



IRON: The Oxygen Carrier

A Small but Mighty Mineral

Iron is a trace mineral, meaning that only a small amount of it is required by the body each day. Iron carries out a number of crucial functions particularly with respect to athletic performance.

Iron Functions – What Iron Can Do for You

Iron is required for the formation of *hemoglobin*, an essential part of the red blood cell. Hemoglobin gives red blood cells their red color and is responsible for the red blood cells' ability to transport oxygen to the muscles and carry carbon dioxide away from the muscles to the lungs where it is released in expired air (i.e., when you exhale). Iron is also important for the synthesis of *myoglobin*, a protein found in skeletal muscle that increases the rate of oxygen transport from the blood to the muscle cells. Finally, iron functions as a co-factor for enzymes involved carbohydrate and protein metabolism.

The Stages of Iron Deficiency

Iron deficiency does not happen overnight, rather, it progresses through a series of stages. An inadequate dietary intake of iron will, over time, result in a depletion of the iron stored in the bone marrow (i.e., *ferritin*). This is the first stage of iron deficiency and is called *iron depletion*. Iron depletion can be assessed by measuring the amount of *ferritin* in the blood. If left untreated, iron depletion may progress to stage 2 at which point the synthesis of red blood cells (i.e.,

Iron Deficiency Stage	Impact on Exercise Performance
Stage 1 (Iron Depletion)	Enzymes requiring iron may be inhibited; increase in glucose oxidation and lactic acid production. (Meaning you feel muscle fatigue faster than normal.)
Stage 2 (iron deficiency erythropoiesis)	Ability to synthesize new red blood cells is decreased; delivery of oxygen to muscle cells may be inhibited especially in high-intensity exercise. (↓ oxygen delivery = ↓ performance)
Stage 3 (iron deficiency anemia)	Hemoglobin synthesis is decreased and oxygen delivery to muscle cells is significantly reduced. Exercise capacity (particularly aerobic/endurance exercise) is severely impaired.

erythropoiesis) is decreased. The third and final stage of iron deficiency is known as *iron deficiency anemia*. It is at this stage that hemoglobin synthesis is reduced and oxygen carrying capacity and carbon dioxide removal is severely compromised.

Iron deficiency and Athletic Performance

Because of the critical roles iron plays in oxygen delivery, carbon dioxide removal, and energy metabolism, it should come as no surprise that iron deficiency will severely and negatively impact athletic performance, particularly aerobic or endurance performance. As shown in the table, even the early stages of iron deficiency (i.e., stages 1 and 2) can negatively impact performance. Moreover, failure to correct iron deficiency during the early stages increases the risk of developing full-blown anemia. Finally, once it develops, anemia is very difficult to treat and complete recovery can take upwards to 6 months or more). In addition to decreased aerobic/endurance performance, athletes with iron deficiency anemia often experience overwhelming fatigue, cold intolerance, impaired training adaptation, delayed recovery, compromised immune function and increased susceptibility to and delayed recovery from illnesses such as the common cold.

Causes of Iron Deficiency

The causes of iron deficiency include inadequate dietary intake combined with excessive losses. Iron is found in a limited number of foods and, as described below, is not particularly well absorbed. Thus, dietary intake is often insufficient to meet needs, especially for those who limit or avoid red meats (e.g., vegetarians). Iron lost as a result of exercise can also predispose athletes to deficiencies. Small amounts of iron are lost in the sweat and as a result of the destruction of red blood cells that often accompanies high impact activities (also known as "foot strike hemolysis"). Finally, females are at an increased risk of iron deficiency due to blood lost during monthly menstruation.

Food Sources of Iron

Iron in food comes in two forms: *heme* and *non-heme*. Heme iron is the iron bound to hemoglobin or myoglobin and, thus, is found only in foods of animal origin such as meat, fish, or poultry.

Non-heme iron is the form of iron found in plant foods including beans, nuts, seeds, breads, grains, vegetables and fruits. Approximately 10-20% of the heme iron consumed is absorbed where as only about 3-5% of non-heme iron is absorbed. In addition, substances in foods can both inhibit and enhance the absorption of non-heme (but not heme) iron.

Enhancers

- Vitamin C
- Protein

Inhibitors

- phytates
- tannins (tea & coffee)
- fiber
- soy
- other minerals (e.g., calcium & zinc)

A careful selection and combination of foods is necessary to optimize iron absorption through your diet. For example, a vegetarian meal rich in spinach should be combined with orange juice in order to increase absorption of iron.

Pumping Iron: Should Athletes Supplement?

Because of the role that iron plays in red blood cell formation and function, some athletes mistakenly believe that supplementing with iron will enhance endurance performance. Nothing could be further from the truth. Unless you are deficient in iron, supplementation will not improve your performance and may even be detrimental. Too much iron can be toxic! High levels of iron can increase the development of free radicals, substances that have been shown to damage body cells and increase inflammation. Because the body is not efficient at excreting excess iron, high intakes cause the accumulation of iron in the vital organs, especially the heart, liver, and pancreas, and can result in multiple organ failure and even death. The best way to ensure that you are receiving just the right amount of iron is to consume iron rich foods regularly. Supplementation should only be done under the orders and supervision of a doctor or registered dietitian.

Iron Content of Popular Ready-to-Eat Cereals

Kellogg's Cereals (1 cup servings):			Quaker Cereals (1 cup servings):		
Complete Bran Flakes	24.2 mg		Oatmeal Squares (all 3 flavors)	24.6 mg	
Frosted Mini-Wheats (all flavors)	17.4 mg		Life Maple & Brown Sugar	13.7 mg	
Smart Start	17.4 mg		Life Original	12.3 mg	
Corn Flakes	7.5 mg		Life Cinnamon	10.9 mg	
Special K Original	6.2 mg		Cap'n Crunch	7.1 mg	
Frosted Flakes	5.1 mg		Cap'n Crunch Chocolate Crunch	7.1 mg	
Raisin Bran	4.3 mg		Cap'n Crunch w/Crunch Berries	6.6 mg	
Apple Jacks	3.9 mg		Cap'n Crunch Peanut Butter Crunch	6.4 mg	
Lowfat Granola w/Raisins	2.9 mg				
Corn Pops	1.9 mg				
Rice Krispies	1.5 mg				
General Mills (1 cup servings):			Post (1 cup servings):		
Total (all flavors)	19.8 mg		Grape Nuts	30.4 mg	
Multi-grain Cheerios	15.9 mg		Trail Mix Crunch (all flavors)	30.4 mg	
Chex	11.6 mg		Honey Bunches of Oats w/Vanilla Clusters	20.3 mg	
Fiber One, Original	8.6 mg		Honey Bunches of Oats	13.5 mg	
Wheaties	7.8 mg		Honey Bunches of Oats w/Almonds	13.5 mg	
Cheerios	7.6 mg		Honey Bunches of Oats w/Strawberries	10.1 mg	
Golden Grahams	5.8 mg		Honey Bunches of Oats w/Peaches	10.1 mg	
Cinnamon Toast Crunch	5.7 mg		Honey Bunches of Oats w/Cinnamon Clusters	10.1 mg	
Reese's Puffs	5.6 mg		Honey Bunches of Oats w/Chocolate Clusters	10.1 mg	
Kix	5.1 mg		Raisin Bran	10.3 mg	
Honey Nut Cheerios	5.0 mg		Golden Crisp	2.2 mg	
Lucky Charms	4.8 mg		Cocoa Pebbles	2.1 mg	
Raisin Nut Bran	4.7 mg		Fruity Pebbles	2.1 mg	
Cookie Crisp (all flavors)	4.5 mg		Honey Comb	2.0 mg	
Cocoa Puffs	4.5 mg				
Trix	4.2 mg				

Food Sources of Iron

Animal sources (3 oz serving)

Beef (all types)	2.5-4.6 mg
Chicken	1.0 mg
Fish	1.0 mg
Pork chops	1.0 mg
Ham (boneless)	1.0 mg

Plant Sources

Cereals (1 oz)	5 -15 mg
Spinach (1/2 cup)	3.0 mg
Beans (1/2 cup)	1.5-2.5 mg
Tortilla (10" flour)	2.5 mg
Hummus (1/2 cup)	2.0 mg
Pasta, rice (1 cup)	1.0 mg
Breads (1 slice)	1.0 mg
Dried Fruit (1/4 cup)	1.0 mg