CHAPTER

7 Minerals

Key Questions Addressed

- What's the big deal about minerals?
- What are minerals?
- What are the major minerals?
- What are the trace minerals?

You Are the Nutrition Coach

Anne participates in triathlons. Recently, in a half-Ironman race, she experienced nausea, intestinal cramping, and diarrhea on the run, leading to a poor performance. The entire race took her nearly 6.5 hours. During the bike portion, she consumed 100 oz of a relatively new sports beverage that she has been training with this year, as well as two gels. On the run, she consumed sips of the sports beverage provided on the course but switched over to water once she started experiencing the nausea, cramping, and diarrhea. She was frustrated by her performance and wants to ensure that it does not happen again. You ask Anne to bring in the new sports beverage she has been consuming so that you can review the Supplement Facts label. Per 8 oz serving, the following nutrients are provided: 60 calories, 15 g carbohydrates, 0 g protein, 0 g fat, 100 mg sodium, 50 mg calcium, 30 mg magnesium, and 100 mg potassium.

Questions

- What could be a potential cause of Anne's nausea, intestinal cramping, and diarrhea during the race?
- What recommendations would you give to Anne to prevent the symptoms from occurring in future races?

What's the big deal about minerals?

Similar to vitamins, minerals play important roles throughout the body and are considered essential; without minerals, the body could not function. Many minerals are involved in important catalytic reactions (e.g., iron aids in gluconeogenesis) or serve as key structural components of tissues (e.g., calcium provides structure to bones) throughout the body.

The role that minerals play in sport performance has been studied over the years. It is clear that minerals are crucial for a variety of bodily functions, keeping athletes healthy and training strong. Certain athlete populations are more prone to mineral deficiencies, warranting a special focus in the diet. For example, female athletes may be more susceptible to iron deficiencies. Therefore, iron as well as vitamins that enhance iron absorption, such as vitamin C, should receive greater emphasis in their diet. In addition to general health, the intake of several minerals, specifically **electrolytes**, has a great impact on sport performance. Sodium and potassium, the main electrolytes (minerals) lost in sweat, must be replaced on a daily basis as well as during endurance and ultra-endurance sports to optimize performance and prevent medical complications. Other minerals are still under investigation, and their ergogenic effects have yet to be elucidated.

electrolytes Positively or negatively charged ions found throughout the body. The body uses the electrolytes to establish ionically charged gradients across membranes in excitable tissues such as muscle and nerves so that they can generate electrical activity. The most well-known electrolytes are sodium (Na^+), potassium (K^+), and chloride (Cl^-).

What are minerals?

Minerals are unique nutrients in several respects. Unlike carbohydrates, fats, proteins, and vitamins, minerals are not organic molecules. They are basically **inorganic** elements or atoms. Also, unlike the macronutrients, minerals contain no calories and, although essential, are needed by the body in very small amounts (i.e., milligrams or micrograms). Furthermore, after ingestion, the structure of minerals is not altered; this is unlike the reaction of macronutrients, which undergo dramatic changes in structure during digestion and utilization by the body. Unlike vitamins, which can be destroyed or altered by exposure to heat, light, alkalinity, or enzymes, minerals remain unaltered. Because of their stability, minerals are unaffected by cooking techniques, digestive processes, and/or exposure to enzymes. In other words, unlike many nutrients, minerals remain unaltered from food source to the human cells.

inorganic A descriptor given to a compound that does not contain carbon atoms in its molecular structure.

However, similar to all nutrients, minerals must be absorbed across the intestinal wall to serve their roles within the body. A variety of factors can affect the bioavailability of minerals. Some minerals are absorbed in proportion to the body's needs. Absorption of other minerals is affected by the fiber content of foods that are ingested simultaneously. High-fiber foods contain compounds that can bind to certain minerals, thus preventing their absorption during passage through the intestines. In some instances, high doses of one mineral, which can occur during supplementation, can cause competition for absorption and thus decrease intestinal uptake of other minerals. Therefore, despite the fact that minerals are needed in limited amounts and are very stable nutrients, athletes cannot afford to be cavalier about their mineral intake, nor can they rely on indiscriminant supplementation to meet their body's mineral requirements.

There are two classifications of minerals: major minerals and trace minerals. The **major minerals** include calcium, phosphorus, magnesium, sodium, chloride, potassium, and sulfur. Minerals are classified as "major" if they are required by the body in amounts greater than 100 milligrams per day. The **trace minerals** include iron, zinc, chromium, fluoride, copper, manganese, iodine, molybdenum, and selenium. Minerals are classified as trace if they are required by the body in quantities less than 100 milligrams per day. Both major and trace minerals are stored in the body; when consumed in excess, stored levels can build and become toxic to the body (e.g., high doses of iron can cause hemachromatosis, a condition discussed later in this chapter). Toxic levels can be achieved through dietary intake, but toxicity is much more likely to be caused by high-dosage supplements.

major minerals The minerals required by the body in amounts greater than 100 milligrams per day. The major minerals include calcium, phosphorus, magnesium, sodium, chloride, potassium, and sulfur.

trace minerals Minerals required by the body in quantities less than 100 milligrams per day. The trace minerals include iron, zinc, chromium, fluoride, copper, manganese, iodine, molybdenum, and selenium.

This chapter discusses the functions, dietary recommendations, effects on energy systems and sport performance, deficiency and toxicity symptoms, food sources, meal-planning tips, and the appropriateness of supplements for athletes in regard to major and trace minerals. Refer to **Table 7.1** for a summary of the DRI values for major and trace minerals.

TABLE 7.1 Dietary Reference Intakes for Major and Trace Minerals

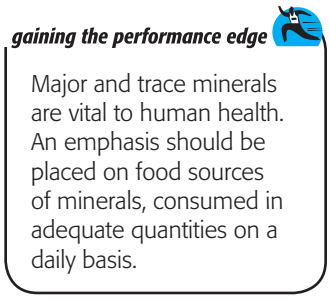
Life Stage Group	Calcium (mg/d)	Phosphorus (mg/d)	Magnesium (mg/d)	Iron (mg/d)	Zinc (mg/d)	Selenium (μg/d)	Iodine (μg/d)	Copper (μg/d)	Manganese (mg/d)	Fluoride (mg/d)	Chromium (μg/d)	Molybdenum (μg/d)
Infants												
0–6 months	200*	100*	30*	0.27*	2*	15*	110*	200*	0.003*	0.01*	0.2*	2*
7–12 months	260*	275*	75*	11	3	20*	130*	220*	0.6*	0.5*	5.5*	3*
Children												
1–3 years	700	460	80	7	3	20	90	340	1.2*	0.7*	11*	17
4–8 years	1000	500	130	10	5	30	90	440	1.5*	1*	15*	22
Males												
9–13 years	1300	1250	240	8	8	40	120	700	1.9*	2*	25*	34
14–18 years	1300	1250	410	11	11	55	150	890	2.2*	3*	35*	43
19–30 years	1000	700	400	8	11	55	150	900	2.3*	4*	35*	45
31–50 years	1000	700	420	8	11	55	150	900	2.3*	4*	35*	45
51–70 years	1000	700	420	8	11	55	150	900	2.3*	4*	30*	45
>70 years	1200	700	420	8	11	55	150	900	2.3*	4*	30*	45
Females												
9–13 years	1300	1250	240	8	8	40	120	700	1.6*	2*	21*	34
14–18 years	1300	1250	360	15	9	55	150	890	1.6*	3*	24*	43
19–30 years	1000	700	310	18	8	55	150	900	1.8*	3*	25*	45
31–50 years	1000	700	320	18	8	55	150	900	1.8*	3*	25*	45
51–70 years	1200	700	320	8	8	55	150	900	1.8*	3*	20*	45
>70 years	1200	700	320	8	8	55	150	900	1.8*	3*	20*	45
Pregnancy												
≤18 years	1300	1250	400	27	12	60	220	1000	2.0*	3*	29*	50
19–30 years	1000	700	350	27	11	60	220	1000	2.0*	3*	30*	50
31–50 years	1000	700	360	27	11	60	220	1000	2.0*	3*	30*	50
Lactation												
≤18 years	1300	1250	360	10	13	70	290	1300	2.6*	3*	44*	50
19–30 years	1000	700	310	9	12	70	290	1300	2.6*	3*	45*	50
31–50 years	1000	700	320	9	12	70	290	1300	2.0*	3*	45*	50

This table presents Recommended Dietary Allowances (RDA) and Adequate Intakes (AI). An asterisk (*) indicates AI. RDAs and AIs may both be used as goals for individual intake.

Sources: Data from Institute of Medicine's *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium and Zinc*. Food and Nutrition Board. Washington, DC: National Academies Press; 2000; *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids*. Food and Nutrition Board. Washington, DC: National Academies Press; 2000; and *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride*. Food and Nutrition Board. Washington, DC: National Academies Press; 1997. Institute of Medicine. *Dietary Reference Intakes for Calcium and Vitamin D*. Food and Nutrition Board. Washington, DC: National Academies Press; 2010.

What are the major minerals?

The major minerals are calcium, phosphorus, magnesium, sodium, chloride, potassium, and sulfur. As mentioned earlier, the daily requirements for these minerals exceed 100 milligrams per day. Many of these minerals play a specific role in sport performance, such as enhancing the integrity of bones to withstand impact during sports, providing electrolytes lost in sweat, and aiding in the prevention of muscle cramps. This section will review the functions, recommended intakes, signs of deficiency, symptoms of toxicity, food sources, and recommendations for supplementation for each major mineral.



Why is calcium important for athletes?

Calcium is widely recognized as a critical mineral for optimal bone health. However, calcium has many other important roles in the body for health and sport performance that are often unrecognized. An area that is receiving more attention is the fact that many individuals are not meeting their calcium needs as a result of low calcium intake and poor calcium absorption. For those who are low in calcium, deficiency signals generated by the body up-regulate calcium absorption. Diets high in oxalates, fiber, phosphorus, and sodium can negatively affect calcium absorption. Some research has also shown that increased animal protein intake can negatively affect calcium absorption. However, the bottom line is that total calcium intake is the most critical component of the formula for ensuring a healthy body.

What is the RDA/AI for calcium?

The RDA for calcium for men ages 19 to 70 years is 1000 milligrams per day.[1] The RDA for women ages 19 to 50 years is 1000 milligrams per day. Daily recommendations are increased to 1200 milligrams per day for men older than 70 years and for women older than 50 years. For a complete listing of calcium recommendations across the lifespan, consult Table 7.1.

What are the functions of calcium for health and performance?

Calcium is widely recognized as a bone-strengthening mineral. However, calcium's role in health and performance extends beyond the skeleton:

- *Blood clotting:* Calcium helps to produce fibrin, the protein responsible for the structure of blood clots.
- *Nerve transmission:* Calcium is required for proper nerve function, releasing neurotransmitters that facilitate the perpetuation of nerve signals and activation.
- *Muscle contraction:* Calcium is pumped into and out of muscle cells to initiate both muscle contraction and relaxation in smooth muscle, skeletal muscle, and the heart.
- *Disease prevention and weight management:* Calcium has received more attention recently in the disease prevention arena, specifically in regard to hypertension and colon cancer. The Dietary Approaches to Stop Hypertension (DASH) study developed the DASH diet, which encourages a balanced diet focusing on calcium, magnesium, and potassium because of their role in moderating blood pressure.[2] It has been proposed that a lack of calcium leads to the excessive contraction of smooth muscle, thereby increasing pressure in blood vessels. The DASH diet recommends consuming a minimum of three servings of low-fat dairy products every day. Colon cancer research has focused on the action of calcium combining with bile salts, which are then excreted from the body, thus protecting the cells within the colon from damage. Additional benefits of calcium specific to weight loss are being researched as they relate to increased dairy and calcium intake. Some of this research suggests that the increase in calcium intake aids in body weight and body fat reduction.[3–6] More research is warranted in all of these areas to fully understand the mechanisms involved and the optimal dietary intake guidelines for disease prevention.
- *Bone and tooth formation:* Bone is living tissue, providing a framework for the human body. Bone is composed of two types of cells—osteoblasts (builders) and osteoclasts (destroyers), which are both in constant action. Osteoblasts secrete collagen and then pull calcium and phosphorus from the blood to form a hardened material that provides the structure of bone. Osteoclasts break down the hardened material, releasing calcium and phosphorus into the blood. During growth and maturation, until peak bone mass is achieved around age 30, the building process dominates over the breakdown process. Throughout adulthood, physical activity levels and diet help to determine whether an individual is in a net state

of building or tearing down. The body adapts to stressors, strengthening in areas that are under stress. Weight-bearing exercises such as walking, running, and weightlifting can create stress that strengthens and builds bone. High calcium intakes help to sustain bone by providing the building blocks for new hardened materials. Calcium is the main component of hydroxyapatite, the solid material of bone. Because calcium is critical for many different functions in the body, if sufficient calcium is not present in the blood, it will be pulled from the reserves located in bone to normalize blood levels. This protective mechanism will ultimately weaken bones if low calcium intake is continued over time.

What are the complications of calcium deficiency?

The body can usually manipulate calcium status by increasing calcium absorption from the intestines or decreasing calcium excretion through the kidneys. Hypocalcemia, or low blood calcium, is uncommon because the body works hard to maintain a constant supply of calcium in the blood. However, in cases of malfunctioning kidneys or other disease states or disorders, it can occur. Signs and symptoms of hypocalcemia include muscle spasms and convulsions. Even though hypocalcemia is rare and occurs mainly in disease states, calcium deficiency in the general population, as well as with athletes, is still one of the most common deficiencies in the United States. The National Osteoporosis Foundation states that more than 18 million people in the United States either have **osteoporosis** or have low bone mass, putting them at high risk for developing osteoporosis in the future (www.nof.org), caused in large part by individuals consuming less than 50% of their calcium requirements daily. Signs and symptoms of calcium deficiency may include impaired muscle contractions and/or muscle cramps; however, these signs are usually rare because the body will pull reserves from bone.

osteoporosis A clinical condition that can result from inadequate calcium intake and is characterized by a significant decrease in bone mass. The result is weak bones that can be easily fractured.

If the body is constantly calcium-challenged, requiring calcium to be withdrawn from the "calcium bank" in the bones, osteoporosis will develop. Osteoporosis, the thinning and weakening of bones, is the most dramatic result of low calcium intake. A strong emphasis needs to be placed on consuming adequate calcium throughout a lifetime, with the younger years being the most influential in creating a high peak bone mass. To prevent low bone density and/or osteoporosis, the U.S. Surgeon General reports that diet and physical activity play a significant role.[7] Consuming the recommended daily intake of calcium and vitamin D and achieving at least 30 to 60 minutes of physical activity per day (including weight-bearing and strength-training activities) are lifestyle approaches that can be started at a young age to prevent poor bone health later in life.

Osteoporosis is also one component of the *female athlete triad*. The triad typically begins with low total calorie intake, which usually equates to low calcium intake, leading to calcium deficiency and low bone density. The lack of sufficient calorie intake on a consistent basis produces hormonal changes resulting in estrogen deficiency. This deficiency, along with other hormonal changes, low calorie intake, and high exercise energy expenditure, can lead to the cessation of menstrual cycles, or amenorrhea. The combination of low calcium intake and amenorrhea contributes to an increased risk for stress fractures, lowered bone mineral density, and potentially osteoporosis.

What are the symptoms of calcium toxicity?

The upper limit (UL) for calcium for men and women ages 19 to 50 is 2500 milligrams per day.[1] For men and women over the age of 50, the UL decreases to 2000 milligrams per day. Toxicity is typically not a problem with food intake but can be a concern with supplement intake. High calcium intake from supplements can impair the absorption of other minerals and in some individuals can contribute to kidney stones.[1] Excess calcium can be deposited in organs and soft tissues and cause altered function. Very high levels of calcium can lead to cardiac arrest and death. Hypercalcemia, or high blood levels of calcium, can be caused by cancer or the overproduction of the parathyroid hormone, often signaled by fatigue, constipation, and loss of appetite.

Which foods are rich in calcium?

Dairy products, including milk, yogurt, and hard cheeses, are some of the richest sources of calcium. Frozen dairy desserts also have calcium, but are higher in fat and calories than other choices. Many soy alternatives to dairy are fortified with calcium and vitamin D, and in most cases provide equivalent amounts of calcium as their dairy counterparts. Green leafy vegetables are a good source of calcium; however, oxalates present in green vegetables bind to the calcium and prevent some absorption. Calcium-processed tofu is another option rich in both calcium

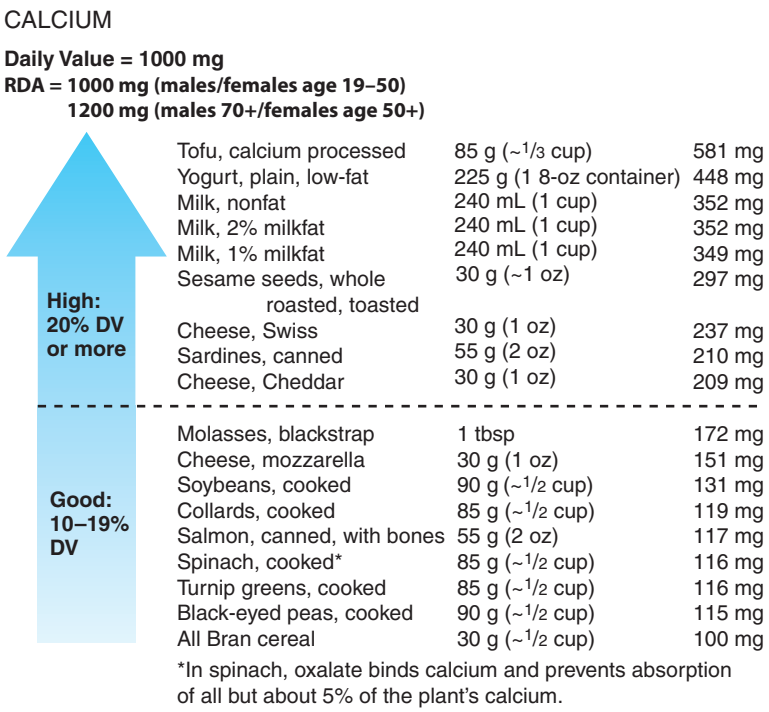


Figure 7.1 Food sources of calcium. Calcium is found in milk and other dairy products, certain green leafy vegetables, and canned fish with bones. *Source:* Data from U.S. Department of Agriculture, Agricultural Research Service, 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory home page. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

and plant-based protein. Orange juices, breads, and some cereals are fortified with calcium, and in some cases provide amounts equivalent to that found in milk. Lactose-intolerant individuals can consume lactose-free products, as well as soy or rice products that are fortified, to meet their calcium needs each day. Refer to Figure 7.1 for the calcium content of specific food sources.

What is a suggestion for a calcium-rich meal or snack?

Breakfast: 1½ cups of a layered yogurt parfait including granola and berries (see **Training Table 7.1**)
Total calcium content = 328 milligrams

Do athletes need calcium supplements?

Calcium supplementation may be indicated for some athletes who are following calorie-restrictive diets. However, the focus should be on calcium-rich foods first. If an athlete is taking calcium supplements, there are a couple things to consider:

- Amounts of calcium greater than 500 milligrams are not well absorbed when consumed at one time; therefore, it is best to spread supplements throughout the day.
- Calcium is absorbed best when broken down first by stomach acids; calcium supplements should be taken with a small bit of food to stimulate the secretion of digestive juices.
- Calcium tablets should not be taken with other supplements because of nutrient–nutrient interactions; for example, calcium competes closely with iron and zinc, altering the absorption of all nutrients involved and potentially creating other problems.
- Not all supplements are created equal;[8] calcium carbonate supplements tend to yield the highest amount of calcium per tablet but are not as well absorbed as calcium citrate supplements. Avoid calcium supplements that are derived from oyster shells or bone meal because they may be contaminated with lead.

Why is phosphorus important to athletes?

Phosphorus is a mineral that is critical for many functions throughout the body. Because of the phosphorus-rich food supply in the United States, average intakes are well above the RDA, and deficiencies are rare. Unfortunately, Americans' more-than-adequate intake has raised concerns regarding the health complications of excessive phosphorus consumption.

What is the RDA/AI for phosphorus?

The RDA for men and women is 700 milligrams per day.[9]

Training Table 7.1: Poolside Parfait

6 oz low-fat plain yogurt
¼ cup granola
½ cup fresh blueberries, raspberries, or blackberries

In a parfait cup or tall glass, layer 2 oz of yogurt, then 2 tbsp granola and ¼ cup berries; repeat. Top with remaining yogurt. Chill before serving.

Serving size: 1½ cups (Recipe makes one serving)

Calories: 290 kcals

Protein: 13 grams

Carbohydrate: 39 grams

Fat: 10 grams

What are the functions of phosphorus for health and performance?

Phosphorus leads to a healthy body in several ways:

- Phosphorus combines with calcium to form hydroxyapatite and calcium phosphate, which provide rigidity to bones and teeth.
- Phosphorus combines with lipids to form phospholipids, which provide integrity to cell membranes.
- Phosphorus activates and deactivates enzymes through phosphorylation.

In regard to athletic performance, phosphorus is a component of ATP, which provides energy for all forms of cellular function. Phosphorus is also needed for the formation of creatine phosphate (CP). In quick, explosive movements, CP provides an immediate form of energy for cells. During endurance activities, phosphorus buffers acidic end products of energy metabolism, allowing an athlete to sustain his or her effort and delay fatigue. Finally, phosphorus plays a role in energy production by phosphorylating glucose, preparing it to proceed through glycolysis.

PHOSPHORUS

Daily Value = 1000 mg
RDA = 700 mg (males/females)

High: 20% DV or more	Cheese, provolone	85 g (3 oz)	422 mg
	Beef liver, cooked	85 g (3 oz)	355 mg
	Yogurt, plain, nonfat	225 g (8 oz)	353 mg
	Sunflower seeds	30 g (~1 oz)	347 mg
	All Bran cereal	30 g (~1/2 cup)	339 mg
	Milk, 2% milkfat	240 mL (1 cup)	275 mg
	Milk, nonfat	240 mL (1 cup)	275 mg
	Milk, 1% milkfat	240 mL (1 cup)	273 mg
	Herring, cooked	85 g (3 oz)	258 mg
	Beef, ground, extra lean, cooked	85 g (3 oz)	224 mg
Good: 10–19% DV	Chicken, white meat, cooked	85 g (3 oz)	184 mg
	Oysters, cooked	85 g (3 oz)	173 mg
	Lentils, cooked	90 g (~1/2 cup)	162 mg
	Tofu, calcium processed	85 g (~1/3 cup)	162 mg
	Chicken, dark meat, cooked	85 g (~3 oz)	152 mg
	Almonds	30 g (1 oz)	142 mg
	Black beans, cooked	90 g (~1/2 cup)	126 mg
	Soy milk	240 mL (1 cup)	120 mg
	Peanut butter	2 tbsp	106 mg

Figure 7.2 Food sources of phosphorus. Phosphorus is abundant in the U.S. food supply. Meats, legumes, nuts, dairy products, and grains tend to have more phosphorus than fruits and vegetables. Note: The DV for phosphorus is higher than the current RDA of 700 milligrams for males and females age 19 and older.
Source: Data from U.S. Department of Agriculture, Agricultural Research Service, 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory home page. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

What are the complications of phosphorus deficiency?

Because of adequate intake and widespread sources in the American diet, phosphorus deficiencies are rare. Certain disease states, hyperparathyroidism, and taking large doses of antacids (which decrease phosphorus absorption) can contribute to phosphorus deficiencies, producing symptoms such as bone malformation, bone pain, and muscle weakness.

What are the symptoms of phosphorus toxicity?

The upper limit for phosphorus is 4000 milligrams per day for adult men and women.[9] As mentioned previously, phosphorus toxicity is of much greater concern in the United States than is phosphorus deficiency. Americans consume plenty of phosphorus but not enough calcium. This intake imbalance can lead to altered calcium metabolism and an increased risk for osteoporosis.

Which foods are rich in phosphorus?

Phosphorus is found predominantly in animal proteins including meat, fish, eggs, and dairy. Nuts, legumes, and cereals are moderate sources of phosphorus; however, these plant foods contain phosphorus in the form of phytic acid, which is not as well absorbed. Refer to Figure 7.2 for the phosphorus content of specific food sources.

What is a suggestion for a phosphorus-rich meal or snack?

Summer barbeque: Grilled hamburger with cheese, 1 cup of fruit salad, and 1 cup of skim milk
Total phosphorus content = 571 milligrams

Do athletes need phosphorus supplements?

Phosphorus supplements marketed to athletes claim to prevent fatigue as a result of the buffering capacity of phosphorus. Actual research results regarding this claim are equivocal. Studies have explored the effects of sodium phosphate, potassium phosphate, or calcium phosphate on maximal oxygen uptake, anaerobic threshold, and power. Some studies have found an increase in VO_2max and ventilatory anaerobic threshold or a decrease in the rating of perceived exertion during submaximal exercise with supplemental phosphates.[10–12]

Other investigators report no significant difference with these same parameters as well as power output with phosphate supplements.[13,14] Because a positive result of phosphate supplementation has not been clearly defined, and because long-term excessive intakes of phosphorus can be detrimental to bone health, athletes should focus on dietary intakes of phosphorus to meet daily needs for health and performance.

Why is magnesium important for athletes?

Magnesium is involved in hundreds of enzymatic reactions, bone health, blood clotting, and the regulation of blood pressure. In addition to its many health-related functions, magnesium has recently been investigated for its performance-enhancing effects.[15] Recent magnesium research has focused specifically on its purported ability to prevent muscle cramps. Although its ergogenic effects are still under debate, there is no doubt that adequate daily magnesium intake is critical for overall health.

What is the RDA/AI for magnesium?

The RDA for males 19 to 30 years old is 400 milligrams per day; for men ages 31 to 70 years it is 420 milligrams daily.[9] Women require slightly less magnesium. The RDA for females 19 to 30 years old is 310 milligrams per day; for women ages 31 to 70 years it is 320 milligrams daily.[9]

What are the functions of magnesium for health and performance?

Magnesium is involved in more than 300 enzyme functions, including DNA and protein synthesis as well as proper blood clotting. Magnesium helps to maintain bone strength through its role in bone metabolism. More recently, magnesium has been highlighted as an aid in the regulation of blood pressure. Research has uncovered that magnesium, potassium, calcium, and protein, as well as the long-time villain sodium, all have an effect on blood pressure. Magnesium has an inverse relationship with blood pressure, with adequate daily intakes protecting an individual from hypertension.

In regard to sports, magnesium plays important roles in bioenergetics. It serves to stabilize the structure of ATP and improves the effectiveness with which the enzyme adenosine triphosphatase acts on ATP and thus releases energy. Magnesium is also involved in glucose and lipid metabolism. It serves as a cofactor for seven key glycolytic enzymes and thus affects both anaerobic and aerobic carbohydrate metabolism. It also plays a role in lipid and protein metabolism. Inside the mitochondria, magnesium is essential for the aerobic production of ATP via the electron transport chain. Finally, during activity, muscles rely on magnesium for proper contraction and relaxation. The important roles that magnesium plays in muscle function and bioenergetics are the driving force behind the development and marketing of sports-related supplements containing magnesium.

What are the complications of magnesium deficiency?

Magnesium deficiency has been shown to cause a variety of problems such as altered cardiovascular function, including hypertension, as well as impaired carbohydrate metabolism.[16,17] Some of the symptoms of magnesium deficiency include loss of appetite, muscle weakness, and nausea. The first signs of a deficiency usually do not surface for several months because a significant amount of magnesium is stored in the bones. If an athlete continues to consume a diet chronically low in magnesium, other symptoms, such as muscle cramps, irritability, heart arrhythmias, confusion, and possibly high blood pressure, will emerge. If the deficiency is left untreated, death can result.

As mentioned previously, magnesium has been connected to the regulation of blood pressure. Magnesium blocks the stimulating effect of calcium, allowing muscles, particularly in the arterioles, to relax, thereby decreasing blood pressure. Insufficient magnesium intake will allow calcium's contracting effect to dominate, and higher blood pressure will ensue.

Observation of the effect of exercise on magnesium levels in athletes is varied, and study results are equivocal. It has been suggested that prolonged or intense exercise may decrease magnesium levels as a result of increased excretion in sweat and urine as well as increased usage by the cells for energy production. A few studies have shown that levels may drop initially, but rebound to normal levels 2 to 24 hours postexercise.[18,19] Some researchers have found that the decrease in serum magnesium levels during long-duration exercise contributes to cramping.[20] As a result of this research, products have been developed, suggesting that increasing magnesium intake during prolonged exercise can prevent muscle cramps. However, if athletes are consuming enough calories daily, they typically will consume sufficient amounts of magnesium and therefore do not require

extra supplementation during activity. Overall, few studies show a direct link between magnesium deficiency and cramping or impaired performance.[21]

What are the symptoms of magnesium toxicity?

Hypermagnesemia, or high blood levels of magnesium, is uncommon except for those with kidney diseases or malfunction. The signs and symptoms of toxic levels of magnesium include nausea, vomiting, diarrhea, and weakness. The upper limit of 350 milligrams per day refers to the maximum daily dosage of magnesium only from supplements and medicines.[9] There is no evidence of health or performance complications from high magnesium intakes from food sources.

Which foods are rich in magnesium?

Magnesium is widely distributed in foods but is concentrated in plant-based sources. Whole grains, green leafy vegetables, legumes, nuts, and seafood are all good sources of magnesium. Processing causes most of the magnesium to be leached from whole grains; therefore, athletes should incorporate whole, unprocessed grains into meals and snacks. Hard water, with a high mineral content, can also be a significant source of magnesium. Meats and dairy products provide moderate amounts of magnesium. High fiber, phosphorus, and calcium intakes, especially from supplements, can decrease magnesium absorption. If a fiber supplement is prescribed, it should be taken between meals. Refer to Figure 7.3 for the magnesium content of specific food sources.

MAGNESIUM

Daily Value = 400 mg
RDA = 400 mg (males age 19–30), 310 mg (females age 19–30), 420 mg (males age 31–70), 320 mg (females age 31–70)

High: 20% DV or more	All Bran cereal	30 g (1/2 cup)	114 mg
	Sesame seeds	30 g (~1 oz)	107 mg
	Halibut, cooked	85 g (3 oz)	91 mg
	Almonds	30 g (~1 oz)	83 mg
	Oysters, cooked	85 g (3 oz)	81 mg
Good: 10–19% DV	Cashews	30 g (~1/4 cup)	78 mg
	Soybeans, cooked	90 g (1/2 cup)	77 mg
	Spinach, raw	85 g (~3 cups)	67 mg
	Black beans, cooked	90 g (~1/2 cup)	63 mg
	Rice, brown, cooked	140 g (~3/4 cup)	60 mg
	Peanut butter	2 tbsp	56 mg
	Crab, Alaska King, cooked	85 g (3 oz)	54 mg
	Tofu, calcium processed	85 g (~1/3 cup)	49 mg
	Black-eyed peas, cooked	90 g (~1/2 cup)	47 mg
	Yogurt, plain, nonfat	225 g (1 8-oz container)	43 mg
	Whole wheat bread	50 g (2 slices)	43 mg
	Molasses, blackstrap	1 tbsp	43 mg
	Wheat bran flakes cereal	30 g (~3/4 cup)	42 mg

Figure 7.3 Food sources of magnesium. Most of the magnesium in the diet comes from plant foods such as grains, vegetables, and legumes. Note: The DV for magnesium correlates with the current RDA for males ages 19 to 30. The DV is higher than the current RDA of 310 and 320 milligrams for females ages 19 to 30 and 31 to 70, respectively, and lower than the current RDA of 420 milligrams for males 31 to 70.
Source: Data from U.S. Department of Agriculture, Agricultural Research Service, 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory home page. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

What is a suggestion for a magnesium-rich meal or snack?

Dinner: Teriyaki chicken stir-fry (see **Training Table 7.2**)
Total magnesium content = 139 milligrams

Do athletes need magnesium supplements?

Recent studies on magnesium supplementation for athletes either are equivocal or show no benefit.[22] Some studies have shown an ergogenic benefit of magnesium potentially enhancing carbohydrate and fatty acid metabolism.[23] A study conducted by Brilla and Haley[24] tested the effects of magnesium supplements on anaerobic performance in young men after a 7-week strength training program. The supplemental group received approximately 500 milligrams of magnesium a day; after the experimental

Training Table 7.2: Teriyaki Chicken Stir-Fry

1/3 cup uncooked brown rice
Cooking spray
1 cup broccoli
1/4 cup sliced green or red peppers
1/4 cup sliced red or yellow onions
3 oz diced chicken breast
1–2 tbsp teriyaki sauce

Cook rice according to package directions. While the rice is cooking, coat a skillet with cooking spray. Sauté the broccoli, peppers, and onions in the skillet over medium-high heat for 3 minutes. Add the teriyaki sauce and chicken and continue to cook for 5 to 10 more minutes until the chicken is cooked through. Serve over rice.

Serving size: 3 cups (Recipe makes one serving)
Calories: 443 kcals
Protein: 36 grams
Carbohydrate: 62 grams
Fat: 5 grams

period, peak knee-extension torque increased more in the supplemental group versus placebo. Other studies testing subjects involved in aerobic activities have found no benefit of magnesium supplementation versus controls. Overall, research has found the greatest benefit of supplementation in those who are currently consuming low dietary levels of magnesium.[25] It has been reported that up to half of the athletic population consumes a diet containing less than the current RDA for magnesium.[26] Therefore, similar to all vitamins and minerals, if an athlete is deficient in magnesium, achieving an optimal intake may be helpful in resolving poor performance or deficiency symptoms such as muscle weakness, muscle cramps, and irritability. Athletes should focus on consuming more magnesium-rich foods versus relying on a supplement. The current volume of research is limited, and therefore recommendations for magnesium supplementation for athletes have not been established. If an athlete chooses to take a sport supplement containing magnesium, ensure that the total daily intake remains below the established upper limit by looking closely at the Supplement Facts label for the serving size and magnesium dosage.

Why is sodium important for athletes?

Sodium is a mineral that causes mixed reactions between the health and performance communities. Sodium is often called a demon to health, leading to hypertension and possibly heart disease. In the athletic world, especially for endurance sports, sodium is heralded as a life saver. So, should athletes consume more sodium or less sodium? In general, moderation is the key, allowing for flexibility in recommendations based on individual needs.

What is the RDA/AI for sodium?

To function properly, the body requires only approximately 500 milligrams of sodium per day. The most current recommendation sets the AI for sodium at 1500 milligrams per day.[27]

What are the functions of sodium for health and performance?

Sodium is important for maintaining blood pressure, nerve impulse transmission, and muscle contraction. Sodium is most noted for its role in blood pressure. A consistently high intake of sodium has been directly linked to high blood pressure. Approximately one-quarter of American adults and half of those older than age 60 have high blood pressure caused in large part by intakes of sodium in excess of the recommended upper limit.[27] A lower sodium intake has been the mantra of health professionals for many years, and it will be renewed when statistics become available in upcoming years on Americans' massive sodium consumption as compared to the new stricter DRI guidelines (the current AI is 1500 milligrams; the previous recommendation was 2400 milligrams).

At the other end of the spectrum, sodium is crowned as a hero for its role during exercise, and its intake is often encouraged. Sodium aids in the absorption of glucose, which makes it a key component of sports beverages designed to provide energy during exercise. Sodium also serves as one of the body's electrolytes. Electrolytes are minerals that become positively or negatively charged ions when dissolved in the fluid medium of the body. They play a role in any physiological function that requires the generation or conduction of electrical signals in the body. An example is the activation of muscle contraction via the spread of electrical activity from the nerves to the muscles. One of the most commonly occurring electrolytes in the body is sodium. The minerals chloride and potassium are other common electrolytes found in the body. Finally, sodium acts in conjunction with the minerals potassium and chloride to create concentration gradients that help maintain proper fluid balance throughout the body. Sodium is lost in sweat during exercise. If the loss is excessive, without replacement, a life-threatening condition called **hyponatremia** can result.

hyponatremia Low blood sodium levels resulting from sodium deficiency and/or the intake of large volumes of water.

What are the complications of sodium deficiency?

Sodium deficiency is not typically a problem on a daily basis because of the checks and balances of hormones regulating uptake and secretion of sodium as well as the high average daily intake. However, short-term sodium deficiency can be an issue for individuals who have prolonged diarrhea or vomiting or who are exercising for a long period of time and have excessive sweat loss. Signs and symptoms of low blood sodium (hyponatremia) include cramping, nausea, vomiting, dizziness, seizures, coma, and—left untreated—death. Hyponatremia can also be caused by consuming only water, versus sports beverages, during long-duration exercise or by routinely avoiding foods and beverages containing sodium.

What are the symptoms of sodium toxicity?

A rapid intake of large volumes of sodium (e.g., drinking salt water) can cause hypernatremia and hypervolemia—high blood concentrations of sodium

and thus high blood volume. This results in swelling and a rise in blood pressure. Most individuals can adequately regulate sodium intake and excretion through the action of aldosterone, the hormone made in the adrenal glands, signaling the kidneys to retain more sodium if intake is low. For those who cannot regulate sodium appropriately, both body fluid volume and blood pressure increase. For these individuals, a reduced-salt diet, below the upper limit of 2300 milligrams per day,[27] can be helpful in regulating blood pressure. It must be noted that sodium is only one player in the game of high blood pressure. Potassium, magnesium, protein, and fiber also have been linked to blood pressure regulation, and therefore intake of all nutrients should be addressed.

Food	Serving Size	Sodium (mg)
Cucumber, fresh	1 large (8¼")	6
Dill pickle	1 large (4")	1730
Roast pork	3 oz (85 g)	50
Ham, cured	3 oz (85 g)	1130
Whole wheat bread	1 slice	150
Biscuit from mix	1 (2 oz)	540
Fresh tomato	1 medium	6
Spaghetti sauce, jar	½ cup	515
2% milk	1 cup (240 mL)	115
American cheese	1 oz	420
Baked potato	1 medium	20
Potato chips	1 oz	170

As food becomes more processed, the sodium content increases

Figure 7.4 Sodium content of various foods.
Source: Data from U.S. Department of Agriculture, Agricultural Research Service, 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory home page. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Some research also shows that high intakes of sodium may lead to increased calcium excretion, thus contributing to osteoporosis. Similar to blood pressure regulation, osteoporosis risk is increased through deficiencies of some nutrients and excessive intakes of others. Consider the whole picture when evaluating an athlete's risk for osteoporosis to avoid tunnel vision on just one nutrient.

Which foods are rich in sodium?

Sodium is widely distributed in the American diet. Table salt (1 tsp = ~2300 milligrams of sodium), soy sauce, condiments, canned foods, processed foods, fast foods, smoked meats, salted snack foods, and soups are all rich sources of sodium. Most Americans consume well above the upper limit of 2300 milligrams per day, with some intakes reaching into the 8000–11,000 milligrams per day range.[27] Refer to Figure 7.4 for the sodium content of specific food sources.

What is a suggestion for a sodium-rich meal or snack?

Lunch: Grilled cheese sandwich with 1 cup tomato soup
Total sodium content = 1391 milligrams

Do athletes need sodium supplements?

In general, sodium supplements are not required; dietary sources of sodium are more than adequate to cover daily needs as well as losses through sweat. In activities lasting more than 4 hours, such as long-distance triathlons or adventure racing, sodium supplements may be indicated.

Why is chloride important for athletes?

As the major extracellular anion, chloride is primarily involved in fluid balance within the body; however, it is also a key component to many other bodily functions. Chloride (Cl) is widely recognized as the partner to sodium (Na) in salt (NaCl), which in fact is the main source of chloride in the American diet.

What is the RDA/AI for chloride?

The AI for chloride for both men and women is 2300 mg per day.[27]

What are the functions of chloride for health and performance?

Chloride acts as a "disinfectant" to maintain health inside the body. Chloride combined with hydrogen forms hydrochloric acid. In the stomach, hydrochloric acid helps to kill harmful bacteria that have been consumed. White blood cells also use chloride to kill invading bacteria throughout the body. In neurons, the movement of chloride, as well as calcium, sodium, and potassium, allows for the transmission of nerve impulses throughout the body.

In regard to athletes' performance, chloride is one of the extracellular electrolytes that is critical for maintaining fluid balance throughout the body.

What are the complications of chloride deficiency?
Low chloride levels can be caused by frequent vomiting, which removes hydrochloric acid from the stomach. For example, individuals with the eating disorder bulimia can have low chloride levels in the body as a result of frequent vomiting as well as decreased intake. The result is dehydration and metabolic alkalosis, or high blood pH. Even a small rise in blood pH can result in abnormal heart rhythm, decreased blood flow to the brain, and reduced oxygen delivery to various tissues. If left untreated, chloride deficiency can ultimately result in death.

What are the symptoms of chloride toxicity?
For sensitive individuals, high intake of both sodium and chloride may cause hypertension. The upper limit for chloride has been set at 3600 milligrams per day.[27]

Which foods are rich in chloride?
Salt, or sodium chloride (NaCl), is the richest source of chloride in the American diet. Chloride can also be found in small amounts in fruits and vegetables. The dietary sources of sodium shown in Figure 7.4 provide examples of chloride-rich sources of foods as well.

What is a suggestion for a chloride-rich meal or snack?
Dinner: Meatball sub sandwich and a small bag of pretzels
Total chloride content = 3092 milligrams

Do athletes need chloride supplements?
Even though chloride is lost in sweat, athletes generally consume plenty of chloride through a balanced diet. Chloride supplements do not appear to enhance physical performance and therefore are not recommended.

Why is potassium important for athletes?

Potassium is involved in the regulation of many bodily processes, including blood pressure. The most recent dietary recommendations for potassium have increased, creating a large gap between the typical American intake and the recommended values. This gap is caused in large part by the increased consumption of processed foods in the United States, which are generally low in or devoid of potassium. All individuals, including athletes, need to put a stronger emphasis on eating potassium-rich foods on a daily basis.

What is the RDA/AI for potassium?
The most recent recommendation by the Food and Nutrition Board sets the AI for potassium at 4700 milligrams per day for men and women.[27]

What are the functions of potassium for health and performance?
Potassium and sodium perform a balancing act throughout the body. Potassium counteracts the effects of sodium on blood pressure, helping to keep blood pressure low. The interchange and flow of potassium and sodium in and out of cells are responsible for the transmission of nerve impulses and muscle contractions. Potassium is one of the intracellular electrolytes that is critical for fluid balance in the body, especially during exercise. Unfortunately, Americans are not doing a good job of balancing their intake of potassium and sodium. Sodium intakes are too high while potassium intakes are too low, leading to problems such as high blood pressure. Athletes need to make an effort to choose potassium-rich foods while keeping sodium intake under control.

What are the complications of potassium deficiency?
Hypokalemia, or low blood potassium, is caused by frequent vomiting, diarrhea, and use of diuretics, as well as low potassium intake. Athletes with high sweat losses are also at risk for potassium deficiency, which may result in muscle cramps. Common symptoms of potassium deficiency include muscle weakness and loss of appetite. A rapid change in potassium status or long-term low potassium levels can lead to heart arrhythmias.

What are the symptoms of potassium toxicity?
In healthy individuals, the kidneys will excrete excess potassium, and therefore no upper limit has been set for potassium.[27] However, in those with impaired kidney function, high intake of potassium (combined with low excretion) can lead to hyperkalemia. High potassium levels in the blood over time can lead to a slowing and eventual stopping of the heart.

Which foods are rich in potassium?
Fruits and vegetables are the richest sources of potassium, with potatoes, spinach, and bananas at the top of the list. Meat, milk, coffee, and tea are also significant sources. Food processing tends to remove potassium and add sodium, thereby contributing to the imbalanced intake of these two minerals. Even if potassium is not removed from a food or beverage,

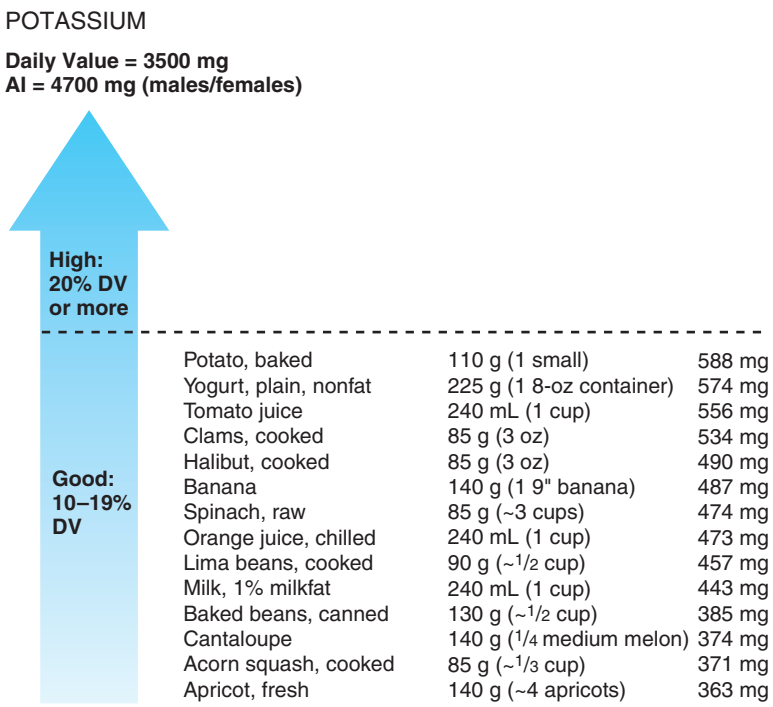


Figure 7.5 Food sources of potassium. The best food sources of potassium are fresh fruits and vegetables, and certain dairy products and fish. Note: The DV for potassium is lower than the current RDA of 4700 milligrams for males and females age 19 and older.
Source: Data from U.S. Department of Agriculture, Agricultural Research Service, 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory home page. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

the addition of sodium disrupts the ratio of sodium to potassium, leading to potential health and performance complications. Refer to Figure 7.5 for the potassium content of specific food sources.

What is a suggestion for a potassium-rich meal or snack?
Snack: Summertime Salad (see **Training Table 7.3**)
Total potassium content = 457 milligrams

Do athletes need potassium supplements?
Potassium supplements are not needed and can cause harm in large doses. For athletes, the emphasis should be placed on food sources of potassium because adequate potassium intake is easily attainable through a balanced diet. Large doses of supplemental potassium, at levels of 18,000 milligrams or higher, can disrupt muscle contraction and nerve transmission, ultimately leading to a heart attack.

Why is sulfur important for athletes?

Sulfur is unique because it is considered an essential nutrient, but it does not have an established RDA, EAR, AI, or UL.[27] Regardless of the lack of hard numbers, sulfur or sulfate is a nutrient that athletes should consume on a daily basis for proper bodily functioning.

What is the RDA/AI for sulfur?
There is no RDA, EAR, or AI for sulfur because of the fact that it can be obtained from food and water, as well as be derived from specific amino acids in the body.[27]

What are the functions of sulfur for health and performance?
Sulfur is a component of hundreds of compounds in the body. The body synthesizes the majority of these compounds using the sulfur consumed in the diet and from sulfur produced in the body from degradation of the amino acids methionine and cysteine. The most notable sulfur-containing compound in the body is 3-phosphoadenosine-5-phosphosulfate (PAPS). Sulfate derived from methionine and cysteine found in dietary proteins and the cysteine component of glutathione provide sulfate for use in PAPS synthesis.[27] PAPS, in turn, is then used in the biosynthesis of other essential body compounds.[27] Sulfur has also been associated with the growth and development of tissues.

In regard to athletic performance, there is no evidence that the ingestion of excess sulfur is ergogenic.

Training Table 7.3: Summertime Salad

This salad tastes best during the summer months when tomatoes are in season.
1 small tomato, diced
1/4 whole cucumber, diced
1/4 cup red onion, diced
2 tbsp light Italian dressing
Mix together the vegetables and dressing.
Chill before serving.
Serving size: 1 1/2 cups (Recipe makes one serving)
Calories: 95 kcals
Protein: 2 grams
Carbohydrate: 12 grams
Fat: 5 grams

What are the complications of sulfur deficiency?
Deficiencies of sulfur are rare, unless a protein deficiency is also present, which would include a deficiency in methionine and cysteine. Under normal conditions, it appears that adequate sulfur spares cysteine from the synthesis of PAPS, allowing cysteine to instead be used for protein synthesis and growth. When sulfur is present in suboptimal levels, cysteine is required for the production of PAPS, thus sacrificing protein synthesis.

What are the symptoms of sulfur toxicity?
There have been reports of individuals suffering from osmotic diarrhea after consuming large quantities of sulfur.[27] An association has also been suggested between high sulfur intakes and the risk of ulcerative colitis. Unfortunately, at this time there is insufficient evidence to formulate recommendations for sulfur intake, including the establishment of an upper limit.[27]

Which foods are rich in sulfur?
Sulfur is found in a variety of foods, with the highest concentrations found in some fruits, soy flour, certain breads, and sausages. Juices, beers, wines, and ciders also contain a significant quantity of sulfur. Drinking water is another common source of sulfur; however, quantities can vary dramatically based on the region of the country and the water source.

gaining the performance edge

The major minerals include calcium, phosphorus, magnesium, sodium, chloride, potassium, and sulfur. Each of these minerals plays a specific and important role in overall health and athletic performance. Athletes should strive to consume these nutrients from whole foods first, and rely on supplements only when individually indicated.

What is a suggestion for a sulfur-rich meal or snack?
Because no RDA/AI level has been set for sulfur, a "sulfur-rich" meal cannot be recommended. Athletes should include sulfur-containing foods on a daily basis in addition to consuming adequate levels of protein.

Food for Thought 7.1

Importance of Mineral Intake for Athletes: Major Minerals

Review the recommendations, food sources, and significance of major minerals for athletes.

Do athletes need sulfur supplements?
Because an insufficient amount of information is available to even draw conclusions on an RDA, EAR, AI, or UL for sulfur, recommending sulfur supplements does not appear to be warranted at this time.

Fortifying

Your Nutrition Knowledge

What Factors Influence Iron Absorption?

The amount of iron absorbed depends on several factors:

1. *Iron status:* The body absorbs iron at the rate needed by the body. If iron stores are low, iron is shuttled into the bloodstream packaged as transferrin (see Figure 7.6), carrying iron to organs and bodily tissues. If iron stores are high, the mineral is stored in the intestinal cells, sloughed off, and excreted when cell life comes to term. Therefore, those with iron-deficiency anemia will absorb iron at a greater rate than those with normal stores.
2. *Gastrointestinal function:* Iron is absorbed in the small intestine, but it must first be prepared for optimal absorption in the stomach. The gastric acids of the stomach help to dissolve iron and convert ferric iron into ferrous iron, which is more readily absorbed through the intestines. Those with altered or malfunctioning gastrointestinal systems, for example, elderly individuals with low production of gastric acid, will have compromised iron absorption.
3. *Type of iron source—heme vs. nonheme:* Heme iron, found mainly in meat/animal products, is most readily absorbed in the body. Nonheme iron, found mainly in plant foods, is absorbed and utilized by the body, but to a lesser degree than heme iron. However, nonheme absorption can be enhanced by consuming vitamin C–rich foods or meat products with nonheme food sources.
4. *Nutrient interactions:* Dietary factors that decrease iron absorption include tannins from tea and coffee, fiber, soy, and high intakes of zinc, calcium, or manganese.

What are the trace minerals?

The trace minerals are equally as important as the major minerals. These minerals are found in smaller amounts in the body than the major minerals and

thus are termed *trace* minerals. The trace minerals include iron, zinc, chromium, fluoride, copper, manganese, iodine, molybdenum, and selenium.

Why is iron important for athletes?

Iron is critical for proper health as well as optimal performance. Iron deficiency is one of the most common nutritional deficiencies in the United States and therefore deserves special mention and attention.

What is the RDA/AI for iron?

The RDA for men ages 19 to 50 years and postmenopausal women is 8 milligrams per day.[28] The RDA for females ages 19 to 50 years is significantly higher at 18 milligrams per day.[28] The difference is caused by the monthly loss of blood for menstruating women. It should also be noted that the requirements for vegetarians are 1.8 times higher due the lower bioavailability of iron

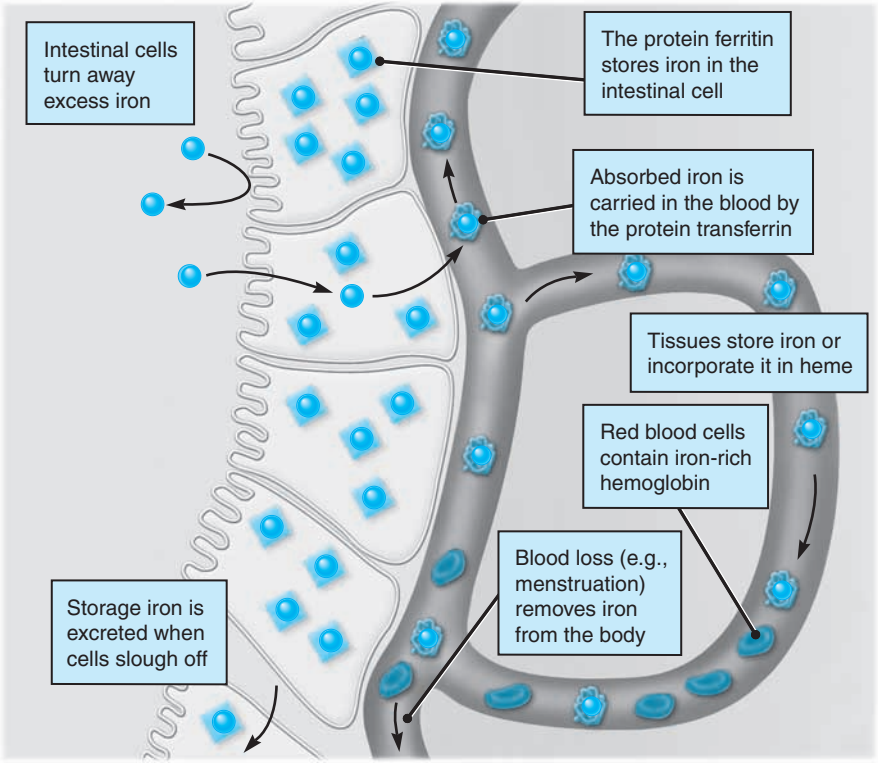


Figure 7.6 Iron absorption. The amount of iron absorbed depends on several factors—normal gastrointestinal function, the need for iron, the amount and kind of iron consumed, and dietary factors that enhance or inhibit iron absorption.

Fortifying

Your Nutrition Knowledge

How Is Iron Status Evaluated?

Iron status can be evaluated in several ways. The following blood test parameters are used to measure iron status:

- *Ferritin:* Stores iron within cells; a small amount also circulates in the blood.
- *Serum iron:* Represents the free iron in the blood (small amount) and the iron bound to transferrin.
- *Serum total iron binding capacity (TIBC):* Measures the capacity of transferrin to bind to iron; as iron levels decrease, the binding capacity increases.
- *Hemoglobin:* Measures the iron-containing protein in the blood that is a component of red blood cells.
- *Hematocrit:* Determines the concentration of red blood cells in the blood.
- *Red blood cell count:* Counts the number of red blood cells in the blood, which reflects iron status because of the need for iron to produce red blood cells. The total number of red blood cells is also related to hemoglobin levels.
- *Transferrin saturation:* Transferrin is the transport protein for iron in the blood. The transferrin saturation reflects the percentage of transferrin saturated with iron.

from plant sources (i.e., 14 milligrams and 32 milligrams per day for men and women, respectively).[28]

What are the functions of iron for health and performance?

Iron is best known for aiding in the formation of compounds essential for transporting and utilizing oxygen; thus, it is critical for aerobic activities and endurance training. Heme is the iron-containing portion of both hemoglobin and myoglobin. Hemoglobin is a protein–iron compound in red blood cells that carries oxygen from the lungs to the cells and tissues of the body. Myoglobin is found in muscle and facilitates the transport of oxygen to the muscle cells. Iron also plays a role in healthy immune function and brain development as well as energy production through its inclusion in various enzymes.

What are the complications of iron deficiency?

Iron deficiency is one of the most common nutrient deficiencies in the United States and worldwide. In contrast to many developing countries, in which iron deficiency affects a large proportion of the population (30–70%), the prevalence of iron deficiency is less than 20% in the industrialized countries of Europe and North America.[29] Iron is lost through skin, hair, sweat, and the intestinal tract. Women lose significantly more iron than men because of monthly iron losses through menstruation. Iron deficiency occurs mainly as a result of poor intake relative to daily needs. Iron deficiency occurs in three stages:

1. *Iron depletion:* Iron stores are depleted from the bone marrow, which is indicated by a low blood ferritin level.
2. *Iron-deficiency erythropoiesis:* Blood results will show a continued decline in serum ferritin and an increase in serum transferrin, while hemoglobin levels remain in the normal range. Athletes will begin to feel the effects of iron deficiency through decreased physical performance results.
3. *Iron-deficiency anemia:* Ferritin and hemoglobin levels are low, resulting in insufficient and/or defective red blood cells. The red blood cells produced are small (microcytic) and pale (hypochromic) in color, and iron-deficiency anemia is diagnosed. Athletes will complain of cold intolerance, low energy levels, decreased performance, and exercise intolerance. Athletes will also look pale and "sickly."

iron-deficiency anemia A clinical condition commonly resulting from poor iron intake that affects the red blood cells and their ability to transport oxygen.

It is important to realize that there are several types of anemia, and it is critical to diagnose the correct one to ensure that individuals receive proper treatment. Refer to Table 7.2 for an explanation of the anemias that are caused by iron, vitamin B_6, vitamin B_{12}, and folate deficiencies.

TABLE 7.2 Types of Vitamin and Mineral Deficiency Anemias

Vitamin/ Mineral	Type of Anemia	Cause of Anemia
Iron	Microcytic, hypochromic anemia	Lack of hemoglobin leads to small red blood cells that are pale in color.
Vitamin B_6	Microcytic, hypochromic anemia	Decreased production of the red blood cells' hemoglobin ring.
Vitamin B_{12}	Pernicious anemia; macrocytic, megaloblastic anemia	Anemia caused by low levels of intrinsic factor, decreasing absorption of B_{12} and thus producing altered red blood cells.
Folate	Megaloblastic anemia	Impaired normal red blood cell development and division leads to large, irregular cells.

Why are athletes at risk for iron-deficiency anemia?

Athletes are at a greater risk than the general population for iron-deficiency anemia. Beard and Tobin reviewed more than two decades of research on iron status and exercise.[30] They state that three groups of athletes appear to be at greatest risk for developing altered body iron: female athletes, distance runners, and vegetarian athletes. In fact, similar reports state that as many as 26–60% of female athletes are affected by iron deficiency.[31–34] Due to the large number of athletes at risk, it has been suggested that these groups should pay particular attention to maintaining an adequate consumption of iron in their diets.[30] Although female athletes, distance runners, and vegetarian athletes may be at higher risk, they are not the only athletes at risk. The reasons that any athlete could be at an increased risk for iron deficiency include:

- *Low dietary intakes for both males and females:* Many athletes consume less than their daily requirements for both total calories and iron.
- *Type of food intake:* Vegetarians may be at higher risk if they do not consume enough nonheme sources of iron. Those following an omnivorous diet appear to be at lower risk for deficiency.

- *Increased demand for myoglobin, hemoglobin, and energy-producing enzymes:* Athletes who are training and competing regularly require more oxygen-carrying compounds and more enzymes to produce energy.
- *Type of sport:* Running and other impact sports appear to put athletes at a higher risk than nonimpact sports. Hematuria is the presence of hemoglobin or myoglobin in the urine, caused by a breakdown of red blood cells or hemolysis (releasing of hemoglobin from the kidneys) resulting from repeated impact. Hemolysis has also been observed in weight lifters because of the mechanical stress of lifting heavy weights. Nonimpact sport athletes, such as rowers or cyclists, can also experience hemolysis resulting from loss from the intestinal wall or in urine or feces due to an irritation caused by equipment and body friction, or the consumption of nonsteroidal anti-inflammatory drugs.
- *Loss through sweat:* This factor may have a greater impact on the iron status of males because men tend to sweat more than women.

Sports anemia is a unique condition and not a true anemia. With sports anemia, hemoglobin levels are at the low end of the normal range, but other blood parameters test normal. Short-term sports anemia can occur in individuals beginning an exercise program or initiating a period of intense training. To compensate for a sudden shift in duration or intensity of exercise, the athlete's blood volume increases quickly. This rapid change dilutes the blood concentration, which shows up on a blood test as a relatively low level of hemoglobin. After 1 to 2 months of consistent training, blood concentration returns to normal, and the sports anemia is remedied. Long-term sports anemia has been found in highly trained endurance athletes. It is theorized to occur because the red blood cells become very efficient at carrying and releasing oxygen to the tissues and therefore do not require a high level of concentration in the blood.

To prevent iron-deficiency anemia in athletes, the development of standard protocols for the annual assessment and treatment of iron deficiency is recommended.[32] Several important steps in the assessment and treatment of iron deficiency anemia are presented in the following **Fortifying Your Nutrition Knowledge.**

What are the symptoms of iron toxicity?

The upper limit for iron is 45 milligrams per day.[28] Iron toxicity is most common in young children who consume a large number of chewable vitamins/minerals at one time. Toxicity is characterized by

Fortifying

Your Nutrition Knowledge

Dietary Assessment and Treatment of Iron Deficiency

To properly diagnose and treat an athlete for iron-deficiency anemia, sports dietitians should follow these steps:

1. *Consult with the athlete's physician:* Determine whether the type of anemia is caused by a lack of iron, B_6, folate, or B_{12} in the diet; the athlete's history of anemia; and the stage of iron-deficiency anemia, if anemia is connected to low iron levels.
2. *Perform a diet analysis:* Review iron intake from foods and supplements, the types of iron sources consumed (heme and/or nonheme), and dietary factors that are enhancing or inhibiting iron absorption at meals and snacks.
3. *Consider the athlete's primary sport and level of training:* Impact versus nonimpact sport, beginner versus experienced athlete, and recreational versus high-volume training regimen.
4. *Inquire about other blood losses:* This could be a result of such causes as a regular blood donation.
5. *Develop a nutritional plan that will increase iron intake and availability, while being sensitive to the athlete's typical dietary patterns:* For example, vegetarians do not have to eat meat to resolve an iron deficiency. Be sensitive to dietary beliefs and patterns and work within those boundaries, as long as the patterns are not related to disordered eating.

hemochromatosis A clinical condition associated with the accumulation of iron in the body's tissues, particularly the liver, which can result in liver failure or cancer.

nausea, vomiting, diarrhea, rapid heartbeat, and dizziness. If left untreated, toxic levels of iron can lead to death within hours.

For adults, high intakes of iron have other common complications. Excessive iron can cause decreased absorption of other nutrients, such as copper. For those who are genetically predisposed, high iron intakes can contribute to a condition termed **hemachromatosis**. This condition causes an accumulation of iron in the liver, which can become toxic and destroy the liver over time. More recent research has shown an increased risk of colon cancer and heart disease with high iron intakes. The theory is that because iron is a pro-oxidant, it may contribute to cell damage, leading to cancerous growths in the colon, or it may accelerate the oxidization of LDL cholesterol, leading to atherosclerosis. The exact link or mechanism still needs to be determined by future research.

Which foods are rich in iron?

The two types of iron are heme and nonheme. Heme iron is found only in animal foods such as beef, poultry, and fish and boasts a greater bioavailability than nonheme iron, which is primarily found in plant foods such as soy products, dried fruits, legumes, whole grains, fortified cereals, and green leafy vegetables. Nonheme iron's bioavailability can be enhanced when sources are consumed with either a meat product or a vitamin C source. For example, drinking a glass of orange juice, rich in vitamin C, at breakfast will aid in the absorption of the iron from a fortified cereal. Iron absorption can be inhibited by calcium, tannins in tea, phytic acid in grains, or excessive fiber. Therefore, foods rich in these nutrients should be present in small amounts when consuming a good source of iron. Refer to Figure 7.7 for the iron content of specific food sources.

What is a suggestion for an iron-rich meal or snack?

Dinner: 2 cups of meat and bean chili, a whole wheat dinner roll, and 2 cups of spinach salad
Total iron content = 11.3 milligrams

Do athletes need iron supplements?

If an athlete is diagnosed with iron-deficiency anemia, iron supplements are typically suggested, and normalizing iron status will improve performance and endurance. For athletes with normal iron intake and blood levels, iron supplementation will probably not enhance performance and may actually cause harm. Nutrition experts suggest that the use of iron supplements should be based not on the likelihood of anemia but rather on hematologic evaluation.[30] Individual iron supplements should be taken only under the care of a physician.

Because endurance athletes, in particular female endurance athletes, are at greater risk for iron deficiency, and it can take 3 to 6 months to reverse

IRON

Daily Value = 18 mg
RDA = 8 mg (males and postmenopausal females), 18 mg (females)

	Exceptionally good sources			
	Product 19 cereal	30 g	1 cup	18.09 mg
	Whole-grain Total	30 g	¾ cup	18.00 mg
High: 20% DV or more	Cereals, oats, instant, regular	177 g	1 packet	10.55 mg
	Rice Krispies cereals	33 g	1¼ cup	10.04 mg
	Cream of Wheat cereal, cooked	251 g	1 cup	9.39 mg
	Cheerios cereal	30 g	1 cup	9.29 mg
	Lentils, cooked	198 g	1 cup	6.59 mg
	Spinach, cooked	180 g	1 cup	6.43 mg
	Bagels, plain	89 g	4" bagel	5.38 mg
	Semisweet chocolate	168 g	1 cup	5.26 mg
	Beef liver, cooked	85 g	3 oz	5.24 mg
	Kidney beans, cooked	177 g	1 cup	5.20 mg
	Chickpeas, cooked	164 g	1 cup	4.74 mg
Good: 10–19% DV	Beets, canned	170 g	1 cup	3.09 mg
	Baked beans, plain canned	254 g	1 cup	3.02 mg
	Prune juice, canned	256 g	1 cup	3.02 mg
	Raisins, seedless	145 g	1 cup	2.73 mg
	Tomato sauce, canned	245 g	1 cup	2.50 mg
	Turkey, cooked	140 g	1 cup	2.49 mg
	Beef, steak, cooked	85 g	3 oz	2.44 mg
	Peas, green, frozen, cooked	160 g	1 cup	2.43 mg
	Lamb, shoulder, cooked	85 g	3 oz	2.30 mg
	Chicken liver, cooked	20 g	1 liver	2.28 mg
	Beef, ground (85% lean), cooked	85 g	3 oz	2.21 mg
	Potato, baked, with skin	202 g	1 potato	2.18 mg
	Collards, cooked	190 g	1 cup	2.15 mg
	Barley, cooked	157 g	1 cup	2.09 mg

Figure 7.7 Food sources of iron. Iron is found in red meats, certain seafoods, vegetables, and legumes and is added to enriched grains and breakfast cereals. Note: The DV for iron is higher than the current RDA of 8 milligrams for males age 19 and older and postmenopausal females.
Source: Data from U.S. Department of Agriculture, Agricultural Research Service, 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory home page. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

it,[35] experts are increasingly recommending that athletes be screened regularly. Screening should involve both a nutrition assessment for iron intake and testing for blood ferritin levels. Identifying athletes at risk for anemia via ferritin testing can allow for early intervention. Unfortunately, the broad normal range of blood ferritin levels (i.e., 12–300 ng/mL and 12–150 ng/mL for men and women, respectively) has created debate over when supplementation should be started. Although determination of a precise threshold for the onset of supplementation has not been established, some evidence suggests that supplementation should be considered when blood ferritin levels fall within or below 20–35 ng/mL.[36,37]

Why is zinc important for athletes?

Zinc is important for every living cell in the body. After ingestion, zinc is transported bound to albumin and is delivered mainly to muscle and bone, with the remainder sent to the liver, kidneys, skin, and other organs. Once at its destination, zinc goes to work to enhance health and athletic performance.

What is the RDA/AI for zinc?

The RDA has been established at 11 milligrams per day for men and 8 milligrams per day for women.[28]

What are the functions of zinc for health and performance?

Zinc is involved in a huge variety of bodily processes and, impressively, is associated with more than 200 enzymatic systems.[38] In addition to its enzymatic role, zinc is critical for optimal health by:

- Playing a role in wound healing, which enhances immune function.
- Aiding in the synthesis of RNA and DNA, thus influencing gene expression.
- Ensuring the growth and maintenance of various tissues.
- Producing hormones.
- Synthesizing protein.
- Facilitating the proper functioning of the reproductive and gastrointestinal systems.
- Maintaining proper brain function.

In the area of sport performance, zinc is a component of various enzymes related to carbohydrate, protein, and fat metabolism, especially during exercise. Zinc is a critical nutrient for exercise recovery because of its role in protein synthesis and repair of tissues. Zinc also interacts with insulin and increases the affinity of hemoglobin for oxygen.

What are the complications of zinc deficiency?

Zinc deficiency is not usually an issue for those consuming adequate total calories. Athletes on calorie-restricted diets or poorly planned vegetarian diets may be at increased risk for zinc deficiency resulting from low zinc intake. Increased needs such as during growth and development, malabsorption caused by chronic iron supplementation or high dietary phytate and fiber, and increased losses by means of chronic diarrhea, diabetes, or sweat losses also contribute to low zinc levels. Zinc deficiency can lead to impaired immune function, loss of appetite, diarrhea, dermatitis, and low testosterone levels in men. Similar to iron, if the body detects a low level of zinc, it compensates by increasing the intestinal absorption of the mineral.

Research results are mixed in regard to the acute and chronic effects of exercise on zinc status. The effects vary for high-intensity, short-duration exercise as compared to lower-intensity, long-duration endurance exercise. In addition, the changes in zinc status vary depending on when the tests for zinc levels were performed. For example, immediately after short-duration, high-intensity exercise there is a reported increase in plasma zinc levels that return to baseline levels within 30 minutes after exercise.[39] In regard to endurance training, plasma zinc levels have been reported to remain unchanged in response to chronic training,[40,41] unchanged immediately after an acute bout of endurance exercise,[42] or decreased when measured within minutes or hours postexercise.[43,44] A study of 26 subjects who completed the Houston marathon showed that urinary and serum zinc concentrations measured 15 minutes after the race were unchanged from baseline data taken 2 weeks prior to the marathon.[42] In the studies reporting postexercise zinc decreases, the explanations given include losses in sweat and urine, increased uptake by the liver and red blood cells, and/or acute inflammation resulting from the exercise. Clearly, controversy exists as to the acute effect of exercise on zinc status. Despite the fact that some studies have reported decreases in plasma zinc levels after endurance-type exercise, the decreases do not appear to lead to long-term zinc deficiencies in endurance athletes, unless athletes are following a calorically restricted diet or are vegetarians.[45,46]

What are the symptoms of zinc toxicity?

The upper limit for zinc is 40 milligrams per day.[28] This level is set based on observed reductions in copper status with intakes of zinc at levels higher than

40 milligrams per day.[28] The body is fairly efficient at excreting excess zinc; therefore, toxicity is rare through a regular diet. However, many athletes are taking zinc supplements in addition to eating zinc-rich foods in their diet. High doses in supplement form can impair iron and copper absorption, which over time may contribute to anemia. Zinc doses of approximately 100 milligrams per day or greater can increase LDL and decrease HDL cholesterol, leading to increased risk for heart disease. More immediate and recognizable signs and symptoms of zinc overload are nausea and vomiting.

Which foods are rich in zinc?

Zinc-rich foods include most animal products, especially beef and other dark meats; fish, with oysters ranking at the top; eggs; whole grains; wheat germ; legumes; and dairy products. Refer to Figure 7.8 for the zinc content of specific food sources.

What is a suggestion for a zinc-rich meal or snack?

Thanksgiving leftovers: A sandwich with 3 oz dark meat turkey and 1 slice of Swiss cheese, ½ cup cranberry sauce and an 8 oz glass of skim milk
Total zinc content = 7.3 milligrams

Do athletes need zinc supplements?

In general, zinc supplements are not essential. Athletes should focus on consuming zinc-rich foods on a daily basis. For individuals who have low dietary intakes and low body stores of zinc, a short-term supplement plan may provide health and performance benefits. For those with adequate intakes and stores, supplementation may have no effect. Research on the effects of zinc supplementation on athletic performance, for those with either low or adequate intakes, is limited and equivocal. Athletes should be encouraged to avoid taking large quantities of supplemental zinc over a long period of time because of toxic effects and mineral–mineral interactions. Zinc supplements are often marketed for common cold prevention and remedy—a claim that is still under investigation. Many zinc supplements recommend a dose that provides several times the RDA. If taken consistently over time, these high dosages can decrease the absorption of iron and copper, leading not only to the toxic effects of zinc, but also to iron and copper deficiency issues.

ZINC

Daily Value = 15 mg
RDA = 11 mg (males), 8 mg (females)

	Exceptionally good source		
High: 20% DV or more	Oysters, cooked	85 g (3 oz)	154 mg
	Wheat bran flakes cereal	30 g (~3/4 cup)	15.8 mg
	Crab, Alaska King, cooked	85 g (3 oz)	6.5 mg
	Ground beef, extra lean, cooked	85 g (3 oz)	6.0 mg
	Beef liver, cooked	85 g (3 oz)	4.5 mg
	Turkey, dark meat, cooked	85 g (3 oz)	3.8 mg
	Cheerios cereal	30 g (~1 cup)	3.8 mg
	Steak, porterhouse, cooked	85 g (3 oz)	3.5 mg
Good: 10–19% DV	Lobster, cooked	85 g (3 oz)	2.5 mg
	Chicken, dark meat, cooked	85 g (3 oz)	2.4 mg
	Ham, extra lean, cooked	85 g (3 oz)	2.4 mg
	Clams, cooked	85 g (3 oz)	2.3 mg
	Yogurt, plain, nonfat	225 g (1 8-oz container)	2.2 mg
	All Bran cereal	30 g (~1/2 cup)	1.8 mg
	Wheat germ	15 g (1/4 cup)	1.8 mg
	Refried beans, canned	130 g (~1/2 cup)	1.5 mg

Figure 7.8 Food sources of zinc. Meats, organ meats, and seafood are the best sources of zinc. Note: The DV for zinc is higher than the current RDA of 11 and 8 milligrams for males and females, respectively, age 19 and older.
Source: Data from U.S. Department of Agriculture, Agricultural Research Service, 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory home page. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Why is chromium important for athletes?

Chromium was virtually unnoticed and unheard of by the general population until it was proposed to aid in weight loss. Dietary supplements of chromium then began to fly off the shelves, only to disappoint most consumers, who found that the dream of effortless weight loss was unfulfilled. Chromium is now receiving more attention in the health maintenance and diabetes prevention arenas.

What is the RDA/AI for chromium?

The AI for chromium is 35 micrograms per day for men and 25 micrograms per day for women.[28] As athletes age, the recommendations are lowered.

What are the functions of chromium for health and performance?

The major function of chromium appears to be its ability to enhance the action of insulin. In other words, chromium increases the effects of insulin on the metabolism of carbohydrates, fats, and proteins. Exactly how chromium enhances insulin activity is poorly understood; however, it is does appear that chromium increases the body's tolerance to sugars through its interaction with glucose tolerance factor (GTF). GTF is a molecular complex that strengthens the interaction between insulin and its receptors on the cell membrane.[38] In addition, chromium may increase the number of insulin receptors, thus further increasing insulin sensitivity and

improving type 2 diabetes. Because of the relationship between chromium and insulin sensitivity, a deficiency in chromium has been suggested to be a contributing factor in a person's risk for diabetes. Other health-related functions of chromium include a link to blood lipid levels and proper immune function.

What are the complications of chromium deficiency?

Because of its association with insulin, chromium deficiency has been proposed as one cause for high blood glucose, which in the long term may lead to type 2 diabetes. Along with decreased insulin sensitivity and high blood glucose levels, lipid abnormalities can develop. If a chromium deficiency is impairing the action of insulin, the result is altered carbohydrate and protein metabolism. Changes in macronutrient metabolism can ultimately decrease endurance performance, as well as the body's ability to build and repair muscle during and after exercise.

What are the symptoms of chromium toxicity?

The absorption rate of chromium is very low. Therefore, toxicity is rare and thus no upper limit has been established.[28] One side effect of chronic high intake of chromium that has been noted is interference with iron and zinc absorption.

Which foods are rich in chromium?

Chromium is found in a unique mix of foods including mushrooms, prunes, nuts, whole grains, brewer's yeast, broccoli, wine, cheese, egg yolks, asparagus, dark chocolate, and some beers. Chromium content in foods is highly variable; therefore, current databases lack thorough information on the quantity of chromium in various dietary sources.[28]

What is a suggestion for a chromium-rich meal or snack?

Dinner: Homemade pasta primavera made with 2 cups of whole wheat pasta and ½ cup each of mushrooms, broccoli, and asparagus in a light tomato sauce sprinkled with 1 tbsp parmesan cheese
Total chromium content = ~35 micrograms

Do athletes need chromium supplements?

Small quantities of chromium have been found to be lost in sweat and urine with strenuous exercise.[47,48] However, supplementation is not warranted for athletes consuming adequate total calories and chromium-rich foods. Athletes who are following a low-calorie diet for an extended period of time, as is often the case with wrestlers, dancers, runners, or gymnasts, should be monitored for adequate daily chromium intakes. Chromium supplements are often marketed to athletes and touted as a fat burner and muscle builder. Typically the claims focus on chromium's ability to enhance insulin action, which in theory might increase muscle anabolism and improve body composition.

A study of 20 male NCAA wrestlers assessed the use of chromium picolinate or placebo on body composition, weight, and sport performance.[49] Researchers found that 14 weeks of supplementation of chromium picolinate enhanced neither body composition nor performance variables (strength, anaerobic power, or aerobic capacity) as compared to placebo or control subjects. In another report, Vincent reviewed over a decade of human studies researching the effects of chromium picolinate and found that the supplement has not consistently demonstrated effects on the body composition of healthy individuals, even when taken in combination with an exercise program.[50]

Athletes should avoid ingesting too much chromium through supplements. Excessive chromium intake can interfere with iron and zinc absorption, creating deficiency problems.[51] Chromium also competes with iron for binding to transferrin, which could potentially decrease performance because of lower oxygen-carrying capacity.[51] The long-term effects of high doses of chromium supplementation are not fully known at this time. Some research warns that excessive chromium intake over time may cause chromosomal damage, leading to a plethora of health and performance issues.[52] In summary, chromium supplements do not appear to be warranted for health or performance reasons and therefore are not recommended.

Why is fluoride important for athletes?

Fluoride is well-known for its role in the prevention of dental caries. A consistent supply of fluoride was introduced into the U.S. diet when the process of fluoridating water began in the 1940s. Fluoride is well absorbed and is transported to bones and teeth, which contain most of the body's fluoride. More than 98% of the fluoride in the body is found in the skeleton.[38]

What is the RDA/AI for fluoride?

The AI for adults is 4 milligrams a day for men and 3 milligrams a day for women.[1]

What are the functions of fluoride for health and performance?

Fluoride is critical for the mineralization of bones and teeth. Fluoride assists in the deposition of calcium and phosphate in bones and teeth, creating strength and stability. Although not directly involved in energy production or metabolism, fluoride is a key mineral

for athletes, considering all sports require a skeleton that is sturdy and enduring. It has also been suggested that fluoride may help strengthen the resistance of interosseous ligaments or muscle tendons during dislocations and sprains and prevent tendonitis in athletes.[38]

What are the complications of fluoride deficiency?

The manifestations of fluoride deficiency are increased dental caries and compromised integrity of bone. Poor denture can lead to a variety of problems in the mouth, which can potentially alter eating patterns or types of foods consumed. Compromised bone integrity can lead to fractures, bone pain, and ultimately decreased performance.

What are the symptoms of fluoride toxicity?

The upper limit established for fluoride is 10 milligrams per day. There is a current debate on whether the U.S. population consumes fluoride in excess of this upper limit on a daily basis. Along with fluoridated water, the use of fluoride toothpaste, floss, mouthwash, and other dental products is common, and thus in theory could lead to overload. **Fluorosis** occurs when too much fluoride is consumed over a period of time, leading to discoloration and pitting of tooth enamel (see Figure 7.9), altered bone formation and fractures, chronic gastritis, and weak and stiff joints. Some claim that long-term high doses of fluoride can also contribute to a higher risk for a variety of diseases and poor health.

fluorosis A condition resulting from the overconsumption of fluoride that can lead to pitting and discoloration of the teeth and/or bone and joint problems.

© NIH/Custom Medical Stock Photo

Figure 7.9 Tooth mottling in fluorosis. During tooth development, prolonged excessive fluoride intake can cause fluorosis, which discolors and damages teeth.

Do athletes need fluoride supplements?

Fluoride supplements are generally not recommended. Ingestion of fluoridated water and the topical application of fluoridated toothpaste, floss, and mouthwash are sufficient for protecting the teeth. Fluoride in drinking water is generally adequate for the proper development of bones. Short-term use of fluoride supplements under medical supervision may be appropriate for bone strengthening for those who have consistently low fluoride intake. Fluoride supplements are inappropriate for long-term use because of toxic effects and the lack of research data on the safety of long-term use.

Which foods are rich in fluoride?

Water is the main source of dietary fluoride in the United States, containing approximately 0.7–2 milligrams per liter. Community water suppliers often fluoridate their water to increase the concentration of fluoride in the drinking water. However, not all water in community supplies is fluoridated, and well water varies greatly in fluoride content. Bottled water has varied amounts of fluoride, and often the fluoride content is low.[53] Teas, seafood, and foods that are prepared with water contain appreciable fluoride (see Figure 7.10).

Food or Beverage	Fluoride (µg/100 grams)
Tea, brewed, regular	373
Tea, brewed, decaffeinated	269
Raisins	234
Crab, canned	210
Grape juice, white	210
Wine, white	202
Shrimp, canned	201
Water, bottled, Dannon Fluoride To Go	78
Water, tap, all regions (municipal and well)	71
Water, bottled, Dannon	11

Figure 7.10 Food sources of fluoride. Teas, seafood, and foods that are prepared with water contain appreciable levels of fluoride.
Source: Data from U.S. Department of Agriculture, Agriculture Research Service, 2005. USDA National Fluoride Database of Selected Beverages and Foods. Nutrient Data Laboratory. Available at: http://www.ars.usda.gov/Services/docs.htm?docid=6312.

What is a suggestion for a fluoride-rich meal or snack?

Snack: 16 oz hot black tea with a teaspoon of honey
Fluoride content = 1.6 milligrams

Why is copper important for athletes?

Because of the rarity of deficiency complications, copper does not receive much attention. However, it does work "behind the scenes" in conjunction with other minerals to aid in optimal health and performance.

What is the RDA/AI for copper?

The RDA for men and women is 900 micrograms per day.[28]

What are the functions of copper for health and performance?

The health and performance benefits of copper are intertwined. Copper is a component of the enzyme ceruloplasmin, which is involved in iron metabolism. Copper converts ferrous iron to ferric iron, enabling iron to be transported in the blood by transferrin, thus aiding in oxygen metabolism and preventing anemia. Copper is an integral part of a variety of antioxidant enzymes, including superoxide dismutase. This enzyme, as well as other substances with antioxidant properties, helps to protect the body against free radical damage. Lysyl oxidase, another copper-dependent enzyme, is needed for the cross-linking of elastin and collagen to ensure the strength of connective tissues for cardiovascular and respiratory functions, among others.[54] Copper also participates in the electron transport chain. Copper is needed as part of cytochrome c oxidase, the terminal enzyme in electron transport and an important part of energy production.[54]

What are the complications of copper deficiency?

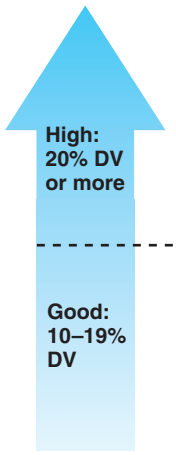
Copper deficiency is rare in the United States. High doses of iron and zinc can interfere with copper absorption and therefore contribute to copper deficiency problems. The signs and symptoms of copper deficiency are anemia, decreased white blood cells, and bone abnormalities. Menkes syndrome is a rare genetic disorder that involves a failure to absorb copper. Instead of being absorbed through the intestinal wall and into the bloodstream, copper accumulates in the intestinal wall and other organs. This buildup of copper can lead to neurological degeneration, abnormal connective tissue development, and low bone mass.

What are the symptoms of copper toxicity?

The upper limit for copper intake is 10,000 micrograms per day.[28] The results of copper overload are gastrointestinal distress and liver damage. Wilson's disease is a genetic disorder characterized by an excessive accumulation of copper, which leads ultimately to anemia, as well as to liver and neurological problems.

COPPER

Daily Value = 2 mg
RDA = 900 µg (males/females)



Exceptionally good sources		
Beef liver, cooked	85 g (3 oz)	12.4 mg
Oysters, cooked	85 g (3 oz)	6.4 mg
Lobster, cooked	85 g (3 oz)	1.6 mg
Crab, Alaska King, cooked	85 g (3 oz)	1.0 mg
Clams, cooked	85 g (3 oz)	0.6 mg
Sunflower seeds	30 g (~1 oz)	0.5 mg
Hazelnuts	30 g (~1 oz)	0.5 mg
Mushrooms, cooked	85 g (~1/2 cup)	0.4 mg
Tofu, calcium processed	85 g (~1/3 cup)	0.3 mg
Baked beans, canned	130 g (~1/2 cup)	0.3 mg
Navy beans, cooked	90 g (~1/2 cup)	0.3 mg
Soy milk	240 mL (1 cup)	0.3 mg
Peanuts	30 g (1 oz)	0.3 mg
All Bran cereal	30 g (~1/2 cup)	0.2 mg
Refried beans, canned	130 g (~1/2 cup)	0.2 mg
Cocoa, dry powder	1 tbsp	0.2 mg

Figure 7.11 Food sources of copper. Copper is found in a limited variety of foods. The best sources are seafood, legumes, and nuts. Note: The DV for copper is higher than the current RDA of 900 micrograms for males and females age 19 and older.

Source: Data from U.S. Department of Agriculture, Agricultural Research Service, 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory home page. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Which foods are rich in copper?

Copper is found in organ meats, seafood, nuts, seeds, wheat bran, cereals, whole grains, and cocoa products. Refer to Figure 7.11 for the copper content of specific food sources.

What is a suggestion for a copper-rich meal or snack?

Lunch: 1½ cups clam chowder, 15 wheat crackers, and 1 cup of fruit salad sprinkled with 1 tbsp sunflower seeds
Total copper content: 610 micrograms

Do athletes need copper supplements?

Because most athletes generally consume adequate levels of copper, supplements are not needed or recommended. For example, Gropper et al. studied 70 female collegiate athletes to assess copper intake as well as ceruloplasmin and serum copper concentrations.[54] They found that copper intake, serum copper, and ceruloplasmin levels were adequate in this population. In addition, high doses of copper can become toxic, leading to side effects such as nausea and vomiting.

Why is manganese important for athletes?

Manganese is not a well-known trace mineral; however, its lack of popularity and recognition is not indicative of its importance to health and performance. Manganese is unique as compared to other minerals in that it can be better absorbed through drinking water and supplements than from whole food products.

What is the RDA/AI for manganese?

The AI for manganese is 2.3 milligrams for men and 1.8 milligrams for women daily.[28]

What are the functions of manganese for health and performance?

Manganese activates a variety of health-related enzymes that are involved in skeletal growth, protein and hemoglobin synthesis, metabolism of lipids and carbohydrates, and antioxidant functions. One of these enzymes is superoxide dismutase, which is important for its antioxidant properties. Another enzyme dependent on manganese is glutamic synthetase. Glutathione peroxidase and other antioxidant enzymes such as superoxide dismutase, catalase, and glutathione reductase function to reduce lipid peroxidation.[23,55] Manganese is also involved in energy metabolism and fat synthesis.

What are the complications of manganese deficiency?

Manganese deficiency leads to poor growth, bone abnormalities, and impaired fat and carbohydrate metabolism. Excessive dietary iron, calcium, and phosphorus inhibit the absorption of manganese. Iron and calcium supplements should be taken between meals to avoid nutrient–nutrient interactions.

What are the symptoms of manganese toxicity?

The upper limit for manganese is 11 milligrams per day.[28] Fatigue and weakness, neurological problems, and mental confusion can all result from large intakes of manganese.

Which foods are rich in manganese?

Whole grains, legumes, green leafy vegetables, tea, and fruit are all good sources of manganese. Refer to Figure 7.12 for the manganese content of specific food sources.

What is a suggestion for a manganese-rich meal or snack?

Dinner: Sweet potato fries (see **Training Table 7.4**)
Total manganese content = 0.85 milligrams

MANGANESE

Daily Value = 2 mg
AI = 2.3 mg (males), 1.8 mg (females)

High: 20% DV or more

Good: 10–19% DV

Exceptionally good sources		
Pineapple, fresh	140 g (~1 cup)	2.3 mg
All Bran cereal	30 g (~1/2 cup)	2.2 mg
Wheat germ	15 g (1/4 cup)	2.0 mg
Hazelnuts	30 g (~1 oz)	1.7 mg
Oatmeal, cooked	1 cup	1.3 mg
Whole wheat bread	50 g (2 slices)	1.2 mg
Blackberries, fresh	140 g (~1 cup)	0.9 mg
Spinach, cooked	85 g (~1/2 cup)	0.8 mg
Lima beans, cooked	90 g (~1/2 cup)	0.7 mg
Soybeans, cooked	90 g (~1/2 cup)	0.7 mg
Tea, brewed	240 mL (1 cup)	0.5 mg
Sweet potato, cooked	110 g (1 small)	0.5 mg
Baked beans, canned	130 g (~1/2 cup)	0.4 mg
Okra, cooked	85 g (~1/2 cup)	0.3 mg
Turnip greens, cooked	85 g (~1/2 cup)	0.3 mg
Beets, cooked	85 g (~1/2 cup)	0.3 mg
Broccoli, cooked	85 g (~1/2 cup)	0.2 mg
Cocoa, dry powder	1 tbsp	0.2 mg

Figure 7.12 Food sources of manganese. Manganese is found mainly in plant foods such as grains, legumes, vegetables, and some fruits. Note: The DV for manganese is lower than the current RDA of 2.3 milligrams for males age 19 and older and higher than the current RDA of 1.8 milligrams for females age 19 and older.

Source: Data from U.S. Department of Agriculture, Agricultural Research Service, 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory home page. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Training Table 7.4: Sweet Potato Fries

These fries are an excellent side dish for grilled meats and burgers.

1 medium sweet potato
1/2 tbsp olive oil
Ground pepper and garlic salt
Cooking spray

Preheat the oven to 450° F. Wash and cut the sweet potato into 1/4- or 1/2-inch wedges. Place the potato wedges in a large plastic bag with the 1/2 tbsp olive oil. Add ground pepper and garlic salt to taste. Close the bag and shake to mix the potato, oil, and spices thoroughly. Spray a cookie sheet with cooking spray and spread the potato wedges evenly on the sheet. Bake the potatoes for 20 to 30 minutes, stirring every 10 minutes to ensure even browning.

Serving size: 1 potato (Recipe makes one serving)

Calories: 222 kcals

Protein: 4 grams

Carbohydrate: 37 grams

Fat: 7 grams

Do athletes need manganese supplements?

Manganese supplements are neither needed nor recommended for athletes. Dietary intake from food sources and daily water intake should be adequate to meet the AI recommended for manganese.

Why is iodine important for athletes?

Iodine has the glory and recognition of being the first vitamin or mineral to be incorporated into a successful fortification program. After more than 75 years, the fortification of salt with iodine is still a success in the prevention of a variety of diseases.

What is the RDA/AI for iodine?

The RDA for iodine is 150 micrograms per day for both men and women.[28]

What are the functions of iodine for health and performance?

The only known role of iodine in humans is to serve as an element essential to the synthesis of hormones secreted by the thyroid gland, namely tetraiodothyronine (thyroxine, or T4) and triiodothyronine (T3). T4 and T3 are involved in the metabolism of all cells of the body during the growth process and in the development of most organs, particularly the brain.[38] Iodine is related to athletic performance through the action of the thyroid hormones, which play a role in protein synthesis in skeletal muscle, energy expenditure, weight control, and body temperature regulation. However, because of the high availability of iodized salt and its use in foods throughout the United States, iodine deficiency is very rare and thus little is known about the impact of iodine on athletic performance.

What are the complications of iodine deficiency?

A lack of dietary iodine can lead to the development of **goiter**, or the enlargement of the thyroid gland. The lack of iodine inhibits the synthesis of the hormones T3 and T4 by the thyroid gland. As a result, the pituitary gland starts producing more thyroid-stimulating hormone in an attempt to initiate the thyroid's production of T3 and T4. The higher blood levels of thyroid-stimulating hormone cause the thyroid gland to grow. In fact, the enlargement of the thyroid can cause a sizeable increase in the outward appearance of the neck. Symptoms of iodine deficiency are similar to symptoms of hypothyroidism, including cold intolerance, weight gain, and decreased body temperature.

goiter A clinical condition resulting from iodine deficiency. Goiter causes enlargement of the thyroid gland and results in an observable enlargement of the lower neck.

IODINE

Daily Value = 150 µg
RDA = 150 µg (males/females)

	Exceptionally good sources		
	Salt, iodized	1.5 g (1/4 tsp)	600 µg
High: 20% DV or more	Cod, cooked	85 g (3 oz)	99 µg
	Corn grits, enriched, cooked	1 cup	68 µg
	Milk, 2% milkfat	240 mL (1 cup)	56 µg
	Milk, nonfat	240 mL (1 cup)	51 µg
	White bread	50 g (~2 slices)	46 µg
	Tortilla, flour	55 g	41 µg
	Beef liver, cooked	85 g (3 oz)	36 µg
	Navy beans, cooked	90 g (~1/2 cup)	35 µg
	Shrimp, cooked	85 g (3 oz)	35 µg
	Potato, baked	110 g (1 small)	34 µg
	Turkey breast, cooked	85 g (3 oz)	34 µg
	Whole wheat bread	50 g (~2 slices)	32 µg
Good: 10–19% DV	Egg, cooked	50 g (1 large)	24 µg
	Oatmeal, cooked	1 cup	16 µg

Figure 7.13 Food sources of iodine. Few foods are rich in iodine; it is found mainly in milk, seafood, and some grain products.
Source: Data from Office of Dietary Supplements, National Institute of Health, 2013. Dietary Supplement Fact Sheet: Iodine. Available at: http://ods.od.nih.gov/factsheets/Iodine-QuickFacts/.

What are the symptoms of iodine toxicity?

The UL of iodine is 1100 micrograms per day.[28] Excessive iodine intake can also lead to the development of a goiter. Large intakes stimulate the thyroid to produce more hormones, thus stimulating the growth and enlargement of the gland.

Which foods are rich in iodine?

The addition of iodine to salt began in 1924 to increase Americans' intake of this mineral to prevent goiter and other related issues. Iodized salt remains one of the largest sources of dietary iodine in the United States, although not all salt is fortified with iodine. As a result, it is important to check the food label to determine if the salt is iodized. Iodine can also be found in seafood, dairy, grains, and cereals. Refer to Figure 7.13 for the iodine content of specific food sources.

What is a suggestion for an iodine-rich meal or snack?

Lunch: A turkey sandwich on whole wheat bread with lettuce and tomato and 1 cup of skim milk
Total iodine content = 105 micrograms

Do athletes need iodine supplements?

Iodine supplements are neither needed nor beneficial for athletes. In general, food sources are sufficient for meeting daily iodine needs.

Why is molybdenum important for athletes?

Molybdenum is often forgotten when discussing vitamins and minerals because deficiency and toxicity of molybdenum are rare. Regardless of the risk to consume too little or too much, this mineral is an important player in the game of health and performance.

What is the RDA/AI for molybdenum?
The RDA for men and women is 45 micrograms per day.[28]

What are the functions of molybdenum for health and performance?
Molybdenum is an essential trace element needed by virtually all life forms. In humans, molybdenum is known to function as a cofactor for three enzymes. Two of the enzymes play a role in serving as antioxidants and detoxifying agents in the body. The third enzyme, sulfite oxidase, catalyzes a reaction that is necessary for the metabolism of sulfur-containing amino acids, such as cysteine. Only sulfite oxidase is known to be crucial for human health.[56]

What are the complications of molybdenum deficiency?
Health complications or consequences of low molybdenum intake have not been observed in humans when consuming an adequate diet.[28] The only documented case of acquired molybdenum deficiency occurred in a patient with Crohn's disease on long-term total intravenous nutrition that was not supplemented with molybdenum.[57] Current understanding of the essentiality of molybdenum in humans is based largely on the study of individuals with very rare inborn errors of metabolism and therefore offers little in regard to application for sports nutrition.

What are the symptoms of molybdenum toxicity?
Molybdenum toxicity is rare. The upper limit has been established at 2000 micrograms per day because large quantities can interfere with copper absorption.[28]

Which foods are rich in molybdenum?
Molybdenum is found mainly in plant products such as cereals, whole grains, and legumes. The molybdenum content of plant foods varies depending upon the soil content in which they are grown.[28] Organ meats are the richest source of molybdenum in animal products. Because the methods for analyzing the molybdenum content of foods are not reliable, specific food content information is limited.

What is a suggestion for a molybdenum-rich meal or snack?
Breakfast: 2 cups bran flakes with 12 oz skim milk and a banana
Total molybdenum content = ~17 micrograms

Do athletes need molybdenum supplements?
Molybdenum supplements are neither needed nor beneficial for athletes. Food sources of molybdenum are sufficient, and the usual intake of molybdenum is well above the dietary molybdenum requirement.[28]

Why is selenium important for athletes?

Selenium has only recently received recognition in the nutrition community as an essential nutrient. The connection between human health and selenium intake was made in 1979 after scientists discovered that Keshan disease could be prevented by providing children in China with selenium supplements. Since then, selenium has quickly climbed the ranks of nutritional importance to become a member of the highly regarded antioxidant category of nutrients.

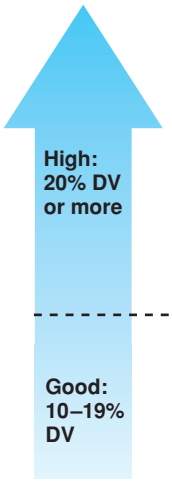
What is the RDA/AI for selenium?
The RDA for selenium is 55 micrograms for both men and women.[58]

What are the functions of selenium for health and performance?
Selenium's role for overall health is closely related to its potential ergogenic effects on athletic performance. Selenium is a component of many bodily proteins, with the selenoproteins being the most notable. Selenocysteine is the selenium form associated with glutathione peroxidase, an antioxidant enzyme that helps to combat free radical damage to cells. Through this breakdown of free radicals, glutathione peroxidase actually helps to spare vitamin E, allowing the vitamin to continue on its free radical scavenger hunt. In other words, selenium and vitamin E work synergistically to quench more free radicals than either nutrient could on its own. Current exercise research has delved into the selenium/antioxidant world, aiming to determine the effects of selenium on exercise-induced free radical formation.

Selenium-associated enzymes have also been linked to proper thyroid and immune function, as well as to the healthy development of fetuses. Selenium's role in immune function has led to cancer risk reduction claims. In general, selenium research is still in its infancy, with all roles, mechanisms, and health/performance effects still under investigation.

SELENIUM

Daily Value = 70 µg
RDA = 55 µg (males/females)



Exceptionally good sources		
Brazil nuts	28 g (1 oz)	544 µg
Oysters, cooked	85 g (3 oz)	60.9 µg
Tuna, canned	55 g (2 oz)	44.2 µg
Lobster, cooked	85 g (3 oz)	36.3 µg
Pork, loin, cooked, lean only	85 g (~3 oz)	36.0 µg
Shrimp, cooked	85 g (3 oz)	33.7 µg
Beef liver, cooked	85 g (3 oz)	30.7 µg
Spaghetti, cooked	140 g (~1 cup)	29.8 µg
Whole-wheat bread	50 g (2 slices)	18.3 µg
Egg, hard cooked	50 g (1 large)	15.4 µg
Oatmeal, cooked	1 cup	11.9 µg
Rice, brown, cooked	140 g (~3/4 cup)	13.7 µg
Rice, white, enriched, cooked	140 g (~3/4 cup)	10.5 µg
Cheerios cereal	30 g (1 cup)	10.4 µg
Cheese, cottage	110 g (~1/2 cup)	9.9 µg
White bread	50 g (2 slices)	8.7 µg
Grits, corn, enriched, cooked	1 cup	7.5 µg

Figure 7.14 Food sources of selenium. Selenium is found mainly in meats, organ meats, seafood, and grains. Note: The DV for selenium is higher than the current RDA of 55 micrograms for males and females age 19 and older.

Source: Data from U.S. Department of Agriculture, Agricultural Research Service, 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory home page. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

What are the complications of selenium deficiency?

Selenium deficiency is rare in the United States and other industrialized nations because of our geographically diverse food supply. The origin of foods is important because the selenium concentration in soil can vary dramatically around the world. If individuals live in a selenium-deficient area and consume only locally grown foods, a selenium deficiency can result. For example, in areas of China with selenium-poor soil, selenium-deficient residents are more susceptible to a form of viral cardiomyopathy called Keshan disease.

Selenium has recently been recognized as an antioxidant mineral, raising questions about the effects of suboptimal intake on cardiovascular parameters and cancer risk. Although it appears that selenium may have a role in these areas, the exact functions, associated mechanisms, and anticipated results of selenium deficiency related to cardiovascular disease and cancer are still under investigation.

gaining the performance edge

The trace minerals include iron, zinc, chromium, fluoride, copper, manganese, iodine, molybdenum, and selenium. Each of these minerals plays a specific and important role in overall health and athletic performance. Athletes should strive to consume these nutrients from whole foods first, and rely on supplements only when individually indicated.

What are the symptoms of selenium toxicity?

The upper limit for selenium has been established at 400 micrograms per day.[58] Consumption of selenium in excess of the upper limit can cause brittle hair and nails; if toxic levels continue to be consumed, the loss of hair and nails can occur.

Which foods are rich in selenium?

Selenium is mainly found in animal products, with seafood ranking near the top of the list. Plant foods contain selenium; however, content can vary dramatically based on the selenium concentration of the soil within the region it was grown. Refer to Figure 7.14 for the selenium content of specific food sources.

What is a suggestion for a selenium-rich meal or snack?

Dinner: Shrimp stir-fry with 3 oz of shrimp, 1 cup of mixed vegetables, and 1 cup of cooked brown rice
Total selenium content = 45 micrograms

Do athletes need selenium supplements?

Research on the ergogenic benefits of selenium supplements is still in its infancy. Some research has shown that the antioxidant status of athletes participating in intense training diminishes, leading to

TABLE 7.3 Review of Other Trace Minerals

Mineral	RDA/AI for Adults ages 19 to 50	Functions for Health/ Performance	Upper Limit	Toxicity Complications
Arsenic	Not determinable	No biological function determined for humans; animal data suggest a requirement.	Not determinable	No adverse effects shown for organic arsenic. Inorganic arsenic known as a toxic substance.
Boron	Not determinable	No biological function determined for humans; animal data suggest a requirement.	20 mg per day	Animal studies reveal reproductive and developmental effects.
Nickel	Not determinable	No biological function determined for humans; animal data suggest a requirement.	1.0 mg per day	Animal studies have observed decreased body weight gain.
Silicon	Not determinable	No biological function determined for humans; animal data suggest it contributes to adverse health effects.	Not determinable	Naturally occurring silicon in foods and water does not appear to be a requirement.
Vanadium	Not determinable	No biological function determined for humans.	1.8 mg per day	Animal studies have observed renal lesions as a result of high intakes.

TABLE 7.4 Food Sources for Other Trace Minerals

Mineral	Food Sources	Supplements Needed for Athletes?
Arsenic	Dairy products, meats, fish, grains, and cereals	No. Currently there is no justification for addition of arsenic to the diet.
Boron	Fruit-based beverages, potatoes, legumes, milk, avocados, and peanuts	No. Currently there is no justification for addition of boron to the diet.
Nickel	Nuts, legumes, cereals, sweeteners, and chocolate powders and candies	No. Currently there is no justification for addition of nickel to the diet.
Silicon	Plant-based foods	No. Currently there is no justification for addition of silicon to the diet.
Vanadium	Mushrooms, shellfish, black pepper, parsley, and dill seed	No. Currently there is no justification for addition of vanadium to the diet.

Food for Thought 7.2

Importance of Mineral Intake for Athletes: Trace Minerals

Review the recommendations, food sources, and significance of trace minerals for athletes.

the proposal that selenium and other antioxidant supplements may be warranted.[59,60] However, because it is relatively easy to consume adequate amounts of selenium in a well-balanced diet, and because of its toxic effects, selenium supplements are not recommended at this time. Once more information is available, these recommendations may change.

Are other trace minerals important for athletes?

The previous sections have discussed the well-known trace minerals; however, there are a few more that were not discussed. These trace minerals are summarized in Tables 7.3 and 7.4.

Food for Thought 7.3

You Are the Nutrition Coach

Apply the concepts from this chapter to several case studies.

The Box Score

Key Points of Chapter

- Minerals are inorganic nutrients that are essential for normal body functioning.
- Minerals are needed in very small quantities relative to other nutrients because they are structurally very stable and they can be repeatedly used in the body without breakdown. Dietary intake of minerals from foods can lead to a toxic buildup; however, most toxicity is caused by ingesting high-dosage supplements.
- Minerals are classified as either major minerals or trace minerals. Major minerals are those needed by the body in amounts greater than 100 milligrams per day. Trace minerals are those required in daily quantities of less than 100 milligrams.
- Calcium, phosphorus, magnesium, sodium, chloride, potassium, and sulfur constitute the major minerals. The trace minerals include iron, zinc, chromium, fluoride, copper, manganese, iodine, molybdenum, and selenium.
- Calcium is not only required for ensuring healthy, strong bones, but it is also important in blood clotting, nerve transmission, and muscle contraction. The AI is approximately 1000 milligrams per day for those 19 to 50 years of age.
- Phosphorus, similar to calcium, is also important for strong bones. It is also an integral part of cell membranes and plays a role in enzyme activation. The RDA for phosphorus is 700 milligrams per day, which is easily achieved in the typical American diet.
- Magnesium plays a role in the regulation of blood pressure, is critical for the proper functioning of many cellular enzymes, and is important for bone formation. The RDA for magnesium ranges from 310–420 milligrams per day, and supplementation with higher doses has not shown any ergogenic effects in athletes.
- Sodium and potassium are important for maintaining blood pressure, nerve impulse transmission, and muscle contraction. The AIs for sodium and potassium are 1500 and 4700 milligrams per day, respectively. Athletes need to make an effort to curb sodium intake and increase potassium consumption to prevent complications such as increases in blood pressure, muscle weakness, and heart arrhythmias.
- Chloride has roles in the body's immune system, digestion of food, and nerve transmission. The AI of 2300 milligrams per day is usually met with diet alone via salted foods.
- Sulfur plays a key role in normal growth and development; however, it does not have an established RDA or AI. Sulfur is found in a variety of foods, and deficiencies are rare.
- The trace mineral iron plays an essential role in the transport and utilization of oxygen throughout the body. Deficiencies do occur in athletes, resulting in anemia; however, universal use of iron supplementation for all athletes is not warranted.
- Zinc is a trace mineral that serves as a cofactor for various enzymes involved in carbohydrate, protein, and fat metabolism during exercise. It also makes an important contribution to recovery because of its role in protein synthesis and repair of tissues. Fortunately, zinc deficiencies are rare in athletes consuming adequate total calories.
- Chromium is a trace mineral touted to increase insulin activity and thus enhance glucose uptake and protein assimilation. As a result, it was speculated that chromium supplementation would increase muscle mass and decrease fat mass. Current research into the effectiveness of chromium supplementation has not supported these claims.
- Fluoride is critical for the mineralization of bones and teeth. Although not directly involved in energy production or metabolism, fluoride is important to athletes given the fact that all sports require a skeleton and connective tissues that are strong and resilient.
- Copper, iodine, manganese, selenium, and molybdenum are trace minerals in which deficiencies are very rare. Although they play critical roles related to enzyme activity, hormone function, and/or free radical neutralization, their effects on athletic performance are relatively unstudied and/or inconclusive. Supplementation of these trace minerals is not warranted.
- Despite the important roles trace minerals play in the body, the small daily requirements are usually met by the typical American diet. As a result, trace mineral supplementation in excess of that provided by diet alone is not recommended and has not been shown to have any ergogenic effects on athletic performance.

Study Questions

1. What role do minerals play in the body?
2. What are the major minerals? What differentiates a major mineral from a trace mineral?
3. What are some of the common food sources for each of the major minerals?
4. Discuss the various conditions that result as a consequence of deficiencies in the major minerals.
5. Should athletes take supplements containing large doses of the major minerals? Defend your answer based on the benefits versus the risks.
6. What role does the trace mineral iodine play in the body? What condition results from iodine

deficiency? Why is this condition very rare in the United States?

7. Besides iodine, list four other trace minerals, discuss their roles in the body, and give specific foods that serve as good sources for each.

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