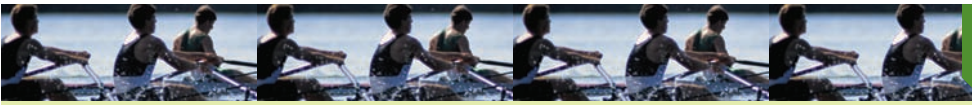
Food Drugs and Related Supplements



CHAPTER THIRTEEN

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

1. Explain the metabolic, physiological, and psychological effects of alcohol in the body, and evaluate its efficacy as an ergogenic acid.
2. Explain the possible beneficial and detrimental effects of alcohol consumption on health.
3. List and explain the several theories whereby caffeine supplementation is proposed to be an effective ergogenic aid, and summarize its effect on exercise performance.
4. Explain the possible beneficial and detrimental effects of caffeine in the body, and cite current recommendations for coffee consumption.
5. Understand the potential health problems associated with dietary supplements containing stimulants such as ephedra.
6. Describe the theory underlying the use of sodium bicarbonate as an ergogenic aid, and understand the current research findings regarding its efficacy to enhance exercise performance.
7. Identify drugs and related dietary supplements used by physically active individuals to stimulate muscle building and summarize the effects on exercise performance and potential health risks associated with their use.
8. Explain the theory as to how ginseng may enhance sport performance, and highlight the research findings regarding its ergogenic efficacy.
9. List those drugs or dietary supplements discussed in this chapter whose use is prohibited in sports.

KEY TERMS

alcoholism 484
anabolic/androgenic steroids (AAS) 497
androstenedione 499
blood alcohol content (BAC) 479
caffeine 485
cirrhosis 482
ciwujia 501
dehydroepiandrosterone (DHEA) 499
ephedra 492
ephedrine 492
ergolytic 481
ethanol 478
fetal alcohol effects (FAE) 483
fetal alcohol syndrome (FAS) 483
ginseng 500
ma huang 492
proof 479
sodium bicarbonate 493

Introduction

As noted in chapter 1, winning in sports is dependent not only on genetic endowment with physiological, psychological, and biomechanical attributes inherent to success in any given sport, but also on optimal training of those attributes. However, over the years athletes have attempted to go beyond training to gain a competitive edge on their opponents, and have used a wide variety of ergogenic aids in the process.

The most historic and popular international sporting event is the Olympic Games. The first Olympics were held in Greece, starting in 776 BC and continuing for over 1,000 years, being cancelled in 393 AD because they were regarded as a pagan ritual. Similar to today, athletes who were successful in these ancient Olympics achieved fame and fortune. Most elite athletes had personal trainers, called *paidotribes,* to plan their exercise program and their diet to prepare them for competition. Several famous Greek scientists, including Galen and Pythagoras, were paidotribes who advocated specific, but different, diets for their athletes; Galen promoted beans as a staple of the athlete's diet, whereas Pythagoras prohibited them. During these early Olympic Games various plants served as sources of drugs. For example, certain mushrooms contained hallucinogens while *Strychnos nux vamica* was the source of strychnine; in small doses both could serve as a stimulant. Athletes in the ancient Olympics were reported to consume such plants for their potential ergogenic effect.

The modern Olympic Games were resurrected in 1896 and continue today with competition among thousands of athletes in dozens of sports. As in the ancient Olympics, athletes in the modern Olympics have been reported to use drugs in attempts to obtain that competitive edge. As several of these drugs are found in some common foods or beverages that we may consume, they have been referred to as *food drugs.* Additionally, some plant extracts may be marketed as dietary supplements designed to imitate ergogenic drugs. Others, particularly herbals, may be used for their pharmaceutical effects by practitioners of alternative medicine.

In this chapter, we will evaluate the effects of several food drugs and related dietary supplements on exercise performance and health. Two very common food drugs, alcohol and caffeine, have been studied for their ergogenic effects for over 100 years, and have been used by athletes as a means to enhance performance since the early 1900s. Each has also been studied extensively for possible health effects, both positive and negative. The dietary supplement Ma Huang contains ephedra, or ephedrine, a stimulant theorized to enhance exercise performance, particularly when combined with caffeine. Ephedrine has also been studied for its potential health effects. Sodium bicarbonate, or baking soda, is used in many food products, and has been studied for eighty years as a means to enhance performance; it also has been marketed as part of a dietary supplement for athletes. Several anabolic hormones, and related steroid drugs, are used to increase muscle mass and have been popular with strength/power athletes for over 50 years. Because the use of such drugs has been controlled and illegal for sport competition for many years, companies have marketed prohormones, or precursors to these hormones, as dietary supplements to avoid drug regulations. However, these prohormones have also recently been classified as controlled drugs and their use is illegal in sports. Use of these anabolic agents may also pose serious health risks. Finally, several herbals, most notably ginseng, are used in alternative medicine for various purposes, one being enhancement of physical performance.

For the interested reader, a complete list of the drugs mentioned in this chapter, plus others, may be found at the World Anti-Doping (WADA) Website, www.wadaama.org.

Alcohol: Ergogenic Effects and Health Implications

The alcohol produced for human consumption is ethyl alcohol, or **ethanol**. Ethanol may be classified as a psychoactive drug, a toxin, or a nutrient.

What is the alcohol and nutrient content of typical alcoholic beverages?

Alcohol is a transparent, colorless liquid derived from the fermentation of sugars in fruits, vegetables, and grains. Although classified legally as a drug, alcohol is a component of many common beverages served throughout the world. In the United States, alco-

hol is consumed mainly as a natural ingredient of beer, wine, and liquors. Although the alcohol content may vary in different types, in general, beer is about 4–5 percent alcohol, wine is about 12–14 percent alcohol, and typical bar liquor (whiskey, rum, gin, vodka) is about 40–45 percent alcohol (figure 13.1). The term **proof** is a measure of the alcohol content in a beverage and is double the percentage; an 86-proof bottle of whiskey is 43 percent alcohol, while a 150-proof bottle of Caribbean rum is 75 percent alcohol.

One drink of alcohol is the equivalent of one-half ounce of pure ethyl alcohol or the equivalent of about 13–14 grams of alcohol. The following amounts of beer, wine, and liquor contain approximately equal amounts of alcohol and are classified as one drink:

12 ounces (one bottle) of beer
4 ounces (one wine glass) of wine
1.25 ounces (one jigger or shot glass) of liquor

However, some beers may contain 10 percent alcohol, some wines are fortified to 18–24 percent, and some liquors are 50–75 percent. Such beverages would provide significantly more alcohol per standard drink. Technically, alcohol may be classified as a nutrient because it provides energy, one of the major functions of food. Alcohol contains about 7 Calories per gram, almost twice the value of an equal amount of carbohydrate or protein. Beer and wine also contain some carbohydrate, a source of additional Calories. In general, a bottle of regular beer has about 150 Calories, while a 4-ounce glass of wine or a shot glass of liquor contains about 100 Calories. Table 13.1 provides an approximate analysis of the caloric content of common alcoholic beverages and nonalcoholic beer.

In general, the alcohol Calories found in beer, wine, and liquor are empty Calories. Although wine and beer contain trace amounts of protein, vitamins, minerals, and phytochemicals, liquor is void of any nutrient value.

What is the metabolic fate of alcohol in the body?

About 20 percent of the alcohol ingested may be absorbed by the stomach; the remainder passes on to the intestine for absorption. The absorption is rapid, particularly if the digestive tract is empty. The alcohol enters the blood and is distributed to the various tissues, being diluted by the water content of the body. A small portion of the alcohol, about 3–10 percent, is excreted from the body through the breath, urine, or sweat, but the majority is metabolized by the liver, the organ that metabolizes other drugs. As the blood circulates, the liver of an average adult male will metabolize about one-third ounce (8–10 grams) of alcohol per hour, or somewhat less than the amount of alcohol in one drink.

Although alcohol is derived from the fermentation of carbohydrates, it is metabolized in the body like fat. The liver helps convert the metabolic by-products of alcohol into fatty acids, which may be stored in the liver or transported into the blood. Several other compounds, such as lactate, acetate, and acetaldehyde, may also be released into the blood. These products may eventually be utilized for energy and converted into carbon dioxide and water. A schematic of alcohol metabolism is presented in figure 13.2.

As noted, the liver of a 150-pound male can metabolize only about one-third ounce of alcohol, or less than one drink, per hour. The rate is lower in smaller individuals and higher in larger individuals. Thus, consumption of alcohol at a rate greater than one drink per hour will result in an accumulation of alcohol in the blood; this is measured as the **blood alcohol concentration (BAC)** in grams per 100 milliliters of blood. For the average male, one drink will result in a BAC of about 0.025; four drinks in an hour would lead to a BAC of approximately 0.10.

1 glass of wine
4 oz. of table wine
12% alcohol by volume
4 × 0.12 = 0.48 oz.
of ethyl alcohol per serving

1 can or bottle of beer
12 oz. of beer
4% alcohol by volume
12 × 0.04 = 0.48 oz.
of ethyl alcohol per serving

1 shot glass with distilled spirits
1.25 oz. of whiskey or other hard liquor
40% alcohol by volume or 80 proof
1.25 × 0.40 = 0.50 oz.
of ethyl alcohol per serving

FIGURE 13.1 Alcohol equivalencies in typical beverages.

Is alcohol an effective ergogenic aid?

For over a century, athletes have consumed alcohol just prior to or during competition in attempts to improve performance. Alcohol has been alleged to alter energy metabolism, improve physiological processes, or modify psychological factors so as to benefit the athlete. Let us look at the available research to evaluate the truth of these allegations.

Use as an energy source Although alcohol contains a relatively large number of Calories and its metabolic pathways in the body are short, the available evidence suggests that it is not utilized to any significant extent during exercise. First, the major sources of energy for exercise are carbohydrates and fats, which are in ample supply in most individuals. Alcohol may help form fats, but there is no evidence that it can substitute for other fat sources in the body. Even if it could, this would be of no benefit because the body has more than enough fat to supply energy

TABLE 13.1 Caloric content of typical alcoholic beverages

		Carbohydrate		Alcohol		Total
Beverage	*Amount*	*Grams*	*Calories*	*Grams*	*Calories*	*Calories*
Beer, regular	12 ounces	13	52	13	91	150
Beer, light	12 ounces	7	28	11	77	109
Beer, nonalcoholic	12 ounces	12	48	1	7	55
Beer, alcohol-free	12 ounces	12	48	0	0	48
Wine, table	4 ounces	4	16	12	84	100
Liquor, 80 proof	1.25 ounces	0	0	14	98	100

The small discrepancies in the calculation of total Calories for beer and liquor may be attributed to a small protein content in beer and trace amounts of carbohydrate in liquor.

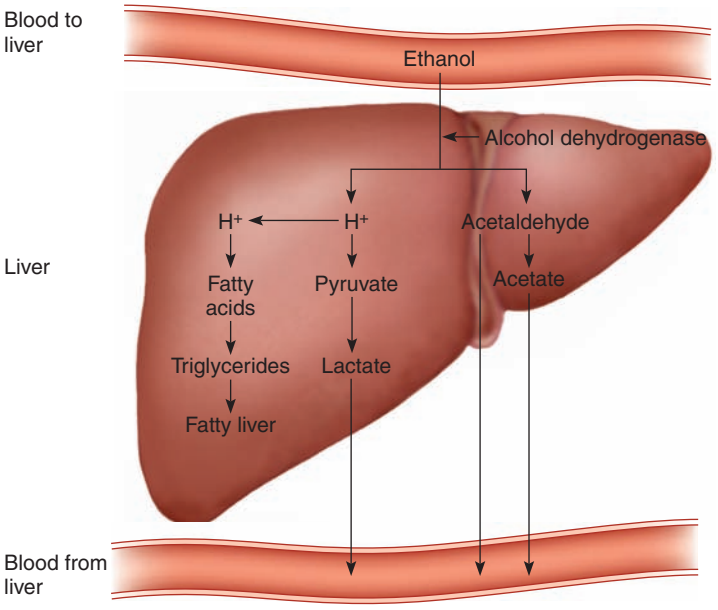


FIGURE 13.2 Simplified metabolic pathways of ethanol (alcohol) in the liver. Hydrogen ions are removed from ethanol as it is converted to acetaldehyde, which may be released into the blood for transport to other tissues. The excess hydrogen ions may combine with fatty acids to form triglycerides or with pyruvate to form lactate. Excessive accumulation of triglycerides may lead to the development of a fatty liver and eventually to cirrhosis.

during prolonged exercise. Second, the by-products of alcohol metabolism that are released by the liver into the blood may enter the skeletal muscles but appear to be of little importance to exercising muscle. Third, even if the energy from alcohol could be used, it would represent an uneconomical source. The amount of oxygen needed to release the Calories from alcohol is greater than for an equivalent amount of carbohydrate and fat. And lastly, the rate at which the liver metabolizes alcohol limits its use as an energy source during exercise, particularly in an individual working at a high level of intensity. In summary, these four factors suggest alcohol is not a key energy source during exercise, and even if it were, it would not offer any advantages over natural supplies of carbohydrate and fat. Recent research with carbon labeling revealed alcohol did not significantly modify endogenous carbohydrate and fat utilization during exercise.

Effect on exercise metabolism Numerous studies have evaluated the potential ergogenic effect of alcohol intake, both in small and large amounts, just prior to various exercise protocols. In general, the resultant effects depend on the alcohol dose and the type of exercise performance.

Research supports the finding that alcohol in small amounts (one to two drinks) neither improves nor deteriorates physiological processes associated with maximal aerobic exercise, including VO_2 max and maximal heart rate; neither does it affect other indicators of maximal aerobic performance such as exercise tests to exhaustion. For example, one study reported an apparent trend toward a deterioration in performance with increased alcohol intake, but there was no adverse effect on 5-mile (8 km) treadmill run time. Moreover, tests of anaerobic performance, such as strength and local muscular endurance, also are not affected.

However, a few studies have reported some potential adverse effects of consuming alcohol before or during submaximal exercise. Most of the studies alluded to above were conducted on males. A recent study reported some adverse acute effects of moderate alcohol consumption on cardiovascular and metabolic responses in females. In a submaximal cycling exercise task for 30 minutes, ingestion of alcohol increased the heart rate, oxygen consumption, blood pressure, and blood lactate, which the investigators indicated were negative effects. Earlier studies have also shown similar effects in males, including decreased pumping capacity of the heart with high BACs. Moreover, some recent research reported a significant decrease in aerobic endurance when alcohol was ingested before and during a treadmill run at

about 80–85 percent VO_2 max, which may have been associated with an impaired glucose metabolism. Impaired performance has also been reported in both an 800-meter and 1500-meter run following alcohol consumption, and the detrimental effect was greater with increasing BACs from 0.01 to 0.10.

Several metabolic effects of alcohol intake could impair endurance performance. Alcohol reduces gluconeogenesis by the liver and glucose uptake by the legs during the latter stages of exercise. In prolonged exercise, such as marathons, these effects could lead to an earlier onset of hypoglycemia or muscle glycogen depletion and a subsequent decrease in performance. Moreover, some studies have reported reduced absorption of vitamin B_1 associated with moderate intakes of alcohol. Theoretically, this could impair physical performance of an endurance nature because vitamin B_1 is involved in the aerobic metabolism of carbohydrate.

Alcohol ingestion may also increase urine production by decreasing release of the anti-diuretic hormone. This effect could possibly impair temperature regulation during exercise under warm/hot environmental conditions. Starting a prolonged endurance event under warm/hot conditions in a dehydrated state could certainly impair performance. As a rehydration fluid after dehydration, drinks containing 4 percent alcohol or more, such as beer, tend to delay the recovery process as measured by restoration of blood and plasma volume.

Additional research is merited to document any adverse effects of alcohol on cardiovascular or metabolic processes during exercise, but at this time it appears that alcohol intake before or during aerobic and anaerobic endurance exercise is not ergogenic and may be **ergolytic**, or impairing exercise performance.

Effect on psychological processes Alcohol also has been used as an ergogenic aid for its psychological effects. It is a narcotic, a depressant, that affects the brain. As a depressant, alcohol would not be advocated as a means to improve performance; however, some have contended that increased feelings of self-confidence, reduced anxiety levels, and a perceived decrease in sensitivity to pain may offset any depressant effects and possibly benefit performance. Moreover, alcohol in small doses may exert a paradoxical stimulation effect. Parts of the brain that normally inhibit behavior may be depressed by alcohol, leading to a transitory sensation of excitement.

Although these effects may occur, research does not support the use of alcohol in sports involving psychological processes such as perceptual-motor abilities. Perceptual-motor activities involve the perception of a stimulus, integration of this stimulus by the brain, and an appropriate motor response (movement). The evidence overwhelmingly supports the conclusion that alcohol adversely affects psychomotor performance skills, such as reaction time, balance, hand/eye coordination, and visual perception. These are important in events with rapidly changing stimuli, such as tennis.

In one form of athletic competition, such as marksmanship in riflery, pistol shooting, dart throwing, and archery, alcohol may be used to decrease hand muscle tremor and thereby improve accuracy for competition. Although research generally is not supportive of an improved performance, one study with archers revealed a tendency toward reduced tremor with low blood alcohol levels, resulting in a smoother release. However, no actual performance data were revealed. Throwing accuracy improved in darts at a BAC of 0.02, but was impaired at a BAC of 0.05. This area of study merits additional research.

Social drinking and sports Only a limited number of studies have been conducted relative to the effect of social drinking upon physical performance, but there is rather general agreement that light social drinking will not impair performance on the following day. Tests of reaction time, strength, power, and cardiovascular performance were not adversely affected following the consumption of one drink the night before. On the other hand, heavy drinking may impair performance on the following day owing to hangover effects, involuntary eye movement, or dehydration.

The use of alcohol by Olympic athletes had been banned previously by the IOC, but because wine and beer are commonly consumed as a part of many traditional European meals it was removed from the banned list prior to the 1972 Olympics. However, individual sports federations within the IOC still may consider alcohol use during competition as grounds for disqualification. At the present time, only several sports, such as those that involve shooting competition, ban the use of alcohol.

In his review, Williams noted that although alcohol consumption is not prohibited for use by most athletes, there are no data supporting an ergogenic effect, and some data to suggest an ergolytic effect. This viewpoint was supported by Burke and Maughan in a recent review. Athletes who drink socially should do so in moderation, and possibly abstain 24 hours prior to a prolonged endurance contest.

What effect can drinking alcohol have upon my health?

Consumption of alcoholic beverages is a popular pastime worldwide. People drink mainly for social reasons, but when and how much they drink may have a significant impact on their health and the health of others. As Klatsky recently noted, the basic disparity underlying all alcohol-health relations is between the effects of lighter and heavier drinking. Although many of the effects of alcohol may negatively affect health status, some effects may be positive. "Both the negative and the positive effects are detailed in a recent National Institute on Alcohol Abuse and Alcoholism (NIAAA) state-of-the-science report on the effects of moderate drinking."

Negative Effects Alcohol affects all cells in the body, and many of these effects may have significant health implications. Room and others noted that alcohol is causally related to more than 60 different medical conditions, and is a major challenge to public health. Drinking alcoholic beverages, particularly in large amounts, is associated with over 100,000 deaths per year.

Direct toxic effects Alcohol has a direct toxic effect on the intestinal walls; it tends to impair the absorption of vitamins

such as thiamin (B_1). Individuals who drink alcohol also have a higher incidence rate of pharyngeal and esophageal cancer, which may possibly be associated with the direct effect of alcohol as it contacts these tissues during ingestion. Combining alcohol with certain medication such as aspirin or nonsteroidal anti-inflammatory agents (ibuprofen) may promote gastrointestinal bleeding. Drinking alcohol may also aggravate certain health conditions, such as peptic ulcers.

Liver function The liver is the only organ in the body that metabolizes alcohol, and alcohol may affect liver function in several ways. It may interfere with the metabolism of other drugs, increasing the effect of some and lessening the effects of others. Even with a balanced diet high in protein, consuming six drinks a day for less than a month has been shown to cause significant accumulation of fat in the liver. If continued for five years or more, the liver cells degenerate. Eventually the damaged liver cells are replaced by non-functioning scar tissue, a condition known as **cirrhosis.** As liver function deteriorates, fat, carbohydrate, and protein metabolism are not regulated properly; this has possible pathological consequences for other body organs such as the kidney, pancreas, and heart.

Nutrients, such as specific lipids from soybeans, are being studied as a means to help prevent this liver degeneration. Some scientists theorize that wine, because it contains antioxidants, may help prevent oxidative stress and subsequent liver damage, and may thus be the alcoholic beverage with less damaging effects. However, liver damage is one of the most consistent adverse effects of excess alcohol intake.

Mental processes Following absorption, the most immediate effects of alcohol are on the brain; often these effects are paradoxical. Although alcohol is a depressant, a small amount often exerts a stimulating effect because it may release some of the normal inhibitory control mechanisms in the brain. For the most part, however, alcohol acts as a depressant, and its effects on the brain are dose-dependent. The effects occur in a hierarchical fashion related to the development of the brain. In general, alcohol first affects the higher brain centers. With increasing dosages, lower levels of brain function become depressed with subsequent disturbance of normal functions. This hierarchy of brain functions, from higher levels to lower levels, and some of the functions affected by alcohol may be generalized as follows:

Thinking and reasoning—Judgment
Perceptual-motor responses—Reaction time
Fine motor coordination—Muscles of speech
Gross motor coordination—Walking
Visual processes—Double vision
Alertness—Sleep, coma
Respiratory control—Respiratory failure, death

An overview of the effects of increasing blood alcohol content on mental and physical functions is presented in table 13.2.

Youth and gender may influence the mental effects of alcohol. Monti and others reported that heavy drinking during the teenage years may cause permanent brain damage, including impaired memory. Mann and others noted that women become dependent on alcohol quicker and suffer adverse effects, such as brain atrophy, faster as compared to men.

TABLE 13.2 Typical effects of increasing blood alcohol content

Number of drinks* consumed in 2 hours	Blood** alcohol content	Typical effects
2–3	.02–.04	Reduced tension, relaxed feeling, relief from daily stress
4–5	.06–.09	Legally drunk in some states, impaired judgment, a high feeling, impaired fine motor ability and coordination
6–8	.11–.16	Legally drunk in all states, slurred speech, impaired gross motor coordination, staggering gait
9–12	.18–.25	Loss of control of voluntary activity, erratic behavior, impaired vision
13–18	.27–.39	Stuporous, total loss of coordination
19 and above	>.40	Coma, depression of respiratory centers, death

*One drink = 12 ounces regular beer
4 ounces wine
1.25 ounces liquor

**BAC based on body weight of 160 pounds (72.6 KG). The BAC will increase proportionally for individuals weighing less (such as a 120-pound female) and will decrease proportionally for individuals weighing more (such as a 200-pound football player). For example, four to five drinks in 2 hours could lead to a BAC of 0.08–0.12 in a 120-pound individual.

If you want to avoid mental impairment associated with alcohol, abstinence is the simplest approach. For those who do drink, abstinence is advised under certain conditions. The acute effects of excessive alcohol consumption include impairment of both motor coordination and judgment—two factors that are extremely important in the safe operation of an automobile. At the least, being arrested for drunk driving may have serious social and personal consequences. At the worst, alcohol is involved as a cause of nearly one-half of all automobile fatalities—20,000 deaths per year in the United States alone. As the saying goes, "Don't drink and drive!"

Alcohol usage also is correlated highly with aggressive tendencies. Laboratory studies have indicated aggressive behavior is directly related to the quantity of alcohol consumed. In a recent meta-analysis investigating the role of alcohol in fatal nontraffic injuries, Smith and others concluded that alcohol was an important factor in homicides, suicides, and unintentional injury deaths. Alcohol abuse is also associated with sexual abuse.

Most of these adverse effects are associated with excessive alcohol intake, particularly as practiced in binge drinking. Recent surveys indicate that almost half of college students binge, and one of the most significant factors underlying alcohol-related behavior problems is the amount of alcohol consumed; the greater the amount of alcohol consumed, the more serious the problem. According to the NIAAA, nationally there are more than 1,400 alcohol-related deaths each year among college students, most due to automobile accidents, but several attributed to heavy binge drinking with resultant respiratory failure.

Many physically active individuals, including competitive athletes, consume alcohol on a regular basis. In their periodic study of NCAA athletes, Green and others recently noted that alcohol was the most widely used drug, with over 80 percent of athletes using alcohol within the past year. O'Brien and Lyons indicated that alcohol-related problems may be more prevalent in the athletic population due to their risk-taking mentality.

DNA damage Laboratory research has shown that *in vitro* (that is, in a test tube) alcohol and acetaldehyde cause changes in DNA (the genetic material in body cells) comparable to changes elicited by carcinogens. This DNA damage may occur at an alcohol concentration equivalent to one to two drinks. In those who drink, this finding could be related to the increased risk of certain forms of cancer, including pharyngeal and esophageal cancer as mentioned earlier, and also breast and colon cancer.

One of the most debated issues is the risk of breast cancer. Possible mechanisms have been identified; in addition to potential DNA damage, alcohol ingestion may also increase estrogen levels, a factor that increases breast cancer risk. Research associating increased incidence of breast cancer with alcohol consumption is epidemiological in nature. The NIAAA indicated that the effect of alcohol intake on the risk for breast cancer remains controversial. In summary, the NIAAA noted that the overall evidence from epidemiologic data seems to indicate that alcohol may be associated with an increase in the risk of breast cancer in the population overall, but the relative effect of moderate consumption is small at the individual level; the increase in risk is most clearly evident for women with a family history of breast cancer and those using estrogen replacement therapy. The NIAAA recommends that women, in conjunction with their health care provider, should weigh their potential increased risk for breast cancer against their potential reduced risk for cardiovascular disease in determining whether alcohol consumption should be reduced.

Women who drink should abstain during pregnancy because even moderate consumption of alcohol, or even a single drinking binge, may affect DNA in the embryo and fetus. The term **fetal alcohol syndrome (FAS)** refers to the effects upon the development of a fetus if a mother consumes alcohol while pregnant. The incidence rate of FAS is very high in the United States, and FAS is currently the major cause of mental retardation in the Western world. The child may experience retardation in growth and mental development as well as facial birth defects (figure 13.3). **Fetal alcohol effects (FAE)** may be observed in children when full-blown FAS is not present. Children with FAE are easily distracted and have poor attention spans. Both FAS and FAE are associated with learning disorders in children. No "safe" amount of alcohol during pregnancy has been determined. Thus, the U.S. Surgeon General indicated that the safest approach is abstinence.

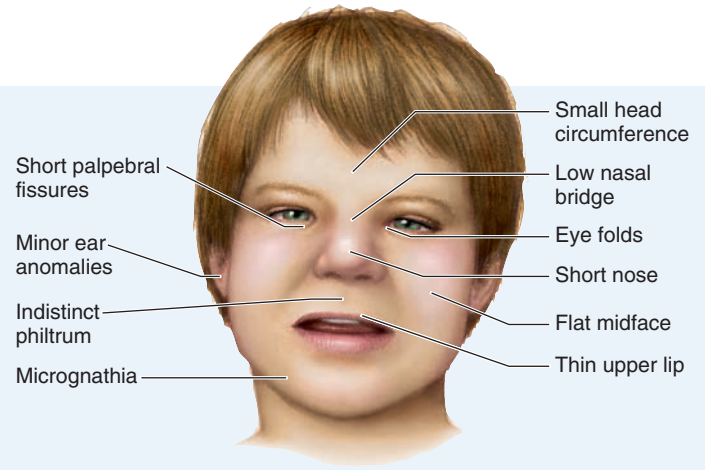


FIGURE 13.3 Common facial characteristics of children with fetal alcohol syndrome (FAS).

Obesity Alcohol is a significant source of Calories, about 7 per gram, somewhat comparable to the caloric content of fat. Recent research has indicated that if small amounts of alcohol (5 percent of daily caloric intake) are interchanged for an equivalent caloric intake from carbohydrates, there is no effect on daily energy expenditure. In other words, alcohol Calories themselves will not increase body fat as long as total daily caloric intake matches daily caloric expenditure. In general, the NIAAA indicates that the relationship between moderate alcohol consumption and obesity remains inconclusive.

However, Yeomans noted that alcohol may increase energy intake in several ways. Alcohol stimulates the appetite, increasing food intake, and alcohol contains energy. Angelo Tremblay, an esteemed scientist in weight control, and his colleagues recently found that alcohol has no inhibitory effect on food intake and its energy content, and when consumed in conjunction with a high-fat diet promotes overfeeding, a primary determinant of obesity. Additionally, Jequier notes that alcohol ingestion reduces fat oxidation and favors a positive fat balance. These points may underlie the conclusion of the recent study by Wannamethee and others, mainly that higher alcohol consumption is positively associated with both overall and abdominal adiposity, irrespective of the type of drink or whether the alcohol is drunk with meals or not. As noted in chapter 11, reducing alcoholic intake may be an important component of an effective weight control program.

Excessive drinking and alcoholism Heavy alcohol consumption aggravates most of the health problems mentioned above and may lead to addiction. Some research has shown that three or more drinks per day increase the risk of developing high blood pressure and may increase blood lipid levels. These conditions are associated with cardiovascular disease, and heavy alcohol consumption is linked to sudden death from heart failure and stroke.

Alcohol abuse is the major drug problem in the United States, posing a problem for one in seven males and one in sixteen females, or about one out of every ten drinkers. Excessive intake of alcohol may lead to a disorder known as **alcoholism,** a condition whose etiology is unknown but probably is related to a variety of physiological, psychological, and sociological factors. Many genes are likely to be involved in increasing an individual's risk for alcoholism, and Gordis indicates that heavy, long-term use of alcohol modifies brain cells in such a way that certain individuals continue to drink despite growing difficulties. The National Council on Alcoholism suggests that there is no pat definition for alcoholism; it may be evidenced by a variety of behaviors. A deficiency of vitamin B may contribute to many of the neuropsychiatric problems seen in alcoholism. The number of behaviors exhibited by the drinker may be related to various stages in the progression toward alcoholism. Appendix C, a questionnaire developed by the National Council on Alcoholism, provides for an assessment of these behaviors.

Positive Effects On the positive side, most recent epidemiological research and reviews have shown that light to moderate consumption of alcohol is associated with lessened mortality. For example, in a recent meta-analysis of the relationship of alcohol consumption to all-cause mortality, Holman and others noted that light drinking (less than 2 drinks per day in males; less than 1 drink per day in females) was associated with a lower relative risk for all-cause mortality compared to abstainers, but that the relative risk returned to normal with moderate alcohol intake and increased to 1.37 for heavy drinkers, those taking six or more drinks daily. Research suggests that light to moderate alcohol intake reduces risk of coronary heart disease and stroke, a major factor in reducing risk for all-cause mortality. The mechanism is not known, but several have been proposed based on epidemiological and experimental studies.

One theory suggests small amounts of alcohol induce a relaxation effect, which may reduce emotional stress, a risk factor associated with CHD. Another theory suggests alcohol decreases platelet aggregability (clotting ability) by increasing the activity of a clot-dissolving enzyme in the blood. Still another theory, proposed by Antinoro and others, indicates that moderate amounts of alcohol may improve blood flow to the brain, which they theorize may help prevent or delay certain brain diseases, such as Alzheimer's and Parkinson's, and might help prevent certain forms of stroke. Other mechanisms may be working as well, such as an enhanced insulin sensitivity, which may help in the prevention of the metabolic syndrome and diabetes, both risk factors for CHD.

The most prevalent theory involves the effect of alcohol to raise levels of HDL-cholesterol, the form of cholesterol that protects against the development of CHD (see discussion on pages 174–177). A significant number of studies have supported this effect, although the mechanisms have not been determined. Some studies have shown an increase in one form of cholesterol, HDL_2, which is believed to be protective. Other studies note an increase in HDL_3, which may also elicit a protective effect. Gaziano and others noted alcohol may reduce the risk of heart disease by raising the levels of both HDL_2 and HDL_3. However, Hines and others noted individuals with a specific genetic predisposition may benefit more from alcohol intake, as they may produce a form of alcohol dehydrogenase that metabolizes alcohol more slowly, leading to greater increases in HDL-cholesterol.

Some investigators have theorized that the consumption of certain types of alcoholic beverages, most notably red wine, is responsible for the reported health benefits. Pigments in red wine contain polyphenols and other phytochemicals that may help prevent coronary heart disease by favorable actions on various processes. For example, de Lorimier indicates that phenolic compounds in wine can also increase HDL, have antioxidant activity, decrease platelet aggregation, and promote vasodilation—all potentially beneficial. Chopra and others noted also that alcohol-free red wine may provide some similar health benefits. However, Denke indicates that there is no evidence to support endorsement of one type of alcoholic beverage over another, noting that beer has its own nutritional value. Compared to wine, beer contains more protein and B vitamins, is rich in flavonoids, and has an equivalent antioxidant content, but of different specific antioxidants derived from barley and hops. In a recent study, Mukamal and others found that men who consumed alcohol 3–4 days per week experienced a reduced risk of myocardial infarction, but the type of beverage consumed did not substantially alter this effect.

Although these factors may be important, Naimi and others contend that individuals who drink moderately may practice other lifestyle behaviors that reduce the risk for CHD. For example, Smothers and Bertolucci recently reported that people who moderate their alcohol intake also engage in more leisure-time activity, which may play an explanatory role in the alcohol-heart disease relationship. As noted in chapter 1, exercise itself may reduce the risk of CHD. Nevertheless, data from the National Runners' Health Study, as reported by Williams, reveals that men's blood pressure increases in association with the amount of alcohol intake, regardless of running level. Thus, it should be reemphasized that although there appear to be some positive health effects associated with light to moderate alcohol intake, or at least no detrimental effects, heavier drinking is another matter.

Because of the potential for abuse, addiction, and all types of injuries, abstinence from alcohol or prudent consumption is generally recommended by health authorities. "Low risk" drinking is an emerging term to represent light to moderate alcohol intake. As noted above, abstinence is the best policy for pregnant women or if you plan to operate a motor vehicle. Health professionals, however, generally support the view that low risk drinking, along with a balanced diet, should not pose any health problem to the average healthy individual. The definition of moderation has varied, but the NIAAA recently indicated that except for individuals at particular risk, consumption of 2 drinks a day for men and 1 for women is unlikely to increase health risks. As risks for some conditions and diseases do increase at higher levels of consumption, men should be cautioned to not exceed 4 drinks on any day and women to not exceed 3 on any day.

Nevertheless, although there are actually some possible health benefits associated with alcohol consumption in moderation, health authorities caution that these potential benefits are not sufficient cause to start drinking if you currently abstain. The NIAAA stipulates that *moderate alcohol use* should not be construed as *healthy alcohol use,* because numerous individual differences, such as age, genetics, and metabolic rate, may affect the response to alcohol. You should consult with your physician if you are considering drinking for its possible health benefits.

Key Concept Recap

- One drink of alcohol contains approximately 13–14 grams of alcohol, or about one-half ounce. One drink is typically the equivalent of 12 ounces of beer, 4 ounces of wine, and 1.25 ounces of 40 proof whiskey. However, the alcohol content in some beverages may be substantially greater.
- Alcohol is not an effective ergogenic aid, and in fact may actually impair athletic performance, that is, it is ergolytic.
- Consumption of alcohol in moderation appears to cause no major health problems for the normal, healthy adult, and may actually confer some health benefits. However, alcohol may be contraindicated for some, such as women during pregnancy. Heavy drinking is associated with numerous health problems.

Check for Yourself

Visit a local beer/wine store that carries a wide variety of products, including microbrews and fortified wines. Check the labels for percentage alcohol content, listing those from lowest to highest. Calculate how much alcohol would be in a standard drink from each.

Caffeine: Ergogenic Effects and Health Implications

Various stimulants have been used in attempts to enhance health and sports performance including caffeine.

What is caffeine and in what food products is it found?

Caffeine is an odorless, bitter, white alkaloid that appears naturally in many plants, and is found in many of the foods and beverages that we consume every day, such as coffee, tea, colas, caffeinated waters, juices, sports drinks and sports bars, and chocolate; it is the most popular social drug in the United States (figure 13.4). It is also found in various dietary supplements, such as kola nuts and guarana, and even some over-the-counter stimulant supplements targeted to athletes; most recently, caffeine has been marketed as *performance candy,* such as Jolt Caffeine-Energy Gum and Buzz Bites, a chocolate chew candy. Yet caffeine is legally classified as a drug and has some powerful physiological effects on the human body. A normal therapeutic dose of caffeine may range from 100–300 milligrams. Some approximate amounts in the beverages we consume are 80–135 mg in a cup of perked coffee, 40–60 mg in a cup of tea, and 35–45 mg in a can of cola. The caffeine content of various products is presented in table 13.3.

FIGURE 13.4 Caffeine is the most popular social drug in the United States. About 90 percent of all adults consume caffeine in one form or another, mainly as coffee.

What effects does caffeine have on the body that may benefit exercise performance?

Caffeine functions as a stimulant of the nervous system. Its primary mode of action is to block the neurotransmitter adenosine, and thus influence a wide variety of metabolic processes throughout the body. Caffeine stimulates heart function, blood circulation, and release of epinephrine (adrenaline) from the adrenal gland. Epinephrine, also a stimulant, augments these effects and also, in conjunction with caffeine, stimulates a wide variety of tissues. Together they potentiate muscle contraction, raise the rate of muscle and liver glycogen breakdown, increase release of FFA from adipose tissue, and increase use of muscle triglycerides. One of the most observed effects at rest is an increase in blood levels of FFA. These varied physiological responses are mediated by the action of caffeine, or epinephrine, to enhance appropriate intracellular functions in specific cells; functions such as increased calcium release to excite muscle contraction or elevated enzymic activity to release FFA from adipose tissue cells. Caffeine also enhances

TABLE 13.3 Caffeine content in selected products

Product	Serving size	Caffeine (milligrams)
Coffee, brewed	8 ounce cup	80–135
Coffee, instant	8 ounce cup	65–100
Coffee, decaffeinated	8 ounce cup	3–4
Tea, brewed	8 ounce cup	40–60
Tea, green	8 ounce cup	15
Hot cocoa	8 ounce cup	15
Sodas, cola	12 ounce can	35–45
Sodas, high caffeine	12 ounce can	55–70
Energy drinks	8 ounce can	80
Performance candy	1 Buzz Bite	100
Stimulants	1 Vivarin tablet	200
Dietary supplements	5 grams guarana	250

Note: Check labels of over-the-counter stimulants and dietary supplements for caffeine content.

psychological processes, increasing alertness and a feeling of well-being. Caffeine is degraded rapidly in the liver to dimethylxanthines, metabolites which may also affect metabolism favorably.

Overall, caffeine may influence central and peripheral metabolic processes, as well as psychological processes, to help delay the onset of fatigue and has been theorized to enhance performance in many types of exercise, including endurance, strength, speed, and power.

Does caffeine enhance exercise performance?

Caffeine has been studied for its possible ergogenic effects for nearly 100 years. Early research focused on improvements in strength, power, and psychomotor parameters such as reaction time. However, since research by Costill's laboratory in the late 1970s suggested caffeine could increase endurance, many researchers have investigated the effects of caffeine on fat metabolism as a means to enhance performance of endurance athletes, such as marathoners, primarily because of caffeine's alleged potential to spare the use of muscle glycogen. In recent years, increased research attention has also refocused on the ergogenic potential of caffeine in tasks of higher exercise intensity and shorter duration.

Literally hundreds of studies have been conducted to test the ergogenic effectiveness of caffeine. Considerable differences exist in the experimental designs of caffeine studies in such aspects as caffeine delivery system (caffeine in coffee or capsule form), caffeine dosage (3–15 mg per kg body weight), the type of exercise task (power, strength, reaction time, short-term endurance, prolonged endurance), the intensity of the exercise (submaximal exercise, maximal exercise), the training status of the subject (trained, untrained), the preexercise diet (high-carbohydrate, mixed), the subjects' caffeine status (user, abstainer), and individual variability (reactor, nonreactor). These differences complicate interpretation of the results. Additionally, some investigators have combined caffeine with other related stimulants, such as ephedrine and theophylline.

Overall, research indicates that caffeine supplementation may be an effective ergogenic for a variety of exercise tests and may improve performance by different mechanisms. Several reviews and a meta-analysis regarding the effect of caffeine on physical performance have been published recently, and the interested reader is referred to the articles by Graham, Doherty and Smith, and Kalmar and Cafarelli. Based on these reviews and an independent analysis of key studies, the following points represent a general summary of the available research.

Effect on Mental Alertness Caffeine can increase alertness, which may improve simple reaction time. Doses of 200 milligrams have been effective, particularly when subjects are mentally fatigued. Hogervorst and others recently noted that caffeine, as part of a carbohydrate-electrolyte solution, improved cognitive function in endurance-trained athletes following a maximal 1-hour time trial on a bicycle ergometer. Larger doses, above 400 milligrams, may increase nervousness and anxiousness in some individuals, and thus may adversely affect performance in events characterized by fine motor skills and control of hand steadiness, such as pistol shooting.

Effect on Muscle Contraction Caffeine may increase the release of calcium from the sarcoplasmic reticulum in the muscle, possibly increasing the force of muscle contraction. Tarnopolsky and Cupido recently evaluated this direct effect of caffeine on muscle contraction in both habitual and nonhabitual caffeine users, stimulating the muscle electrically at different intensities to induce a 2-minute tetanic contraction. They found that caffeine potentiated the force of muscle contraction during the last minute of stimulation and suggested that the data support the hypothesis that some of the ergogenic effect of caffeine in endurance exercise performance occurs directly at the skeletal muscle level. Some studies support such a direct effect. Kalmar and Cafarelli reported significant improvement in a maximal isometric endurance task just over 1 minute in duration. In his recent review, Graham noted that although there are fewer studies with resistance exercise, the available literature would suggest that caffeine could increase endurance in repeated contractions.

Effect on High-intensity Exercise The vast majority of earlier studies revealed that caffeine did not improve performance in events characterized by strength, speed, power, or local muscular endurance, nor in endurance events lasting less than 30 minutes, and this is the general conclusion of the review by Williams,

which focuses on high-intensity exercise performance. More recent studies are inconsistent. Several support this general conclusion. For example, in a recent well-controlled crossover study, Paton and others investigated the effect of caffeine (6 mg/kg) on repeated 20-meter sprints in well-trained male team-sport athletes and observed no significant effect on mean sprint performance and fatigue over ten sprints.

However, other recent well-designed, double-blind, placebo, crossover studies have shown caffeine-induced improvement in several high-intensity exercise tasks. For example, Bruce and others reported increased mean power and improved 2000-meter rowing time in eight competitive rowers; Collomp and others reported faster 100-meter swim times in highly trained swimmers; Wiles and others noted significantly faster run times for 1,500 meters, particularly increased speed in the latter part of the race, in trained middle-distance runners; MacIntosh and Wright found significantly faster times in a 1,500-meter swim; Jackman and others reported increased time to exhaustion when exercising at 100 percent VO_2 max, a time approaching 5 minutes. Stuart and others reported significant improvements in repetitive bouts of speed and power typical of high-intensity team sports such as rugby.

The enhanced performance noted in these exercise tasks may be attributed to psychological factors. In support of this point, Cole and others recently had subjects perform cycling tasks at several set ratings of perceived exertion (RPE), which is a scale representing how psychologically stressful the exercise appeared to be. In the three levels of RPE used, the subjects produced more work in 10 minutes following caffeine ingestion as compared to the placebo. Although the subjects perceived the work tasks to be identical by the RPE scale, they actually generated more work with caffeine.

Effect on FFA Mobilization and Use It is well established that caffeine may raise serum FFA levels at rest just before exercise, but there appears to be some controversy regarding serum FFA levels during exercise when trials with and without caffeine are compared. A number of studies that involved subjects who consumed caffeine beverages regularly and who also used a small dose of caffeine (5 mg/kg) have reported no significant differences between caffeine and placebo trials. The most likely reason is that exercise itself, as a stressor, stimulates epinephrine release and raises FFA levels comparable to the small dose. However, other studies that have involved subjects who were not regular caffeine users or who abstained from caffeine use for 4–7 days and which also employed large doses of caffeine (15 mg/kg) have noted significantly higher levels of FFA during exercise compared to placebo trials. Bucci reported fifteen studies in which caffeine increased FFA over the effect of exercise alone. Whether or not there are changes in plasma FFA may be irrelevant, for as Tarnopolsky notes, plasma concentrations do not provide us with appropriate information regarding the flux of the FFA, that is, the rate at which it appears in the blood from the adipose tissue and the rate of entry into the muscle cell.

Even though caffeine may elevate FFA during exercise, whether the use of fat as an energy source is increased during exercise is debatable. Several reviewers have noted an inconsistency in the results when the respiratory quotient (RQ) was used to assess fuel utilization; the RQ may serve as a general guide to the percentage use of carbohydrate and fat during submaximal, mild- to moderate-intensity exercise.

Several recent studies provide strong evidence that caffeine may not increase fat utilization during exercise. Graham and others monitored fatty acid metabolism directly at the leg level during exercise and found that caffeine (6 mg/kg), although stimulating the sympathetic nervous system, did not alter the fat metabolism in the monitored leg. In a related study, Mora-Rodriguez and Coyle infused epinephrine intravenously in low, moderate, and high amounts to evaluate the effect on fat utilization during low-intensity exercise. Although elevations in plasma epinephrine progressively increased whole body lipolysis, fatty acid oxidation decreased. Based on the most recent research, Graham noted that it appears unlikely that increased fat oxidation is the prime ergogenic mechanism underlying caffeine use as an ergogenic aid.

Effect on Muscle Glycogen Sparing Previously, several well-designed studies had supported the concept that caffeine would increase fat utilization and spare muscle glycogen, which could contribute to enhanced endurance performance. About 25 years ago, Essig noted that caffeine elicited an increased utilization of muscle triglycerides during exercise and spared the use of muscle glycogen. In studies that have taken muscle biopsies, caffeine has been shown to exert a glycogen-sparing effect. Well-designed studies headed by Lawrence Spriet and Terry Graham from Guelph University in Canada show clearly that caffeine will spare the use of muscle glycogen during the first 15 minutes of exercise, supporting the research findings of Essig years ago. In the study by Spriet and others, no crossover design was used, for all subjects received the placebo first and then 1 week later, the caffeine. Muscle biopsies were taken at the point of exhaustion in the placebo trial. During the caffeine trial, the subjects were stopped for a muscle biopsy at the exact same time they reached exhaustion in the placebo trial; they were still performing but were stopped for the biopsy and then continued cycling. The muscle glycogen was higher in the caffeine trial compared to the placebo trial, strong evidence of a glycogen-sparing effect that allowed the athletes to continue to cycle.

However, more recent studies suggest caffeine does not spare muscle glycogen during exercise. As noted above, Graham and others found no effect of caffeine on fat metabolism during exercise while monitoring fuel use at the leg level, and they also reported no effect on carbohydrate metabolism. In another study from Graham's research group, Greer and others reported that neither caffeine (6 mg/kg) nor the related stimulant theophylline (4.5 mg/kg) affected muscle glycogen utilization during cycling exercise at 80 percent VO_2 max until exhaustion. Laurent and others used nuclear magnetic resonance spectroscopy to evaluate muscle glycogen levels before and after exercise (cycling 2 hours at 65 percent VO_2 max), and found that caffeine (6 mg/kg) did not spare use of muscle glycogen in glycogen-loaded subjects. Thus, based on current research findings from his own and other research groups, Graham indicated that

caffeine does not appear to induce a glycogen-sparing effect during exercise.

Effect on Aerobic Endurance Performance As the duration of the endurance event increases to an hour or more, the research indicates, although not uniformly so, that caffeine may enhance performance. In many studies with improved performance, the psychological effect of caffeine was hypothesized as the cause. A number of studies have shown that caffeine may exert a stimulating effect on psychological processes, such as alertness and mood, which may diminish the perception of effort during exercise and thereby improve performance.

Several recent well-designed studies have shown significant increases in epinephrine levels during exercise following caffeine ingestion, both in elite and recreational athletes. Epinephrine responses to caffeine ingestion may be greater in nonusers versus habitual caffeine users. Epinephrine may exert a stimulating psychological effect, although the mechanism underlying improved performance has not been determined.

Numerous studies have reported significant improvements in endurance performance following caffeine ingestion. For example, in a recent study Greer and others reported that both caffeine (6 mg/kg) and theophylline (4.5 mg/kg), enhanced performance during cycling exercise at 80 percent VO_2 max until exhaustion. In their classic study, Graham and Spriet used elite distance runners as subjects and found that caffeine improved mean run time to exhaustion at 85 percent of VO_2 max from 49.2 minutes following the placebo to 71.0 minutes after caffeine (9 mg/kg body weight), a 44 percent improvement. Performance on a comparable cycling test to exhaustion revealed similar results. In most studies, the caffeine was taken 1 hour prior to performance, but French and others found that caffeine was effective even if taken immediately before the performance task.

In their recent meta-analysis, Doherty and Smith confirmed the ergogenic effects of caffeine in a variety of exercise tasks, particularly so in tests of aerobic endurance (see figure 13.5). Jeukendrup and Martin, in their review on how to improve cycling performance, quantified the ergogenic effects of caffeine, suggesting that low doses could improve 40-kilometer cycling performance by 55–84 seconds. No wonder caffeine is popular with professional cyclists.

Effect of Dietary Carbohydrates Previous research has shown that carbohydrate loading and having a high-carbohydrate breakfast prior to competition may negate the metabolic effects of caffeine. High-carbohydrate levels stimulate insulin release, which appears to block the effect of caffeine in raising FFA levels. However, given the conflicting data as to whether or not plasma FFA accurately reflect the FFA flux, this observation may not be too meaningful. Moreover, the subjects in the study by Graham and Spriet did load with carbohydrates for several days prior to the exercise task, both in the placebo and caffeine trials, and it did not appear to affect the ergogenic effect of caffeine adversely. Research has also shown that caffeine ingestion does not impede the resynthesis of muscle glycogen during the carbohydrate-loading protocol.

FIGURE 13.5 Caffeine may enhance performance in a wide variety of exercise endeavors, particularly events involving aerobic endurance.

Effect of Caffeine Status One possible factor determining whether caffeine is an effective ergogenic aid is the caffeine status of the subjects. In many of the studies that report an ergogenic effect, subjects abstained from caffeine use for 2–4 days prior to the experiment; they became caffeine-free for several days to possibly heighten the caffeine effect when taken. This abstention period was based on some research reporting no effects of caffeine on epinephrine or FFA levels if subjects abstained for less than 1 day. Other research documented a decreased sensitivity to caffeine following 6 weeks of increased caffeine ingestion; that is, the epinephrine level was decreased during exercise following this period of increased caffeine intake. However, in a recent review, Graham and Spriet suggest that caffeine withdrawal may have little effect on actual performance, and that subjects may consume caffeine products up to the day of the event.

Effect of Delivery System Another factor influencing caffeine's effectiveness may be how it is consumed. Graham and others compared the effects of consuming the same dose of caf-

feine in coffee or as a capsule in water. In a well-designed, double-blind, repeated-measures study with 5 trials (3 caffeine and 2 placebo), they found that although the plasma epinephrine increased with the coffee, the increase was significantly greater with the caffeine capsule. Additionally, the caffeine capsule was the only treatment to improve exercise performance, a treadmill run to exhaustion at 85 percent VO_2 max. They suggested some component or components in coffee may moderate the effect of caffeine. However, other studies have reported significant ergogenic effects when coffee was used to deliver caffeine. Moreover, McLellan and Bell recently reported that consuming coffee 30 minutes prior to taking capsulated caffeine did not negate its beneficial ergogenic effect on cycling endurance performance. Drinking coffee would not seem to impair the potential ergogenic effect of caffeine tablets.

Effect as a Diuretic Caffeine is a diuretic and also stimulates metabolism. Theoretically, increased water losses and an elevated metabolism before competition could impair exercise performance under warm, humid environmental conditions, possibly because of retarded sweat losses and excessive increases in body temperature. However, research has shown no changes in sweat loss, plasma volume, or body temperature following caffeine ingestion. Moreover, Cohen and others reported that caffeine ingestion did not impair performance in a 13.1-mile (21.1 km) half-marathon run outdoors under hot, humid conditions. Although running performance was not impaired by caffeine, neither was it improved. In a recent review of over ten studies comparing caffeinated beverages with water consumption, Armstrong noted there were few differences between the two regarding body fluid retention and urine production. Armstrong concluded that athletes will not incur detrimental fluid-electrolyte imbalances if they consume caffeinated beverages in moderation and eat a typical diet. Additionally, Armstrong and others recently reported that consuming caffeine, either 3 or 6 milligrams per kilogram body weight for five days, did not cause hypohydration, and questioned the widely accepted notion that caffeine consumption acts chronically as a diuretic.

Effect of Dosage: Legality and Safety Caffeine use has been widespread in sports for over a century, and its legality has varied. The International Olympic Committee (IOC) banned the use of caffeine as a drug prior to the 1972 Olympics. However, because caffeine is a natural ingredient in some beverages that athletes consume, the IOC removed it from the doping list from 1972 to 1982. The use of large amounts of caffeine was again banned for the 1984 Olympic games, probably because research had suggested that caffeine could artificially improve performance. Olympic athletes were permitted to consume small amounts of caffeine, but the use of large doses was grounds for disqualification. Until 2004, the maximal dose that could be used without exceeding the legal limit for doping approximated 8–10 mg/kg body weight. For a 70-kg athlete this would be 560–700 milligrams of caffeine, or about 4–6 cups of coffee or 3 Vivarin tablets. In their study Bruce and others found that many subjects consuming 9 mg caffeine/kg body weight exceeded the legal limit for doping in effect at that time. However, effective January 1, 2004, the World Anti-Doping Agency (WADA), in conjunction with the medical commission of the International Olympic Committee, removed caffeine from the list of stimulants prohibited for use by athletes. Although research suggests that caffeine is an effective ergogenic aid for various types of athletic endeavors, WADA felt that the doping list should be adjusted to reflect changing times. The removal of caffeine from the prohibited list may be a reflection of the increased prevalence of caffeinated beverages, such as specialty coffees, fortified colas, energy drinks, and even sport drinks. These drinks, which may be larger and contain more caffeine, may be consumed in quantity by athletes.

Currently, athletes need not worry about drinking caffeinated beverages and then being tested positive for use of caffeine as a performance-enhancing substance. However, a recent report suggested WADA is once again considering returning caffeine to the list of restricted performance-enhancing substances.

Individuality In general, studies have not reported a decrease in performance following caffeine ingestion. However, it should be noted that individuals vary in their responses to any drug. For example, in several of the studies the investigators reported that some subjects had adverse reactions to the caffeine and thus had an impaired performance.

Caffeine appears to be an effective ergogenic aid in doses that are both safe and legal. However, some athletes believe taking caffeine may be considered unethical because it is an artificial means of enhancing performance. Given its safety and legality, the decision to use caffeine as a performance-enhancer rests with the ethical standards of the individual athlete. Although combining ephedrine with caffeine may increase the ergogenic effect of caffeine alone, ephedrine use may be illegal—so its use to increase sports performance is unethical.

Self-experimentation If you are considering using caffeine as a potential ergogenic aid, it is wise to experiment with its use in training prior to use in competition. You might start by taking 200–400 milligrams of caffeine about an hour prior to some of your workouts. For example, if you are a distance runner, do your long runs periodically with and without the coffee or other caffeine source, and judge for yourself if it works for you. To make it a more valid case study, have someone randomly give you, blinded, a placebo (vitamin capsule) or caffeine capsule before the runs, but without informing you which until you have done each several times. Try this procedure also after abstaining from caffeine for 4–5 days. Keep a record of your feelings and times after the runs so you can compare differences.

Does drinking coffee, tea, or other caffeinated beverages pose any significant health risk?

This is one of the most hotly debated questions over the past quarter century, as about 90 percent of American adults use caffeine in one form or another, mainly coffee. In the early 1970s and 1980s a number of epidemiological studies linked coffee or caffeine consumption with the development of a variety of health problems, including heart

disease and associated risk factors such as high serum cholesterol and high blood pressure; pancreatic cancer; fibrocystic breast disease; osteoporosis; and pregnancy-related problems such as infertility, miscarriages, low birth weight, and birth defects. Conversely, other epidemiological studies have shown no relationship between coffee or caffeine consumption and these health problems. Investigators have looked at a variety of factors, including different sources of caffeine such as coffee versus tea, regular versus decaffeinated coffee, and even the method of preparing coffee, such as filtered versus boiled.

Many of the earlier reported adverse findings associated with caffeine consumption were derived from rather small epidemiological studies or from animal research using rather high doses of caffeine. However, more contemporary, larger epidemiological studies have been conducted, and several recent reviews have evaluated these reports and summarized the effect of caffeine on a variety of health problems. The following represent the key points presented in the reviews by James, Signorello and McLaughlin, Daly and Fredholm, Tufts University, and the Consumers Union, as well as other independent sources.

Cardiovascular Disease and Associated Risk Factors Caffeine is a stimulant that may affect heart function. In some individuals it may cause a slight arrhythmia, or irregular heart beat. However, recent research by Frost and Vestergaard reported that low to moderate consumption of caffeine, as coffee, does not cause the most common type of serious arrhythmia known as atrial fibrillation.

Caffeine may also acutely increase blood pressure in individuals who are caffeine sensitive and also in individuals who are under stress. Not all studies have shown that increased caffeine use is associated with high blood pressure. However, in a recent critical review of dietary caffeine and blood pressure, James concluded that findings from experimental and epidemiologic studies converge to show that blood pressure remains reactive to the pressor effects of caffeine in the diet; overall, the impact of dietary caffeine on population blood pressure levels is likely to be modest, probably increasing blood pressure by about 4 and 2 mmHg for systolic and diastolic blood pressure, respectively.

Several recent reviews have investigated the relationship between coffee consumption and serum lipid levels, noting an inconsistency in the results of most studies. Some studies have shown that both caffeinated and decaffeinated coffee may raise serum cholesterol, but others have reported no effects. In some cases where the cholesterol levels rose, the authors noted the increases were of little clinical significance. Increased serum cholesterol levels have been associated with the method of preparation, particularly boiling coffee as practiced in Scandinavia and other parts of the world. Several cholesterol-raising substances (cafestol and kahweol) have been found in the oil droplets formed in the boiling process. These substances are removed when coffee is filtered, the major means of coffee preparation used in the United States and Canada.

Homocysteine may be a risk factor for CHD, and Verhoef and others recently found that coffee may increase homocysteine levels in the blood. The increase is partly attributed to its caffeine content, but other factors may contribute as well. Caffeine raised homocysteine levels 5 percent, while coffee containing caffeine raised it 11 percent. The effect of such an increase on the risk of CHD has not been determined.

On a positive note, Salazar-Martinez and others, in a large epidemiological study, reported that total caffeine intake from coffee and other sources was associated with a statistically significantly lower risk for type 2 diabetes in both men and women; the relative risk (RR) was lower for those who drank 4 to 5 or more cups of coffee a day. The investigators suggest caffeine may increase the body's sensitivity to insulin, while others suggest coffee contains various nutrients, such as magnesium and various phytochemicals that may help the body regulate glucose metabolism.

Based on contemporary research, most health professional groups, such as the American Heart Association, recommend that moderate coffee consumption, about 1–2 cups daily, is safe and not associated with heart disease. However, the effects of consuming greater amounts of coffee are not as well known. James indicated that the effect of caffeine to increase blood pressure could account for premature deaths in the region of 14 percent for coronary heart disease and 20 percent for stroke, and indicates that strategies for encouraging reduced dietary levels of caffeine deserve serious consideration. Individuals who are hypertensive, or who are under stress, or who may have other risk factors for heart disease, should consult their physician regarding the use of caffeine.

Cancer The American Cancer Society, after reviewing the available scientific evidence, indicated there is no known association between the consumption of coffee, tea, or other caffeinated beverages and the development of any type of cancer. In support of this viewpoint, Michels and others presented data from two large epidemiological studies involving men and women, and reported that the consumption of caffeinated coffee, tea with caffeine, or caffeine was not associated with incidence of colon or rectal cancer.

Fibrocystic Breast Disease Fibrocystic breast disease involves the development of benign fibrous lumps in the breast tissue that might develop tenderness or become painful. Although an earlier anecdotal report suggested an association with caffeine intake, a major study by the National Cancer Institute (NCI) revealed no evidence supporting such an association. Both the NCI and a health committee of the American Medical Association stated there is no association between caffeine intake and fibrocystic breast disease.

Osteoporosis Factors underlying the development of osteoporosis are discussed in detail in chapter 8. Essentially, calcium loss may lead to osteoporosis. For now, we may note that caffeine tends to accelerate the loss of calcium from bones and lead to its excretion in the urine. However, the amount is very small, approximating only 5 milligrams of calcium loss for every cup of coffee. Using 2 tablespoons of milk in the coffee would replace the amount of lost calcium. In a recent report, the National Institutes of Health indicated caffeine use does not cause significant losses of calcium. However, drinking milk or eating calcium-rich foods is highly recommended if you drink caffeinated beverages.

Pregnancy-Related Health Problems Animal research has suggested that very high doses of caffeine, administered directly into the stomach via tubes, could impair fertility or interfere with fetal development, causing detrimental pregnancy consequences such as miscarriage, low birth weight, or birth defects. However, other animal research, administering caffeine in fluids as normally consumed by humans, did not produce such effects. In a recent meta-analysis of 32 human studies, Fernandes and others concluded that there is a small, but statistically significant, increase in the risks for spontaneous abortion and low birthweight babies in pregnant women consuming more than 150 milligrams of caffeine per day. However, the authors noted that they could not control for other possible confounders, such as smoking and alcohol use. In a subsequent review, Signorello and McLaughlin indicated that most of the studies were biased, and concluded that evidence for a causal link between caffeine intake and spontaneous abortion remains inconclusive. The Food and Drug Administration and the American Dietetic Association recommend that pregnant women consider abstaining from caffeine use, or if they do drink caffeine beverages to do so in moderation. In its recent report, the Consumers Union recommended they drink no more than two cups of coffee a day to avoid the possible risk of miscarriage.

Drinking caffeine beverages when breast feeding may make the child jittery as caffeine gets into breast milk.

Weight Control Caffeine use may stimulate metabolism, increasing the resting metabolic rate about 10 percent for several hours, an effect which theoretically could facilitate weight loss. Greenway notes that caffeine has a long history of safe, nonprescription use as a weight-loss supplement, and that the benefits of treating obesity appear to outweigh the small associated risk. Nevertheless, excessive amounts may cause adverse effects in some individuals, especially when combined with ephedrine as discussed below. Proper weight-control procedures are discussed in chapters 10 and 11.

Sleeplessness Caffeine use, particularly before retiring for the night, may delay the onset of sleep because of its stimulant effects.

Gastric Distress Some individuals experience stomach irritation due to increased secretion of gastric acids following ingestion of caffeinated beverages. In such cases, individuals should consult their physician or avoid caffeine.

Caffeine Naivete Abstainers or those who consume little caffeine may experience nervousness, irritability, headaches, or insomnia with moderate doses, although long-term consumption of coffee leads to development of tolerance and reduction of these "coffee nerves" symptoms. Youngstedt and others recently reported that moderate aerobic exercise may reduce the anxiety sometimes associated with caffeine intake.

Caffeine Dependence In a recent cover story for *National Geographic,* coffee was labeled a the world's most popular psychoactive drug—buzzing our brains, fraying our nerves, and robbing our sleep. Yet we simply refuse to survive without it. Although not classified as an addictive drug, some individuals may develop caffeine dependence, often referred to as caffeinism; caffeine dependence is listed in the *Diagnostic and Statistical Manual of Mental Disorders* published by the American Psychiatric Association. Juliano and Griffiths noted that caffeine-dependent individuals may experience various symptoms upon caffeine withdrawal, including headaches and nervousness, fatigue or drowsiness, depression, irritability, and difficulty concentrating. However, caffeine dependence is not considered a serious form of drug abuse.

Death Although rare, death may result from overdoses of caffeine-containing diet or stimulant pills. Individuals who take several different over-the-counter dietary supplements may be taking substantial amounts of caffeine along with other drugs. Such combinations, in excess, may be fatal.

Summary In general though, most professional health organizations note that caffeine is regarded to be a safe drug. If you are healthy and are not on medications, several cups of coffee or caffeinated beverages should pose no health problems. Where moderation is recommended, the dosage is the equivalent of less than 300 milligrams of caffeine per day, or about 2 cups of coffee. And we are talking 6-ounce cups of coffee or so, not the supersize 20-ounce cups or higher from local convenience stores.

Caffeine may actually confer some possible health benefits. Caffeine increases alertness, promotes clearer thinking, and diminishes drowsiness. These factors may contribute to safer automobile operation under certain conditions. Coffee intake is one of the few techniques Horne and Reyner reported as useful to prevent vehicle accidents related to sleepiness. Some of these mental effects may underlie the findings of the study by Ascherio and others indicating that coffee may fend off Parkinson's disease.

Key Concept Recap

- Caffeine is a stimulant drug, and can affect a variety of metabolic and psychological processes in the body that may impact exercise performance and health.
- Research suggests that caffeine may improve performance in a variety of athletic endeavors, particularly prolonged aerobic endurance exercise. An effective dose is approximately 5 milligrams per kilogram body weight.
- In general, caffeine is regarded to be a safe drug, but physicians may recommend abstinence or use in moderation for some individuals. Various health professionals define moderation as 1–2 cups per day.

Check for Yourself

Procure an automatic blood pressure monitor, or have a colleague record your blood pressure. While resting, record your blood pressure several times over a course of 15–20 minutes. Drink a cup of coffee or two, and then record your blood pressure again, about every 15 minutes over the course of an hour, again while resting. Plot the results. Does caffeine affect your blood pressure?

Ephedra (ephedrine): Ergogenic Effects and Health Implications

What is ephedra (ephedrine)?

Ephedra sinica, a plant most commonly referred to as **ephedra,** contains a variety of naturally occurring alkaloids, including **ephedrine** and pseudoephedrine. The Chinese version of ephedra is known as **ma huang** (see figure 13.6). Ephedrine is considered the most active alkaloid, and its synthetic version is ephedrine hydrochloride. Pure ephedrine is regulated as a drug, and the FDA allows only very small amounts in over-the-counter drugs such as cold medications.

Like caffeine, ephedrine is a stimulant and because it is derived from the plant ma huang, it may be classified as a dietary supplement. Ephedra or ephedrine-containing dietary supplements have been marketed to promote weight loss, increase energy, and enhance sports performance, with such names as Xtream Lean, MetabolLoss, Ripped Force, and Performance Orange. Dosages in such products may vary, but 20–25 milligrams per tablet is about average; recommended doses from supplement manufacturers may total 70–90 milligrams per day. However, Haller and others note that product inconsistency is common and the actual content of ephedrine may vary from that specified on the label.

As noted below, ephedrine use may pose some serious health risks. In 2004, the FDA prohibited the sale of ephedra or ephedrine-containing dietary supplements. However, the FDA ruling has been challenged in the courts, and as of this writing ephedrine-containing products are back in the marketplace.

FIGURE 13.6 Seeds of Ephedra sinica, or Ma Huang. The seeds may be processed into tablets for sale as a dietary supplement.

Does ephedrine enhance exercise performance?

In general, although a powerful stimulant, ephedrine by itself has not been shown to consistently enhance exercise performance. In their recent review, Rawson and Clarkson concluded that although there are few studies of the efficacy of ephedrine in improving exercise performance, these studies are consistent in their findings of no ergogenic effects. Shekelle and others, in a meta-analysis, supported this viewpoint, as did Magkos and Kavouras in their recent review, indicating that ephedrine and related alkaloids have not been shown, *as yet,* to result in any significant performance improvements. However, subsequent research has supported an ergogenic effect of ephedrine. Jacobs and others reported that the acute ingestion of caffeine and ephedrine, as well as ephedrine alone, increases local muscular endurance during the first set of traditional resistance-training exercise; however, the performance enhancement was attributed primarily to the effects of ephedrine as there was no additive effect of caffeine. If ephedrine remains in the marketplace, additional research appears to be merited.

Ephedrine with caffeine Graham indicated that the combination of ephedrine with caffeine has been suggested to be more potent than caffeine alone. Several recent studies by Bell and associates, working with Ira Jacobs at the Defence and Civil Institute of Environmental Medicine in Canada, have shown that caffeine/ephedrine combinations may enhance exercise performance in various exercise performance tasks, many of a military nature. Using pharmaceutical-grade caffeine and ephedrine doses approximating 4–5 mg/kg and 0.8–1.0 kg, respectively, they reported significant improvements in exercise tasks such as a 30-second Wingate test of anaerobic capacity, a maximal cycle ergometer performance about 12.5 minutes in duration, the Canadian Forces Warrior Test (3.2-kilometer run wearing combat gear weighing about 11 kilograms), and a 10-kilometer run wearing similar gear. In their recent review, Magkos and Kavouras indicated that caffeine-ephedrine combinations have been reported in several instances to confer a greater ergogenic benefit than either drug by itself. Research appears to support an ergogenic effect of caffeine/ephedrine supplementation in a number of studies, several involving exercise tasks of a military nature that may be applicable to enhancement of sports performance.

Legality in sports Use of ephedrine, ephedra, and ma huang in competition is prohibited by WADA and the IOC. However, caffeine, as well as pseudoephedrine, has been removed from the WADA doping list. Nevertheless, ephedrine appears to be popular with athletes. In one survey, Bents and others reported that more than half of college ice hockey players admitted using ephedrine, even when knowing such use was prohibited by the NCAA. As ephedra is banned in competition only, athletes may use it in training. Magkos and Kavouras suggested that caffeine-ephedra mixtures may become one of the most popular ergogenic aids. Indeed, sports bars containing caffeine and ephedrine from ma huang are commercially available.

Do dietary supplements containing ephedra pose any health risks?

Of all dietary supplements, the Consumers Union noted that the herbal supplement ephedra may be the most hazardous. Bent and others noted that ephedra use is associated with a greatly increased risk for adverse reactions compared with other herbs; they indicated that ephedra products accounted for 64 percent of all adverse reactions to herbs in the United States even though these products represented less than 1 percent of herbal product sales.

Use of ephedra has been associated with numerous health problems. Maglione and others reported adverse psychiatric effects of ephedra use, including psychosis, severe depression, mania or agitation, hallucinations, sleep disturbance, and suicidal ideation. Haller and others implicated ephedra with seizures. Naik and Freudenberger indicated ephedra was associated with heart arrhythmias, myocardial infarction, cardiac arrest, and even sudden death. Haller and others reported that although ephedra alone may be dangerous, ephedra combined with caffeine exaggerates the potential adverse risks.

The Ephedra Education Council notes that 100 milligrams of ephedrine per day is safe, and may be useful for individuals on a weight-loss program mainly by increasing the resting metabolic rate. However, this dose may cause problems in individuals with existing disease, such as high blood pressure or heart disease, who are attempting to lose weight. Moreover, some individuals may exceed the recommended dosage. Indeed, Haller and Benowitz noted that ephedrine misuse may be associated with significant health risks.

In recent years, the deaths of several prominent collegiate and professional athletes made headlines when it was discovered they were using ephedra-containing supplements during training under warm environmental conditions. The risk-taking behavior associated with sports participants is well known, so athletes taking more than the recommended dose is one of the major problems. Additionally, the purity and amount of ephedra in a product are not well controlled. Given these possibilities, and given its physiological effects, ephedrine could be involved in such tragedies.

Synephrine Ephedra-free dietary supplements have recently been marketed for weight loss (see figure 13.7). These products may contain synephrine, an extract from the Seville orange, or bitter, or sour orange. Synephrine is a dietary supplement in the United States, but classified as a drug in Europe. Synephrine is structurally similar to ephedrine, and has been marketed as a safe alternative to ephedra.

However, the Consumers Union indicates there is little evidence that synephrine is effective or safe, and experts suspect it could cause the same kinds of problems that ephedra does, particularly when it is combined with caffeine. Bent and others reported that synephrine was of no statistically significant benefit for weight loss. Bouchard and others reported a case study indicating that synephrine may be associated with ischemic stroke.

For individuals interested in weight loss, safer approaches are available, as detailed in chapter 11.

FIGURE 13.7 Ephedra-free dietary supplements are marketed for weight loss; many contain synephrine, a compound similar to ephedrine (see text for discussion).

Key Concept Recap

- Ephedra, or ma huang, although classified as a dietary supplement, contains a potent stimulant drug, ephedrine.
- In general, research suggests that ephedra or ephedrine supplementation does not enhance exercise or sport performance. However, supplementation with caffeine/ephedrine compounds has been shown to enhance performance in various exercise tasks.
- Use of ephedra or ephedrine-containing supplements has been associated with serious health problems, including psychiatric disorders and increased cardiovascular risk factors.

Check for Yourself

Visit a local health food store that primarily sells dietary supplements, including sports supplements. Ask the clerk to show you products containing ephedra or ephedrine for weight loss and enhanced sport performance, and also ask if there are any health risks related to their use. Record the response for class discussion.

Sodium Bicarbonate: Ergogenic Effects, Safety, and Legality

What is sodium bicarbonate?

Sodium bicarbonate is an alkaline salt found naturally in the human body. It is the major component of the alkaline reserve in the blood, whose major function is to help control excess acidity by buffering acids. Thus, sodium bicarbonate is also known as a buffer salt. Its action is comparable to that of medications you may take to control an upset stomach caused by gastric acidity. Sodium bicarbonate may be purchased in a supermarket as baking soda

(see figure 13.8), and it also has been marketed to athletes as part of a sports supplement.

Does sodium bicarbonate, or soda loading, enhance physical performance?

During high-intensity anaerobic exercise, sodium bicarbonate helps buffer the lactic acid that is produced when the lactic acid energy system is utilized. You may recall from chapter 3 that the accumulation of excess lactic acid in the muscle cell may interfere with the optimal functioning of various enzymes and thus lead to fatigue. The natural supply of sodium bicarbonate that you have in your blood can help delay the onset of fatigue during anaerobic exercise. It may facilitate the removal of the hydrogen ions associated with lactic acid from the muscle cell, thereby mitigating the adverse effects of the increased acidity (see figure 13.9). However, fatigue is inevitable if the rate of lactic acid production exceeds the capacity of your sodium bicarbonate supply to buffer it. Theoretically, an increase in the alkaline reserve could delay the onset of fatigue.

Alkaline salt supplementation has been studied for its ergogenic potential on all three human energy systems, but mainly the lactic acid energy system. Most studies have used a double-blind placebo design in which all subjects took all treatments. In the popular literature, sodium bicarbonate supplementation has been referred to as *soda loading,* from baking soda, or *buffer boosting,* for increasing the natural blood buffer content.

Lactic Acid Energy System Over a half-century ago, German scientists reported that the ingestion of sodium bicarbonate and other alkaline salts could help improve anaerobic work capacity. Since then, many studies have failed to support this finding, but now a substantial number of well-controlled experiments by highly respected investigators in sport nutrition research have provided supportive data.

FIGURE 13.8 Baking soda is a commercial version of sodium bicarbonate.

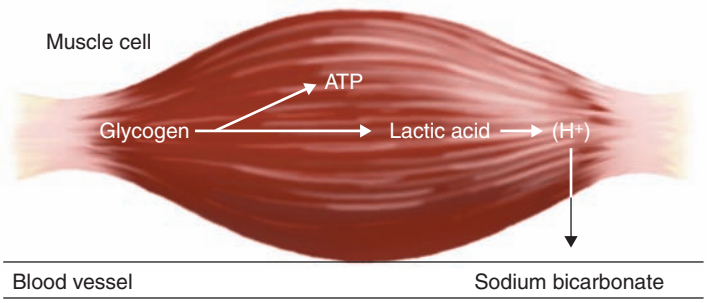


FIGURE 13.9 Alkaline salts, such as sodium bicarbonate, are theorized to reduce the acidity in the muscle cell by facilitating the efflux of hydrogen ions from the cell interior, promoting a more homeostatic environment for continued muscle contraction.

The usual experimental protocol has been to have subjects, about 1–3 hours before the exercise task, ingest a dosage of 0.15–0.30 grams of sodium bicarbonate per kilogram body weight. Recent research by McNaughton has indicated 0.30 grams per kilogram body weight appears to be the optimum dose, with higher dosages providing no additional benefits. This amount totals less than 1 ounce for the average adult. Some studies have used sodium citrate in similar dosages, because it has been shown to increase the alkaline reserve. The exercise task selected was normally one that stressed the lactic acid energy system, or about 1–3 minutes of maximal exercise. Often these exercise tasks were classified as supramaximal, because they used workloads greater than 100 percent VO_2 max. Repeated bouts of intense exercise interspersed with short rest periods have also been used, such as five 100-yard swims with a 2-minute rest between each.

A recent study by Raymer and others, using magnetic resonance spectroscopy, provided support for the main theory underlying the ergogenic efficacy of sodium bicarbonate supplementation. They reported that sodium bicarbonate ingestion delayed the onset of intracellular acidification during incremental exercise, which would help maintain a more homeostatic cellular environment to delay the onset of fatigue.

Based on the available scientific evidence, sodium bicarbonate supplementation does appear to enhance performance in exercise tasks dependent upon the lactic acid energy system (see figure 13.10). A consistent finding is an increased serum pH following sodium bicarbonate supplementation, the desired effect to induce buffering of lactic acid. Regarding other factors that have been investigated, approximately half of the well-controlled laboratory studies suggest that ingestion of sodium bicarbonate will reduce acidosis in the muscle cell, decrease the psychological sensation of fatigue at a standardized level of exercise, and increase performance in high-intensity anaerobic exercise tasks to exhaustion. Most studies provided the alkaline salt supplement an hour or more prior to exercise testing, but McNaughton and others have recently shown that chronic bicarbonate ingestion for a period of 5 days also provided ergogenic benefits on 60-second high-intensity exercise performance. Various field studies have reported significant improvements in events that primarily use the lactic acid energy system, such as 400 or 800 meters in highly trained track athletes, 100-meter swims in experienced

FIGURE 13.10 Sodium bicarbonate may enhance sports performance in a variety of events dependent primarily upon the lactic acid energy system (anaerobic glycolysis), such as the 400-meter sprint in track.

swimmers, and 5-kilometer bicycle races in trained cyclists. In support of these field studies showing improved performance following sodium bicarbonate supplementation, a recent laboratory study by Van Montfoort and others, comparing different sodium mixtures, reported that sodium bicarbonate improved run time to exhaustion in a test designed to evaluate the lactic acid energy system; the run to exhaustion approximated 77–82 seconds.

However, as with most research with nutritional ergogenic aids, not all studies find positive effects. For example, Kozak-Collins and her associates recently reported that sodium bicarbonate supplementation taken at moderate altitude did not improve the performance of competitive female cyclists on repeated 1-minute interval cycle tasks at 95 percent VO_2 max, nor did van Someren and others find any benefits on repeated 45-second high-intensity cycling bouts. Using well-trained wrestlers as subjects, Aschenbach and others reported no ergogenic effect of sodium bicarbonate during high-intensity arm ergometry involving eight 15-second maximal effort intervals with 20 seconds recovery. Portington and others also reported no effects of sodium bicarbonate supplementation on 5 maximal sets of leg press repetitions, but indicated the exercise intensity may have been lower compared to studies that have shown ergogenic effects. It should also be noted that although performance was not improved in these studies, neither was it impaired.

Several recent reviews by Matson and Tran, McNaughton, and Requena, have all concluded that sodium bicarbonate is an effective ergogenic aid in events that may depend primarily on the lactic acid energy system. Matson and Tran provided the most convincing analysis, using the meta-analytic technique to statistically compare the effects reported in twenty-nine of the best studies. In general, they noted that the ingestion of sodium bicarbonate enhanced performance, and in studies that measured exercise time to exhaustion, there was a mean improvement of 27 percent. The majority of the studies conducted subsequent to these reviews have indicated sodium bicarbonate or sodium citrate supplementation was an effective ergogenic aid.

ATP-PCr Energy System Based on the available scientific data, alkaline salt supplementation does not appear to be an effective ergogenic aid for exercise tasks dependent primarily upon the ATP-PCr energy system, since most studies have reported no beneficial effects on performance in exercise bouts lasting less than 30 seconds or in resistive exercise tasks stressing strength, power, or short-term local muscle endurance. For example, McNaughton and Cedaro reported no ergogenic effect on maximal cycle ergometer performance in either 10-second or 30-second trials. This lack of an ergogenic effect is most likely because such exercise tasks do not maximally stress the normal alkaline reserve. However, Price and others reported that ingestion of sodium bicarbonate improved performance in multiple, intermittent 14-second maximal sprints (one sprint every 3 minutes) during a 30-minute cycle ergometer trial. Moreover, Bishop and Claudius reported that sodium bicarbonate ingestion can improve intermittent-sprint performance. The test protocol involved two 36-minute halves with prints interspersed with lesser intensity exercise tasks, and the investigators suggested sodium bicarbonate may be a useful supplement for team-sport athletes. Performance in these multiple sprints may have been somewhat dependent on the lactic acid energy system.

Oxygen Energy System Although sodium bicarbonate has been studied mainly for its buffering effects, the sodium content could theoretically expand blood volume and benefit aerobic endurance performance. The effect of alkaline salt supplementation on performance in events that depend increasingly on the oxygen energy system, such as events approximating 4 minutes or more in duration, are equivocal. Several studies have shown ergogenic effects. McNaughton and Cedaro reported an increased cycle ergometer work output in a 4-minute trial, as did Linossier and others in an exhausting exercise task at 120 percent of VO_2 peak lasting 4–5 minutes. Bird and others found that sodium bicarbonate supplementation improved 1,500-meter run performance while Shave and others found that sodium citrate, as compared to a sodium chloride placebo, improved performance in a 3,000-meter run by almost 11 seconds. Using well-trained male college runners as subjects, Oopik and others found that sodium citrate supplementation improved performance in a simulated 5-kilometer treadmill run by 30 seconds. Although primarily aerobic in

nature, such exercise tasks may still depend somewhat on the lactic acid energy system. However, several studies have shown ergogenic effects of alkaline salt supplementation on exercise tasks that depend primarily on oxidative metabolism. Potteiger and others reported that sodium citrate supplementation significantly improved performance by 1.7 minutes in 30-kilometer cycling performance, and McNaughton and others reported that sodium bicarbonate supplementation, compared to the placebo trial, produced a 13 percent improvement in maximal cycle ergometer work over 60 minutes.

Conversely, other studies report no ergogenic effect of alkaline salt supplementation. Potteiger and others reported no beneficial effect of sodium bicarbonate supplementation to male runners on performance in a run to exhaustion at 110 percent of the lactate threshold following 30 minutes of running at the lactate threshold. Ball and Maughan also reported no significant effect of sodium citrate supplementation on cycle ergometer endurance at 100 percent VO_2 max. Stephens and others reported that although sodium bicarbonate supplementation induced a small muscle alkalosis, there was no effect on exercise performance. The exercise task consisted of cycling at 77 percent VO_2 max for 30 minutes, and then completing a set workload as fast as possible, which took about another 30 minutes. In a well-designed crossover study involving endurance-trained cyclists using their own bikes, Schabort and others also found no effect of varying doses of sodium citrate (0.2, 0.4, and 0.6 g/kg) on cycling endurance. The laboratory cycling protocol was designed to compare with an actual 40-kilometer road race, with 10 sets of sprints within the 40-kilometer distance. Although the sodium citrate produced dose-dependent changes in blood alkalinity, there was no significant effect on total 40-kilometer time nor on the various sprint performance times. Other studies have shown no ergogenic effects on 1,500-meter run performance. Additional research is needed to clarify this equivocality.

Stephens and others indicated that sodium bicarbonate ingestion has been shown to increase both muscle glycogenolysis and glycolysis during brief submaximal exercise, which could be detrimental to performance during more prolonged, exhaustive exercise. However, no studies have evaluated this potential ergolytic effect.

Is sodium bicarbonate supplementation safe and legal?

The dosage of sodium bicarbonate used in most of these studies, about 300 milligrams per kilogram body weight, appears to be effective yet medically safe. Relative to possible disadvantages, several investigators have noted that some subjects developed gastrointestinal distress, including nausea and diarrhea. Shave and others noted a high potential for gastrointestinal distress in their study that used 0.5 grams of sodium citrate per kilogram body weight, and suggested that this may limit the use of this strategy by athletes in competition. Excessive doses could lead to alkalosis, with symptoms of apathy, irritability, and possible muscle spasms. Given the potential gastrointestinal distress often associated with an acute high dose of sodium bicarbonate, research by McNaughton and Thompson suggests that a chronic loading protocol, or taking the same total amount of sodium bicarbonate spread over a 6-day period, may be just as effective.

Use of sodium bicarbonate currently is not prohibited by WADA. As noted, sodium bicarbonate (baking soda) use by athletes has been dubbed *soda loading,* possibly to liken it to *carbohydrate loading.* As you may recall, the purpose of carbohydrate loading is to increase the storage of muscle and liver glycogen as a means to prevent fatigue in prolonged endurance events. Soda loading is viewed by some in a similar context, an attempt to increase the supply of a natural body ingredient helpful as a means to delay fatigue. However, because sodium bicarbonate may be regarded as a drug, it remains to be seen whether this technique will be deemed illegal. Tim Noakes, in the recent edition of his classic text *Lore of Running,* indicated that the use of sodium bicarbonate may be prohibited by the International Olympic Committee in the near future. Currently there is no test to detect its use, except for urinary pH, which can also be affected by some antacids, and at present sodium bicarbonate is considered to be legal for use in sports.

Key Concept Recap

- Sodium bicarbonate supplementation appears to be an effective ergogenic aid in exercise tasks that depend primarily upon the lactic acid energy system (anaerobic glycolysis), such as a 400-meter dash in track.
- Sodium bicarbonate supplementation may also enhance performance in other types of exercise tasks involved in various sports, such as multiple sprints and high-intensity endurance runs, if such activities depend somewhat on the lactic acid energy system.
- Ingestion of sodium bicarbonate is generally regarded as safe, but may cause acute gastrointestinal distress and diarrhea. Supplementation over a longer time frame may be effective and less likely to cause intestinal problems.

Anabolic Hormones and Dietary Supplements: Ergogenic Effects and Health Implications

Several hormones in the body may exert significant anabolic effects on body composition by stimulating protein synthesis, particularly insulin, human growth hormone (HGH), and testosterone. As noted in previous chapters, several nutrient supplements, such as specific amino acids, have been utilized in attempts to increase the secretion of these hormones for anabolic purposes. Two of these hormones, HGH and testosterone, as well as drugs patterned after testosterone, have been used directly to increase muscle mass. Additionally, several prohormones that may be converted into testosterone have been marked as dietary supplements.

Is human growth hormone (HGH) an effective, safe, and legal ergogenic aid?

HGH is a natural hormone secreted by the anterior pituitary gland in the brain; HGH is an anabolic hormone that stimulates bone growth and the development of muscle tissue through its effects on protein, carbohydrate, and fat metabolism. A detailed discussion of the role of HGH is beyond the scope of this text. It is important to note, however, that extensive research into its effects began only recently when genetically engineered versions (recombinant HGH, or rHGH) of the natural body hormone became available in the early 1990s. rHGH injections are therapeutic for individuals with impaired HGH pituitary production or secretion. Available data suggest that in elderly men, who normally have reduced levels of HGH, injections of the hormone modify body composition, decreasing body fat and increasing lean body mass. However, in a recent review, Frisch indicated that the increase in lean body mass in rHGH-treated individuals was not due to increased muscle contractile protein but rather to water and connective tissue. Several studies have supported this viewpoint, particularly when rHGH is used during resistance training. For example,Yarasheski and others studied the effect of rHGH versus a placebo on adult males who weight-trained for 12 weeks. They reported significant increases in lean body mass in the group receiving rHGH, but there were no significant increases in skeletal muscle protein synthesis and size, as measured by magnetic resonance imaging, or in muscular strength, over the effects produced by weight training alone in the placebo group. They suggested that rHGH may influence the development of other tissues. More recently, Taaffe and others reported no significant increase in muscle fiber size, as determined by muscle biopsy, following 10 weeks of resistance training and rHGH injections. Several other well-controlled studies reported similar findings with rHGH supplementation to experienced resistance-trained athletes. However, Healy and others recently reported that HGH injections exerted an anabolic effect during rest and exercise and increased whole body protein in endurance-trained athletes, but whether the increase was muscle mass was not determined. Nevertheless, these investigators indicated that short-term administration of HGH may have short-term benefits for physical performance. The interested reader is referred to the recent review by Dean, who noted that there is no evidence of increased muscle strength with HGH use in trained athletes. The reader is referred also to recent reviews by Kraemer and others, Frisch, and Zachwieja and Yarasheski.

Some athletes use rHGH to train harder and build muscle, and anecdotal reports suggest that it may work for these intended purposes. However, at present, there are no good scientific data to support an ergogenic effect of rHGH on muscle size, strength, or power beyond the effect generated by a proper weight-training program. Additionally, HGH use by athletes is prohibited by the International Olympic Committee.

The potential adverse health effects of rHGH are substantial, including insulin resistance, high blood pressure, and increased risk of congestive heart failure. Most researchers also caution that the long-term health risks of HGH administration, either as rHGH or produced by amino acid supplementation, are unknown. This is particularly distressing as one report indicated approximately 5 percent of high school students have used HGH. In some pathological conditions, the pituitary gland secretes excess HGH, which is associated with acromegaly, or thickening of soft tissues in the face, hands, and feet. Excess HGH may also cause enlargement of body organs, such as the liver, and may lead to diabetes.

Are testosterone and anabolic/androgenic steroids (AAS) effective, safe, and legal ergogenic aids?

Testosterone, the male steroid sex hormone produced by the testes, was one of the first anabolic agents used in attempts to enhance physical performance, possibly as early as the 1936 Berlin Olympic Games. As documented in the study by Bhasin and the review by Evans, testosterone is a very effective ergogenic aid, increasing lean muscle mass, decreasing body fat, and increasing strength even without resistance training; these anabolic effects were augmented in subjects who also trained. Testosterone must be injected because ingested testosterone will be catabolized by digestive enzymes. Although injected testosterone use is still prevalent among various athletic groups, oral drug forms of testosterone have been developed, as noted here.

Anabolic/androgenic steroids (AAS) represent a class of synthetic drugs designed to mimic the effects of testosterone. The chemical structure of testosterone may be modified in attempts to maximize the anabolic muscle-building effects and minimize the androgenic male secondary sex characteristics; both oral and injectable AAS have been developed.

In the United States, AAS are classified as Schedule III drugs under the Controlled Substances Act, and may be used medically for several conditions, such as treatment of anemia, osteoporosis, and gonadal dysfunction. Earlier research suggested that AAS may be useful in older males by helping to prevent sarcopenia (loss of muscle) with the aging process, but Liu and others indicate AAS supplementation is not recommended because of potential health problems, as noted below.

AAS are the drugs of choice for many strength athletes and bodybuilders to improve performance and appearance. AAS have been used by professional athletes for years, as documented in the revealing book, *Wild Times, Rampant 'Roids, Smash Hits, and How Baseball Got Big* written by a former professional baseball player.

Bahrke and others noted that recent surveys indicate the use of AAS is also prevalent among adolescent athletes, particularly boys in strength-related sports. Their use is even common among young male nonathletes, and increasing numbers of teen-age girls, according to Yesalis and others, who desire to increase muscle mass for an enhanced self-image. Faigenbaum and others recently reported AAS use in middle-school students, ages 9–13, with the belief that they improved sports performance and physical appearance. In general, surveys have indicated that approximately 4–6 percent of boys and 1–2 percent of girls have used AAS.

Although resistance training does not cause drug use, DuRant and others recently noted that adolescent AAS users in the United

States, both athletes and nonathletes, are more likely to engage in strength training. AAS use is also associated with use of other recreational drugs. Thus, young adolescent athletes and nonathletes engaged in strength training should be educated about the health risks associated with AAS use.

The effects of AAS on body composition and strength have been studied rather extensively, and although there may be some flaws in the experimental designs used, most reviewers agree that AAS use may increase muscle mass and strength and decrease total body fat, a judgment supported by recent reviews of laboratory studies that included meta-analysis as part of the evaluative criteria. The increased muscle mass may be attributed to hypertrophy and the formation of new muscle fibers, in which key roles are played by the androgen receptors, as depicted in figure 13.11.

However, AAS use has been associated with a number of medical problems, as documented in recent reviews by Hartgens and Kuipers, and Yesalis and Bahrke. Some are relatively minor such as acne and loss of hair. AAS may also adversely affect psychological processes, leading to increased aggression, hostility, depression, and possible suicide attempts, and an increased tendency to commit violent crimes, including homicide. Continued use may predispose adults to coronary heart disease by inducing structural changes in the heart-muscle, decreasing HDL-cholesterol, and increasing blood pressure as documented in both epidemiological and experimental studies, and recently reviewed by Nnakwe. Prolonged steroid use may possibly lead to impaired development of tendons, decreasing their strength and contributing to a potential for rupture. Prolonged use has resulted in severe liver diseases, including cancer. Anabolic steroids may cause premature cessation of bone growth in children and adolescents and may result in the appearance of several male secondary sex characteristics in females, some of which may be irreversible, such as deepening of the voice. Table 13.4 highlights many of the health problems associated with abuse of AAS.

However, many of the adverse health effects of AAS use appear to be reversible. For example, Hartgens and others found that bodybuilders who cycled off AAS steroids for 3 months had similar lipoprotein profiles and liver enzymes as their non-drug-using counterparts. Moreover, earlier reviews noted that although the short-term health effects of AAS have been increasingly studied and reviewed, and while AAS use has been associated with adverse and even fatal effects, the incidence of serious effects thus far reported has been extremely low. However, subsequent to these reviews, Urhausen and others reported that several years after discontinuation of anabolic steroid abuse, strength athletes (bodybuilders and powerlifters) who used AAS showed a slight concentric left ventricular hypertrophy in comparison with AAS-free strength athletes; left ventricular hypertrophy increases the risk of heart attack.

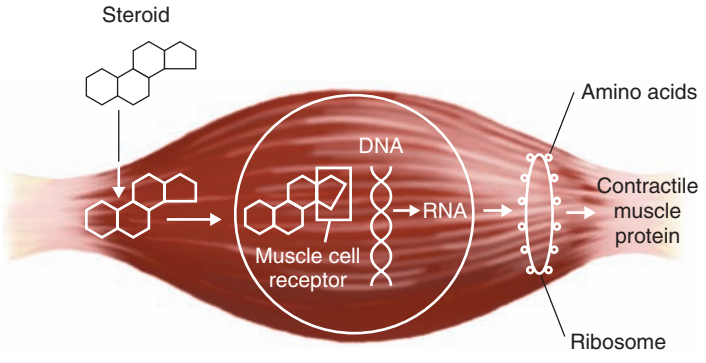


FIGURE 13.11 Anabolic steroids picked up by androgen in the cell nucleus initiate the process of protein formation in cells such as muscle fibers, leading to muscle hypertrophy.

TABLE 13.4 Possible Health Risks Associated with Use of Anabolic/Androgenic Steroids (AAS)

Cosmetic-related effects
Facial and body acne
Female-like breast enlargement in males (gynecomastia)
Premature baldness
Masculinization in females
Facial and body hair growth in females
Premature closure of growth centers in adolescents, leading to stunted growth
Deepening of the voice in females
Psychological effects
Increased aggressiveness and possible violent behavior
Reproductive effects
Reduction of testicular size
Reduction of sperm production
Decreased libido
Impotence in males
Enlargement of the prostate gland
Enlargement of the clitoris
Cardiovascular risk factors and diseases
Atherosclerotic serum lipid profile
Decreased HDL-cholesterol
Increased LDL-cholesterol
High blood pressure
Impaired glucose tolerance
Increase size of left ventricle
Stroke
Heart disease
Liver function
Jaundice
Peliosis hepatis (blood-filled cysts)
Liver tumors
Athletic injuries
Tendon rupture

Because of the potential health risks, one of the risk-reduction objectives in *Healthy People 2010* is the reduction of AAS use among high school students. Moreover, the U.S. Congress has passed legislation to classify AAS as controlled substances, thus limiting their production and distribution by pharmaceutical companies. Penalties may be severe. Additionally, most individuals obtain these drugs illegally on the black market where quality is not controlled, and chemical analysis has revealed some potentially hazardous constituents in these "homemade" drugs. AAS users are known to use other illicit drugs as well, each carrying independent health risks.

As is obvious, the use of testosterone or AAS for the purpose of gaining body weight and strength is not recommended. Moreover, their use by athletes is grounds for disqualification for future competition. The American College of Sports Medicine has developed a position statement on the use of anabolic steroids in sports. Although an extensive discussion of AAS is beyond the scope of this text, the ACSM report provides a detailed review for the interested reader, as does the most recent review by Yesalis and Bahrke.

Are anabolic prohormone dietary supplements effective, safe, and legal ergogenic aids?

Several dietary supplements marketed to athletes as potent anabolic agents are of special interest, particularly dehydroepiandrosterone (DHEA), androstenedione, and related compounds. These supplements are classified as prohormones because they are precursors for testosterone and are thus theorized to increase muscle mass and decrease body fat. They may be derived from certain plants, such as wild yams. Although these prohormones have been marketed as dietary supplements, in 2005 the FDA classified them as controlled drugs, similar to anabolic steroids.

Dehydroepiandrosterone (DHEA) and its sulfated metabolite (DHEAS) are produced in the body by the adrenal and gonadal glands, and may be converted into androstenedione with subsequent conversion to testosterone in peripheral tissues, including fat and muscle tissue. Body levels of DHEA are high in young adulthood and gradually decrease to low levels with aging. Although Abbasi and others reported a low, but significant, inverse relationship between natural DHEA levels and body fat in men aged 60–80 years, there are no data supporting beneficial effects of DHEA supplementation. Using well-controlled experimental designs, recent studies by Wallace and Brown and their associates revealed no significant effects of DHEA supplementation (50–100 milligrams/day for 8–12 weeks) on serum testosterone levels, lean body mass, or muscular strength in either healthy middle-aged or young men involved in resistance training.

DHEA has also been marketed as an anti-aging agent to help prevent the development of chronic diseases, but in a recent review, Sirrs and Bebb indicated no good scientific data support this speculation. They caution against use of DHEA supplements as high serum DHEA levels have been associated with several health risks, including several forms of cancer. Nevertheless, a recent study by Villareal and others provided some preliminary data supporting positive effects of DHEA supplementation on bone mineral density, body fat, and lean body mass in elderly subjects with very low levels of natural DHEA. The authors recommended additional research. These data with elderly subjects with very low DHEA levels do not support DHEA supplementation to young or middle-aged individuals. For example, Conrad Earnest, an expert in anabolic dietary supplements, reported that DHEA supplementation at relatively low doses (50–150 milligrams) does not enhance serum testosterone in young men. Moreover, Acacio and others found that six months supplementation with DHEA to young men aged 18–42 elevated levels of a metabolite that raised concerns about the potential negative impact of DHEA supplementation on the prostate gland.

Androstenedione and related compounds, such as androstenediol and norandrostenediol are potent anabolic agents, one step removed from the formation of testosterone. Androstenedione received considerable notoriety during the 1998 baseball season when Mark McGwire, who established a home run record at that time, acknowledged using the dietary supplement. Subsequently, androstenedione-related products flooded the marketplace for resistance-trained individuals, even though no reputable research was available supporting beneficial effects.

Based on previous research with testosterone, Leder and others suggest large doses of androstenedione may be ergogenic, particularly with individuals who take multiple doses daily. However, several subsequent studies have evaluated the ergogenic effects of androstenedione supplementation, and most have shown no beneficial effects. In a short-term study, Rasmussen and others found no effect of oral androstenedione supplementation (100 milligrams/day for 5 days) on serum testosterone or muscle protein anabolism in young men. In a more prolonged study, Wallace and others reported no significant effects of androstenedione supplementation (100 milligrams/day for 12 weeks) on serum testosterone levels, lean body mass, or muscular strength in resistance-trained middle-aged men. Using three individual 100-milligram androstenedione doses daily (total 300 milligrams/day), King and others reported no significant effects on serum testosterone, body fat, lean body mass, muscle fiber diameter, or muscular strength in young men during 8 weeks of resistance training. Other studies, using somewhat higher doses, reported positive findings. Leder and others, although finding no significant effects of a 100-milligram dose, reported significant increases in serum testosterone in adult men following a 300-milligram dose, but no exercise performance was measured. Earnest and others also reported significant, but small, increases in total testosterone with a 200-milligram dose of androstenedione, but not androstenediol, supplementation. In a study with young women, Brown and others reported that androstenedione intake (100 or 300 milligrams) significantly increased serum testosterone concentrations.

Recent reviews do not support an ergogenic effect of androstenedione and its congeners. Earnest noted that even though increases in testosterone following androstenedione ingestion have been found to be statistically significant, they have not been accompanied by favorable changes in protein synthesis or metabolism, muscle mass

or lean body mass, or strength. These findings have also been supported in reviews by Tim Ziegenfuss and Ron Maughan.

Use of androstenedione and its congeners may be associated with increased health risks. Earnest indicated that androstenedione supplementation has been associated with impaired lipid metabolism, such as decreased HDL-cholesterol and increased LDL-cholesterol, which might increase risk for cardiovascular disease. Several studies have reported significant increases in estrogen hormones (estradiol or estrone), which could exert feminizing effects in males, such as gynecomastia (breast enlargement). Other adverse effects on gonadal hormones may be associated with testicular shrinkage and infertility. Leder also notes women and children who use such supplements may be at risk. Unfortunately, given the recency of such supplements, no long-term safety data are available.

For athletes who may be tested for doping, the use of DHEA or androstenedione and related prohormones has been banned by WADA and the International Olympic Committee; their use has also been banned by other sports organizations, including the National Collegiate Athletic Association and the National Football League. Although anabolic metabolic prohormones are currently banned for sale in the United States, a number of substitutes for these products are being marketed on the Internet. However, athletes should be aware that such products may be contaminated. In a recent study, Geyer and others secured 634 nutritional supplements from 13 countries, and 14.8 percent contained anabolic androgenic steroids not declared on the label, and the administration of some of the supplements resulted in positive doping tests.

Key Concept Recap

- The use of anabolic drugs or hormones to increase body weight may be effective but may also lead to a variety of health problems.
- Research has shown that prohormone dietary supplements marketed as anabolic agents, such as androstenedione, do not effectively increase muscle mass or strength. Moreover, such prohormones have been classified as controlled anabolic steroids and their use is illegal.

Check for Yourself

Go to the Internet search engine www.google.com, type in anabolic steroids, and check the advertisements and information related to laws and use of such products. Share the information with your classmates. Now that androstenediol products are illegal, check advertisements for various replacements, such as androstenetrione.

Ginseng, Herbals, and Exercise and Sports Performance

Numerous herbals, which may be regulated as drugs in some countries, have been marketed as ergogenic aids for athletes. Unfortunately, with the exception of ginseng and related products, limited research has evaluated their ability to enhance exercise or sport performance.

Do ginseng or ciwujia enhance exercise or sport performance?

Ginseng and ciwujia are comparable herbs, and both have been studied for their potential effects on exercise or sport performance.

Ginseng Extracts derived from the plant family Araliaceae contain numerous chemicals that may influence human physiology, the most important being the glycosides, or ginsenosides. Collectively, these extracts are referred to as **ginseng,** and their physiologic effects vary depending on the plant species, the part of the plant used, and the place of origin. The most common forms of ginseng include Chinese or Korean (Panax ginseng), American (Panax quinquefolium), Japanese (Panax japonicum), and Russian/Siberian (Eleutherococcus senticosus). Eleutherococcus senticosus is a totally different plant from Araliaceae, but it is recognized by some as a legitimate form of ginseng and its ginsenosides are also referred to as eleutherosides. The type and amount of ginsenosides present vary greatly among the different forms of ginseng.

Using such labels as Ginseng Energy, ginseng has been marketed in various forms as a means of enhancing health and physical performance (see figure 13.12). Although the underlying mechanisms are unknown, ginseng is believed to influence neural and hormonal activity in the body and has also been theorized to enhance the immune system. The most prevalent theory suggests ginseng may stimulate the hypothalamus, the part of the brain that controls the pituitary gland, an endocrine gland often referred to as the master gland. The pituitary gland releases hormones that influence other endocrine glands in the body, such as the adrenal gland. The adrenal gland releases cortisol, a hormone involved in the response to stress. The Russians conducted much of the early research with ginseng, and used the term "adaptogens" to characterize its ability to increase resistance to the catabolic effects of stress. Because excessive stress is believed to influence the development of a number of chronic diseases, particularly coronary heart disease, ginseng has been used for its alleged therapeutic properties.

The Russians believed that ginseng helped develop resistance not only to mental stress but also to the physical stress of intense exercise training. Other theories suggest ginseng supplementation may influence physical performance in other ways as well, such as increased cardiac function, blood flow, and oxygen transport during exercise; increased oxygen utilization and decreased lactic acid levels during exercise; enhanced muscle glycogen synthesis after exercise; and a positive effect on nitrogen or protein balance. In essence, given these theorized antistress effects, restorative effects, and metabolic effects, ginseng supplementation is theorized to enhance sport performance by allowing athletes to train more intensely and by influencing physiological processes associated with an antifatiguing effect that increase stamina during competition. It should be noted that although numerous theories have

FIGURE 13.12 Various gingseng products are available as dietary supplements, some being marketed directly to athletes.

been advanced in attempts to explain the alleged ergogenic effects of ginseng supplementation, an underlying mechanism has yet to be determined.

Although numerous studies investigated the ergogenic possibilities of ginseng supplementation, few were well-controlled. Research design flaws included no control or placebo group, no double-blind protocol, no randomization of order of treatment, and no statistical analysis. Highlighting these methodological problems in an extensive 1994 review of the ergogenic effect of ginseng supplementation, Michael Bahrke and William Morgan concluded that there is a lack of controlled research demonstrating the ability of ginseng to improve or prolong performance.

Subsequent to the review by Bahrke and Morgan, several well-controlled studies evaluated the ergogenic effects of both standardized ginseng extracts and commercial products and reported no significant effects. For example, Dowling and others reported no effect of Eleutherococcus senticosus on metabolic (oxygen uptake and lactic acid accumulation), physiologic (heart rate and ventilation), or psychologic (ratings of perceived exertion) responses to submaximal and maximal running. Using a similar research protocol but with cycling, Engels and Wirth reported no ergogenic effect of Panax ginseng. Other well-controlled studies by Engels and his associates have found no ergogenic effect of Panax ginseng on high-intensity, interval anaerobic exercise protocols. However, Ziemba and others reported that although Panax ginseng did not influence exercise capacity in soccer players, it did improve multiple-choice reaction time before and during a cycling exercise task. Such an effect may be of benefit to athletes who must react quickly in sports. This finding merits additional research.

Overall, in a recent update of their 1994 review, which includes an additional 35 reports, Bahrke and Morgan note that although more well-controlled research is needed, they again concluded that there is an absence of compelling research evidence regarding the efficacy of ginseng use to improve physical performance in humans. In an analysis of herbal supplements and exercise performance, Williams and Branch cited several other recent major reviews supporting the conclusions of Bahrke and Morgan. Most recently, Goulet and Dionne reviewed studies evaluating the effect of Eleutherococcus senticosus on exercise performance, and concluded that it offers no advantage during exercise endurance tests ranging in duration from 6 to 120 minutes.

Most commercial ginseng preparations appear to have relatively low acute or chronic toxicity when taken in dosages recommended by the manufacturer. Coon and Ernst noted that the most commonly experienced adverse events of Panax ginseng are headache and sleep and gastrointestinal disorders. In general, they found that Panax ginseng, when taken alone and not combined with other substances, is rarely associated with adverse effects. These effects may be attributed to the postulated stimulant effect of ginseng, or possibly to additional substances in the commercial preparation, such as the stimulant ephedrine. For athletes involved in sports that may use drug testing, the use of ginseng products containing ephedrine could lead to disqualification.

Some research suggests long-term ginseng supplementation may prevent some adverse effects of stress on the immune system. Although not studied extensively in athletes, a healthier immune system could help prevent illness or some of the symptoms of the overtraining syndrome during high-intensity training. However, Engels and others recently reported Panax ginseng had no significant effect on immune functions during recovery from intense anaerobic exercise.

Given the available scientific evidence, ginseng supplements cannot be recommended. The consumer should also be aware that commercial ginseng products may suffer from quality control. A recent assay of fifty commercial ginseng preparations indicated that over 10 percent of the products contained no detectable ginsenosides, and the amount in the remaining products varied from 1.9–9.0 percent. Many commercial products contain alcohol.

Individuals who desire to experiment with long-term ginseng supplementation should consult with their physicians, because ginseng use may exacerbate various health problems, such as high blood pressure.

Ciwujia **Ciwujia,** a Chinese herb, is similar to ginseng. Cheuvront and others indicate that ciwujia is extracted from Araliaceae, the same plant family as Panax ginseng. Along with Plowman and others, they also note that it may be derived from the leaves of Eleutherococcus senticosus. Ciwujia is the main active ingredient in the commercial product, Endurox™. Endurox™ is marketed to endurance athletes, and literature published by its manufacturers suggest that it can increase fat oxidation (possibly sparing muscle glycogen), increase oxygen consumption, reduce lactate accumulation, and improve heart rate recovery after exercise. However, most of these claims are based on clinical trials

with poor experimental designs. Plowman and others noted that none of the studies followed a randomized crossover or double-blind protocol, nor was the use of a placebo mentioned. None have been published in peer-reviewed journals.

Two recent studies by Plowman, Cheuvront, and their associates, using double-blind, placebo-controlled, crossover experimental designs and published in peer-reviewed journals, reported that supplementation with Endurox™ (800 mg for 7–10 days) had no significant effect on heart rate, oxygen consumption, respiratory exchange ratio (a measure of fat oxidation), lactic acid accumulation, or ratings of perceived exertion during either cycle ergometer or stair-climbing exercise. The investigators indicated their studies did not verify the claims made for Endurox™.

Based on the available evidence, products containing ciwujia do not appear to enhance exercise performance, and thus are not recommended for use by endurance athletes.

What herbals are effective ergogenic aids?

As noted earlier, caffeine may be derived from various herbals, such as guarana and the kola nut, whereas ephedra is a constituent of ma huang. Other than these and ginseng, athletes have experimented with a variety of other herbals, including cayenne for energy and gamma-oryzanol to increase muscle mass.

Kundrat, in a report on herbs and athletes, indicated that double-blind, placebo-controlled human research on herb use by athletes is limited or nonexistent. One reason may be that, at least in the United States, herbs are regulated as dietary supplements and are not required to be standardized, so there is little consistency among different brands. Moreover, herbal sport supplements may often contain several herbals and other substances in a commercial product, so it is difficult to isolate the potential ergogenic effect of a single ingredient.

Studies conducted with such commercial herbal-based sports supplements, such as the recent study by Earnest and others, generally report no significant ergogenic effects.

Nevertheless, several reviews of herbal supplementation and exercise performance are available. In their review, Williams and Branch noted that much of what we know about the efficacy of herbal supplements as ergogenics is based on anecdotal data and poorly controlled studies. However, based on their analysis, they concluded that none of the following herbals have sufficient research support as a means of enhancing exercise or sport performance: bee pollen, capsicum, gamma-oryzanol, ginkgo biloba, kava kava, St. John's wort, Tribulus terrestris, and yohimbine.

Subsequent to these reviews, several other herbals have been studied for their purported ergogenic potential. The herb Cordyceps sinensis is a health tonic from China; although it is rare, a synthetic version is now available; one version is CordyMax Cs-4. Cordyceps sinesis is theorized to have favorable effects on the heart and circulation to improve oxidative capacity and endurance performance. However, Parcell and others reported that 5 weeks of CordyMax Cs-4 supplementation had no effect on aerobic capacity of endurance-trained male cyclists.

Rhodiola rosea, like ginseng, is categorized as an adaptogen, and has been theorized to enhance endurance performance through a stimulating effect. In a preliminary study, De Bock and others found that an acute dose (200 milligrams) of Rhodiola rosea improved time to exhaustion by 3 percent on a cycle ergometer, but there was no significant effect following four weeks of supplementation with 200 milligrams daily. There was no effect on maximal strength or various measures of reaction time or movement time. The improved time to exhaustion following an acute dose may have been a chance finding, and this study merits replication; as the authors noted, it was a preliminary study.

Cytoseira canariensis has been marketed as a new sports supplement designed to increase muscle mass and decrease body fat by inhibiting myostatin. Myostatin is a protein known as a growth and differentiation factor, and its role is to inhibit (not promote) the growth of muscles. Theoretically, by inhibiting the effects of myostatin, muscle growth may be increased. However, Darryn Willoughby, an exercise scientist at Baylor University, reported that 1,200 milligrams/day of Cystoseira canariensis supplementation during 12 weeks of resistance training had no effect on serum myostatin levels, not did it have any effect on muscle mass, muscle strength, or body fat.

Kundrat indicated that athletes should be concerned about the safety of herbals, as there may be some side effects or herb-drug interactions. For athletes using herbals for weight loss, Pittler concluded that the potential health risks recommended against such use due to an increased risk relative to benefit. Athletes contemplating using herbals should consult with their health care professional.

Key Concept Recap

- Results from well-controlled research indicate that ginseng and related adaptogens, such as ciwujia, are not effective ergogenic aids.
- There is limited well-controlled research regarding the effect of herbals on exercise or sport performance, and that which is available suggests herbal sports supplements are not effective ergogenic aids.

APPLICATION EXERCISE

If you or one of your colleagues is physically trained or an athlete, you might want to conduct a small case study with caffeine. Either of you should be physically trained to run a mile, swim 500 meters, or some comparable exercise task of 5–10 minutes of high-intensity exercise. Other exercise tasks of shorter duration may be selected. The activity is best done indoors to control environmental conditions. One of you can serve as the investigator and the other as the subject. A third colleague will administer the treatment on a double-blind basis. Randomly, over a 5-week period, the subject will participate in five trials, each involving maximal performance for the selected activity. Thirty minutes before the test, the subject should consume either two caffeine tablets, each containing 200 milligrams of caffeine (Vivarin or comparable over-the-counter tablet) or a comparable placebo (two multivitamin tablets) with some water. The subject's eyes should be closed while taking the tablets. Here is the weekly protocol.

Week 1—Learning protocol; no placebo or caffeine
Week 2—Placebo or caffeine
Week 3—Caffeine or placebo (opposite of week 2)
Week 4—Placebo or caffeine
Week 5—Caffeine or placebo (opposite of week 4)

Record the performance times for each, average the two placebo and two caffeine trials, and compare the results for improvement, if any.

Caffeine Trial

	Week 1 (no placebo or caffeine)	Week 2 (placebo or caffeine)	Week 3 (opposite of week 2)	Week 4 (placebo or caffeine)	Week 5 (opposite of week 4)
Performance Time					

Review Questions—Multiple Choice

1. Of the drugs and supplements discussed in this chapter, which have the most research supporting their ability to enhance exercise or sports performance?
   (a) caffeine and androstenedione
   (b) gingseng and ephedrine
   (c) alcohol and DHEA
   (d) androstenedione and ephedrine
   (e) sodium bicarbonate and caffeine
2. About how many milligrams of caffeine are in a 6-ounce cup of perked coffee?
   (a) 25–30
   (b) 100–125
   (c) 300–400
   (d) 500–600
   (e) 1,000
3. Which of the following is not a physiological effect of caffeine?
   (a) decreases the metabolic rate
   (b) stimulates the central nervous system
   (c) increases the secretion of epinephrine
   (d) increases heart rate and force of contraction
   (e) increases force of skeletal muscle contractility
4. For an average-size male adult (150 pounds), the consumption of four (4) drinks within a very short period of time would elevate the blood alcohol concentration (BAC) to about what level?
   (a) 0.01
   (b) 0.02
   (c) 0.05
   (d) 0.10
   (e) 0.15
5. As a potential ergogenic aid, sodium bicarbonate would be most likely suited to which type of athlete?
   (a) marathon runner (26.2 miles)
   (b) 100-meter sprinter (track)
   (c) 400-meter sprinter (track)
   (d) pole vaulter (field)
   (e) discus thrower (field)
6. Increasing reearch suggests that moderate alcohol consumption, or "low risk" drinking, may reduce the risk of CHD and all-cause mortality. All of the following, except which, are hypothesized to contribute to this reduced risk?
   (a) a relaxation effect and reduced anxiety
   (b) decreased platelet aggregability (decreased possibility of blood clots)
   (c) increased blood flow to the brain
   (d) reduces caloric intake, induces weight loss, and prevents metabolic syndrome
   (e) an increase in HDL-cholesterol
7. Research generally supports the theory that caffeine may enhance performance in long-distance endurance events. Which of the following is the *least* likely hypothesis?
   (a) It may exert a psychological stimulating effect.
   (b) It stimulates the release of epineprhine from the adrenal gland.
   (c) It decreases the use of both free fatty acids and muscle glycogen.
   (d) It may decrease the perception of effort during exercise.
   (e) It may exert a direct effect on the muscles to increase muscle contractile force.
8. Anabolic/androgenic steroids (AAS) are drugs popular with individuals with

muscle dysmorphia, or those who desire to increase muscle mass even though already very muscular. AAS are designed to mimic mainly the anabolic effects of which natural hormone in the body?
(a) insulin
(b) human growth hormone (HGH)
(c) testosterone
(d) androsterone
(e) estrogen

9. Which of the following dietary supplements marketed to strength-trained individuals are precursors, or prohormones, for testosterone?
(a) creatine and conjugated linoleic acid
(b) gamma oryzanol and ginseng
(c) Cordycepts sinensis and Cytoseira canariensis
(d) HMB and tribulous terrestris
(e) androstenedione and DHEA

10. Which of the following ergogenic aids are currently permitted for use by athletes in all sports competitions according to the doping list created by the World Anti-Doping Agency (WADA)?
(a) caffeine and ephedrine
(b) sodium bicarbonate and caffeine
(c) caffeine and alcohol
(d) androstenedione and DHEA
(e) ginseng and ephedrine

Answers to multiple choice questions: 1. e; 2. b; 3. a; 4. d; 5. c; 6. d; 7. c; 8. c; 9. e; 10. b.

Review Questions—Essay

1. Discuss both the potential beneficial and adverse health effects of consuming various amounts of alcohol.
2. Discuss the efficacy, safety, and legality of caffeine supplementation as an ergogenic aid for aerobic endurance athletes.
3. Discuss the efficacy, safety, and legality of sodium bicarbonate supplementation as an ergogenic aid. In which types of sports would it appear to be most effective?
4. Compare and contrast the effects of testosterone, versus its congeners DHEA and androstenedione, as ergogenic aids for the development of muscle mass and strength. Discuss possible health risks associated with use of each.
5. What is ginseng, why is it purpoted to be an ergogenic aid, and does research support its efficacy as an ergogenic?

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