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CHAPTER 4

Fats

Key Questions Addressed

- What's the big deal about fats?
- What are fats?
- How are lipids (fats) classified?
- How much fat is recommended in an athlete's diet?
- Which foods contain fat?
- How can the percentage of calories from fat be calculated for specific foods?
- What's the big deal about cholesterol?
- How can fats affect daily training and competitive performance?
- What type, how much, and when should fats be consumed before exercise?
- What type, how much, and when should fats be consumed during exercise?
- What type, how much, and when should fats be consumed after exercise?

You Are the Nutrition Coach

Shelley is a marathoner from Austin, Texas. She has been competing in marathons for more than 5 years and is the type of person who enjoys taking on new physical challenges. Although she is not an experienced swimmer, she has agreed to join some friends in tackling the challenge of swimming the English Channel. The plan is to train for a year and then make an attempt at swimming the Channel. Because of the energetic demands of her sport, she is extremely lean and in excellent cardiovascular shape. She loves the warm temperatures in the South and gets chilled easily, which is a concern of hers because she knows the water temperatures in the Channel are very cold.

Question

- What nutrition recommendations would you give Shelley in regard to fat intake to address both her physical and dietary needs over the next 12 months as she trains for the swim? Include suggestions for fat intake before, during, and after the actual Channel swim.

What's the big deal about fats?

Fats, similar to carbohydrates, are an important nutrient for both athletes and nonathletes. They serve as a primary energy source at rest and during light- to moderate-intensity exercise. In addition, dietary fat provides essential fatty acids required for normal physiological functioning of the body, adds flavor to foods, and is a calorie-dense nutrient capable of meeting the high daily energy needs of athletes.

However, fat is an often maligned nutrient because of the well-known association of cholesterol and saturated fats with heart disease. The thought of body fat also raises negative feelings, particularly in athletes who are aware of the potential impact excessive levels of body fat can have on sport performance. In some instances, extreme behaviors are adopted to maintain or decrease body fat levels. The purpose of this chapter is to provide the reader with the knowledge required to keep a healthy and informed perspective on an essential nutrient that is often feared and shrouded in misconceptions.

What are fats?

Fats are molecules that belong to a group of compounds known as lipids. Lipids are organic, carbon-containing compounds that are **hydrophobic** (water insoluble), **lipophilic** (fat soluble), and have a physical characteristic of feeling greasy to the touch. The fact that lipids are not water soluble affects how they are digested, absorbed, and transported throughout the body compared to the other macronutrients, such as carbohydrates and proteins. Calorically, lipids are an energy-rich nutrient yielding 9 calories per gram, compared to only 4 calories per gram for both carbohydrates and proteins.

Similar to other nutrients, lipids are obtained from foods and beverages. Lipids are found in foods of both plant and animal origin. In addition, nonlipid molecules can be converted into lipids within the body. For example, if carbohydrates or proteins are consumed in excess, they will be converted into lipids (i.e., fats) and stored in adipose tissue for later use as energy.

How are lipids (fats) classified?

A number of different chemical compounds are found in food and within the body that are classified as lipids. However, the most important ones fall into three main categories based on their molecular structure: triglycerides, phospholipids, and sterols. Although all three of these are lipids, each plays a significantly different role in the body.

Triglycerides make up the majority of lipids found within the body and in foods and beverages. In fact, triglycerides provide much of the flavor and texture in foods. **Phospholipids** are found in both plants and animals and have a unique molecular structure that allows them to be both fat and water soluble. Phospholipids constitute the cell membranes of various tissues found throughout the body. In addition, because they are water soluble, phospholipids help suspend other hydrophobic lipids in water. Finally, a very small percentage of fats in the body exist as **sterols**. Sterols are quite different from both triglycerides and phospholipids in their structure and function. The most commonly known sterol is cholesterol. Triglycerides, phospholipids, and sterols are discussed in more detail in the following sections.

What are triglycerides?

Triglycerides are commonly occurring fats that are more accurately classified as simple lipids. Triglycerides, also referred to as **triacylglycerols**, are the predominant form of fats found in the human diet. An estimated 98% of dietary fats are triglycerides.[1] In addition, triglycerides are the most common type of fat found in the human body. Triglycerides serve as a major energy reserve and are stored primarily in adipocytes located throughout the body. Triglycerides are also stored in lesser amounts in the liver and muscle, where they are more readily available for use as energy during exercise. Because triglycerides make up the overwhelming majority of fats found in the diet and body, the terms *triglycerides* and *fats* are used interchangeably throughout this text.

What is the molecular structure of a triglyceride?

The structure of a triglyceride is a combination of **glycerol** and three fatty acids. The glycerol "backbone" of a triglyceride molecule is always constant; however, the

hydrophobic Term used to describe molecules or compounds that are water insoluble. Lipids are hydrophobic substances.

lipophilic Substances that are fat soluble.

phospholipid A type of lipid that consists of a glycerol backbone, two fatty acids, and a phosphate group. Phospholipids are derived from both plant and animal sources and are both water and fat soluble. Phospholipids constitute the cell membranes of tissues throughout the body.

sterols A category of lipids that possess carbon rings in their structure rather than carbon chains. Cholesterol is the most commonly known sterol.

triacylglycerols A category of lipids composed of a glycerol molecule with three attached fatty acids; more commonly referred to as triglycerides.

glycerol A three-carbon molecule that makes up the backbone of mono-, di-, and triglycerides.

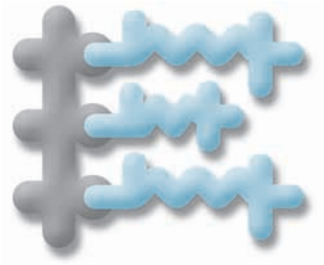

Figure 4.1 Generic triglyceride structure.

three fatty acids attached to the glycerol may differ (see Figure 4.1). During triglyceride breakdown, one fatty acid may be removed, leaving a diglyceride, or two fatty acids may be removed, leaving a monoglyceride. The fatty acids cleaved from the glycerol backbone become what are known as free fatty acids (see "What are fatty acids?" later in this chapter) and are available for use by the body as needed. When all three fatty acids have been stripped from the triglyceride, the remaining glycerol backbone can be metabolized for energy or used to form blood glucose in the liver.

What are some of the functions of triglycerides in the body?

As noted earlier, triglycerides are the predominant form of fat found in the body. Fats perform a variety of critical roles and thus are considered essential nutrients. The following are the six main functions of fats in the body; the functions of other lipids in the body, primarily phospholipids and sterols, are discussed later in this chapter.

1. *Triglycerides serve as an important source of energy at rest and during exercise.* At rest, in well-fed individuals, dietary and stored fats can supply approximately 60–80% of the body's energy needs. During exercise, both fats and carbohydrates serve as fuel sources, with fats being the predominant energy source during low to moderate exercise intensities.
2. *Fat serves as an abundant energy reserve for the body.* In athletic populations, fat tissue accounts for approximately 8–12% and 18–22% of body weight in males and females, respectively. Some is stored as visceral fat (i.e., in adipocytes surrounding the internal organs), but most fat is stored subcutaneously (i.e., beneath the surface of the skin). Small amounts of fat are stored in muscle, where it serves as a readily available energy source. In total, as much as 80,000–100,000 calories can be stored as fat in a 70-kilogram man who is within a healthy body fat range. These fats are available to provide fuel when energy intake is lower than expenditure.

   Energy stored as fat in the body is advantageous for two reasons. First, fats yield more than twice the number of calories per gram (9 kcal/gram) than proteins or carbohydrates (4 kcal/gram). In other words, fats are a concentrated storage form of energy in that twice the calories can be stored for an equivalent increase in body weight resulting from stored carbohydrates as glycogen. Second, because fats are hydrophobic, they are stored with much less water than carbohydrates. Carbohydrates are hydrophilic—each gram of stored carbohydrate (i.e., glycogen) is associated with 3 grams of water. Therefore, fats not only yield twice the energy, but also are a much lighter storage form of energy for the body (see **Table 4.1**).
3. *Visceral and subcutaneous fat provide protection to vital organs and serve as a thermal and electrical insulator in the body.* Visceral fat stores act like gel-packing used to protect fragile materials during shipping. Essentially, their gel-like consistency helps to cushion internal organs, thus preventing damage during falls, jarring types of activities, and contact sports. Visceral fat is relatively inert and is less likely to be utilized as an energy source unless adipose tissue is depleted. Subcutaneous fat provides a layer of protection for skeletal muscles and also acts

TABLE 4.1 Difference in Weight with Fat Versus Carbohydrate Storage

Average calories stored in body fat = 80,000–100,000 calories

Fat	Carbohydrate
80,000 calories	80,000 calories
÷ 9 kcal/gram	÷ 4 kcal/gram
8889 grams	20,000 grams
× 0.1 grams water stored/ gram fat	× 3 grams water stored/ gram carbohydrate
889 additional grams	60,000 additional grams
889 + 8889 = 9778 grams of energy stored as fat	60,000 + 20,000 = 80,000 grams of energy stored as carbohydrate
9778 ÷ 454 g/lb = **21.5 lb**	80,000 ÷ 454 g/lb = **176 lb**

as a thermal insulator for the body. Fat keeps heat from transferring away from the body, especially in cold weather and water sports. This is critical because maintenance of body temperature is important for normal internal organ and cellular function. In the case of distance swimmers, body fat not only serves as an energy source and insulator, but also buoys the swimmer in the water, thus decreasing drag, which can potentially increase performance. Finally, fats are also used in the formation of myelin, a fatty substance that serves as insulation for nerve cells. This fatty myelin insulation helps speed conduction of electrical signals along the appropriate neural pathway and prevents unwanted spread of electrical activity to adjacent nerves. In other words, myelin is analogous to the plastic sheath found on electrical wires that directs the electrical flow along the length of the wire but prevents it from spreading to any other wires that may be lying beside it.

4. *Fats play an important role as carriers of substances into the body and within the bloodstream.* Fats carry fat-soluble vitamins A, D, E, and K; carotenoids; and other fat-soluble phytochemicals. Without fat in the diet, fat-soluble vitamins would not be absorbed and deficiencies would result. Fats also aid in the absorption of other fat-soluble substances such as lycopene. Lycopene, a phytochemical, is absorbed more readily when tomato-based products contain some fat. For example, canned tomatoes mixed with an olive oil vinaigrette dressing will enhance the absorption of lycopene. When fat is removed from a product such as skim milk, the fat-soluble vitamins are removed as well. Therefore, as indicated on the label, nonfat milk is "Vitamin A and D fortified" because the fat-soluble vitamins need to be added back into the product.
5. *Fats enhance the sensory qualities of foods.* Chemicals within the fat molecules of food provide flavor, odor, and texture. Cooking fatty foods or frying foods in fat releases the odors and seals in flavor. Fats in baked goods provide products with a moist and light texture and a flaky structure. Fats also offer a creamy, smooth mouthfeel to many products, thus enhancing their appeal.
6. *Fat consumption during meals or snacks can enhance satiety level.* Fats are calorically dense compared to carbohydrates or proteins. Fats take longer to digest and can provide a physical feeling of satiation for a longer time between meals.

Figure 4.2 Generic fatty acid structure.

What are fatty acids?

Fatty acids are basically carbon atoms linked in a chainlike fashion. All fatty acids have an organic acid group or a carboxyl acid (COOH) at one end and a methyl (CH_3) group at the other end (see Figure 4.2). The carboxyl group is referred to as the alpha end, and the methyl group makes up the omega end of the fatty acid. Paying attention to the different ends of the fatty acid chain is important because it provides for a consistent way of classifying fatty acids based on chain length and the number and location of single and/or double bonds. These differences determine not only the type of fatty acid, but also its physical characteristics, how it is digested and assimilated, and the role it will play within the body.

What is the effect of fatty acid chain length?

As mentioned earlier, the carbon chains of fatty acids vary in length. The number of carbons in a chain affects how the fatty acid is digested, absorbed, and used in the body. Short-chain fatty acids (SCFAs) consist of 2 to 4 carbons in a chain, medium-chain fatty acids (MCFAs) contain between 6 and 10 carbons, and long-chain fatty acids (LCFAs) contain 12 or more carbons (see Figure 4.3). The shorter the carbon chain, the more liquid the fat is at room temperature and the more soluble it is in water. SCFAs and MCFAs are digested and absorbed more quickly than LCFAs. Rarely are SCFAs found naturally in food sources, with the exception of butyric acid, which is found in milk fat. The SCFAs are a by-product of bacterial fermentation of undigested food in the large intestine. Most commonly, bacteria work on soluble fiber in the colon and produce SCFAs. The short-chain fatty acids that are produced in this process are absorbed by the colon cells and used as an energy source. The fermentation process is anaerobic; thus, less energy is recovered from fiber than the 4 calories/gram recovered from other carbohydrates.[1] The number of actual calories is still

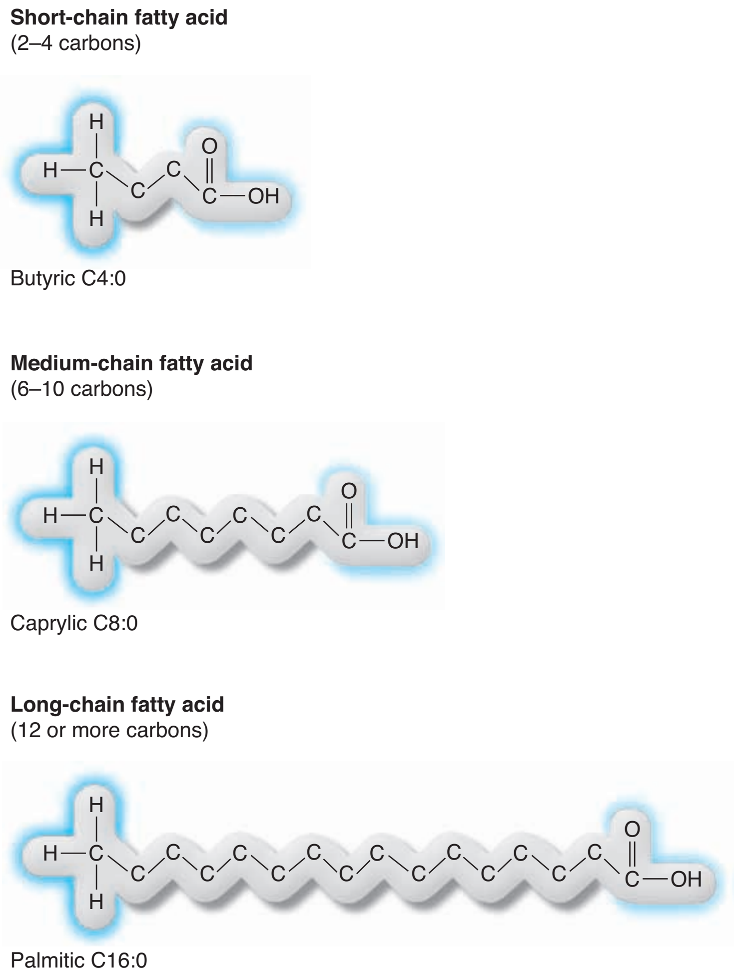

Figure 4.3 Fatty acid chain length. Fatty acids can be classified by their chain length as short-, medium-, and long-chain fatty acids.

unclear, but it is likely that the energy yield is 1.5–2 calories per gram.[2,3] Some research suggests that butyric acid stimulates colon cells to suppress cancer growth, a finding that may explain how dietary fiber, when bacteria attack fiber and release other SCFAs, may aid in the prevention of colon cancer.[4]

What does fatty acid saturation level indicate?

Each carbon in a fatty acid carbon chain has four bonds. The bonds between the carbons can be either single bonds or double bonds. The remaining bonds that branch from the carbon backbone can be filled by other atoms. Hydrogen is the atom commonly filling the other bonds in fatty acids (see Figure 4.4). When the carbons in a chain are linked by single bonds and the remaining two bonds are filled with hydrogen, the fatty acid is termed saturated. This means that all bonds are full (saturated) with hydrogen atoms. Unsaturated fatty acids have one or more double bonds between carbons in the chain. With unsaturated fats, the carbons attached by the double bond can accept only one hydrogen atom. A monounsaturated fatty acid (MUFA) has one double bond in its carbon chain, whereas a polyunsaturated fatty acid (PUFA) has two or more double bonds (see Figure 4.4).

Hydrogenation is a chemical process in which hydrogen atoms are added to unsaturated fatty acids. The introduction of the hydrogen atoms breaks some of the double bonds between the carbons and thus causes the previously unsaturated fat to become more saturated. This artificial hydrogenation process allows foods containing unsaturated fats to take on the somewhat desirable physical properties of saturated fats. As the saturation content of the fat in food increases, the food becomes harder at room temperature. For example, stick margarine is produced through the hydrogenation of unsaturated vegetable oils. Vegetable oil is liquid at room temperature, but it becomes solid after hydrogenation, making it more desirable for baking and cooking.

Although foods are often labeled as containing either saturated or unsaturated fatty acids, it is important to realize that foods actually contain a combination of unsaturated and saturated fats. Plant foods generally are lower in saturated fats than foods from animal sources. However, food labels can help individuals identify the total and saturated fat content of foods. **Table 4.2** lists common foods that contain fat and their respective amounts of saturated and unsaturated fats.

Information regarding the total fat content and the type of fat in foods is important because saturated fats have been implicated in cardiovascular disease. They have been found to contribute to atherosclerosis, the buildup of fatty plaques on the interior arterial walls, particularly in the arteries of the heart and neck. Reducing saturated fat intake by reducing total fat intake and substituting mono- and

saturated fatty acid A fatty acid in which all hydrogen-binding sites are filled, and thus no double bonds exist in its hydrocarbon chain.

unsaturated fatty acid A fatty acid whose hydrocarbon chain contains one or more double bonds.

monounsaturated fatty acid A fatty acid whose hydrocarbon chain contains one double bond.

polyunsaturated fatty acid A fatty acid whose hydrocarbon chain contains two or more double bonds.

hydrogenation A chemical process in which hydrogen atoms are added to unsaturated fatty acids. Hydrogenation of fatty acids leads to the formation of trans fatty acids, which are a growing health concern in regard to cardiovascular disease.

atherosclerosis The progressive narrowing of the lumens of arteries caused by fatty deposits on their interior walls. Over time these fatty plaques can block blood supply to vital tissues, causing poor delivery of oxygen; complete blockage results in cell death.

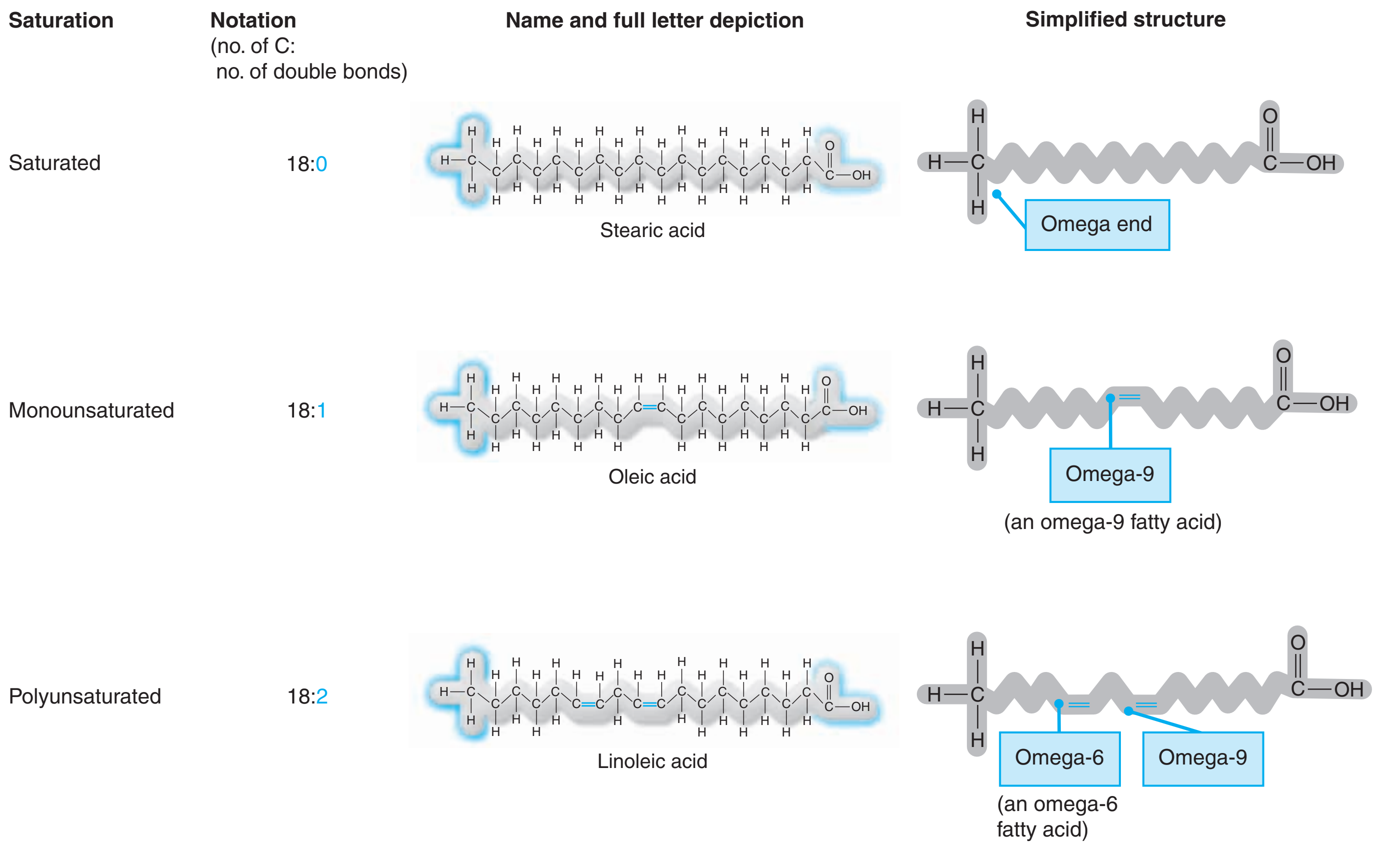

Figure 4.4 Saturation of fatty acids. Saturated, monounsaturated, and polyunsaturated fatty acids. Hydrogens saturate the carbon chain of saturated fatty acids. Unsaturated fatty acids are missing some hydrogens and have one (mono) or more (poly) carbon–carbon double bonds.

isomer Compounds like unsaturated fats that may have the exact same molecular makeup as another compound but exist in a different geometric shape.

cis A type of molecular configuration in which the atoms surrounding a double bond are arranged on the same side of the molecule. Most naturally occurring unsaturated fatty acids exist in the cis configuration.

trans A type of molecular configuration in which the atoms surrounding a double bond are arranged on opposite sides of the molecule. Trans fatty acids are not common in nature but are formed during the process of hydrogenation.

polyunsaturated fats in the diet are recommended to reduce cardiovascular disease risk.

What is a trans fatty acid?

Unsaturated fatty acids that are identical in molecular makeup but exist in different geometric forms (i.e., shapes) are known as isomers. The location of the hydrogen atoms on each side of the double bond in the fatty acid determines whether the fat is in the cis or trans position. In the cis position, the hydrogen atoms on either side of the double bonds are on the same side of the carbon chain. This causes the fatty acid to bend slightly. In the trans position, the hydrogen atoms on either side of the double bond are on opposite sides of the carbon chain, and thus the fatty acid is straight rather than bent (see Figure 4.5). Fatty acids in nature are almost exclusively found in the cis formation; however, the commercial processing of foods has increased the occurrence of trans fats in our diets.

The commercial process of hydrogenation adds hydrogen at some of the double-bond locations creating the trans positioning at one or more of the bonds. Most trans fatty acids are monounsaturated (contain one double bond) and are found in foods such as stick margarine, solid vegetable shortenings, snack items, and packaged foods. The problem with trans fats is that recent studies have implicated them with raising blood cholesterol levels.

What are omega fatty acids?

The methyl end of a fatty acid is the omega end. The double bond that occurs closest to this end identifies the omega classification. Because there are double bonds in all of these classifications, the omega fatty acids are all unsaturated fatty acids. The omega-3, -6, and -9 classifications signify that the first double-bond location from the omega end is at the third,

TABLE 4.2 Fat Content of Various Foods

Food Item	Serving Size	Total Fat (grams)	Saturated Fat (grams)	Monounsaturated Fat (grams)	Polyunsaturated Fat (grams)
Grains					
Oatmeal, dry	½ cup	2.5	0.5	1.0	1.0
English muffin	1 muffin	1	0.1	0.2	0.5
Pasta, cooked	1 cup	0.9	0.1	0.1	0.4
Brown rice	1 cup	1.8	0.4	0.6	0.6
Whole wheat bread	1 slice	1.2	0.3	0.5	0.3
Whole wheat pita	1 pita (6½″)	1.7	0.3	0.2	0.7
Blueberry muffin, made from a mix	1 muffin	6.2	1.2	1.5	3.1
Biscuit	1.2 oz	4.6	0.9	2.8	0.2
Fruits/Vegetables					
Pear	1 medium	1	< 0.1	0.1	0.2
Orange	1 medium	0	0	0	0
Watermelon	1 cup	0.7	0.1	0.2	0.2
Banana	1 medium	0.5	0.2	< 0.1	0.1
Spinach, raw	½ cup	0	0	0	0
Broccoli, cooked	½ cup	0.1	< 0.1	< 0.1	< 0.1
Carrots, cooked	½ cup	0.1	< 0.1	< 0.1	< 0.1
Avocado	1 medium	27	5.3	14.8	4.5
Dairy/Alternative					
Skim milk	8 oz	0.5	0.4	0.2	< 0.1
1% milk	8 oz	2.6	1.6	0.7	0.1
2% milk	8 oz	4.7	2.9	1.4	0.2
Whole milk	8 oz	8	5.1	2.4	0.3
Cottage cheese, 2%	¼ cup	4.4	2.8	1.2	0.1
Swiss cheese	1 oz	8	5.0	2.1	0.3
Soy milk	8 oz	5	0.5	1.0	3.0
Protein Foods					
Ground beef, lean	3 oz	13.2	5.2	5.8	0.4
Chicken with skin	3 oz	9	2.4	3.4	1.9
Chicken without skin	3 oz	3.1	0.9	1.1	0.7
Turkey, white meat, without skin	3 oz	3	1.0	0.6	0.9
Turkey, dark meat, without skin	3 oz	6	2.2	1.5	2.0
Pork chop	3 oz	6.9	2.5	3.1	0.5
Salmon, pink	3 oz	4	1.0	0.8	0.6
Orange roughy	3 oz	1	< 0.1	0.5	< 0.1
Veggie burger	1 patty	0.5	0.1	0.3	0.2
Almonds	1 oz	15	1.1	9.5	3.6
Oils					
Margarine, stick	1 tbsp	11	2.1	5.2	3.2
Butter	1 tbsp	12	7.2	3.3	0.4
Olive oil	1 tbsp	14	1.8	9.9	1.1
Salad dressing, ranch	2 tbsp	18	2.5	NA	NA
Salad dressing, reduced calorie ranch	2 tbsp	5	0.4	NA	NA

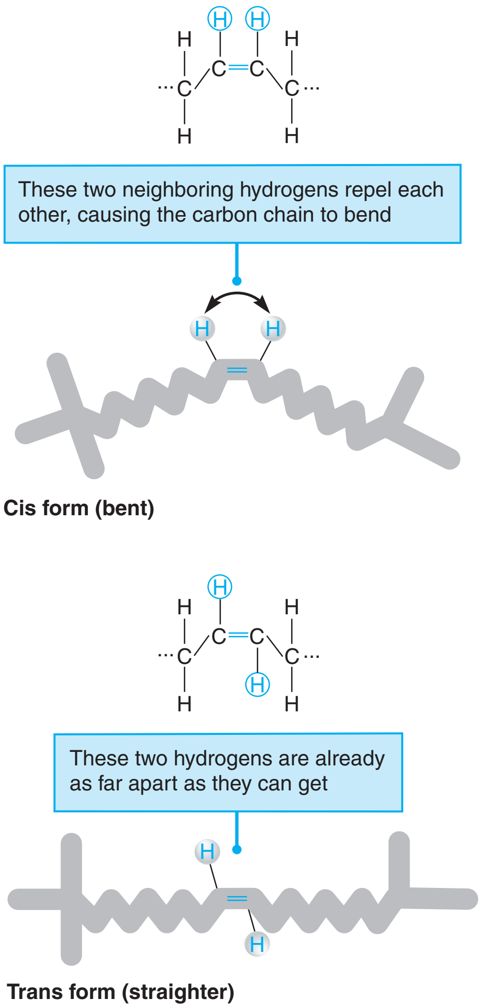

Figure 4.5 Structure of cis and trans fatty acids. Fatty acids with the cis form are more common in food than those in the trans form.

sixth, or ninth carbon in the chain, respectively. A common omega-3 fatty acid is linolenic acid; linoleic acid is the most commonly known omega-6 fatty acid, and oleic acid is the most common omega-9 fatty acid.

The omega fatty acid chain can have more than one double bond; the classification merely signifies the first double bond from the omega end. All of these omega fats are utilized as an energy source. However, these fatty acids may be used to synthesize other compounds, and they can have quite different functions in the body. For example, omega-3 fatty acids are used to form localized hormones known as eicosanoids that cause dilation of blood vessels and reduce inflammation and blood clotting. In contrast, eicosanoids formed from omega-6 fatty acids do the opposite. They promote the inflammatory process, increase blood clotting, and cause vasoconstriction. Therefore, the presence and ratio of omega-3 to omega-6 fatty acids in the diet is attracting the attention of researchers because of the possible negative role that higher levels of omega-6 fatty acids play in cardiovascular disease.

eicosanoids A group of localized, hormone-like substances produced from long-chain fatty acids.

essential fatty acids Fatty acids that must be obtained from the diet. Linoleic acid and linolenic acid are considered essential fatty acids.

nonessential fatty acid A fatty acid that can be made by the body and thus does not have to be consumed in the diet.

Which fatty acids are considered essential?

Linoleic acid (an omega-6 fatty acid) and linolenic acid (an omega-3 fatty acid) are considered essential fatty acids because the body cannot manufacture these fats. The body can make saturated and omega-9 fatty acids; therefore, they are considered nonessential fatty acids. However, nonessential does not mean unimportant; it simply means it is not essential to consume these fats in the diet. The body can produce an adequate supply of the nonessential fatty acids as demand occurs.

Linoleic acid is found primarily in vegetable oils such as safflower, soy, corn, sunflower, and peanut oils. Linolenic acid is found in leafy greens, soy products, seafood, nuts, seeds, and canola oil. Dietary recommendations for adequate intake of essential fatty acids are met if fat comprises approximately 5% of total calorie intake. The AI for linoleic acid is 17 g/day for men 19–50 years of age (14 g/day for 50+ years) and 12 g/day for women 19–50 years of age (11 g/day for 50+ years); the AI for linolenic acid is 1.6 g/day and 1.1 g/day for men and women 19 years of age and older, respectively.[1]

What are phospholipids?

Phospholipids are another classification of lipids, although they are not as abundant in the body and diet as triglycerides. Phospholipids are found in a small number of specific foods such as egg yolks, liver, soybeans, and peanuts. Fortunately, phospholipids are not essential in the diet because the body can readily synthesize them when needed.

Phospholipids have the same glycerol backbone as triglycerides but with only two fatty acids attached to it rather than three (see Figure 4.6). The third site on the glycerol is attached to a phosphate group. The unique structure of phospholipids allows them to be both water and fat soluble. The fatty acids in the structure attract and attach to fat-soluble substances, and the phosphate/nitrogen compound attracts and attaches to water-soluble substances. Phospholipids

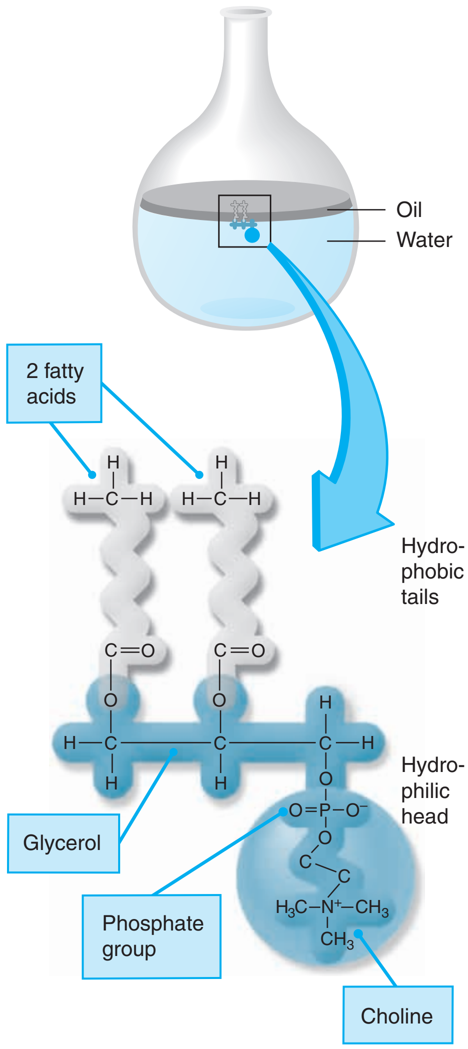

Figure 4.6 Phospholipid structure. A phospholipid is soluble in both oil (i.e., fat) and water. This is a useful property for transporting fatty substances in the body's watery fluids.

are located primarily in the cell membranes of tissues throughout the body.

What functions do phospholipids serve both inside and outside of the body?

Because of their unique structure, phospholipids are ideal emulsifiers. Emulsifiers keep fat-soluble substances suspended in a watery environment. Emulsification is a process that allows two substances that normally do not mix (water and fat in this case) to mix. Phosphatidylcholine, or lecithin, is an emulsifier found naturally in foods of animal origin and in the body. Lecithin is a food additive that can also be derived from plant oils. Lecithins in foods help keep fats from separating, such as the water and oil in dressings, and keep fats in suspension and dispersed in foods such as canned soups, chili, and frozen entrees.

Phospholipids are a major component of cell membranes, which consist of a double layer of phospholipids. The hydrophilic glycerol and phosphate heads line up adjacent to the watery environments of both the outside and the inside of the cell. The inside of the double phospholipid layer contains the fatty acid tails that are hydrophobic.

Phospholipids also provide transport functions in the body. Their ability to combine with water and fatty substances allows them to break fats in the stomach into smaller particles during digestion; bile contains phospholipids that help produce emulsifying effects. Phospholipids also coat the surface of lipoproteins that carry lipid particles to their destinations in the body.

What are sterols?

Sterols are a category of lipids found in both plants and animals. Although sterols are classified as lipids, they differ significantly from triglycerides and phospholipids in structure and function. Unlike the other lipids discussed thus far, most sterols do not contain fatty acid chains. Instead, sterol molecules consist of multiple rings made primarily of carbon and hydrogen atoms that are attached to each other. Despite their different molecular makeup, they have the same hydrophobic and lipophilic characteristics as triglycerides.

Cholesterol is a sterol consisting of a hydrocarbon with a multiple-ring structure (see Figure 4.7). Although it is much maligned because of its relation-

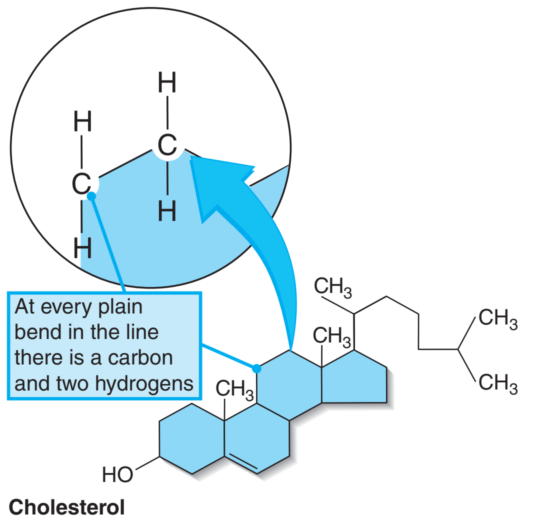

Figure 4.7 Structure of cholesterol. Sterols are multi-ring structures. Cholesterol is the best known sterol because of its role in heart disease.

ship to heart disease, cholesterol serves some critical roles in the body. It is essential for:

- Providing for the proper structure of cell membranes, especially in nerve and brain tissues.
- Producing vitamin D in the body (cholesterol is the precursor to vitamin D).
- Forming steroid hormones such as progestins, glucocorticoids, androgens, and estrogen.
- Manufacturing bile acids.

Approximately 0.5–2 grams of cholesterol are produced in the liver, small intestine, and walls of arteries daily, so it is therefore not considered an essential nutrient in the diet.

Two compounds that are similar in structure to cholesterol but also are very different from cholesterol are the plant sterols and plant stanols. The plant sterols and stanols are found only in plants, whereas cholesterol is found in animals and humans. Plant sterols are found naturally in small quantities in many vegetables, fruits, nuts, seeds, legumes, cereals, and vegetable oils. Plant stanols are found naturally in similar foods but in much lower quantities than the plant sterols. Both plant sterols and stanols are found in greater quantities in certain margarines and dressings as well as in some dietary supplements.

Both plant sterols and stanols have cholesterol-lowering effects in the body. With consumption of adequate amounts, the most prominent effect on blood lipid levels is the lowering of low-density lipoprotein (LDL) cholesterol. The maximum cholesterol-lowering benefits are achieved at doses of 2–3 grams/day.[5–7] To achieve this level of plant sterols and stanols, consumption of certain margarines and dressings and/or supplements is necessary because the quantities naturally found in food are significantly lower than the therapeutic dosage. The food labels of products that contain at least half the amount per serving of the recommended daily doses of the stanols and sterols include a health claim that describes the health benefits of plant sterols and stanols in reducing the risk of heart disease.

Is there such a thing as artificial fats?

Because of an increase in the public demand for low-fat and lower calorie foods, food manufacturers have responded by formulating artificial fats, better known as **fat substitutes**. Fat substitutes are popular in a variety of foods, including "luxury" foods such as ice cream, salad dressings, and desserts. The goal of using fat substitutes is to decrease calories while maintaining the texture and taste functions of fat in foods. Fat substitutes can be made from carbohydrates, proteins, or fats. Table 4.3 provides examples of some of the more common fat substitutes found in the U.S. food supply.

fat substitutes Artificial fats derived from carbohydrates, proteins, or fats that provide foods with the same texture and taste functions of fat but with fewer calories.

TABLE 4.3 Common Fat Substitutes

Fat Substitute Name	Main Ingredient	Calories	Typical Uses	Approval	Comments
Oatrim	Whole oats with beta-glucan	4 kcal/g	Sauces, gravies, baked goods	GRAS*	Can be used in baked products as a substitute for some or all of the fat; consumers can alter the amount substituted to meet acceptable texture.
Simplesse	Whey protein	1–4 kcal/g depending on water content	Frozen desserts, dressings, and spreads	GRAS*	Not as versatile as other substitutes because it cannot be used in heated products.
Benefat	Glycerol and fatty acids	5 kcal/g	Reduced-fat candies, baked goods	GRAS*	Variety of uses in many types of candies; can also be used in heated products but not in high-temperature frying.
Olean	Sucrose and fatty acids	0 kcal/g	Fried snack foods	FDA approved for use in select fried snack foods only	Can bind fat-soluble vitamins; therefore A, D, E, K are added; may cause oily diarrhea and abdominal cramping, especially if too much product is consumed.

*GRAS = Generally Recognized As Safe

The common carbohydrate-based fat substitutes are made from starches, fibers, and gums. They typically reduce calories because carbohydrates contain only 4 calories per gram versus 9 calories per gram of fat. Carbohydrate-based fat substitutes bind water in the product, increasing moisture and thickness, thereby creating the same smooth mouthfeel as fats but with fewer calories. These substitutes are used primarily in baked goods such as cookies, cakes, biscuits, and muffins. Oatrim is a carbohydrate-based fat substitute that is a flour-like product extracted from whole oats (see Table 4.3). It is used as a replacement for half the amount of fat in baked goods and can also be used to thicken sauces, gravies, and salad dressings.

Proteins can also be modified to produce similar qualities to fats but with fewer calories. Typically whey protein from dairy or egg whites is the protein used to produce these protein-based fat substitutes. Proteins are generally broken down by high heat; therefore, fat substitutes made from protein are not heat stable. Simplesse is a patented, multifunctional dairy ingredient made from whey protein concentrate that undergoes a unique microparticulation process. It is approved for use as a thickener or texturizer in frozen desserts, but it is not heat stable and cannot be used in baking or frying (see Table 4.3).

Specialty fats have been produced to provide the market with fat substitutes that are more heat stable and have more of the qualities of whole fats. These are engineered molecular structures that manipulate the degree of saturation and fatty acid chain length to produce similar qualities in food products as fats and oils. Olestra and salatrim are two such fat substitutes that have gained popularity in the last decade (see Table 4.3). Benefat is the trade name for salatrim, which is made of a triglyceride blend of short- and long-chain fatty acids. Benefat contains 5 kcal/gram instead of the 9 kcal/gram in traditional fat. It provides the same creaminess and mouthfeel as fat and maintains these sensory qualities in baking but not during high-temperature frying.

Olestra (trade name Olean) is a unique combination of sucrose and fat. Instead of the glycerol backbone with three fatty acids, as in a triglyceride, olestra is a sucrose polyester that has a sucrose backbone with six to eight fatty acids attached. Different fatty acids can be attached to the sucrose backbone, altering olestra's characteristics to produce fat-like qualities in foods. The arrangement of olestra prevents hydrolysis and therefore olestra is nondigestible and not absorbed, making olestra calorie free. Olestra is also highly heat stable and has been approved for use in limited amounts of fried snack foods such as potato and corn chips.

How much fat is recommended in an athlete's diet?

Fat is an essential nutrient in the diet; however, no RDA or AI is set for total fat intake because there is insufficient data to determine a defined level of fat intake at which risk of inadequacy or prevention of chronic disease occurs.[1] The AMDR for fat intake has been set at 20–35% of total energy for adults.[1] The American Heart Association promotes a slightly stricter range, recommending a total fat intake of 30% or less of total energy intake for decreasing cardiovascular disease risk. The National Cholesterol Education Program (NCEP) recommends less than or equal to 30% of total calories from fat with 10% polyunsaturated, 10% monounsaturated, and a range of 7–10% saturated fat, keeping individuals with high cholesterol levels at or below 7%. The newest guidelines recommended by the NCEP and listed in the Adult Treatment Panel III report[8] were developed as treatment guidelines for individuals with high LDL cholesterol levels. These guidelines may not be appropriate for athletes unless they have higher than recommended cholesterol and LDL cholesterol levels. For a summary of the general daily fat intake recommendations see **Table 4.4**.

In general, athletes report an average fat intake of 35% of total calories; however, fat intake varies among athletes in different sports.[9] Endurance athletes tend to have lower fat and higher carbohydrate intake than sprinters and short-distance runners.[9] Athletes dieting for weight loss and those involved in sports requiring weigh-ins or judging on appearance also tend to have lower fat intakes. Appearance sport athletes such as ice skaters, divers, cheerleaders, and gymnasts may become so fixated on low-fat/low-caloric intake that in some cases they may exhibit disordered eating habits that can lead to more serious conditions such as anorexia nervosa or bulimia nervosa.[10,11] Conversely, collegiate athletes, many of whom are living away from home, may consume too much dietary fat because of an overreliance on fast foods. Overconsumption of fats usually leads to ingesting too many calories. Excessive calories can lead to increases in body fat deposition, and in most cases this has detrimental effects on sport performance. Clearly, athletes must be aware of their dietary fat intake to ensure optimal

TABLE 4.4 Daily Fat Intake Recommendations

Fats	Recommendation
Total intake	20–35% of total calories
Saturated	~7–10% of total calories
Monounsaturated	~10% of total calories
Polyunsaturated	~10% of total calories
Linoleic acid	17 grams/day for men* 12 grams/day for women*
Linolenic acid	1.6 grams/day for men** 1.1 grams/day for women** (EPA + DHA: 0.3–0.5 grams/day; alpha-linolenic acid: 0.8–1.1 grams/day)

*19–50 years of age
**19 years of age or older

energy levels, body composition, and, ultimately, sport performance.

Athletes should focus not only on the total amount of fat in their diet but also on the type of fat consumed. Saturated and trans fats should be kept to a minimum. These fats have been shown to be the most detrimental to cardiovascular health because they increase cholesterol levels. Saturated fats are found mainly in meat and high-fat dairy products. Trans fats are widespread in processed, packaged foods. Athletes should look for "hydrogenated" or "partially hydrogenated" oils within the ingredients listing of the food label because these terms indicate trans fats. Monounsaturated and polyunsaturated fats are beneficial to health, leading to more favorable cholesterol levels and possibly aiding in the prevention of cancer and arthritis. Monounsaturated fats are found mainly in plant foods, including olives, olive oil, canola oil, nuts, seeds, and avocados. Polyunsaturated fats can be further broken down into omega-3 and omega-6 fatty acids.

Recently, the omega-3 fatty acids have received attention for their beneficial effects on the cardiovascular system. Research thus far has suggested that these fatty acids are protective by lowering triglyceride levels and blood pressure and decreasing the growth of atherosclerotic plaque and inflammation.[12] Because of these positive effects, and because most Americans are deficient, athletes are encouraged to increase their intake of omega-3 fatty acids. As mentioned previously in this chapter, the AI for linolenic acid is 1.1 g/day and 1.6 g/day for women and men 19 years of age and older, respectively. This recommendation can be further broken down to 0.3–0.5 g/day of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) combined (marine-derived omega-3 fatty acids), plus 0.8–1.1 g/day of alpha-linolenic acid (plant-derived omega-3 fatty acids).[12] As with many nutrients, it appears that focusing on food sources of omega-3 fatty acids, versus supplements, is the best approach. The American Heart Association recommends that individuals consume at least two servings of fish per week (providing EPA + DHA), as well as vegetable sources of omega-3 fatty acids (providing alpha-linolenic acid).[12] Vegetable sources of these fats include walnuts, flaxseed, soybeans, and canola oil (see **Table 4.5**). Americans appear to be consuming plenty of omega-6 fatty acids, which are found in corn, sunflower, and safflower oils. These oils can be included in a healthy diet but should not be emphasized as heavily as omega-3 fatty acids. By focusing mainly on plant sources of fats, athletes will consume mainly beneficial fats, leading to good health and optimal performance. Although there is no direct evidence that omega fatty acids enhance athletic performance, there is some evidence to suggest that omega-3 fatty acids may decrease inflammation and improve blood flow during exercise.[13] Clearly, decreasing muscle pain due to inflammation and improving blood flow during exercise can both positively affect athletic performance; however, much more research regarding the impact of omega fatty acids in athletic performance is needed before specific recommendations can be made.

Can a diet be too low in fat?

Because dietary fat contributes a significant amount of calories per gram, low fat intakes can affect energy balance. Low dietary fat intake combined with low total caloric, carbohydrate, and protein intake can lead to negative energy balance in individuals. For athletes, negative energy balance is counterproductive except in athletes for whom weight loss is indicated. However, when energy balance is negative, training often suffers. Therefore, athletes need to balance their fat and calorie intake with general health and weight-loss goals.

Essential fatty acid deficiency is rare in the United States. A lack of the essential omega-6 fatty acid, linoleic acid, is characterized by rough, scaly skin and dermatitis. Lack of essential and other fatty acids decreases the body's ability to transport fat-soluble

TABLE 4.5 Omega-3 Fatty Acids in Selected Foods

	18:3 (mg)	20:5 (EPA) (mg)	22:6 (DHA) (mg)
1 Tbsp canola oil	1279		
1 Tbsp soybean oil	923		
1 Tbsp walnut oil	1414		
1 Tbsp flaxseed oil	7258		
3 oz canned sockeye salmon (fatty fish)		440	637
3 oz cooked mackerel (fatty fish)		428	594
3 oz flounder (lean fish)		143	112
3 oz cooked shrimp		115	120
1 Tbsp cod liver oil		938	1492
1 Tbsp salmon oil		1771	2480

Fish and seafood also contain small amounts of 18:3, which are not included on this table.

It sounds like a lot of omega-3. But remember, these are milligrams! Dietary fat is usually measured in grams. The 267 milligrams (0.267 g) of EPA and DHA in a serving of shrimp is not much in relation to a diet that has 50+ grams of fat and is a bit less than half the recommendation for daily intake.

Source: Data from US Department of Agriculture, Agricultural Research Service. USDA Nutrient Database for Standard Reference, Release 25. 2012. www.ars.usda.gov/ba/bhnrc/ndl. Accessed 1/20/13.

vitamins and phytochemicals throughout the body. The omega-3 essential fatty acid, linolenic acid, can be converted to EPA and DHA, which have been shown to be beneficial in reducing vascular disease. A lack of linolenic acid could decrease the amount of converted EPA or DHA, thus reducing these positive health benefits.

Can a diet be too high in fat?

Consuming too much fat can lead to the overconsumption of total calories, resulting in weight gain in the form of body fat. Excess body fat in athletes inhibits performance in most sports. Body fat is a less active tissue and does not produce energy for exercise as easily as stored carbohydrates. Because fat tissue does not help produce movement, it acts as "dead weight." In sports such as track, gymnastics, basketball, volleyball, and many others, the overfat athlete is weighted down by excess fat, and his or her performance can be hindered. Yet in some sports, higher body weights are beneficial. Athletes in football or other throwing and contact sports may benefit from some additional body fat weight (as well as muscle tissue) to provide extra mass for their activities.

Food for Thought 4.1

The Importance of Fat Intake for Athletes

In this exercise, you will define types of fats, list sources, and consider health benefits of appropriate fat intake.

Which foods contain fat?

Fats are found within most food groups of the MyPlate food guidance system. The richest sources of fat are found within the oils. Some grain products as well as certain vegetables provide a small to moderate amount of fat. Fruits provide minimal or no fat. Dairy/alternative products and protein food products can vary from low to high in fat. Because the type of fat consumed is important for overall health and performance, it is imperative that athletes choose the healthiest selections within each food group to include a variety of fat sources in sufficient, but not excessive, amounts each day.

How much fat is in the grains group?

Many of the foods within the grains group of MyPlate are very low in fat, although specific selections can be very high in fat. Whole grains, such as oatmeal, barley, bulgur wheat, millet, and spelt, contain less than 1–3 grams of fat per serving.

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Unsaturated fats are found mainly in plant products, including olives, olive oil, canola oil, avocados, nuts, seeds, and flax, as well as in fish of all types. Saturated and trans fats are found mainly in meats, high-fat dairy products, cheeses, butter, margarine, desserts, and snack foods. Athletes should focus mainly on unsaturated fats while minimizing saturated fats.

The fat in these grains is mainly unsaturated. At the other end of the fat spectrum are foods such as biscuits and croissants. These foods are high in fat, with a larger percentage coming from saturated and trans fats, and therefore intake should be minimized. Table 4.2 earlier in the chapter lists a variety of bread, cereal, rice, and pasta options and their respective fat content. **Training Table 4.1** provides some tips on including low-fat grains in meals.

How much fat is in the fruit and vegetable groups?

In general, fruits and vegetables contain minimal to no fat. However, certain vegetables, such as avocados and olives, contain a considerable amount of fat, although mainly unsaturated. The higher-fat vegetables should be included in a well-balanced diet in moderate amounts because of their favorable fat profile. Table 4.2 lists a variety of fruits and vegetables and their respective fat content. **Training Table 4.2** provides some tips on using fruits and vegetables rich in unsaturated fats.

How much fat is in the dairy/alternative group?

Dairy/alternative foods and beverages span both ends of the spectrum in regard to fat content. Full-fat dairy products, such as whole milk or hard cheeses, may contain 8–10 grams of fat per serving, with a high percentage coming from saturated fat. Low-fat or nonfat dairy products, such as skim milk, low-fat yogurt, and cottage cheese, may have only 1–4 grams of fat or less per serving. To help minimize the intake of saturated fats, as well as overall fat, low-fat and nonfat dairy products are the preferred choice.

Most soy, rice, or other dairy alternative products contain approximately 1–6 grams of fat per serving. The fats in dairy alternative choices are mainly unsaturated fats, and therefore are excellent substitutes for full-fat dairy products.

If fortified, the low-fat/nonfat dairy and alternative products contain the equivalent amounts of calcium and vitamin D as their full-fat counterparts. Therefore, athletes should choose the lower-fat options to gain the proteins, carbohydrates, calcium, and vitamin D benefits of dairy/alternative foods without the drawback of higher fat and saturated fat consumption. Table 4.2 lists a variety of dairy/alternative products and their respective fat content. **Training Table 4.3** provides tips on including low-fat dairy/alternative products in meal planning.

Training Table 4.1: Meal Planning Tips for Using Low-Fat Grains

- Cook bulgur wheat with oatmeal for a hot cereal in the morning, topped with fresh fruit.
- Use kamut or wheat berries for stir-fry and casseroles.
- Make a pilaf with couscous, canned beans, chopped tomatoes, and fresh parsley for a light summer lunch.
- Add dry oatmeal to pancake batter for fluffier and heartier pancakes.

Training Table 4.2: Meal Planning Tips for Using Fruits and Vegetables Rich in Unsaturated Fats

- Toss olives on top of fresh green salads.
- Make homemade guacamole for burritos or a chip dip (see the *Goalie Guacamole* recipe).
- Include olives in pasta primavera.
- Slice avocado for sandwiches or burgers.

Goalie Guacamole

2 avocados, peeled and chopped
2 tomatoes, chopped
1 tsp chili powder
$\frac{1}{2}$ tsp garlic salt
1–2 tsp chopped cilantro
juice of one lime

Mash the avocados in a medium-sized mixing bowl. Stir in the tomatoes and mash together slightly. Add the remaining ingredients, mixing well. Serve with chips, tacos, or burritos.

Serving Size: 3–4 tbsp (Recipe makes 4 servings)

Calories: 165 kcal

Protein: 2.4 grams

Carbohydrates: 9.2 grams

Fat: 15.0 grams (12.75 grams unsaturated)

Training Table 4.3: Meal Planning Tips Using Lower-Fat Dairy/Alternatives

- Choose 1%, skim, or soy milk for cereal.
- Replace half the fat in a recipe with low-fat yogurt.
- Order a latte or café mocha with skim or soy milk.
- Substitute low-fat yogurt for a portion or all of the sour cream in dips or sauces. (See the *Volleyball Veggie Dip* recipe.)

Volleyball Veggie Dip

1 cup plain low-fat yogurt
1 cup nonfat sour cream
1 10 oz package frozen spinach, thawed and drained
¼–½ cup chopped green onions
¼ tsp salt
¼ tsp ground black pepper
2 tbsp fresh dill or 1 tbsp dried dill

Mix all ingredients together and refrigerate for several hours to chill. Serve as a dip for crackers or raw vegetables.

Serving Size: ¼ cup (Recipe makes 16 servings)

Calories: 28 kcal

Protein: 2.0 grams

Carbohydrates: 4.9 grams

Fat: 0.3 grams

Training Table 4.4: Meal Planning Tips for Using Lower-Fat Protein Foods

- Choose 90–95% lean ground beef for sloppy joes and meatloaf.
- Cook salmon on the grill and serve with a couscous pilaf.
- Scramble 2–3 egg whites together and add low-fat cheese.
- Use tempeh or texturized soy protein for a barbeque sandwich. (See the *Baseball Barbeque Sandwiches* recipe.)

Baseball Barbeque Sandwiches

1 package of tempeh, cut into cubes (or a 13 oz. can of chicken)
½–¾ cup barbeque sauce

2 whole wheat buns

Preheat oven to 350°F. Mix cubed tempeh and barbeque sauce together in a small mixing bowl. Transfer tempeh to a lightly greased baking dish. Bake in the oven for 10–15 minutes. Serve tempeh on buns for an open face or closed sandwich.

Serving Size: one sandwich (half tempeh mixture and one bun)

Calories: 498 kcal (600 kcal)*

Protein: 27.7 grams (56 grams)*

Carbohydrates: 69.6 grams (51 grams)*

Fat: 12.7 grams (17 grams)*

*Nutrient content when using chicken.

How much fat is in the protein foods group?

Foods in this group vary greatly in regard to the quantity of fat per serving as well as the type of fat predominating in the product. In general, beef contains a higher quantity of fat and a higher percentage of saturated fat than most other foods in this group. Therefore, athletes should focus mainly on lean cuts of beef. Chicken, turkey, and pork contain moderate amounts of total fat and saturated fat. Some fish are very lean, such as orange roughy, whereas other choices are higher in fat, such as salmon. However, a majority of the fat in fish is unsaturated, and the higher-fat fish are a rich source of omega-3 fatty acids.

Eggs are relatively low in fat, especially the egg white. Nuts and seeds contain higher levels of fat, but, similar to fish, contain mainly unsaturated fats. Legumes are very low in fat, and the little they do contain is unsaturated. Soy products range from low-fat choices such as tofu to higher-fat choices such as soy nuts, but they also consist mainly of unsaturated fats. Table 4.2 lists a variety of protein foods and their respective fat content. **Training Table 4.4** provides meal-planning tips for using low-fat protein foods.

How much fat is in the oils?

This category contains the richest sources of fat. The best choices include the unsaturated oils, such as olive, canola, flax, and sesame oils. Saturated and trans fatty acids found in butter, margarine, snack items, desserts, and other fried or processed foods should be kept to a minimum. Table 4.2 lists a variety of fats, sweets, and oils and their respective fat content. **Training Table 4.5** provides some healthier options within the oils.

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Fats are found throughout the MyPlate food guidance system. Athletes should focus on the consumption of unsaturated fats and minimize saturated fats and trans fatty acids. It is nutritionally ideal to obtain fats from foods such as vegetables and low-fat dairy that contain other nutrients, instead of from high-fat, low-nutrient-density choices, such as dressings and desserts.

Training Table 4.5: Meal Planning Tips for Healthier Food Flavoring with Oils

- Dip whole grain bread in olive oil for an appetizer.
- Use 1–2 tbsp of sesame oil in tofu or chicken stir-fry.
- Spread peanut butter or almond butter on toast, English muffins, pita bread, or homemade bran muffins.
- Marinate vegetables for the grill in a mixture of olive oil, balsamic vinegar, and spices.

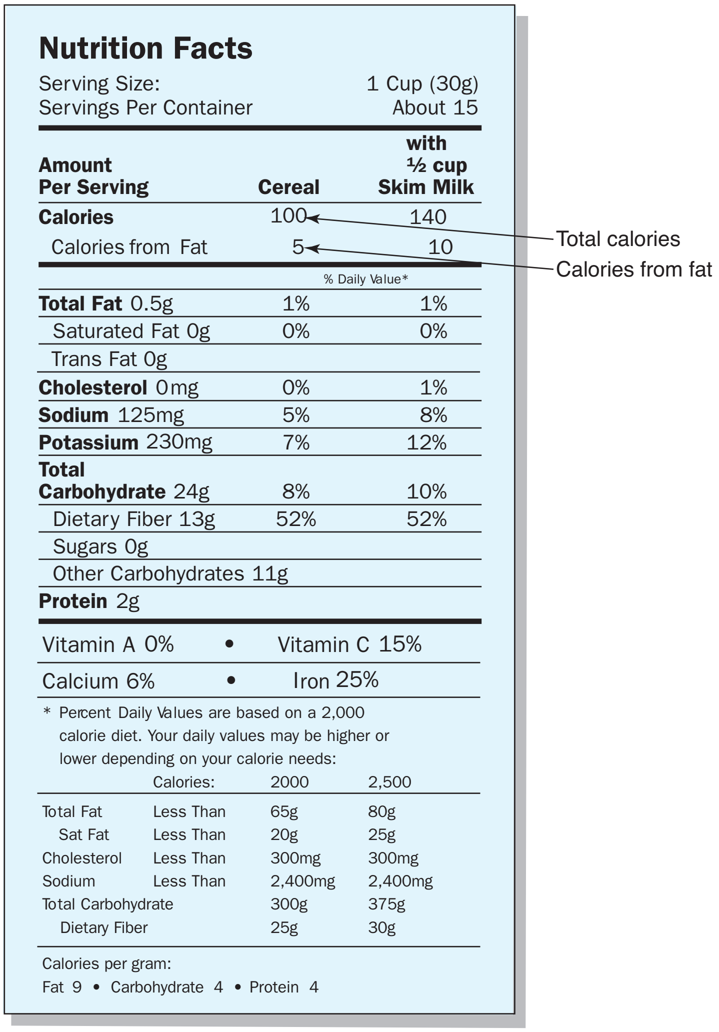
How can the percentage of calories from fat be calculated for specific foods?

The Institute of Medicine, the American Heart Association, and even the NCEP have all published recommendations for daily fat consumption. The fat intake recommendation is often stated as a percentage of total calories rather than an absolute number. Many athletes wonder, "What does the percentage mean, and how do I figure out the percentage of fat in the foods I eat?" This section explains how to interpret the percentage and how to calculate the percentage of calories from fat in specific foods. For general health, it has been suggested that total fat intake should remain at or below 30–35% of total calories per day. Saturated and trans fat combined should contribute no more than 10% of total calories per day. For most athletes, total fat intake should range from 20–30%, leaving plenty of room in the diet for carbohydrates and proteins. Therefore, all athletes should be aware of how to calculate the percentage of calories from fat in various foods in order to make healthy food choices (see Figure 4.8). The percentage of total calories from fat, saturated fat, or trans fat for any food item can be calculated by the following basic formula:

% calories from fat = (calories from fat/total calories) × 100

In order to complete the equation, an athlete will need to do some fact-finding on the Nutrition Facts panel and also know how to calculate the calories from total, saturated, or trans fat. The total calories per serving and total calories from fat are listed at the top of the Nutrition Facts panel on any food product. Divide the calories from fat by the total calories and then multiple by 100 to calculate the percentage.

If the calculated percentage is less than 35%, the athlete knows the product fits within healthy eating guidelines. However, athletes should keep in mind that the recommendation for 20–35% of total calories coming from fat is a guideline for the overall diet—not necessarily for every individual food eaten in the diet. Sometimes athletes will take this recommendation too far and exclude all foods that do not fall into this category. However, this approach is not necessary and can steer athletes


Nutrition Facts

Serving Size: 1 Cup (30g)
Servings Per Container About 15

Amount Per Serving	Cereal	with ½ cup Skim Milk
Calories	100	140
Calories from Fat	5	10
	% Daily Value*	
Total Fat 0.5g	1%	1%
Saturated Fat 0g	0%	0%
Trans Fat 0g		
Cholesterol 0mg	0%	1%
Sodium 125mg	5%	8%
Potassium 230mg	7%	12%
Total Carbohydrate 24g	8%	10%
Dietary Fiber 13g	52%	52%
Sugars 0g		
Other Carbohydrates 11g		
Protein 2g		

Vitamin A 0% • Vitamin C 15%
Calcium 6% • Iron 25%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2000	2,500
Total Fat	Less Than	65g	80g
Sat Fat	Less Than	20g	25g
Cholesterol	Less Than	300mg	300mg
Sodium	Less Than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Figure 4.8 Calculating the percentage of total calories from fat using the food label. Athletes need to know how to calculate the percentage of fat in foods they consume. The food label lists the total number of calories and the total number of calories from fat in one serving, which can be used to calculate this percentage. In this example, the calculation is (5/100) × 100 = 5%, meaning 5% of the total calories are contributed from fat.

away from healthy choices. An example of a very healthy food that does not fall into the 20–35% range is peanut butter. By studying the label, the consumer can see that the percentage of calories from fat can range from 50–80%. Therefore, peanut butter does not fall into the 20–35% goal. However, if an athlete has a peanut butter sandwich on whole wheat bread with an apple and a cup of yogurt, then the percentage of calories from the whole meal is less than 30%, which would be classified in the healthy category. Plus, nuts are full of other nutrients, such as fiber, protein, and zinc, and the fat in nuts is mainly unsaturated fat. Use the percentage of calories from fat, along with other nutritional benefits or drawbacks, to fully evaluate a food or beverage in the context of an entire meal. If the athlete is calculating the percentage of calories from saturated fat or trans fat or is obtaining nutrition information about a product through means other than the food label, the only information needed is:

1. Total calories per serving
2. Total grams of fat, saturated fat, or trans fat per serving

One extra step is required before the numbers can be plugged into the same equation as listed previously: *Multiply the number of grams of fat, saturated fat, or trans fat by 9 (because there are 9 calories per gram of any type of fat) to obtain the total number of calories from fat.* For example, if a package of crackers has 130 total calories per serving and 1 gram of saturated fat, the calculation would be as follows:

1 gram saturated fat × 9 = 9 calories from saturated fat
(9 calories from saturated fat/130 total calories) × 100 = 6.9% of total calories from saturated fat

As stated previously, if the percentage of saturated fat, as well as monounsaturated and polyunsaturated fat, is approximately 7–10%, the athlete will know the product fits within healthy eating guidelines. Trans fats should be kept to a minimum.

The FDA approved a regulation in 2003 that all food labels must list the amount of trans fats contained in the product.[14] The trans fats must be listed in grams and shown on all food labels directly below the listing for saturated fats. Trans fats, similar to saturated fats and dietary cholesterol, can raise LDL cholesterol levels, potentially increasing risk for cardiovascular disease. Currently, there is not an RDA for trans fats and no specific recommendations for the maximum number of grams of trans fat to consume daily. Therefore, trans fats will not have a Percent Daily Value (%DV) listed on the food label. However, athletes who want to limit trans and saturated fats can use the gram amounts listed on the food label. By combining the grams of saturated fat and trans fat on the food label, similar products can be compared for their fat content. Athletes should choose the product with the least amount of these two fats combined.

Athletes need to be careful not to confuse the percentages listed under the Percent Daily Value column as the respective percentage of calories from fat. The %DV is based on a 2000-calorie diet. At this calorie level, the FDA recommends consuming no more than 65 grams of total fat and 20 grams of saturated fat. Therefore, the %DV is providing the relationship between eating one serving of a product and how that compares to total daily needs. Refer to the label of the package of instant oatmeal in Figure 4.9 for an example.

Another common labeling statement that often creates questions is when foods are labeled "95% fat-free." An athlete might assume that 95% fat-free means that only 5% of the total calories come from fat and that this would be a healthy choice. However, these statements are based on the total weight of the food product, not on the total calorie content of the product. Some foods have higher water contents, and therefore the amount of fat compared to the total weight will be small; however, the percentage related to total calorie content may be moderate or high. For example, these statements are commonly found at the meat counter describing options for ground meats. A 95% fat-free meat does not mean that only 5% of the total calories are coming from fat. These meats can still have a significant amount of fat and saturated fat compared to the calorie content of one serving of meat. However, these statements can still be a good tool for decision making, regardless of whether they help an athlete determine exactly how much fat is in a product. An athlete should look for a product labeled as a higher percentage fat free, which indicates a leaner item and thus a healthier choice. For example, a meat product labeled as 98% fat free is leaner than a 95% fat-free product.

Nutrition Facts

Serving Size: 1 cup (28g)
Servings Per Container: About 18

Amount Per Serving

Calories 160 Calories from fat 20

	% Daily Value*
Total Fat 2g	3%
Saturated Fat 0g	0%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 300mg	13%
Total Carbohydrate 29g	10%
Dietary Fiber 1g	4%
Sugars 2g	
Other Carbohydrates 26g	
Protein 6g	

Vitamin A 15% • Vitamin C 25%
Calcium 0% • Iron 45%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less Than	65g	80g
Sat Fat	Less Than	20g	25g
Cholesterol	Less Than	300mg	300mg
Sodium	Less Than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Figure 4.9 Difference in the percentage of calories from fat and the Percent Daily Value for fat. A serving of cereal may have 160 total calories with 20 calories coming from fat, which equals 12.5% of the total calories from fat. The label lists the %DV associated with total fat as 3%. This means 2 grams is 3% of the total daily recommendation of 65 grams, not that the product has 3% of its total calories from fat. Therefore, use the %DV as an indication of how much fat one serving contributes to total daily needs; use the numbers indicated for Total Calories and Calories from Fat to determine whether the product is low fat.

What's the big deal about cholesterol?

As mentioned several times earlier in this chapter, it is recommended that fat intake be kept at a moderate level for the prevention of cardiovascular disease. So, what is the connection between dietary fat and an increased risk of the disease? On the basis of ongoing research in the area of cardiovascular health, blood cholesterol has been strongly associated with a higher risk for cardiovascular disease. Therefore, blood cholesterol levels have been targeted as one of the first lines of defense in the prevention of the disease. One of the most influential ways to modify blood cholesterol levels is to adapt lifestyle factors such as exercise and diet, specifically dietary fat, saturated fat, and cholesterol.

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>
> Athletes should aim for 20–35% of their total calories from fat. The percentage can be calculated from information provided within the Nutrition Facts panel on the food label. Athletes should keep in mind that the 20–35% guideline is for the overall diet, not necessarily for every individual food. A specific food should be evaluated based on both its total fat percentage and its overall nutrient contribution to a healthy diet.

What is cholesterol, and which foods contain it?

As mentioned earlier in this chapter, cholesterol is a sterol. Cholesterol is found only in animal products (see Table 4.6). All meats contain cholesterol, with organ meats having the highest amounts. Eggs and dairy products also contain cholesterol, with nonfat dairy options having the least. Some breads, muffins, and baked goods will have cholesterol if they were made with eggs and/or dairy products.

Plant products, such as fruits, vegetables, whole grains, legumes, and soy, are cholesterol free. These foods do contain plant sterols, however, which have a similar ring structure to cholesterol. Plant sterols or stanols have recently been researched for their potential effects as cholesterol-lowering substances. Plant sterols and stanols are poorly absorbed by humans and, therefore, may reduce the amount of cholesterol absorbed in the intestinal tract.

How is blood cholesterol classified?

Cholesterol is measured by taking a sample of blood and analyzing the levels of total cholesterol, high-density lipoprotein (HDL), and low-density lipoprotein (LDL). Each component can provide unique information regarding an individual's risk for heart disease (see Table 4.7). Several other cholesterol components can be tested to contribute additional information, such as triglycerides, very low-density lipoproteins (VLDLs), and lipoprotein(a). Blood cholesterol measurements are most accurate after a 9- to 12-hour fast. Total cholesterol can be estimated with portable machines, often used at health fairs, which require only a finger stick to obtain a small droplet of blood to be quickly analyzed. These results should be verified by also taking a test completed after a fast.

TABLE 4.6 Cholesterol Content of Various Foods

Food Item	Serving Size	Cholesterol Content (mg)
Grains		
Bran flakes	¾ cup	0
Bagel	1 bagel	0
Spelt	½ cup	0
Fruits/Vegetables		
Apple	1 medium	0
Plum	1 medium	0
Acorn squash	½ cup	0
Olives	10 medium	0
Dairy/Alternative		
Skim milk	8 fl oz	4
1% milk	8 fl oz	10
2% milk	8 fl oz	18
Whole milk	8 fl oz	33
Low-fat yogurt	6 oz	10
Cheddar cheese	1 oz	30
Soy milk	8 fl oz	0
Protein Foods		
Ground beef, lean	3 oz	82
Chicken breast with skin	3 oz	82
Chicken breast without skin	3 oz	73
Turkey, white meat, without skin	3 oz	69
Turkey, dark meat, without skin	3 oz	85
Pork chop	3 oz	79
Salmon, pink	3 oz	20
Orange roughy	3 oz	22
Whole egg	1 large	212
Egg white	1 egg white	0
Veggie burger	1 patty	0
Almonds	1 oz	0
Oils		
Margarine, stick	1 tbsp	0
Butter	1 tbsp	33
Olive oil	1 tbsp	0
Salad dressing, ranch	2 tbsp	5
Salad dressing, reduced calorie ranch	2 tbsp	10

Athletes are inherently helping to lower their cholesterol levels because of their active lifestyles. However, many athletes are not focused on dietary approaches that are protective and therapeutic. Physical activity alone is not enough to keep cholesterol levels in the desirable range; a healthy diet is also critical.

What is total cholesterol?
Total cholesterol is a measurement that combines the levels of HDL, LDL, and triglycerides in the blood. It can provide a general estimate of risk, but it is not as informative as the breakdown of the various lipoproteins. The NCEP recommends a total cholesterol level below 200 mg/dL. A level between 200 and 239 mg/dL is considered borderline high; and 240 mg/dL and above is considered high. Both borderline and high total cholesterol levels require changes to lower the level to the desirable range. Total cholesterol can be lowered by making dietary and physical activity changes that will decrease LDL and triglycerides.

What is HDL?
HDL is often referred to as the "good" cholesterol. HDL has a higher protein content and a smaller triglyceride and cholesterol content than LDL. HDL is a "scavenger," picking up cholesterol from the bloodstream and arteries and delivering it to the liver to be packaged into bile and excreted from the body. Because of this action, HDL often is considered protective against cardiovascular disease. However, researchers have not conclusively determined that alterations to HDL through modifications to diet and exercise lead to a reduced risk of cardiovascular disease. More research is required before firm dietary and physical activity guidelines can be set based on a proven track record of protection. In the meantime, individuals should focus on the lifestyle factors that have been shown to increase HDL—weight management and regular exercise. In terms of the diet influence on HDL, very low-fat eating plans can lead to a lowering of HDL levels. Therefore, individuals should follow a moderate-fat diet, with 20–35% of total calories coming from fat, and a strong emphasis should be placed on the unsaturated fats. The desirable level for HDL set by the NCEP is 60 mg/dL or higher. An HDL level of 40 mg/dL or lower is considered too low, requiring lifestyle modifications.

What are VLDL and lipoprotein(a)?
VLDLs contain a triglyceride-rich core.[15] Lipoprotein lipase digests some of the triglycerides from the VLDL, leaving an intermediate-density lipoprotein

TABLE 4.7 National Cholesterol Education Program: Classification of Lipoprotein Levels

Lipoprotein	Desirable	Borderline	Undesirable
Total cholesterol	<200 mg/dL	200–239 mg/dL	≥240 mg/dL
Low-density lipoprotein	<100 mg/dL	130–159 mg/dL	≥160 mg/dL
High-density lipoprotein	≥60 mg/dL	40–59 mg/dL	<40 mg/dL

Source: Data from U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute (2001). National Cholesterol Education Program. ATP III At-A-Glance: Quick Desk Reference. Available at: http://www.nhlbi.nih.gov/guidelines/cholesterol/atp3xsum.pdf. Accessed September 8, 2013.

(IDL). The IDL travels through the bloodstream to the liver, where it is converted into LDL. VLDL can be measured in a blood test, similar to HDL and LDL. However, the NCEP has not established guidelines for screening, prevention, or treatment of high VLDL.

Lipoprotein(a) has been receiving more attention over the years as an indicator of risk for heart disease. Lipoprotein(a) is structurally similar to LDL and has been linked to heart disease because of its involvement in atherogenesis and thrombogenesis. Similar to VLDL, a recommended level of lipoprotein(a) is not carved in stone. More research is needed to determine the recommended levels of lipoprotein(a) for use in screening individuals as well as the influence of diet and exercise to modify VLDL and lipoprotein(a) levels over time.

What is LDL?

LDL is the rival to HDL and is termed the "bad" cholesterol. This cholesterol-rich lipoprotein delivers cholesterol to the cells of the body to be used for a variety of functions. The problems begin when cells, specifically those in the arterial walls, are damaged as a result of a variety of environmental factors, genetics, disease states, and/or medical conditions. White blood cells rush to the areas of damage and bind to LDL, which releases its cholesterol, leading to a buildup on the arterial wall and eventually escalating into atherosclerosis (see Figure 4.10). Because of this action of LDL and the large volume of evidence linking LDL to greater risk for cardiovascular disease, LDL has become the primary target of therapy. Ideally, LDL should be < 100 mg/dL, with levels of 100–129 mg/dL considered near optimal/above optimal, 130–159 mg/dL borderline high, 160–189 mg/dL high, and ≥ 190 mg/dL very high.

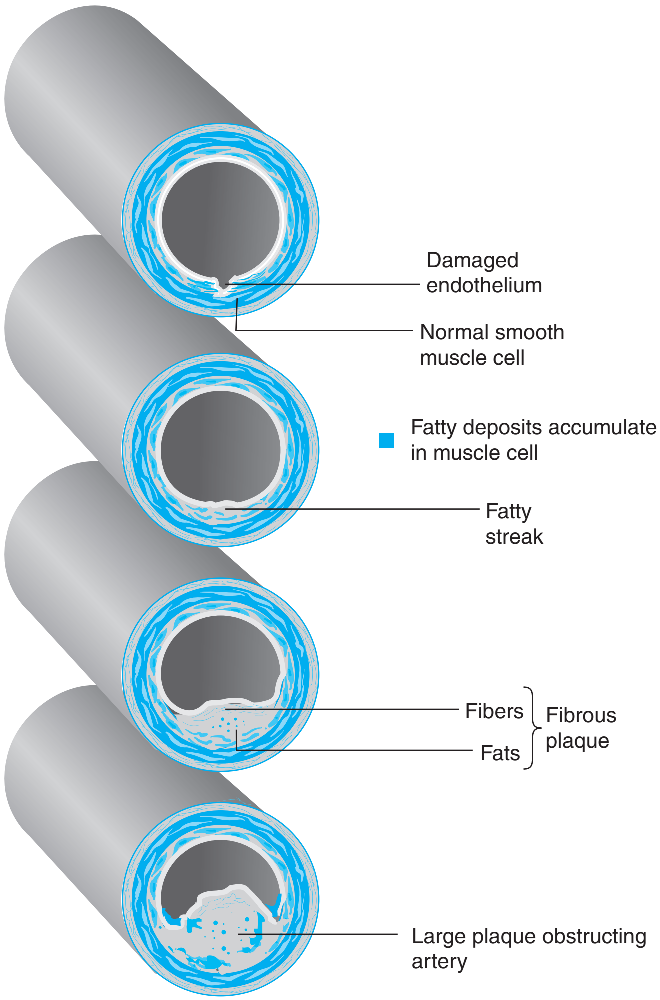

Figure 4.10 Buildup in an artery leads to atherosclerosis. High LDL cholesterol levels can contribute to plaque formation in artery walls and atherosclerosis.

LDL increases when saturated fats, trans fats, and cholesterol are consumed in excess through the diet. LDL can be lowered by substituting polyunsaturated and monounsaturated fats for

Training Table 4.6: How Can the Cholesterol Guidelines Be Applied to a Daily Meal Plan?

High-Fat, High-Cholesterol Diet	Cholesterol-Lowering Diet
Breakfast	*Breakfast*
2 eggs scrambled with 2 tbsp cheddar cheese	2 cups bran flakes with 1 cup skim milk and ½ cup strawberries
2 pieces of toast with 2 tsp butter	2 pieces toast with 2 tbsp peanut butter
Banana	12 oz orange juice
12 oz 2% milk	
Snack	*Snack*
2 oz pretzels	Banana
Lunch	*Lunch*
3 oz roast beef sandwich on white bread with 1 tbsp mayonnaise	3 oz turkey sandwich on whole wheat bread with 2 tsp mustard
1.5 oz bag of potato chips	1½ cups black bean soup
20 oz diet soda	Pear
Snack	*Snack*
Protein sports bar	8 oz low-fat yogurt
	2 tbsp raisins
Dinner	*Dinner*
9 oz steak	6 oz chicken stir-fry with 2 cups of broccoli, carrots, and mushrooms, and 1 cup brown rice
1.5 cups mashed potatoes	2 cups green salad with 2 tbsp olive oil and vinegar dressing
½ cup green beans	12 oz skim milk
12 oz 2% milk	2 oatmeal cookies
2 cups ice cream	
Daily Totals	*Daily Totals*
Calories: 3400	Calories: 3130
Fat: 148 grams (39% of total calories)	Fat: 71 grams (20% of total calories)
Saturated fat: 63 grams	Saturated fat: 16 grams
Trans fat: 24 grams	Trans fat: 6 grams
Cholesterol: 871 mg	Cholesterol: 223 mg

saturated fats and increasing soluble fiber, plant sterols/stanols, and soy protein intake. Weight loss, for those who are overweight, can also decrease LDL levels.

The NCEP has developed a list of dietary recommendations for lowering LDL blood levels and preventing cardiovascular disease. See **Fortifying Your Nutrition Knowledge** for an explanation of the NCEP plan for therapeutic lifestyle changes. Also listed in **Training Table 4.6** are two diets—a typical American diet high in fat and cholesterol and an example of a cholesterol-lowering diet plan. Recognizing the difference in these meal plans can help athletes achieve their nutrient needs while minimizing cholesterol intake.

How can fats affect daily training and competitive performance?

Fats are a major fuel source for muscle cells. Fats are the primary source of energy at rest, during low- to moderate-intensity activities, and in periods of recovery between intense bouts of activity. Endurance training improves the body's ability to utilize fats for energy by enhancing the body's ability to mobilize fats from adipocytes, thus making more fatty acids available to the working muscle.[16] In addition, endurance training improves the working muscle's capacity to oxidize the fats that are delivered. Increased muscle blood flow, improved transport of fats into the muscle cells, larger and

Fortifying
Your Nutrition Knowledge

The National Cholesterol Education Program's Therapeutic Lifestyle Recommendations

In May 2001, the National Cholesterol Education Program (NCEP) released the Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). The series of seven steps posted in the report provides a framework for detecting risk for heart disease and treating those who have heart disease or who present significant risk factors for developing heart disease. Also included in the report are therapeutic lifestyle changes that can be implemented to lower LDL cholesterol levels in the blood.

The therapeutic lifestyle changes suggested are as follows:

- *Consume a diet with less than 7% of total calories from saturated fat:* Saturated fat comes mainly from animal products such as meats and full-fat dairy. The only vegetable oils containing a significant amount of saturated fat are coconut, palm, and palm kernel oils.
- *Keep dietary cholesterol intake to less than 200 mg per day:* Cholesterol is found only in animal products such as meats and higher-fat dairy products.
- *Increase soluble fiber to 10–25 grams per day:* Soluble fiber is found only in plant products such as oats, oat bran, legumes, and some fruits and vegetables.
- *Consider consuming plant stanols/sterols (2 grams per day) to help lower cholesterol:* Derived from plant foods, plant stanols/sterols can be found in commercial products such as Take Control or Benecol margarines and have been shown to actively aid in lowering blood cholesterol.
- *Maintain a healthy body weight:* Balance calorie intake (diet) with calorie expenditure (exercise, training, competition, and daily movement) on a daily basis.
- *Increase physical activity:* Achieve at least 30 minutes, preferably 60 minutes, of physical activity every day of the week.

For more information on the Third Report of the Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults, visit http://www.nhlbi.nih.gov/guidelines/cholesterol/atp3xsum.pdf. In 2004, the NCEP updated the report based on the results from new clinical trials. The updates applied to moderately high and high-risk patients only, and thus will not be discussed here. However, to get the updated information go to www.nhlbi.nih.gov/guidelines/cholesterol/atp3upd04.htm.

more numerous mitochondria, and increased quantities of enzymes involved in fat metabolism are adaptations that help explain the enhanced ability of trained muscles to utilize fats for energy.[17,18] Clearly, the adaptations that occur with endurance training indicate the importance of fats as an energy source.

However, despite the body's abundant fat reserves and ability to increase fat utilization in response to endurance training, fats are still not the most efficient fuel for working active muscles, particularly at higher levels of exercise intensity. The limitation of fat utilization for energy during exercise is the relatively slow rate of ATP production as compared to carbohydrates. Fats must be aerobically metabolized to produce ATP. There must be adequate availability of oxygen to the muscle cells for fats to be broken down, not to mention that fat metabolism is a complicated process involving three metabolic pathways (see Figure 4.11). Finally, although some fats are stored within the muscles, research evidence to date does not support the contention that these fats provide much energy during exercise.[19,20] This means that the fats must be released from adipocytes and then delivered to the working muscles via the blood. Taking all of this into account, the delivery and metabolic disassembly of fats for energy is not only slower than that of carbohydrates at responding to changes in activity, but also slower

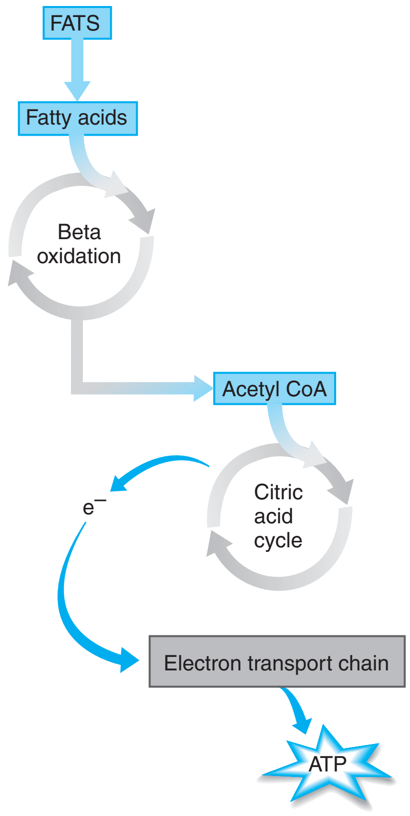

Figure 4.11 Metabolic mill for fats. The metabolic mill for fats can produce nearly limitless amounts of ATP; however, the delivery and metabolic disassembly of fats to the working muscle are slow.

at producing ATP. The advantage of fat utilization is that the metabolic mill for producing ATP from fats can produce almost limitless amounts of ATP. If fats could be made more readily available to muscle via dietary manipulation, then conceivably endurance sport performance could be enhanced. The following discussions explore what is currently known about dietary fat intake and sport performance.

What type, how much, and when should fats be consumed before exercise?

Current research has focused on the potential of dietary fat to enhance performance, mainly in endurance activities.[21–25] Some information suggests that an increase in dietary fat in the weeks leading up to a competition, sometimes referred to as fat loading, can enhance the body's ability to utilize fat and therefore spare glycogen and prolong exercise. Others claim that a permanent shift to higher fat intakes allows the body to burn more fats for fuel, decreasing adipose stores and therefore improving an athlete's body composition. The following sections will explore the ability of fat to enhance performance in a single high-fat meal prior to exercising, a short-term pattern of high-fat meals and snacks, and a long-term diet plan consisting of high-fat foods. In conclusion, recommendations will be stated for fat intake prior to exercise based on the research and information presented.

Is a single high-fat meal prior to exercise beneficial?

Previous research has demonstrated that the rate of fat utilization for energy during exercise increases as the availability of fatty acids in the blood increases.[26,27] In other words, the more fat that is delivered or made available to a working muscle, the more fat the working muscle will metabolize for energy. Therefore, it has been proposed that a high-fat meal prior to competition would increase fatty acid levels in the blood and, in turn, enhance endurance performance compared to a high-carbohydrate meal. Some studies have provided meals to athletes with as high as 60–75% of total calories from fat in the 4 hours prior to exercise. Others have experimented with ingestion of medium-chain (6 to 10 carbons) and long-chain (> 12 carbons) fatty acids with the hope of increasing fatty acids in the blood by providing a fat source that is readily broken down and absorbed. Unfortunately, to date the majority of studies have not found any benefit to ingesting high-fat meals prior to competition when compared to high-carbohydrate meals.[27,28] In fact, many athletes find that a meal high in fat eaten 1 to 4 hours prior to an exercise session, or especially a competition, leads to gastrointestinal distress, including bloating, diarrhea, stomach cramping, and a sense of fullness.[29] Therefore, it is not recommended that athletes eat a high-fat meal immediately prior to exercise.

Is a short-term pattern of eating high-fat meals beneficial to exercise performance?

"Short-term" for the purposes of this question includes periods of time less than 2 weeks. Carbohydrate stores in the body are limited and can be depleted by 3 hours or less of continuous exercise. The significance of depleting carbohydrate stores is that it results in fatigue and decreases exercise

gaining the performance edge

It is not recommended that athletes eat a high-fat meal immediately prior to exercise because of the potential for gastric upset.

performance. However, fat stores on even very lean individuals are ample enough to fuel activity for several days. A theory has developed that if an athlete consumes a relatively high-fat diet in the 1 to 2 weeks prior to an important training session or competitive event, the body will adjust to the higher fat intake and become more efficient at using fat for fuel during exercise. This has been termed "fat adaptation." In other words, if an athlete is able to shift to a heavier reliance on fat for energy, carbohydrate usage declines, thus delaying the depletion of carbohydrate stores and increasing the time to exhaustion.

Several studies have shown an increase in fat oxidation during submaximal exercise after fat adaptation.[30–32] Fat intakes in these studies have ranged from 60–70% of total calories, and the exercise tests are generally conducted at 60–70% of maximal oxygen uptake for relatively short periods of time. Unfortunately, when the effects of a short-term dietary manipulation of fat intake on athletic performance are examined, the switch to a high-fat diet does not appear to increase time to exhaustion. In fact, the majority of studies involving short-term alteration of fat intake show the opposite effect, causing a decreased time to exhaustion, increased perceived exertion, and an impaired ability to metabolize carbohydrates for energy.[27,32–34] However, several studies do exist that report an increase in endurance performance after a high-fat diet adaptation.[35,36] Therefore, more research with consistent methodology is warranted in this area. At this time, however, short-term high-fat intake does not appear to be an effective practice for improving athletic performance.

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Short-term (i.e., 2 weeks or less) high-fat diets do not appear to be effective for improving endurance performance.

Is a long-term pattern of eating high-fat meals beneficial to exercise performance?

For the purposes of this question, "long-term" includes patterns of eating followed for longer than 2 weeks. Although short-term high-fat diets to date have not consistently panned out as a good dietary practice for endurance athletes, it has been suggested that 2 weeks or less is not enough time for the body to make sufficient metabolic adjustments. Numerous studies investigating the effects of long-term high-fat dietary interventions have been published.[37–39] Overall, no benefit has been found over balanced, high-carbohydrate, moderate-protein, low- to moderate-fat diets.[40] It appears that although high-fat diets can cause favorable shifts in fat metabolism, they also lead to lower muscle glycogen stores. Unfortunately, the improvement in fat utilization is not enough to offset the effect of diminished glycogen stores. Even in cases when adaptation to a high-fat diet is followed by a short carbohydrate-loading period, suboptimal endurance performance persists, suggesting deleterious effects of a high-fat diet beyond carbohydrate availability.[38] In addition, high-fat diets have resulted in higher perceived exertion ratings despite maintaining comparable training intensities.[37] This also can have negative ramifications if the athletes are not as motivated to train during the high-fat dietary period. Only a few studies have explored the effects of a long-term high-fat diet on high-intensity activities. Fleming et al.[37] performed 30-second Wingate anaerobic tests on subjects following a high-fat diet (61% of total calories) for 6 weeks. Peak power output decreased in the high-fat group as compared to the low-fat control group. More research on high-intensity activities needs to be conducted to determine the short- and long-term effects on athletic performance.

Typically, diets containing 20–30% fat are recommended for athletes to allow adequate carbohydrate intake and to assist weight management when needed. Specific recommendations for fat intake should be individualized and based on body size, weight, and body composition goals, as well as the sport played and sport performance goals. Using the broader AMDR recommendation of 20–35% of calories from fat provides flexibility in the amount of fat intake to meet specific total macronutrient needs of individual athletes with varying training schedules and performance goals.

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Long-term (i.e., more than 2 weeks) high-fat dietary intakes are not recommended as a means to improve athletic performance.

What are the recommendations for fat intake prior to exercise?

As with any macronutrient, athletes need to experiment with the best preexercise meal for their digestive system and sport. Fat will create a feeling of satiety to prevent an athlete from feeling hungry before exercising. However, consuming too much fat 4 hours or less prior to exercise can cause bloating, intestinal cramping, or diarrhea. Therefore, meals and snacks within 4 hours of training sessions and/or

Training Table 4.7: Examples of Preexercise, Well-Balanced Meals Containing Small Amounts of Fat (grams of fat)

- 1½ cups cold cereal, 1 cup 1% milk, 1 cup orange juice (3 g)
- 2 pancakes, 2 tbsp syrup, 6 oz fruited low-fat yogurt (4 g)
- Grilled chicken sandwich [1 bun, 3 oz chicken, lettuce, tomato], 2 tsp light mayonnaise (7 g)
- Granola bar or sports bar (6 g)

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Keep preexercise fat intake to a minimum. Include just enough for flavoring and to sustain satiety for several hours. Athletes will vary in their tolerance for preexercise fat; allow time, months in advance, for preexercise fat intake trial-and-error before an important race or competition.

competitions should be low in fat and focused mainly on the unsaturated fats.[41] Athletes should determine their personal upper limit of fat ingestion for the 1 to 4 hours prior to exercise. Encourage athletes to start conservatively in their experimentation, limiting fat to small quantities. A "small amount" of fat may be obtained by consuming peanut butter (1 tbsp) on toast or olive oil (1–2 tsp) on a salad. These quantities are generally well tolerated before exercise, but individual tolerances will vary.

If the athlete finds that he or she becomes hungry before starting exercise, have the athlete try eating the same meal closer to exercise or add a little more fat to the same meal in the same time frame. For example, if an athlete eats a breakfast of toast with 1 tablespoon of peanut butter and a banana 3 hours before training, ask the athlete to test (1) eating the same meal 1.5 to 2 hours before training or (2) adding 2 tablespoons of peanut butter to the toast instead of 1. The breakfast, lunch, or snack options in **Training Table 4.7** contain a small amount of fats, while maintaining a balance of carbohydrates and proteins.

What type, how much, and when should fats be consumed during exercise?

Our bodies use fat for energy during exercise. The fat stored in adipose tissue is burned relatively slowly as compared to intramuscular fats. Recent studies have explored ways to increase the amount of fat burned during exercise and/or to increase the body's reliance on fat for energy, thus sparing carbohydrates. In the previous section, it was determined that at this point existing research does not consistently reveal a benefit to consuming high-fat meals in the hours, days, or months leading up to exercise or competition. But what about if fat is consumed during exercise? Would the body then rely more heavily on fats for fuel versus carbohydrates? To answer these questions, studies have focused on the effects of long-chain triglycerides (LCTs) and medium-chain triglycerides (MCTs).

As mentioned earlier in this chapter, LCTs (dietary fats) are composed of three long fatty acid chains connected to a glycerol backbone. They are digested by bile acids in the liver and by lipase from the pancreas. The absorption rate of LCTs is slow, and therefore consuming high-fat foods during exercise is not beneficial. Athletes can include small amounts of fat in their preexercise meal or snack but should avoid consuming fat while exercising.

Conversely, the theory surrounding the proposed beneficial effects of MCTs is based on the fact that, unlike LCTs, MCTs are easily digested, readily absorbed into the blood, and oxidized rapidly.[42,43] MCTs are broken down into medium-chain fatty acids (MCFAs), which are water-soluble and therefore do not delay gastric emptying and are absorbed rapidly through the intestinal wall into the bloodstream. MCFAs are then delivered to muscle cells, where they pass through the plasma membrane and enter the mitochondria for oxidation. MCTs are oxidized in the first 30 minutes of exercise and can be absorbed across the mucosal membrane, similar to glucose. For these reasons, MCTs have spurred interest in the potential benefit of including MCTs in sports beverages, foods, or other products to delay fatigue.

Early studies regarding MCTs' effects on performance involved consuming small amounts (~ 30 grams) of MCTs before exercise.[44,45] These studies reported no effect on carbohydrate or lipid oxidation. Therefore, subsequent studies increased the MCT dosage to determine whether the quantity ingested was a limiting factor on changes in metabolism.[46,47] Researchers reported that intakes of ~45–85 grams of MCTs either before or during exercise can affect metabolism, shifting away from a reliance on carbohydrates and thus improving time trial performance. However, more recent

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Consumption of fats, in any form, during exercise is not recommended as a performance enhancer.

studies on MCT ingestion have not reproduced these positive results.[40] When a carbohydrate-rich meal is consumed several hours prior to exercise and MCT ingestion, the glycogen-sparing effects and performance improvements have not been shown.[48–50] In many MCT studies, subjects complain of moderate to severe gastrointestinal distress, thus hindering athletic performance.

What type, how much, and when should fats be consumed after exercise?

Unlike carbohydrates and proteins, it is not essential to replace fats used during exercise by consuming certain quantities or types of fat immediately following training or competition. The body's stores of fat are so great that they will not be depleted in an exercise session, even after prolonged endurance events. Carbohydrates and proteins are the main priorities after exercising to replace, restore, and replenish muscles. Therefore, fats should be kept to a minimum immediately after exercise. Fats cause the stomach to empty more slowly than do carbohydrates and proteins, which could potentially delay the delivery of nutrients to the muscles in a timely fashion. However, fats add flavor to foods and create a sense of satiety and therefore can be included in small amounts in the postexercise meal or snack.

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The dietary guidelines for fats that pertain to daily meal planning can also be applied to the postexercise meal. The focus should be placed on unsaturated fats, in small quantities. The postexercise meal should be consumed as soon as possible after exercise.

Consuming fats in meals after exercise has received much less research attention in the sports arena than has consuming carbohydrates and proteins. In one small study, seven active individuals were studied to determine the effect of adding fat calories to meals after exercise and its effects on glucose tolerance.[51] They found that the addition of approximately 1500 calories as fat after exhaustive exercise did not alter muscle glycogen resynthesis or glucose tolerance the next day. The subjects consumed the same amount of carbohydrates in a low-fat versus high-fat postexercise diet trial. The high-fat diet increased intramuscular triglyceride storage after exercise. Because the study's purpose was to determine the effect of high- or low-fat diets on glucose tolerance, it is not clear whether there are implications to the increased intramuscular triglycerides as an attempt at improving postexercise recovery or utilization of more intramuscular triglycerides in subsequent exercise bouts. **Training Table 4.8** provides some examples of postexercise meals that contain small amounts of fats.

Training Table 4.8: Examples of Postexercise Meals Containing Small to Moderate Amounts of Fat (grams of fat)

- 6 oz low-fat yogurt, 2 tbsp mixed nuts, 1/4 cup oatmeal (12 g)
- Scrambled tofu [3 oz tofu, 1/4 cup onions, 1/4 cup peppers, 2 tbsp sunflower seeds], 1 slice toast, 1 tbsp jelly (14 g)
- Turkey sandwich [2 slices whole wheat bread, 2 oz turkey, 1 slice tomato, 2 slices cucumber, 2 slices avocado] (11 g)
- Chicken and bean burrito, 1/4 cup salsa, 2 tbsp guacamole (12 g)

Food for Thought 4.2

You Are the Nutrition Coach

Apply the concepts from this chapter to several case studies.

The Box Score

Key Points of Chapter

- Fats are an important nutrient for athletes. Not only are dietary fats a primary energy source during rest, light to moderate exercise, and recovery, but they also provide the body with essential fatty acids, serve as vitamin carriers, and provide taste and texture to food.
- Fats belong to a group of compounds known as lipids and can be obtained in the diet from both plants and animals.
- Fats are classified based on their molecular structure. Triglycerides make up the majority of fats in the body; however, other classifications include phospholipids and sterols.

- Triglycerides are composed of a glycerol backbone with three attached fatty acid chains. The fatty acid chains vary in length and saturation level.
- Fatty acids are carbon atoms linked in a chainlike fashion. They can be short (≤ 4 carbons), medium (6 to 10 carbons), or long chains (≥ 12 carbons). In addition, fatty acids can be classified as saturated or unsaturated, and essential or nonessential.
- Fat substitutes have been formulated from carbohydrates, proteins, or fats and offer fewer calories without sacrificing the texture and taste of food. Examples include Oatrim, Benefat, Simplesse, and Olestra.
- No RDA or AI has been set for total dietary fat because of insufficient data to determine a defined level of fat intake at which risk of inadequacy or prevention of chronic disease occurs. The AMDR for fat intake has been set at 20–35% of total energy for adults.
- The formula for calculating the percentage of calories from fat equals the total fat calories divided by the total calories, multiplied by 100.
- Cholesterol serves several vital functions in the body. However, high levels of cholesterol in the blood are related to an increased risk for cardiovascular disease. Of particular concern in regard to cardiovascular disease is the level of low-density lipoprotein (LDL) in the blood, which optimally should be less than 100 mg/dL.
- Fats are an important energy source during endurance activities. However, high-fat diets either weeks before or hours before competition have not been shown to improve endurance performance.
- Fat consumption during exercise, particularly in ultra-endurance sports, has garnered research interest because of the extreme caloric demands of the sports. However, recent research has not supported the practice of fat intake during exercise. Performance decrements and gastrointestinal distress make fat intake during exercise a dietary practice to avoid. Care must be taken when ingesting MCTs during exercise because they can cause gastrointestinal upset.
- Fat intake after exercise is not as critical as carbohydrate and protein intake because of the body's ample stores of fat; however, small amounts of fats in the postexercise meal or snack can add taste and create a sense of satiety.

Study Questions

1. How do fats differ from carbohydrates both structurally and energetically (i.e., in the number of calories they yield)?
2. What functions do fats serve in the body?
3. What is cholesterol, and what is its role in the body?
4. Discuss the advantages and disadvantages of fat substitutes.
5. Would cutting out all dietary fat be an appropriate recommendation for an athlete wanting to decrease body fat? Defend your answer.
6. What is the difference between unsaturated, saturated, and hydrogenated fatty acids?
7. Explain how to find and calculate the percentage of calories from saturated fat in a particular food.
8. What would be an appropriate suggestion for fat intake prior to a morning exercise session for an athlete who does not like nuts or seeds?
9. How would you counsel/respond to an endurance athlete who enjoys eating potato chips during long-duration training sessions because they taste salty?

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