for selenium analysis. Toenails are thought to reflect selenium status over the previous year. After three and a half years of data collection, researchers compared toenail selenium levels of nurses with and without cancer. Those nurses with higher levels of selenium in their toenails did not have a reduced risk of cancer.

Two important long-term studies, the SU.VI.MAX study in France and the Selenium and Vitamin E Cancer Prevention Trial (SELECT) study in the U.S., are now underway to further investigate the selenium/cancer prevention link.

The SU.VI.MAX Study is a prevention trial looking at the effects of antioxidant vitamins and minerals on chronic diseases such as cancer and cardiovascular disease. Doses of the nutrients provided in the study are one to three times higher than recommended intakes, including a daily supplement of 100 $\mu$g selenium.

The SELECT study, a long-term study sponsored by the NIH, is investigating whether supplemental selenium and/or vitamin E can decrease the risk of prostate cancer in healthy men. Past evidence as well as pre-clinical trials for the SELECT study suggests that these two nutrients may be effective in preventing prostate cancer. A daily supplement containing 200 $\mu$g of selenium will be given to individuals in the selenium-only study group, while men in the combined-nutrients group will receive a daily supplement containing 200 $\mu$g selenium and 400 mg vitamin E. The study, which will span from 2001 to 2013, will include 32,400 healthy adult men.

**Selenium and Heart Disease**

Some population surveys have suggested an association between lower antioxidant intake and a greater incidence of heart disease. Evidence also suggests that oxidative stress from free radicals, which are natural by-products of oxygen metabolism, may promote heart disease. For example, it is the oxidized form of low-density lipoproteins (LDL, often called "bad" cholesterol) that promotes plaque build-up in coronary arteries. Selenium is one of a group of antioxidants that may help limit the oxidation of LDL cholesterol and thereby help to prevent coronary artery disease. Currently there is insufficient evidence available to recommend selenium supplements for the prevention of coronary heart disease; however, the SU.VI.MAX study mentioned earlier is looking at the effects of antioxidant nutrients such as selenium on heart disease.
Selenium and Arthritis
Surveys indicate that individuals with rheumatoid arthritis have reduced selenium levels in their blood. In addition, some individuals with arthritis have a low selenium intake.

The body's immune system naturally makes free radicals that can help destroy invading organisms and damaged tissue, but that can also harm healthy tissue. Selenium, as an antioxidant, may help to relieve symptoms of arthritis by controlling levels of free radicals. Current findings are considered preliminary, and further research is needed before selenium supplements can be recommended for individuals with arthritis.

Selenium and HIV
HIV/AIDS malabsorption can deplete levels of many nutrients, including selenium. Selenium deficiency is associated with decreased immune cell counts, increased disease progression, and high risk of death in the HIV/AIDS population. HIV/AIDS gradually destroys the immune system, and oxidative stress may contribute to further damage of immune cells. Antioxidant nutrients such as selenium help protect cells from oxidative stress, thus potentially slowing progression of the disease. Selenium also may be needed for the replication of the HIV virus, which could further deplete levels of selenium.

An examination of 125 HIV-positive men and women linked selenium deficiency with a higher rate of death from HIV. In a small study of 24 children with HIV who were observed for five years, those with low selenium levels died at a younger age, which may indicate faster disease progression. Results of research studies have led experts to suggest that selenium status may be a significant predictor of survival for those infected with HIV.

Researchers continue to investigate the relationship between selenium and HIV/AIDS, including the effect of selenium levels on disease progression and mortality. There is insufficient evidence to routinely recommend selenium supplements for individuals with HIV/AIDS, but physicians may prescribe such supplements as part of an overall treatment plan. It is also important for HIV-positive individuals to consume recommended amounts of selenium in their diet.

Selenium Toxicity
High blood levels of selenium (greater than 100 µg/dL) can result in a condition called selenosis. Symptoms of selenosis include gastrointestinal upsets, hair loss, white blotchy nails, garlic breath odor, fatigue, irritability, and mild nerve damage.
Selenium toxicity is rare in the U.S. The few reported cases have been associated with industrial accidents and a manufacturing error that led to an excessively high dose of selenium in a supplement. The Institute of Medicine of the National Academy of Sciences has set a tolerable upper intake level (UL) for selenium at 400 micrograms per day for adults to prevent the risk of developing selenosis. The table below lists ULs for selenium, in micrograms per day, for infants, children, and adults.

**Tolerable Upper Intake Levels for selenium:**

<table>
<thead>
<tr>
<th>Age</th>
<th>Males and Females (µg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 6 months</td>
<td>45</td>
</tr>
<tr>
<td>7 - 12 months</td>
<td>60</td>
</tr>
<tr>
<td>1-3 y</td>
<td>90</td>
</tr>
<tr>
<td>4-8 y</td>
<td>150</td>
</tr>
<tr>
<td>9-13 y</td>
<td>280</td>
</tr>
<tr>
<td>14-18 y</td>
<td>400</td>
</tr>
<tr>
<td>19 y +</td>
<td>400</td>
</tr>
</tbody>
</table>

**Zinc**

**Overview**

Zinc is an essential mineral that is found in almost every cell. It stimulates the activity of approximately 100 enzymes, which are substances that promote biochemical reactions in your body. Zinc supports a healthy immune system, is needed for wound healing, helps maintain your sense of taste and smell, and is needed for DNA synthesis. Zinc also supports normal growth and development during pregnancy, childhood, and adolescence.

**Zinc in Food**

Zinc is found in a wide variety of foods. Oysters contain more zinc per serving than any other food, but red meat and poultry provide the majority of zinc in the American diet. Other good food sources include beans, nuts, certain seafood, whole grains, fortified breakfast cereals, and dairy products. Zinc absorption is greater from a diet high in animal protein than a diet rich in plant proteins. Phytates, which are found in whole grain breads, cereals, legumes and other products, can decrease zinc absorption.

Good dietary sources of zinc are red meat, poultry, fortified breakfast cereal, some seafood, whole grains, dry beans, and nuts provide zinc. Fortified foods including breakfast cereals make it easier to consume the RDA for zinc, however
they also make it easier to consume too much zinc, especially if supplemental zinc is being taken. Anyone considering taking a zinc supplement should first consider whether their needs could be met by dietary zinc sources and from fortified foods.

**Recommended Dietary Intake for Zinc**

The latest recommendations for zinc intake are given in the new Dietary Reference Intakes developed by the Institute of Medicine. Dietary Reference Intakes (DRIs) is the umbrella term for a group of reference values used for planning and assessing nutrient intake for healthy people. The Recommended Dietary Allowance (RDA), one of the DRIs, is the average daily dietary intake level that is sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals. For infants 0 to 6 months, the DRI is in the form of an Adequate Intake (AI), which is the mean intake of zinc in healthy, breastfed infants. The AI for zinc for infants from 0 through 6 months is 2.0 milligrams (mg) per day. The RDAs for zinc for infants 7 through 12 months, children and adults in mg per day are:

### Recommended Dietary Allowances for Zinc

<table>
<thead>
<tr>
<th>Age</th>
<th>Infants and Children</th>
<th>Males</th>
<th>Females</th>
<th>Pregnancy</th>
<th>Lactation</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 months to 3 years</td>
<td>3 mg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 to 8 years</td>
<td>5 mg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 to 13 years</td>
<td>8 mg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 to 18 years</td>
<td>11 mg</td>
<td>9 mg</td>
<td>13 mg</td>
<td>14 mg</td>
<td></td>
</tr>
<tr>
<td>19+</td>
<td>11 mg</td>
<td>8 mg</td>
<td>11 mg</td>
<td>12 mg</td>
<td></td>
</tr>
</tbody>
</table>

Results of two national surveys, the National Health and Nutrition Examination Survey (NHANES III 1988-91) (12) and the Continuing Survey of Food Intakes of Individuals (1994 CSFII) (13) indicated that most infants, children, and adults consume recommended amounts of zinc.

**Zinc Deficiency**

Zinc deficiency most often occurs when zinc intake is inadequate or poorly absorbed, when there are increased losses of zinc from the body, or when the body’s requirement for zinc increases. Signs of zinc deficiency include growth retardation, hair loss, diarrhea, delayed sexual maturation and impotence, eye and skin lesions, and loss of appetite. There is also evidence that weight loss, delayed healing of wounds, taste abnormalities, and mental lethargy can occur.
Zinc Supplementation

There is no single laboratory test that adequately measures zinc nutritional status. Medical doctors who suspect a zinc deficiency will consider risk factors such as inadequate caloric intake, alcoholism, digestive diseases, and symptoms such as impaired growth in infants and children when determining a need for zinc supplementation. Vegetarians may need as much as 50% more zinc than non-vegetarians because of the lower absorption of zinc from plant foods, so it is very important for vegetarians to include good sources of zinc in their diet.

Maternal zinc deficiency can slow fetal growth. Zinc supplementation has improved growth rate in some children who demonstrate mild to moderate growth failure and who also have a zinc deficiency. Human milk does not provide recommended amounts of zinc for older infants between the ages of 7 months and 12 months, so breast-fed infants of this age should also consume age-appropriate foods containing zinc or be given formula containing zinc. Alternately, pediatricians may recommend supplemental zinc in this situation. Breastfeeding also may deplete maternal zinc stores because of the greater need for zinc during lactation. It is important for mothers who breast-feed to include good sources of zinc in their daily diet and for pregnant women to follow their doctor’s advice about taking vitamin and mineral supplements.

Low zinc status has been observed in 30% to 50% of alcoholics. Alcohol decreases the absorption of zinc and increases loss of zinc in urine. In addition, many alcoholics do not eat an acceptable variety or amount of food, so their dietary intake of zinc may be inadequate.

Diarrhea results in a loss of zinc. Individuals who have had gastrointestinal surgery or who have digestive disorders that result in malabsorption, including sprue, Crohn's disease and short bowel syndrome, are at greater risk of a zinc deficiency. Individuals who experience chronic diarrhea should make sure they include sources of zinc in their daily diet and may benefit from zinc supplementation.

Zinc and Health Issues

Zinc, Infections, and Wound Healing
The immune system is adversely affected by even moderate degrees of zinc deficiency. Severe zinc deficiency depresses immune function. Zinc is required for the development and activation of T-lymphocytes, a kind of white blood cell that helps fight infection. When zinc supplements are given to individuals with low zinc levels, the numbers of T-cell lymphocytes circulating in the blood increase and the ability of lymphocytes to fight infection improves. Studies show that poor, malnourished children in India, Africa, South America, and Southeast Asia experience shorter courses of infectious diarrhea after taking zinc supplements. Amounts of zinc provided in these studies ranged from 4 mg a day up to 40 mg.
per day and were provided in a variety of forms (zinc acetate, zinc gluconate, or zinc sulfate). Zinc supplements are often given to help heal skin ulcers or bed sores, but they do not increase rates of wound healing when zinc levels are normal.

Zinc and the Common Cold
The effect of zinc treatments on the severity or duration of cold symptoms is controversial. A study of over 100 employees of the Cleveland Clinic indicated that zinc lozenges decreased the duration of colds by one-half, although no differences were seen in how long fevers lasted or the level of muscle aches. Other researchers examined the effect of zinc supplements on cold duration and severity in over 400 randomized subjects. In their first study, a virus was used to induce cold symptoms. The duration of illness was significantly lower in the group receiving zinc gluconate lozenges (providing 13.3 mg zinc) but not in the group receiving zinc acetate lozenges (providing 5 or 11.5 mg zinc). None of the zinc preparations affected the severity of cold symptoms in the first 3 days of treatment. In the second study, which examined the effects of zinc supplements on duration and severity of natural colds, no differences were seen between individuals receiving zinc and those receiving a placebo (sugar pill). Recent research suggests that the effect of zinc may be influenced by the ability of the specific supplement formula to deliver zinc ions to the oral mucosa. Additional research is needed to determine whether zinc compounds have any effect on the common cold.

Zinc and Iron Absorption
Iron deficiency anemia is considered a serious public health problem in the world today. Iron fortification programs were developed to prevent this deficiency, and they have been credited with improving the iron status of millions of women, infants, and children. Some researchers have questioned the effect of iron fortification on absorption of other nutrients, including zinc. Fortification of foods with iron does not significantly affect zinc absorption. However, large amounts of iron in supplements (greater than 25 mg) may decrease zinc absorption, as can iron in solutions. Taking iron supplements between meals will help decrease its effect on zinc absorption.

Zinc Toxicity
Zinc toxicity has been seen in both acute and chronic forms. Intakes of 150 to 450 mg of zinc per day have been associated with low copper status, altered iron function, reduced immune function, and reduced levels of high-density lipoproteins. One case report cited severe nausea and vomiting within 30 minutes after the person ingested four grams of zinc gluconate (570 mg elemental zinc). The National Academy of Sciences has established tolerable upper levels (UL), the highest daily intake associated with no adverse health effects, for zinc for infants, children, and adults. The ULs do not apply to individuals who are receiving zinc for medical treatment, but it is important for
such individuals to be under the care of a medical doctor who will monitor for adverse health effects. The Upper Levels for infants, children and adults are:

Upper Levels for Zinc:

<table>
<thead>
<tr>
<th>Age</th>
<th>Infants and Children</th>
<th>Males and Females</th>
<th>Pregnancy and Lactation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 6 months</td>
<td>4 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 to 12 months</td>
<td>5 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 to 3 years</td>
<td>7 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 to 8 years</td>
<td>12 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 to 13 years</td>
<td>23 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 to 18 years</td>
<td>34 mg</td>
<td></td>
<td>34 mg</td>
</tr>
<tr>
<td>Ages 19+</td>
<td>40 mg</td>
<td>40 mg</td>
<td></td>
</tr>
</tbody>
</table>

Iodine

Overview

Iodine is a trace element that is naturally present in some foods, added to others, and available as a dietary supplement. Iodine is an essential component of the thyroid hormones thyroxine (T4) and triiodothyronine (T3). Thyroid hormones regulate many important biochemical reactions, including protein synthesis and enzymatic activity, and are critical determinants of metabolic activity. They are also required for proper skeletal and central nervous system development in fetuses and infants.

Thyroid function is primarily regulated by thyroid-stimulating hormone (TSH), also known as thyrotropin. It is secreted by the pituitary gland to control thyroid hormone production and secretion, thereby protecting the body from hypothyroidism and hyperthyroidism. TSH secretion increases thyroidal uptake of iodine and stimulates the synthesis and release of T3 and T4. In the absence of sufficient iodine, TSH levels remain elevated, leading to goiter, an enlargement of the thyroid gland that reflects the body’s attempt to trap more iodine from the circulation and produce thyroid hormones.

Iodine may have other physiological functions in the body as well. For example, it appears to play a role in immune response and might have a beneficial effect on mammary dysplasia and fibrocystic breast disease.
The earth’s soils contain varying amounts of iodine, which in turn affects the iodine content of crops. In some regions of the world, iodine-deficient soils are common, increasing the risk of iodine deficiency among people who consume foods primarily from those areas. Salt iodization programs, which many countries have implemented, have dramatically reduced the prevalence of iodine deficiency worldwide.

Iodine in food and iodized salt is present in several chemical forms including sodium and potassium salts, inorganic iodine (I₂), iodate, and iodide, the reduced form of iodine. Iodine rarely occurs as the element, which is a gas, but rather as a salt; for this reason, it is referred to as iodide and not iodine. Iodide is quickly and almost completely absorbed in the stomach and duodenum. Iodate is reduced in the gastrointestinal tract and absorbed as iodide. When iodide enters the circulation, the thyroid gland concentrates it in appropriate amounts for thyroid hormone synthesis and most of the remaining amount is excreted in the urine. The iodine-replete healthy adult has about 15–20 mg of iodine, 70%–80% of which is contained in the thyroid.

**Recommended Intakes**

Intake recommendations for iodine 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). DRI is the general term for a set of reference values used for planning and assessing nutrient intakes of healthy people. These values, which vary by age and gender, 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 populations but not individuals.
- **Tolerable Upper Intake Level (UL):** maximum daily intake unlikely to cause adverse health effects.
The current RDAs for iodine:

<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
<th>Pregnancy</th>
<th>Lactation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth to 6 months</td>
<td>110 mcg*</td>
<td>110 mcg*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7–12 months</td>
<td>130 mcg*</td>
<td>130 mcg*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–3 years</td>
<td>90 mcg</td>
<td>90 mcg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4–8 years</td>
<td>90 mcg</td>
<td>90 mcg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9–13 years</td>
<td>120 mcg</td>
<td>120 mcg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14–18 years</td>
<td>150 mcg</td>
<td>150 mcg</td>
<td>220 mcg</td>
<td>290 mcg</td>
</tr>
<tr>
<td>19+ years</td>
<td>150 mcg</td>
<td>150 mcg</td>
<td>220 mcg</td>
<td>290 mcg</td>
</tr>
</tbody>
</table>

* Adequate Intake (AI)

**Sources of Iodine**

**Food**
Seaweed (such as kelp, nori, kombu, and wakame) is one of the best food sources of iodine, but it is highly variable in its content. Other good sources include seafood, dairy products (partly due to the use of iodine feed supplements and iodophor sanitizing agents in the dairy industry), grain products, and eggs. Dairy products, especially milk, and grain products are the major contributors of iodine to the American diet. Iodine is also present in human breast milk and infant formulas.

Fruits and vegetables contain iodine, but the amount varies depending on the iodine content of the soil, fertilizer use and irrigation practices. Iodine concentrations in plant foods can range from as little as 10 mcg/kg to 1 mg/kg dry weight. This variability in turn affects the iodine content of meat and animal products because it affects the iodine content of foods that the animals consume. The iodine content of different seaweed species also varies greatly.

**Iodized Salt**
More than 70 countries, including the United States and Canada, have salt iodization programs. As a result, approximately 70% of households worldwide use iodized salt, ranging from almost 90% of households in North and South America to less than 50% in Europe and the Eastern Mediterranean regions. In the United States, salt manufacturers have been adding iodine to table salt since the 1920s, although it is still a voluntary program. The U.S. Food and Drug Administration (FDA) has approved potassium iodide and cuprous iodide for salt iodization while the WHO recommends the use of potassium iodate due to its greater stability, particularly in tropical climates. According to its label, iodized salt in the United States contains 45 mcg iodine/g salt (between 1/8 and 1/4 teaspoon); measured salt samples have an average level of 47.5 mcg iodine/g.
DIETARY MINERALS

salt. However, the majority of salt intake in the United States comes from processed foods, and food manufacturers almost always use non-iodized salt in processed foods. If they do use iodized salt, they must list the salt as iodized in the ingredient list on the food label.

Dietary supplements
Many multivitamin/mineral supplements contain iodine in the forms of potassium iodide or sodium iodide. Dietary supplements of iodine or iodine-containing kelp (a seaweed) are also available. A small study found that potassium iodide is almost completely (96.4%) absorbed in humans.

Iodine Intakes
The Total Diet Study (TDS), an FDA monitoring program, provides estimated iodine intakes of the U.S. population. Through the TDS program, foods that represent the average U.S. diet are purchased and analyzed for several components, including iodine. Based on analytical results from TDS food samples collected, combined with food consumption estimates, average iodine intakes in the United States range from 138 to 353 mcg/day across all age and gender groups.

TDS data do not include iodine that people obtain from the discretionary use of iodized salt. Because many U.S. households use iodized salt, TDS data likely underestimate the true iodine intake of most U.S. residents. Data from the National Health and Nutrition Examination Survey (NHANES) indicate that 28–29% of adults use iodine-containing dietary supplements; this use also adds to the population's total iodine intake.

Iodine Deficiency
Iodine deficiency has multiple adverse effects on growth and development, and is the most common cause of preventable mental retardation in the world. Iodine deficiency disorders result from inadequate thyroid hormone production secondary to insufficient iodine. During pregnancy and early infancy, iodine deficiency can cause irreversible effects.

Under normal conditions, the body tightly controls thyroid hormone concentrations via TSH. Typically, TSH secretion increases when iodine intake falls below about 100 mcg/day. TSH increases thyroidal iodine uptake from the blood and the production of thyroid hormone. However, very low iodine intakes can reduce thyroid hormone production even in the presence of elevated TSH levels. If a person's iodine intake falls below approximately 10–20 mcg/day, hypothyroidism occurs, a condition that is frequently accompanied by goiter. Goiter is usually the earliest clinical sign of iodine deficiency.
In pregnant women, iodine deficiency of this magnitude can cause major neurodevelopmental deficits and growth retardation in the fetus, as well as miscarriage and stillbirth. Chronic, severe iodine deficiency in utero causes cretinism, a condition characterized by mental retardation, deaf mutism, motor spasticity, stunted growth, delayed sexual maturation, and other physical and neurological abnormalities.

In infants and children, less severe iodine deficiency can also cause neurodevelopmental deficits such as somewhat lower-than-average intelligence as measured by IQ. Mild to moderate maternal iodine deficiency has also been associated with an increased risk for attention deficit hyperactivity disorder in children. In adults, mild-to-moderate iodine deficiency can cause goiter as well as impaired mental function and work productivity secondary to hypothyroidism. Chronic iodine deficiency may be associated with an increased risk of the follicular form of thyroid cancer.

Historically, iodine deficiency was endemic in mountainous regions of the United States and Mexico, and in the so called "goiter belt" around the Great Lakes. Thanks to a more national food supply, iodized salt and other factors, iodine deficiency is now uncommon in North America. Worldwide however, iodine deficiency remains a public health problem in 47 countries, and about 2.2 billion people (38% of the world’s population) live in areas with iodine deficiency. International efforts since the early 1990s have dramatically reduced the incidence of iodine deficiency, but some groups of people are still at risk of inadequate iodine intake.

Iodine and Health Issues

Due to its important role in fetal and infant development and thyroid hormone production, iodine is a critical nutrient for proper health at all life stages. This section focuses on four areas of biomedical research examining iodine’s role in health and disease: fetal and infant development, cognitive function during childhood, fibrocystic breast disease, and radiation-induced thyroid cancer.

Fetal and infant development
Iodine sufficiency during pregnancy is extremely important for proper fetal development. During early pregnancy, when fetal thyroid gland development is incomplete, the fetus depends entirely on maternal T4 and therefore, on maternal iodine intakee. Production of T4 increases by approximately 50% during pregnancy, requiring a concomitant increase in maternal iodine intake. Sufficient iodine intake after birth is also important for proper physical and neurological growth and maturation.

Research suggests that infants are more sensitive to the effects of iodine deficiency than other age groups, as indicated by changes in their TSH and T4 levels in response to even mild iodine deficiency. To accommodate increased
iodine needs during pregnancy and lactation, the iodine RDA is 220 mcg/day for pregnant women and 290 mcg/day for lactating women. Similarly, the WHO recommends 250 mcg/day during pregnancy and lactation.

Although severe iodine deficiency disorders are uncommon in the United States, mild-to-moderate iodine insufficiency during pregnancy may subtly affect fetal development. In a 2009 study, researchers measured the neuropsychological status of Spanish infants whose mothers received daily supplements of 300 mcg iodine (as potassium iodide) during pregnancy and lactation. The mothers were moderately, but not severely, iodine deficient. Iodine supplementation resulted in significant improvements in some but not all aspects of neurodevelopment (as measured by Bayley Psychomotor Development scores) at 3–18 months of age compared with infants whose mothers did not receive iodine supplements.

Breast milk contains iodine, although concentrations vary based on maternal iodine levels. Infants who are exclusively breastfed depend on maternal iodine sufficiency for optimal development. In a study of 57 healthy lactating women from the Boston area, median breast milk iodine content was 155 mcg/L. Based on reported infant iodine needs and the typical volume of breast milk consumed, the authors calculated that 47% of the women may have been providing their infants breast milk containing insufficient amounts of iodine. During the weaning period, infants not receiving iodine-containing complementary foods may also be at risk of iodine deficiency, even in countries with iodized salt programs.

To ensure that adequate amounts of iodine are available for proper fetal and infant development, several national and international groups recommend iodine supplementation during pregnancy, lactation, and early childhood. For women living in countries with weak, sporadic, or uneven iodized salt distribution, the WHO recommends iodine supplementation for all women of childbearing age to achieve a total iodine intake of 150 mcg/day. For pregnant and lactating women in these countries, iodine intakes of 250 mcg/day from both supplements and dietary sources are recommended. WHO recommendations for these countries also include breastfeeding through 24 months of age, combined with complementary foods fortified with iodine for children between the ages of 7–24 months. In the United States and Canada, the American Thyroid Association recommends iodine supplementation (150 mcg/day) as part of a prenatal vitamin/mineral supplement for pregnant and lactating women. Currently, it is estimated that only 51% of the types of prenatal multivitamins marketed in the United States contain iodine and according to NHANES data, 15% of lactating women and 20% of non-pregnant and pregnant women in the United States take a supplement containing iodine.

Results from a 2010 study however, raise some questions as to the safety of widespread iodine supplementation in areas of relative iodine sufficiency. In this cross-sectional study, pregnant women living in Spain had a significantly increased risk of hyperthyrotropinemia (TSH >3 microU/mL) if they consumed
iodine supplements in doses ≥200 mcg/day compared with those who consumed doses <100 mcg/day. These findings suggest that taking higher doses of supplemental iodine during pregnancy could induce thyroid dysfunction in some women and underscore the need for additional research into the effects on maternal thyroid function of iodine supplementation during pregnancy.

Taken as a whole, these findings indicate that increased public awareness of iodine's importance during pregnancy and lactation is warranted and that further research into the effects of iodine supplementation during pregnancy is needed. Many researchers, as well as the American Thyroid Association, stress the importance of continued iodine status monitoring among women of reproductive age.

Childhood Cognitive Function

The effects of severe iodine deficiency on neurological development are well documented. Results from several studies suggest, for example, that chronic, moderate-to-severe iodine deficiency, particularly in children, reduces IQ by about 12–13.5 points. A Cochrane review concluded that iodine supplementation in children living in areas of iodine deficiency appears to both positively affect physical and mental development and decrease mortality with only minor and transient adverse effects.

The effects of mild iodine deficiency during childhood are more difficult to quantify. Some research suggests that mild iodine deficiency is associated with subtle neurodevelopmental deficits and that iodine supplementation might improve cognitive function in mildly iodine-deficient children.

In a 2009 randomized, placebo-controlled study, 184 children aged 10–13 years in New Zealand with a median urinary iodine concentration of 63 mcg/L received iodine supplements (150 mcg/day) or placebo for 28 weeks. Iodine supplementation improved iodine status (median urinary iodine concentration after supplementation was 145 mcg/L) and significantly improved measures of perceptual reasoning and overall cognitive score compared with children taking a placebo. These findings suggest that correcting mild iodine deficiency in children could improve certain components of cognition. Additional research is required to fully understand the effects of mild iodine deficiency and iodine supplementation on cognitive function.

Fibrocystic Breast Disease

Fibrocystic breast disease is a benign condition characterized by lumpy, painful breasts and palpable fibrosis. It commonly affects women of reproductive age, but it can also occur during menopause, especially in women taking estrogens. Breast tissue has a high concentration of iodine, especially during pregnancy and lactation). Some research suggests that iodine supplementation might be helpful for fibrocystic breast disease, although a specific mechanism of action has not been established and data are limited.
In a double-blind study, researchers randomly assigned 56 women with fibrocystic breast disease to receive daily supplements of iodine (70 to 90 mcg I₂/kg body weight) or placebo for 6 months. At treatment completion, 65% of the women receiving iodine reported decreased pain compared with 33% of women in the placebo group. A more recent randomized, double-blind, placebo-controlled clinical trial had similar findings. In this study, researchers randomly assigned 111 women (18–50 years of age) with fibrosis and a history of breast pain to receive tablets containing 0 mcg, 1,500 mcg, 3,000 mcg, or 6,000 mcg of iodine per day. After 5 months of treatment, women receiving doses of 3,000 or 6,000 mcg iodine had a significant decrease in breast pain, tenderness, and nodularity compared with those receiving placebo or 1,500 mcg iodine. The researchers also reported a dose-dependent reduction in self-assessed pain. None of the doses was associated with major adverse events or changes in thyroid function test results.

Although the results of these studies are promising, more research is needed to clarify iodine’s role in fibrocystic breast disease. Moreover, the doses used in these studies (approximately 1,500–6,000 mcg per day) are several times higher than the iodine UL of 1,100 mcg for adults. Doses of this magnitude should only be used under the guidance of a physician.

Radiation-Induced Thyroid Cancer
Nuclear accidents can release radioactive iodine into the environment, increasing the risk of thyroid cancer in exposed individuals, especially children. Thyroidal uptake of radioactive iodine is higher in people with iodine deficiency than in people with iodine sufficiency. For this reason, iodine-deficient individuals have a particularly high risk of developing radiation-induced thyroid cancer when exposed to radioactive iodine.

The FDA has approved potassium iodide as a thyroid-blocking agent to reduce the risk of thyroid cancer in radiation emergencies involving the release of radioactive iodine. The FDA recommends that exposed people take a daily pharmacological dose (16–130 mg potassium iodide, depending on age) until the risk of significant radiation exposure ends. Potassium iodide was widely used in Poland following the 1986 Chernobyl accident and childhood thyroid cancer rates did not increase substantially in subsequent years. In areas where iodide prophylaxis was not used, such as Belarus and Ukraine, where many children were mildly iodine-deficient, the incidence of thyroid cancer sharply increased among children and adolescents.

Toxicity
High intakes of iodine can cause some of the same symptoms as iodine deficiency—including goiter, elevated TSH levels, and hypothyroidism—because excess iodine in susceptible individuals inhibits thyroid hormone synthesis and
thereby increases TSH stimulation, which can produce goiter. Iodine-induced hyperthyroidism can also result from high iodine intakes, usually when iodine is administered to treat iodine deficiency. Studies have also shown that excessive iodine intakes cause thyroiditis and thyroid papillary cancer. Cases of acute iodine poisoning are rare and are usually caused by doses of many grams. Acute poisoning symptoms include burning of the mouth, throat, and stomach; fever; abdominal pain; nausea; vomiting; diarrhea; weak pulse; and coma.

Responses to excess iodine and the doses required to cause adverse effects vary. Some people, such as those with autoimmune thyroid disease and iodine deficiency, may experience adverse effects with iodine intakes considered safe for the general population.

The FNB has established iodine ULs for food and supplement intakes:

<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
<th>Pregnancy</th>
<th>Lactation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth to 6 months</td>
<td>Not possible to establish*</td>
<td>Not possible to establish*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7–12 months</td>
<td>Not possible to establish*</td>
<td>Not possible to establish*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–3 years</td>
<td>200 mcg</td>
<td>200 mcg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4–8 years</td>
<td>300 mcg</td>
<td>300 mcg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9–13 years</td>
<td>600 mcg</td>
<td>600 mcg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14–18 years</td>
<td>900 mcg</td>
<td>900 mcg</td>
<td>900 mcg</td>
<td>900 mcg</td>
</tr>
<tr>
<td>19+ years</td>
<td>1,100 mcg</td>
<td>1,100 mcg</td>
<td>1,100 mcg</td>
<td>1,100 mcg</td>
</tr>
</tbody>
</table>

* Formula and food should be the only sources of iodine for infants.

In most people, iodine intakes from foods and supplements are unlikely to exceed the UL. Long-term intakes above the UL increase the risk of adverse health effects. The ULs do not apply to individuals receiving iodine for medical treatment, but such individuals should be under the care of a physician.

**Interactions with Medications**

Iodine supplements have the potential to interact with several types of medications. A few examples are provided below. Individuals taking these medications on a regular basis should discuss their iodine intakes with their health care providers.

**Anti-thyroid Medications**

Anti-thyroid medications, such as methimazole (Tapazole®), are used to treat hyperthyroidism. Taking high doses of iodine with anti-thyroid medications can have an additive effect and could cause hypothyroidism.

**Angiotensin-converting enzyme (ACE) inhibitors**

Angiotensin-converting enzyme (ACE) inhibitors, such as benazepril (Lotensin®), lisinopril (Prinivil® and Zestril®), and fosinopril (Monopril®), are used primarily to
treat high blood pressure. Taking potassium iodide with ACE inhibitors can increase the risk of hyperkalemia (elevated blood levels of potassium).

**Potassium-sparing diuretics**

Taking potassium iodide with potassium-sparing diuretics, such as spironolactone (Aldactone®) and amiloride (Midamor®), can increase the risk of hyperkalemia.

**Sodium**

**Overview**

Sodium is an essential nutrient and is needed by the body in relatively small quantities, provided that substantial sweating does not occur. On average, the higher an individual's sodium intake, the higher the individual's blood pressure. A strong body of evidence in adults documents that as sodium intake decreases, so does blood pressure. Moderate evidence in children also has documented that as sodium intake decreases, so does blood pressure. Keeping blood pressure in the normal range reduces an individual’s risk of cardiovascular disease, congestive heart failure, and kidney disease. Therefore, adults and children should limit their intake of sodium.

Virtually all Americans consume more sodium than they need. The estimated average intake of sodium for all Americans ages 2 years and older is approximately 3,400 mg per day.

**Sodium Sources**

Sodium is primarily consumed as salt (sodium chloride). As a food ingredient, salt has multiple uses, such as in curing meat, baking, masking off-flavors, retaining moisture, and enhancing flavor (including the flavor of other ingredients). Salt added at the table and in cooking provides only a small proportion of the total sodium that Americans consume. Most sodium comes from salt added during food processing. Many types of processed foods contribute to the high intake of sodium.

Some sodium-containing foods are high in sodium, but the problem of excess sodium intake also is due to frequent consumption of foods that contain lower amounts of sodium, such as yeast breads (which contribute 7% of the sodium in the U.S. diet). Other sources of sodium include chicken and chicken mixed dishes (7% of sodium intake), pizza (6%), and pasta and pasta dishes (5%). Some of the sources can be purchased or prepared to be lower in sodium. For example, chicken naturally contains little sodium. Chicken and chicken mixed dishes can be prepared by purchasing chicken that has not had sodium added to it and by not adding salt or ingredients containing sodium.
Americans can reduce their consumption of sodium in a variety of ways:

- Read the Nutrition Facts label for information on the sodium content of foods and purchase foods that are low in sodium.
- Consume more fresh foods and fewer processed foods that are high in sodium.
- Eat more home-prepared foods, where you have more control over sodium, and use little or no salt or salt-containing seasonings when cooking or eating foods.
- When eating at restaurants, ask that salt not be added to your food or order lower sodium options, if available.

**Recommended Dietary Intake**

Because a Recommended Dietary Allowance for sodium could not be determined, the Institute of Medicine (IOM) set Adequate Intake (AI) levels for this nutrient. The AI is the recommended daily average intake level of a nutrient, and usual intakes at or above the AI have a low probability of inadequacy. The sodium AI is based on the amount that is needed to meet the sodium needs of healthy and moderately active individuals. It covers sodium sweat losses in unacclimatized individuals who are exposed to high temperatures or who become physically active, and ensures that recommended intake levels for other nutrients can be met. The sodium AI for individuals ages 9 to 50 years is 1,500 mg per day. Lower sodium AIs were established for children and older adults (ages 1 to 3 years: 1,000 mg/day; ages 4 to 8 years: 1,200 mg/day; ages 51 to 70 years: 1,300 mg/day; ages 71 years and older: 1,200 mg/day) because their calorie requirements are lower.

For adolescents and adults of all ages (14 years and older), the IOM set the Tolerable Upper Intake Level (UL) at 2,300 mg per day. The UL is the highest daily nutrient intake level that is likely to pose no risk of adverse health effects (e.g., for sodium, increased blood pressure) to almost all individuals in the general population. The IOM recognized that the association between sodium intake and blood pressure was continuous and without a threshold (i.e., a level below which the association no longer exists). The UL was based on several trials, including data from the Dietary Approaches to Stop Hypertension (DASH)-Sodium trial. The IOM noted that in the DASH-Sodium trial, blood pressure was lowered when target sodium intake was reduced to 2,300 mg per day, and lowered even further when sodium was targeted to the level of 1,200 mg per day. An intake level of 2,300 mg per day was commonly the next level above the AI of 1,500 mg per day that was tested in the sodium trials evaluated by the IOM.
Sodium Reduction

Americans should reduce their sodium intake to less than 2,300 mg or 1,500 mg per day depending on age and other individual characteristics. African Americans, individuals with hypertension, diabetes, or chronic kidney disease and individuals ages 51 and older, comprise about half of the U.S. population ages 2 and older. While nearly everyone benefits from reducing their sodium intake, the blood pressure of these individuals tends to be even more responsive to the blood pressure-raising effects of sodium than others; therefore, they should reduce their intake to 1,500 mg per day. Additional dietary modifications may be needed for people of all ages with hypertension, diabetes, or chronic kidney disease, and they are advised to consult a health care professional. Given the current U.S. marketplace and the resulting excessive high sodium intake, it is challenging to meet even the less than 2,300 mg recommendation—fewer than 15 percent of Americans do so currently. An immediate, deliberate reduction in the sodium content of foods in the marketplace is necessary to allow consumers to reduce sodium intake to less than 2,300 mg or 1,500 mg per day now.

Chromium

Overview

Chromium is a mineral that humans require in trace amounts, although its mechanisms of action in the body and the amounts needed for optimal health are not well defined. It is found primarily in two forms: 1) trivalent (chromium 3+), which is biologically active and found in food, and 2) hexavalent (chromium 6+), a toxic form that results from industrial pollution. The following information focuses exclusively on trivalent (3+) chromium.

Chromium is known to enhance the action of insulin, a hormone critical to the metabolism and storage of carbohydrate, fat, and protein in the body. In 1957, a compound in brewers’ yeast was found to prevent an age-related decline in the ability of rats to maintain normal levels of sugar (glucose) in their blood. Chromium was identified as the active ingredient in this so-called "glucose tolerance factor" in 1959.

Chromium also appears to be directly involved in carbohydrate, fat, and protein metabolism, but more research is needed to determine the full range of its roles in the body. The challenges to meeting this goal include:

- Defining the types of individuals who respond to chromium supplementation;
- Evaluating the chromium content of foods and its bioavailability;
- Determining if a clinically relevant chromium-deficiency state exists in humans due to inadequate dietary intakes; and
Developing valid and reliable measures of chromium status.

Sources of Chromium

Chromium is widely distributed in the food supply, but most foods provide only small amounts (less than 2 micrograms [mcg] per serving). Meat and whole-grain products, as well as some fruits, vegetables, and spices are relatively good sources. In contrast, foods high in simple sugars (like sucrose and fructose) are low in chromium.

Recommended Intake of Chromium

Recommended chromium intakes are provided in the Dietary Reference Intakes (DRIs) developed by the Institute of Medicine of the National Academy of Sciences. Dietary Reference Intakes is the general term for a set of reference values to plan and assess the nutrient intakes of healthy people. These values include the Recommended Dietary Allowance (RDA) and the Adequate Intake (AI). The RDA is the average daily intake that meets a nutrient requirement of nearly all (97 to 98%) healthy individuals. An AI is established when there is insufficient research to establish an RDA; it is generally set at a level that healthy people typically consume.

In 1989, the National Academy of Sciences established an "estimated safe and adequate daily dietary intake" range for chromium. For adults and adolescents that range was 50 to 200 mcg. In 2001, DRIs for chromium were established. The research base was insufficient to establish RDAs, so AIs were developed based on average intakes of chromium from food as found in several studies.

Adequate Intakes (AIs) for chromium:

<table>
<thead>
<tr>
<th>Age</th>
<th>Infants and children (mcg/day)</th>
<th>Males (mcg/day)</th>
<th>Females (mcg/day)</th>
<th>Pregnancy (mcg/day)</th>
<th>Lactation (mcg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 6 months</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 to 12 months</td>
<td>5.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 to 3 years</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 to 8 years</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>9 to 13 years</td>
<td></td>
<td>25</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 to 18 years</td>
<td></td>
<td>35</td>
<td>24</td>
<td>29</td>
<td>44</td>
</tr>
<tr>
<td>19 to 50 years</td>
<td></td>
<td>35</td>
<td>25</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>&gt;50 years</td>
<td>30</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

mcg = micrograms

Adult women in the United States consume about 23 to 29 mcg of chromium per day from food, which meets their AIs unless they're pregnant or lactating. In contrast, adult men average 39 to 54 mcg per day, which exceeds their AIs.
The average amount of chromium in the breast milk of healthy, well-nourished mothers is 0.24 mcg per quart, so infants exclusively fed breast milk obtain about 0.2 mcg (based on an estimated consumption of 0.82 quarts per day). Infant formula provides about 0.5 mcg of chromium per quart. No studies have compared how well infants absorb and utilize chromium from human milk and formula.

**Chromium Absorption**

Absorption of chromium from the intestinal tract is low, ranging from less than 0.4% to 2.5% of the amount consumed, and the remainder is excreted in the feces. Enhancing the mineral's absorption are vitamin C (found in fruits and vegetables and their juices) and the B vitamin niacin (found in meats, poultry, fish, and grain products). Absorbed chromium is stored in the liver, spleen, soft tissue, and bone.

The body's chromium content may be reduced under several conditions. Diets high in simple sugars (comprising more than 35% of calories) can increase chromium excretion in the urine. Infection, acute exercise, pregnancy and lactation, and stressful states (such as physical trauma) increase chromium losses and can lead to deficiency, especially if chromium intakes are already low.

**Chromium Deficiency**

In the 1960s, chromium was found to correct glucose intolerance and insulin resistance in deficient animals, two indicators that the body is failing to properly control blood-sugar levels and which are precursors of type 2 diabetes. However, reports of actual chromium deficiency in humans are rare. Three hospitalized patients who were fed intravenously showed signs of diabetes (including weight loss, neuropathy, and impaired glucose tolerance) until chromium was added to their feeding solution. The chromium, added at doses of 150 to 250 mcg/day for up to two weeks, corrected their diabetes symptoms. Chromium is now routinely added to intravenous solutions.

**Chromium Supplementation**

There are reports of significant age-related decreases in the chromium concentrations of hair, sweat and blood, which might suggest that older people are more vulnerable to chromium depletion than younger adults. One cannot be sure, however, as chromium status is difficult to determine. That's because blood, urine, and hair levels do not necessarily reflect body stores. Furthermore, no chromium-specific enzyme or other biochemical marker has been found to reliably assess a person's chromium status.

There is considerable interest in the possibility that supplemental chromium may help to treat impaired glucose tolerance and type 2 diabetes, but the research to
date is inconclusive. No large, randomized, controlled clinical trials testing this hypothesis have been reported in the United States. Nevertheless, this is an active area of research.

**Chromium and Health Issues**

Chromium has long been of interest for its possible connection to various health conditions. Among the most active areas of chromium research are its use in supplement form to treat diabetes, lower blood lipid levels, promote weight loss, and improve body composition.

**Type 2 diabetes and Glucose Intolerance**

In type 2 diabetes, the pancreas is usually producing enough insulin but, for unknown reasons, the body cannot use the insulin effectively. The disease typically occurs, in part, because the cells comprising muscle and other tissues become resistant to insulin's action, especially among the obese. Insulin permits the entry of glucose into most cells, where this sugar is used for energy, stored in the liver and muscles (as glycogen), and converted to fat when present in excess. Insulin resistance leads to higher than normal levels of glucose in the blood (hyperglycemia).

Chromium deficiency impairs the body's ability to use glucose to meet its energy needs and raises insulin requirements. It has therefore been suggested that chromium supplements might help to control type 2 diabetes or the glucose and insulin responses in persons at high risk of developing the disease. A review of randomized controlled clinical trials evaluated this hypothesis. This meta-analysis assessed the effects of chromium supplements on three markers of diabetes in the blood: glucose, insulin, and glycated hemoglobin (which provides a measure of long-term glucose levels; also known as hemoglobin A1C). It summarized data from 15 trials on 618 participants, of which 425 were in good health or had impaired glucose tolerance and 193 had type 2 diabetes. Chromium supplementation had no effect on glucose or insulin concentrations in the non-diabetic subjects nor did it reduce these levels in subjects with diabetes, except in one study. However, that study, conducted in China (in which 155 diabetics were given either 200 or 1,000 mcg/day of chromium or a placebo) might simply show the benefits of supplementation in a chromium-deficient population.

Overall, the value of chromium supplements for diabetics is inconclusive and controversial. Randomized controlled clinical trials in well-defined, at-risk populations where dietary intakes are known are necessary to determine the effects of chromium on markers of diabetes.

**Lipid Metabolism**

The effects of chromium supplementation on blood lipid levels in humans are also inconclusive. In some studies, 150 to 1,000 mcg/day has decreased total
and low-density-lipoprotein (LDL or "bad") cholesterol and triglyceride levels and increased concentrations of apolipoprotein A (a component of high-density-lipoprotein cholesterol known as HDL or "good" cholesterol) in subjects with atherosclerosis or elevated cholesterol or among those taking a beta-blocker drug. These findings are consistent with the results of earlier studies.

However, chromium supplements have shown no favorable effects on blood lipids in other studies. The mixed research findings may be due to difficulties in determining the chromium status of subjects at the start of the trials and the researchers’ failure to control for dietary factors that influence blood lipid levels.

**Body Weight and Composition**
Chromium supplements are sometimes claimed to reduce body fat and increase lean (muscle) mass. Yet a recent review of 24 studies that examined the effects of 200 to 1,000 mcg/day of chromium (in the form of chromium picolinate) on body mass or composition found no significant benefits. Another recent review of randomized, controlled clinical trials did find supplements of chromium picolinate to help with weight loss when compared to placebos, but the differences were small and of debatable clinical relevance. In several studies, chromium's effects on body weight and composition may be called into question because the researchers failed to adequately control for the participants' food intakes. Furthermore, most studies included only a small number of subjects and were of short duration.

**Toxicity**
Few serious adverse effects have been linked to high intakes of chromium, so the Institute of Medicine has not established a Tolerable Upper Intake Level (UL) for this mineral. A UL is the maximum daily intake of a nutrient that is unlikely to cause adverse health effects. It is one of the values (together with the RDA and AI) that comprise the Dietary Reference Intakes (DRIs) for each nutrient.
Chromium and Medication Interactions

Certain medications may interact with chromium, especially when taken on a regular basis.

<table>
<thead>
<tr>
<th>Medications</th>
<th>Nature of interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antacids</td>
<td>These medications alter stomach acidity and may impair chromium absorption or enhance excretion</td>
</tr>
<tr>
<td>Corticosteroids</td>
<td></td>
</tr>
<tr>
<td>H2 blockers (such as cimetidine, famotidine, nizatidine, and ranitidine)</td>
<td></td>
</tr>
<tr>
<td>Proton-pump inhibitors (such as omeprazole, lansoprazole, rabeprazole, pantoprazole, and esomeprazole)</td>
<td></td>
</tr>
<tr>
<td>Beta-blockers (such as atenolol or propanolol)</td>
<td>These medications may have their effects enhanced if taken together with chromium or they may increase chromium absorption</td>
</tr>
<tr>
<td>Corticosteroids</td>
<td></td>
</tr>
<tr>
<td>Insulin</td>
<td></td>
</tr>
<tr>
<td>Nicotinic acid</td>
<td></td>
</tr>
<tr>
<td>Nonsteroidal anti-inflammatory drugs (NSAIDS)</td>
<td></td>
</tr>
<tr>
<td>Prostaglandin inhibitors (such as ibuprofen, indomethacin, naproxen, piroxicam, and aspirin)</td>
<td></td>
</tr>
</tbody>
</table>

Supplemental Sources of Chromium

Chromium is a widely used supplement. Estimated sales to consumers were $85 million in 2002, representing 5.6% of the total mineral-supplement market. Chromium is sold as a single-ingredient supplement as well as in combination formulas, particularly those marketed for weight loss and performance enhancement. Supplement doses typically range from 50 to 200 mcg.

The safety and efficacy of chromium supplements need more investigation. Please consult with a doctor or other trained healthcare professional before taking any dietary supplements.

Chromium supplements are available as chromium chloride, chromium nicotinate, chromium picolinate, high-chromium yeast, and chromium citrate. Chromium chloride in particular appears to have poor bioavailability. However, given the limited data on chromium absorption in humans, it is not clear which forms are best to take.
DIETARY MINERALS

References


Dietary Minerals

Post-Test

1. The two main forms of calcium found in supplements are __________.
   A. calcium carbonate and calcium gluconate
   B. calcium lactate and calcium phosphate
   C. calcium citrate and calcium lactate
   D. calcium carbonate and calcium citrate

2. Which of the following is NOT one of the high risk groups for calcium deficiency?
   A. Post-menopausal women
   B. Hemophiliacs
   C. Lactose intolerant individuals
   D. Vegetarians

3. Which of the following is CORRECT concerning dietary iron?
   A. Heme iron is primarily found in plants.
   B. Vitamin C improves the absorption of heme iron.
   C. Absorption of heme iron is significantly affected by diet
   D. Absorption of heme iron is greater than the absorption of nonheme iron.

4. A common side effect of taking iron supplements is __________.
   A. low grade headache
   B. constipation
   C. tingling or numbness of the distal extremities
   D. hyper pigmentation of the nail beds

5. Which of the following is NOT an identified risk factor associated with magnesium deficiency?
   A. Crohn’s disease
   B. Poorly controlled diabetes
   C. Sickle cell anemia
   D. Chronic alcoholism

6. __________ is generally considered to be the best absorbed and utilized form of selenium.
   A. Selenomethionine
   B. Sodium selenate
   C. Selenium peroxidase
   D. Elemental selenium
7. Which specific laboratory test is performed to conclusively determine an individual’s zinc nutritional status?
   A. Tamar-Hayon Titration
   B. Niva-Ronit Assay
   C. Wheeler Blot Test
   D. None of the above

8. Which of the following statements concerning Iodine is TRUE?
   A. TSH secretion decreases thyroidal uptake of iodine.
   B. Natural sea salt has high levels of iodine.
   C. A goiter is usually the earliest clinical sign of iodine deficiency.
   D. None of the above is true.

9. The estimated average intake of sodium for all Americans ages 2 years and older is approximately ____________.
   A. 3,400 mg per day
   B. 2,800 mg per day
   C. 2,300 mg per day
   D. 1,200 mg per day

10. Chromium is known to ____________.
    A. oxidize free radicals in damaged cells
    B. combine with sulfites to promote myelin production
    C. enhance the action of insulin
    D. facilitate mitochondrial production and repair