CHAPTER 8 Water

Key Questions Addressed

- What's the big deal about water?
- What are the consequences of poor water balance?
- How much fluid do individuals need on a daily basis?
- What is the role of preexercise hydration?
- What is the role of hydration during exercise?
- What is the role of postexercise hydration?

You Are the Nutrition Coach

Chad is a collegiate lacrosse player in Arizona. During preseason and in-season training, the team will practice for hours, often in 80- to 90-degree weather. The coach incorporates fluid breaks during practice; however, he allows the athletes to consume only water. The coach believes that sports beverages hinder performance and therefore forbids the athletes to consume them. The athletes complain of feeling fatigued, lethargic, and light-headed by the end of practices.

Questions

- What are the problems in this scenario?
- What should the athletes do to feel better throughout the duration of their practices?

What's the big deal about water?

Water is arguably the most essential of all the nutrients for athletes despite the fact that it does not provide the body with energy. Death occurs more rapidly in the absence of water than in the absence of any other nutrient. Water restriction can result in death in as little as 3 days. Armed with this knowledge, it doesn't take much imagination to realize the consequences of dehydration on training and/or sport performance.

The phrase "you are what you eat" should be reworded to "you are what you drink." Roughly 55–60% of the average human's body weight is water. Two-thirds of body water is found inside the cells and is referred to as **intracellular water**. Muscle tissue, which is of obvious importance to athletes, is approximately 70% water. This is just another reason why water is so critical to sport performance. The remaining one-third of body water is found outside of cells and is known as **extracellular water**. Most of the extracellular water is found in the spaces between cells, in lymph, and in blood plasma. Intracellular and extracellular water content vary based on several factors:

intracellular water Body water that is found inside the cells. Approximately 66% of the total amount of water in the body is located inside the cells.

extracellular water Body water that is found outside of cells that make up the various tissues of the body. Examples of extracellular water are saliva, blood plasma, lymph, and any other watery fluids found in the body.

- *Protein content of tissues:* Muscle, composed of a large amount of protein, contains a much greater percentage of water than adipose tissue, which is composed of fats. The percentage of total body water can vary tremendously from a lean, muscular athlete with a low body fat composition to an obese, sedentary individual with a high body fat composition.
- *Carbohydrate content of tissues:* Glycogen consists of linked glucose molecules and is stored inside cells along with water. For every gram of glycogen, 3 grams of water are stored. The water released from glycogen breakdown during exercise can be useful for preventing dehydration.
- *Electrolyte concentration within and outside cells:* Intracellular and extracellular minerals such as sodium, chloride, potassium, and calcium affect the flux of fluid into and out of cells.

Large fluctuations in body water storage can contribute to a variety of health concerns as well as poor physical performance in sports. Balancing daily fluid losses with intake is critical in preventing the ill effects of dehydration, as well as overhydration.

What are the functions of water in the body?

As stated earlier, water does not provide the body with energy (i.e., calories), but it is second only to oxygen in regard to its importance for maintaining life (see Figure 8.1). In addition to providing structural integrity to cells, water serves as the body's delivery and waste removal medium. Blood plasma distributes nutrients, hormones, immune cells, and oxygen, just to name a few items, to the billions of cells that make up the tissues of our bodies. In addition, the blood carries away from the cells substances such as carbon dioxide, lactic acid, and ammonia that are formed during the breakdown of nutrients for cellular energy.

The watery environment of the body's tissues serves as a reactive medium. Water is often a product or reactant in many of the chemical reactions that occur in the body. For example, one of the end products of aerobic metabolism is water. Water also serves as the solvent for many essential molecules, such as glucose, certain vitamins, minerals, proteins, and enzymes.

Body water also helps in maintaining a stable body temperature. Water has excellent conductive properties and helps move warm temperatures from the core of the body to the periphery. In fact, water conducts heat 26 times faster than air. Body water also serves as the source for sweat that is produced by specialized glands called **sweat glands**. The sweat is

sweat glands Specialized glands located in the deep layer of the skin responsible for the production of sweat and its delivery to the surface of the skin for the purpose of evaporative cooling.

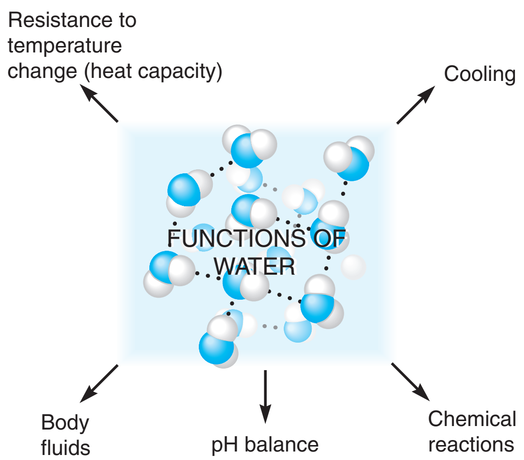

Figure 8.1 Functions of water. Water has many critical functions in the body.

Fortifying Your Nutrition Knowledge

Dressing Appropriately for the Temperature

How should athletes dress for exercise in the heat?

When exercising in the heat, it is critical that the clothing worn be functional, not fashionable. The body relies on four processes to cool itself: conduction, convection, radiation, and evaporation. *Conduction* is the transfer of heat from one object to another by direct contact; for example, heat is lost via conduction when a cold water bottle is placed on the skin of the neck. *Convection* is heat loss from the body by the passage of air or fluid molecules over the skin of the body; for example, using a fan to circulate air molecules past the body enhances cooling by convection. *Radiation* is a means of heat loss via electromagnetic waves. Objects that are hotter than their surroundings emit heat waves and thus lose heat. Radiation of heat is how most (~60%) of the body's heat is lost during rest. All three of these mechanisms aid in heat loss as long as the environmental temperatures are below body temperature. Of course, the closer the environment's temperature gets to body temperature, even though it is still below it, the less effective they are at providing cooling. The fourth avenue of heat loss is *evaporation*. It is the process of heat loss via the vaporization of a fluid to a gas, and it is the most important cooling mechanism for the body during exercise. Evaporation of sweat accounts for up to 80% of the body's cooling during exercise or activity. Thus, when thinking about appropriate dress for exercise in the heat, consideration of all of these processes will ensure maximal cooling for the body.

When exercising in the heat, clothing should be light colored, porous, and constructed of thin material. For example, a cap that is light colored and made of mesh material would be appropriate to wear. It is beneficial to have as much skin exposed to outside air as possible. Some athletes may wet their clothing with water before beginning to exercise.

How should athletes dress for exercising in the cold?

When dressing for activity in the cold, the four mechanisms of heat loss must still be considered; however, the goal is to diminish their effectiveness so that the body conserves heat. It is best to dress in multiple layers of thin clothing that cover as much skin as possible. The outside layer should be of a dark color and made of wind-breaking material. The innermost layer should be constructed of absorbent material capable of wicking any sweat away from the surface of the skin. The head and ears should be covered, and a balaclava can be used to cover the face.

When dressing for the cold, it is critical to not overdress. Overdressing will cause excessive sweating, which can soak through all the layers of clothing and thus make a conductive channel for loss of body heat. A simple test to determine the appropriate level of dress for the cold is for an athlete to dress and then step out into the elements. If the athlete is immediately comfortable out in the elements, the athlete is overdressed; if the athlete is slightly chilled and a bit uncomfortable, the level of dress is appropriate. Once exercise has begun, body heat production will increase and the athlete will no longer feel chilled.

directed to the surface of the skin by ducts leading directly from the sweat glands. Once on the surface of the skin, the sweat drop is exposed to the air and can evaporate. It is the evaporation of the sweat that actually provides the cooling effect.

Water also plays a crucial role in maintaining the body's acid–base balance. It serves as the transport medium for protein buffers such as hemoglobin and plays an indirect role in the functioning and formation of the blood's most potent chemical buffer, **sodium bicarbonate**. Under resting conditions when relatively little lactic acid is being produced, the body's pH is slightly alkaline (pH = 7.4).

sodium bicarbonate A chemical compound found in the blood that helps maintain the body's normal acid–base balance. Sodium bicarbonate is considered the blood's most potent chemical buffer.

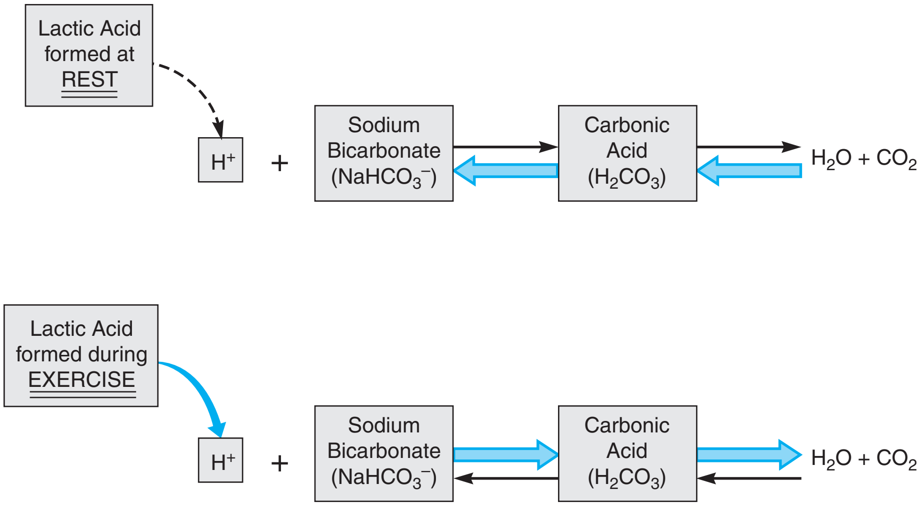

Figure 8.2 The role of water in the sodium bicarbonate buffering system. Water plays a crucial role in maintaining the body's acid–base balance. As depicted, water can either increase or decrease acidity via its relationship to the formation or breakdown of carbonic acid.

Because of the lower hydrogen ion levels (i.e., H^+) at rest, water combines with CO_2 to form carbonic acid, which in turn dissociates into sodium bicarbonate and hydrogen ions, thus maintaining resting H^+ concentrations (see Figure 8.2). Conversely, intense exercise or sport participation results in the formation of lactic acid, which is buffered by sodium bicarbonate to form carbonic acid. The carbonic acid then dissociates to water and CO_2, which is expelled at the lungs.

Finally, water is critical to the maintenance of blood volume. Adequate blood volume directly affects blood pressure and cardiovascular function. Dehydration, resulting in the loss of as little as 3–5% of body weight, begins to compromise cardiovascular function, which has a direct impact on sport performance, particularly for aerobic sports.

What are the sources of water?

Water is obtained from several different sources. Approximately 80% of daily water needs are supplied in the form of fluids. Less than 20% comes from the water found in fruits, vegetables, and other foods. The remainder is actually formed by the body during normal cellular metabolism. Carbohydrates, fats, and proteins are broken down via the aerobic energy system to form carbon dioxide and water. The water formed during aerobic metabolism is known as "metabolic water." Hydrogen molecules that are part of the chemical structure of carbohydrates, fats, and proteins are basically stripped off and carried to the electron transport chain. The electron transport chain is the last metabolic pathway associated with the aerobic energy system, and it is here that the hydrogen ions are ultimately transferred to an oxygen atom to form H_2O. In other words, our bodies are constantly producing metabolic water; however, the body does not make enough to satisfy total daily needs.

Is bottled water better than other sources of water?

Bottled water costs more than tap water, but that does not mean that it is superior. Water is water no matter where it comes from. The difference most athletes cite between water sources is the taste, which is determined by what is dissolved in the water. In the case of tap water, the minerals from the ground that leach into the water give it its taste. Each location in the world has its own unique mineral composition, and as a result water can taste very different from location to location. This does not mean that the water itself is more or less effective in hydrating the body; however, it can make a difference in whether athletes drink the water.

Bottled water is usually filtered, and in some instances minerals and/or flavoring have been added back, which enhances only palatability. Of course, savvy marketing would have athletes think that the water is better because it came from natural springs or clear mountain water. However, athletes should not assume that because the water is bottled it comes from a pristine area. As with food labels, read the water label. Many times the bottled water is coming from the municipal system of a large city, whose water just happens to taste good.

Finally, athletes should not assume that bottled water is safer to drink than tap water. According to the National Resources Defense Council, the FDA's rules completely exempt 60–70% of the bottled water sold in the United States from the agency's bottled water standards because the FDA says its rules do not apply to water packaged and sold within the same state. Unfortunately, policing of water regulations within states is underfunded, and one in five states imposes no regulations at all. Even when bottled waters are covered by the FDA's bottled water standards, those rules are less stringent in many ways than Environmental Protection Agency (EPA) rules that apply to big city tap water. The take-home message is that athletes should not assume that bottled water is better than what comes out of the tap. If athletes do not like the taste of their tap water, many different types of in-home water filtration devices can be purchased, including faucet-mounted filters, pitchers, and even individual water bottles with a filter. These filters will improve the taste of the water and can save the athlete a lot of money.

The exception to this rule pertains to international travel. Each country imposes its own regulations related to water safety. In some instances, bottled water may be safer to consume than tap water. Athletes should investigate the safety of tap water at their destinations before traveling abroad.

What are the ways in which we lose body water?

Body water is lost via urination, defecation, sweating, and insensible processes (see Figure 8.3). Roughly 60% of the body water lost at rest is via formation of urine. However, during exercise in warm environments, sweat formation becomes the primary culprit and can account for up to 90% of water losses. The degree to which sweat formation contributes to water loss is dependent on several factors: the environment (temperature, humidity, and wind velocity), the intensity of the exercise (the metabolic demand and thus the amount of heat generated), the duration of the exercise, and the size of the individual. Water is also lost via a process known as **insensible perspiration**. This is different from the process of sweating. Insensible perspiration is when water from within the body actually seeps through the skin to the skin's surface, where it then evaporates into the air. It is labeled as insensible because, unlike sweat that forms at rates high enough to notice, the water seepage through the skin occurs at a very slow rate, but is ongoing 24 hours a day.

insensible perspiration Loss of water from the body via seepage through tissues and then eventual evaporation into the air. It is labeled as insensible because, unlike sweating, the water loss via seepage through the skin or respiratory passageways occurs relatively slowly and thus goes unnoticed.

Approximately 15% of the water lost daily is lost by insensible perspiration. Insensible perspiration also includes water lost during breathing. The air breathed into the body is warmed and humidified by the respiratory passageways that direct the incoming air to the lungs. The drier the air or the greater the volume of air breathed, such as during exercise, the greater the loss of body water via this

Figure 8.3 Typical daily fluid intake and output. To maintain fluid balance, your body regulates its fluid intake and output.
Data from U.S. Department of Agriculture, Agricultural Research Service, 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory home page. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

process. Water loss via the respiratory system can be quite significant, particularly in high-altitude sports in cold climates because cold air is very dense and holds little moisture, thus making cold air very dry air. Intense exercise that greatly increases breathing rates, in turn, increases water loss from the respiratory passageways. The take-home message is that despite the fact that the climate is cold and sweating may not be as great as in warm environments, water intake is still critical to ensure maintenance of hydration levels. The only way to maintain hydration on a daily basis is to ensure that daily water intake is equal to daily water loss. If water intake equals water loss, then **water balance** has been achieved.

water balance Term used to describe the body's state of hydration. If water intake equals water loss, then water balance has been achieved. If water loss exceeds water intake, then negative water balance results. The converse is positive water balance.

What are the consequences of poor water balance?

Failing to maintain water balance can have dire consequences not only in regard to sport performance, but also in regard to survival. With all environmental conditions being the same, a net loss of body water (i.e., poor water balance) can lead to increases in body temperature compared to the hydrated state when performing the same activity (see Figure 8.4). The combination of impaired thermoregulation and environmental heat stress can lead to heat-related disorders such as heat cramps, heat exhaustion, and heat stroke (see **Table 8.1**).

The good news is that heat-related disorders are completely avoidable if commonsense practices regarding heat exposure and hydration are followed. The requirements for maintaining water balance are highly variable among individuals based on size, body composition, activity level, and climate, just to mention a few. If daily water intake is less than daily water loss, the body is in negative balance and **dehydration** will result if water intake is not increased. The opposite scenario, in which the body is in a positive water balance, is referred to as **hyperhydration**.

dehydration A condition resulting from a negative water balance (i.e., water loss exceeds water intake).

hyperhydration A condition resulting from a positive water balance (i.e., water intake exceeds water loss).

Being slightly hyperhydrated is preferable to being slightly dehydrated in regard to sport performance. Dehydration leads to a multitude of physiological function changes that are detrimental to training and performance (see Figure 8.5). Dehydration leads to loss of blood volume, which, in turn, leads to decreases in the amount of blood the heart can pump to the working muscles. Decreased blood flow to muscles means less oxygen is being delivered, and therefore less work can be performed by the muscles. When the aerobic capabilities of muscle to make energy are diminished because of poor delivery of oxygen, the muscles begin to rely more heavily on anaerobic metabolism. The more the body has to rely on anaerobic metabolism, the quicker lactic acid levels build, the higher the rating of perceived exertion, and the faster fatigue will occur if the athlete does not decrease his or her level of activity. The end result is less-than-optimal sport performance.

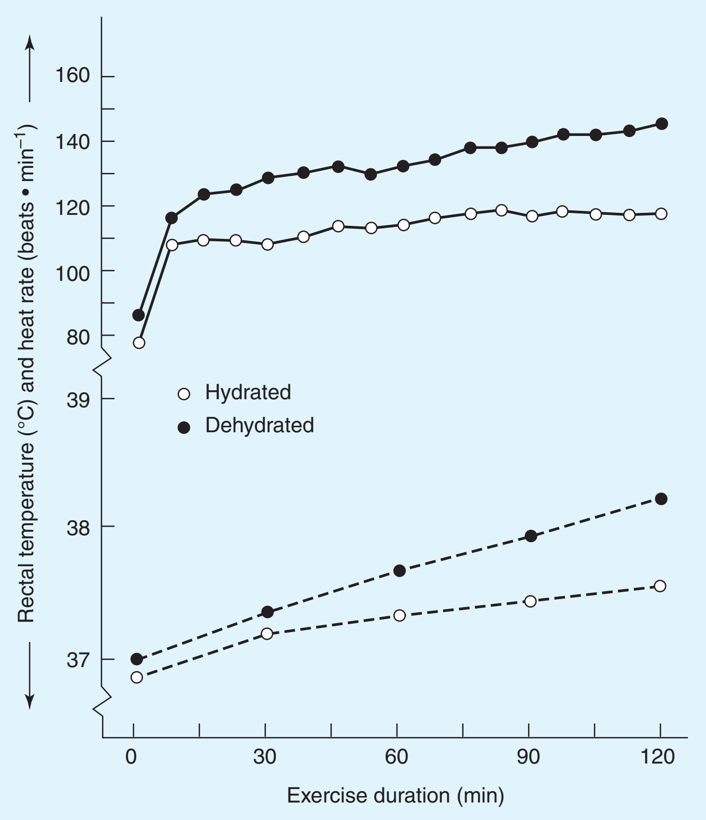

Figure 8.4 Effect of dehydration on heart rate and rectal temperature during exercise of the same intensity. Rectal temperature and heart rate both increase with advancing dehydration.

Source: Reproduced with permission of the McGraw-Hill Companies from Brooks GA, Fahey TD, Baldwin K. *Exercise Physiology: Human Bioenergetics and Its Applications*. 4th ed. Boston, MA: McGraw-Hill; 2004.

Dehydration also leads to extra heat and cardiovascular stress during exercise. As little as a 2–3% decrease in body weight caused by dehydration can result in increases in body temperature and heart

TABLE 8.1 Heat-Related Disorders

Heat-Related Disorder	Degree of Severity	Signs and Symptoms	Corrective Actions
Heat cramps	Least	Muscle cramping	Stretch muscle Moderate activity Provide fluids
Heat exhaustion	Moderate	Profuse sweating Cold, clammy skin Faintness Rapid pulse Hypotension	Cease activity Rest in shade Lie down Consume fluids
Heat stroke	Highest	Lack of sweat Dry, hot skin Muscle incoordination Mental confusion Disorientation	Call for medical help Initiate cooling of body (e.g., fanning, cold towels or ice packs around neck, under arms, and at groin) Immerse or douse with cold water

rate despite the fact that exercise intensity remained the same. The progressive increase in heart rate in the absence of an increase in exercise intensity is known as **cardiac drift**. Cardiac drift occurs because of decreasing blood volume, which in turn requires the heart to pump faster to deliver enough blood to the working muscle (see Figure 8.5). Athletes must understand that intense exercise in hot, humid environments can result in such rapid fluid losses that even increasing fluid intake alone may not be enough to enable the athlete to prevent dehydration. As a result, athletes must be taught that they may also have to modify their intensity (i.e., pace and/or effort) during competition in hot, humid environments. Failure to do so will lead to progressive dehydration that can eventually lead to cardiovascular collapse, severe heat illness (see Table 8.1), or both. Clearly, maintaining hydration before, during, and after training and/or sport participation is critical.

cardiac drift A progressive increase in heart rate in the absence of an increase in exercise intensity. It is the result of a loss in blood volume.

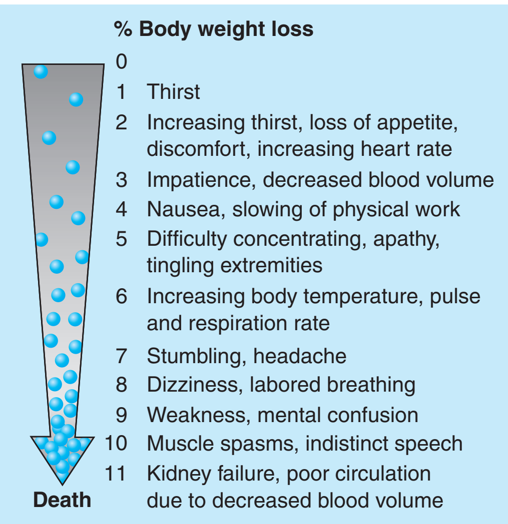

Figure 8.5 Effects of progressive dehydration.

Is it possible to overhydrate the body?

Although rare, it is possible to consume too much water. The resulting condition is known as **hyponatremia**, more commonly referred to as **water intoxication**. With the advance of extreme endurance sports, hyponatremia has become a more frequent occurrence. *Hypo* means too "low," *na* means "sodium," and *emia* means "blood"; thus hyponatremia is a condition in which the fluids of the body become very low in sodium content. Sodium is an important electrolyte and is critical to normal function of muscle and the nervous system. Symptoms of hyponatremia mimic those of someone who is intoxicated and include muscle weakness, muscle

hyponatremia A rare condition resulting from the dilution of sodium levels in the body. Endurance and ultra-endurance athletes who drink copious amounts of water without regard to sodium replacement increase their risk for hyponatremia.

water intoxication A condition resulting from the excessive intake of water. The end result can be a clinical condition known as hyponatremia.

incoordination, disorientation, and eventually seizures and coma, if the condition is not recognized and treated.

Endurance and ultra-endurance athletes are at greatest risk for hyponatremia because of their repeated exposure to long training bouts that result in significant fluid loss via sweat. Because sodium and chloride are the main electrolytes lost in sweat, rehydration without replacement of these electrolytes will eventually lead to dilution of their concentrations in the body.[1] One way to prevent hyponatremia is to have athletes ingest sports drinks containing electrolytes, particularly sodium. In regard to nonendurance athletes, hyponatremia is very rare. As a result, the use of electrolyte sports drinks by nonendurance athletes is of lesser importance because of the fact that diet alone in most instances provides enough sodium chloride (i.e., salt) to cover losses in training.

How can hydration status be monitored?

Hydration status can be measured in several ways prior to exercise (see **Table 8.2**). Each method has pros and cons in regard to the ease of administration and related costs. One easy way to monitor whether water balance is being achieved is to monitor body weight. Daily weight fluctuations are caused primarily by changes in water status. As a result, changes in body weight that occur within a 24-hour time frame can give an indication of whether water intake is replenishing daily water loss. For example, if an individual weighs 120 pounds prior to her workout and 118 pounds after the workout, the weight lost during exercise was a result of water loss. The rule of thumb for rehydrating is that 1 pound of weight lost is equal to 2–3 cups (8 oz = 1 cup) of water. An excellent practice for athletes, particularly those in warm climates, is to monitor changes in their pre- and postpractice weights and then follow the rehydrating rule of thumb. If their prepractice weight is not back to the previous day's prepractice weight, then their attempt at rehydrating needs to be increased to prevent progressive dehydration.

Although monitoring body weight is a quick, easy, and inexpensive hydration assessment method, several potentially confounding physical and mental issues need to be considered. Physically, other factors besides water loss during a training session, such as food intake, the time weight was taken from

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Your Nutrition Knowledge

Teaching Athletes to Self-Monitor Hydration Status

Athletes should be well-versed on the following methods for self-monitoring of daily hydration status:

- *Urine color:* Urine that is clear or the color of pale lemonade indicates positive hydration. Urine the color of apple juice or that is bright yellow or amber in color indicates dehydration. Athletes should monitor urine color throughout the day, not just before or after practice or competition.
- *Urine volume:* Adequately hydrated athletes will need to urinate approximately every 1 to 2 hours during waking hours. Athletes should notice if they have gone several hours without urinating as a sign that they may be becoming dehydrated. The average daily urine output under normal conditions is approximately 1.5–2.5 liters per day.[2] Athletes, however, will consume more fluids, sweat more, and may have greater urine output. It is not practical to measure urine output; therefore, monitoring the number of times athletes urinate is more practical and helpful to determine hydration status.
- *Daily morning weight:* Athletes may choose to weigh each morning during high heat, humidity, and intense preseason training. A decrease of more than 1% of body weight or more than 1 pound suggests possible dehydration.
- *Weighing in pre- and postpractice:* Athletes should weigh themselves in light clothing before practice and in the same amount of clothing after practice. Be sure to have athletes remove sweaty T-shirts and towel off before the postpractice weight. Replenish with fluids in the amount of 16–24 ounces for every pound of weight lost.

last meal, bowel movement patterns, and bladder content at the time of weighing, can affect body weight over the course of 24 hours. As a result, it can be difficult to distinguish which of those factors are contributing to a higher- or lower-than-normal weight, and this can provide confusing or misleading information regarding specific hydration status. Weighing athletes at the same time of day and with an empty bladder can help control for some of these variables and provide a more accurate picture of hydration level.

One mental factor that often is overlooked is the effect of frequent or daily weigh-ins. Requiring an athlete to step on a scale repeatedly in 1 week, especially if in front of other teammates and coaches, can cause the athlete to become excessively focused on weight, which can spiral into distorted eating and body image issues. Because of this risk, other methods of measuring hydration status should be considered for some athletic populations.

One sport that depends heavily on body weight measurements is wrestling. Concern has risen in recent years about unhealthy weight loss practices, including severe dehydration, to cut weight. New guidelines have been instituted through the National Collegiate Athletic Association and the National Federation of State High School Associations to establish a minimum weight for each athlete at the beginning of the competitive season.[3,4] Because it was discovered that wrestlers were arriving at minimum weight testing in a dehydrated state to secure a lower weight minimum, both organizations have included body composition and other hydration tests to be used in conjunction with weigh-ins.

Several other methods of assessing hydration status are related to urine: color, specific gravity, and volume.[5] Urine can be collected in a sample container and compared to a color chart, measured for specific gravity with a refractometer, or evaluated on total volume. Comparing urine color to a chart can be quick and easy but also expensive over time because of the cost of collection containers (see Figure 8.6). Athletes can also subjectively evaluate urine color—typically dark, concentrated urine with a strong smell indicates dehydration. Using a refractometer is simple; however, there are costs associated with purchasing the equipment and issues of ease of portability. Urine volume can be a good indicator of hydration, but it tends to be cumbersome to collect and measure.

Urine Rating #	Description of Urine Color
1	Urine is clear of color
2	Urine has a very light yellow tint
3	Urine has a light yellow color
4	Urine has a vivid, canary yellow color
5	Urine has a dingy yellow, almost orange color
6	Urine has a medium tan color
7	Urine has a burned orange color
8	Urine has a dark, almost olive-brown color

Figure 8.6 Urine color comparison. Athletes can compare their urine color to the descriptions of urine color in the chart to determine hydration status. The goal for adequate hydration is clear to pale yellow urine (i.e., urine rating 1 or 2). A urine color rating equal to 5 or 6 indicates significant dehydration.

Source: Adapted from Casa DJ, Armstrong LE, Hillman SK, et al. National Athletic Trainers' Association position statement: fluid replacement for athletes. *J Athlet Train.* 2000;35(2):212–224.

TABLE 8.2 Indexes of Hydration Status

Condition	% Body Weight (BW) Change*	Urine Color**	Urine Specific Gravity
Well-hydrated	+1 to −1	1 or 2	<1.010
Minimal dehydration	−1 to −3	3 or 4	1.010–1.020
Significant dehydration	−3 to −5	5 or 6	1.021–1.030
Serious dehydration	>−5	>6	>1.030

* % BW change = ([postexercise BW − preexercise BW]/preexercise BW) × 100

** See Figure 8.6.

Source: Reproduced from Casa DJ, Armstrong LE, Hillman DK, et al. National Athletic Trainers' Association position statement: fluid replacement for athletes. *J Athlet Train.* 2000;35(2):212–224. Reprinted with permission.

Each athlete or team needs to determine the most accurate, realistic, convenient, and cost-effective method for measuring hydration status prior to exercise. For any sports requiring weight classes, such as wrestling, trainers are strongly encouraged to measure hydration status in several ways before allowing an athlete to participate in an event. The National Athletic Trainers' Association (NATA) recommends that athletes should be screened for urine specific gravity and urine color at the time of weigh-ins. The upper end of the acceptable range for hydration status is a urine specific gravity of less than or equal to 1.020 or urine color of less than or equal to 4 (see Table 8.2 and Figure 8.6). Body weight changes during and after exercise are also excellent indicators of fluid dynamics and should be included in hydration assessments.

TABLE 8.3 Dietary Reference Intake Values for Total Water

Gender and Age Group	AI (L/day) from Foods	AI (L/day) from Beverages	AI (L/day) Total Water
Males, 4–8 years	0.5	1.2	1.7
Males, 9–13 years	0.6	1.8	2.4
Males, 14–18 years	0.7	2.6	3.3
Males, >19 years	0.7	3.0	3.7
Females, 4–8 years	0.5	1.2	1.7
Females, 9–13 years	0.5	1.6	2.1
Females, 14–18 years	0.5	1.8	2.3
Females, >19 years	0.5	2.2	2.7

Source: Data from Institute of Medicine. *Dietary Reference Intakes: Water, Sodium, Chloride, Potassium and Sulfate.* Food and Nutrition Board. Washington, DC: National Academies Press; 2004.

How much fluid do individuals need on a daily basis?

Water is the largest constituent of the human body and is critical for maintaining life, general health, and optimal athletic performance. Proper daily water intake prevents the deleterious effects of dehydration, including metabolic and functional abnormalities. Because water has not been shown to directly prevent chronic diseases, and because of great individual differences in fluid needs based on climate, activity level, and metabolism, an AI has been set for water rather than an RDA.

What are the current recommendations for daily fluid intake?

The AI for water, published by the Institute of Medicine, reflects the current research and population survey data. For men and women older than age 19, the recommended intake is 3.7 liters and 2.7 liters of water per day, respectively.[6] Refer to **Table 8.3** for the recommendations for younger men and women. These daily quantities reflect total water intake from drinking water as well as from other beverages containing water and from solid foods.

U.S. survey data from the National Health and Nutrition Examination Survey (NHANES) III provide an estimation of the percentage of water required from drinking water and other beverages versus solid food. The results of the survey reveal that fluids provide 81% of total water intake, whereas foods contribute 19%. Based on the total water recommendations, men should be consuming approximately 3 liters of fluid (101 oz or ~13 cups) and women should aim for 2.2 liters of fluid (74 oz or ~9 cups) each day. Athletes may need to modify these fluid recommendations to match their individual requirements based on physical activity, environmental conditions during training/competition, and outdoor climate. In general, daily fluid intake driven by thirst can adequately maintain hydration status.

Another method for estimating fluid needs for the average individual under normal circumstances and in moderate environmental conditions relates total energy intake to fluid requirements. It has been estimated that individuals require approximately 1 milliliter of water for every calorie of energy consumed.[7] The average American consumes approximately 2000 calories per day, which equates to 2000 milliliters of fluid. Milliliters are converted to ounces by dividing the number of milliliters by 240, because there are 240 milliliters in 8 ounces of fluid (2000 milliliters ÷ 240 = 8.33 cups of fluid per day). Therefore, the commonly prescribed 8 cups (8 oz each) of water per day holds true for the average American.

Determining water needs based on calorie intake can provide a more individualized approach for athletes' daily water needs. Athletes have varied energy intakes based on weight, energy expenditure, and sport performance goals. As energy needs increase and caloric consumption increases, so does the requirement for fluids. For example, according to the calorie and fluid connection, an athlete who consumes 2500 calories per day would need 2.5 liters of fluid per day, but a different athlete who consumes 5000 calories per day would require twice as much fluid daily. Clearly, 5.0 liters of water is more than the values shown in Table 8.3, but athletes in general usually have greater fluid needs. In fact, during intense training of long duration and in high heat and humidity, even the higher water intake recommendation based on the 1 milliliter per calorie method may be insufficient to maintain water balance. Vigilant assessment of water loss during exercise activities and replacement of these losses at appropriate levels, as described later in this chapter, will help athletes meet their fluid needs for both daily hydration and hydration before, during, and after exercise activities.

Fluid losses can be replenished through drinking water, other beverages containing water, and foods. Water, juices, milk, coffee, tea, and soda all contribute to a person's daily fluid intake. Water is always a good choice because it is calorie free and inexpensive. Juices and milk contribute not only fluid, but also macronutrients, vitamins, and minerals. They should be consumed in moderation, however, because they can add a significant amount of total calories to the daily diet. Caffeinated coffee and tea will have a slight diuretic effect; therefore, decaffeinated varieties are preferable. Regular sodas are not recommended because of the large quantity of refined sugars they contain. Diet sodas are often considered a better option than regular sodas; however, because of the inconsistent results from research studies on the long-term safety of artificial sweetener consumption, diet sodas should be kept to a minimum.

Solid foods also contribute water to an athlete's total daily fluid intake. Fruits and vegetables contain a large percentage of water, upward of 70–90%. Meats, dairy products, and grain products consist of lower percentages of water; however, percentages still range from 30–50%. Refer to Figure 8.7 for the water content of various foods. Not only do solid foods directly contribute to water consumption, but the metabolism of foods creates water as a by-product.

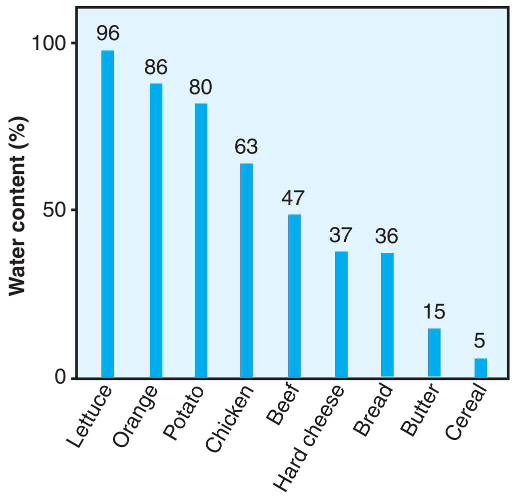

Figure 8.7 Water content of various foods.

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The hydration needs of an athlete can be estimated using the following formula: total calories/240 = number of cups of fluid needed each day. For example, the number of 8 oz cups of fluid required by an athlete consuming 3000 calories a day can be estimated as follows: 3000 calories/240 = 12½ cups per day. It is important to remember that fluid losses during exercise must be added to the calculated estimation to cover the hydration needs of athletes.

Can certain beverages, foods, or medications contribute to fluid losses?

Caffeine and alcohol have been shown to have a diuretic effect, causing the body to excrete fluids in urine. However, the consumption versus loss is not necessarily a 1:1 ratio. For example, humans lose approximately 1 milliliter of water for every milligram of caffeine consumed.[6] One cup (240 milliliters) of brewed coffee contains an average of 80 milligrams of caffeine. Consumption of this product would lead to a loss of approximately 80 milliliters of water, but a gain of 160 milliliters of water. The fluid loss also tends to be transient in nature, and thus doesn't cause major shifts in fluid balance. Therefore, the Institute of Medicine reports that caffeinated and alcoholic beverages can contribute to an individual's total water intake. For athletes, these beverages should comprise only a small portion of total fluid intake per day because of the damaging physical and mental effects of excess alcohol consumption and the potentially unwanted side effects of large doses of caffeine. However, there appears to be no need to completely eliminate caffeine specifically from the diet. Moderate caffeine intake is unlikely to cause detrimental fluid–electrolyte imbalances, if athletes are eating and drinking normally on a daily basis.[8]

High-protein diets also have the potential to increase water losses. The normal metabolism of protein produces urea. The human body considers urea a toxic chemical that must be excreted as waste through the urine. Individuals who are consuming large quantities of protein daily, in excess of their daily requirements, may be causing the body to excrete more fluid to flush out the urea. More research is needed in this area to confirm the association between high protein intakes and fluid losses as well as the establishment of any variance to the current daily fluid recommendations for those choosing a high-protein meal plan.

Many prescribed and over-the-counter medications have a diuretic effect on the body. The extent of the diuresis depends on the drug dosage and individual response. Athletes should discuss the side effects of any prescription or over-the-counter drug taken on a routine basis with their physician and adjust their fluid intake accordingly. Coaches need to be aware of the dangers of athletes taking excessively high doses of diuretics without the supervision of a physician. Typically, wrestlers and other athletes attempting to make a weight cut-off, as well as disordered eating athletes, are the individuals taking diuretics. Large doses can cause potassium and other electrolyte disturbances, which can lead to muscle weakness and ultimately cardiac problems.

What are some practical guidelines for consuming fluids on a daily basis?

The goal of daily fluid consumption is to ensure the maintenance of optimal health. To achieve this goal, athletes should consider the following hydration guidelines:

- Each athlete should be aware of his or her individual daily fluid needs and consume fluids accordingly.
- Optimal hydration should stimulate urination approximately every 1 to 2 hours.
- Urine that is pale or clear in color typically indicates adequate hydration. Athletes need to realize that vitamin and mineral supplementation can create a yellow tint to urine and therefore the color of urine may or may not be an accurate reflection of hydration status.
- Fluids can be obtained from water, milk, juices, coffee, tea, and sports beverages as well as watery foods such as soup, fruits, and vegetables.
- Caffeine should be consumed in moderation. Alcohol consumption should be minimized if not eliminated.
- Athletes should follow a well-balanced diet, including moderate amounts of protein to avoid diuresis as a result of high-protein diets.
- Athletes and coaches should be aware of the diuretic side effects of any medications taken on a regular basis and adjust daily fluid recommendations accordingly.

What is the role of preexercise hydration?

Proper hydration before exercising sets the stage for optimal sport performance. Athletes who avoid fluids intentionally or unintentionally before training sessions or competitive events tend to fatigue quickly, complain of dizziness or faintness, demonstrate a faster rise in core body temperature, have increased heart rates and perceived levels of exertion, and perform suboptimally.[9–11] In contrast, drinking excessive amounts of fluid prior to exercise can lead to frequent and disruptive urination and possibly hyponatremia. Athletes need to know the benefits of optimal hydration before exercising, accurate measurements of hydration status, and the current guidelines for the quantity, type, and timing of fluid ingestion prior to training sessions and competitive events.

How much fluid should be consumed before exercise?

When establishing a plan for fluid consumption before exercise, consider not only the volume of fluid, but also the timing of ingestion. Generous, but not excessive, amounts of fluids should be consumed in the 24 hours before exercise. Drinking enough fluids to meet daily recommendations will allow an athlete to start an exercise session well hydrated. Fluid intake within the 1 to 2 hours prior to exercise can enhance thermoregulation and lower heart rate during exercise.[10,12] The American College of Sports Medicine (ACSM),[13] the NATA, and the Academy of Nutrition and Dietetics (AND) all recommend the following hydration schedule in the hours immediately prior to exercise:

- Slowly drink approximately 400–600 milliliters (13–20 oz) or the equivalent of about 5–7 milliliters per kilogram of body weight (mL/kg) at least 4 hours prior to exercise.
- If urine is not produced or is dark and highly concentrated, slowly drink more fluid (e.g., ~3–5 mL/kg) about 2 hours before exercise.
- Drink 200–300 milliliters (7–10 oz) in the 10 to 20 minutes prior to exercise.

These volumes of fluid will ensure that athletes are properly hydrated while allowing the kidneys to regulate total body fluid.

What types of fluids should be consumed?

Athletes can choose from a variety of fluids in the hours leading up to a training session or competition, including water, juices, milk, coffee, tea, sports drinks, sodas, and beverages containing glycerol (see Figure 8.8). Each beverage has benefits and drawbacks; therefore, it is critical that athletes experiment with the different choices prior to actual practice or competition to determine their preference and individual tolerance. Water is an appropriate choice, especially if accompanied by a substantial snack or meal. Solid food can provide carbohydrates and electrolytes before exercise whereas water provides fluid without further increasing the concentration or **osmolarity** of the stomach and intestinal contents. Water is also inexpensive and easy to obtain.

osmolarity Similar to osmolality, it is an indicator of the concentration of dissolved particles per liter of a solvent (mOsm/L). The higher the osmolarity, the greater the tendency to attract water rather than be absorbed.

Juices, specifically 100% juices, provide fluid, carbohydrates, and electrolytes, which are all beneficial prior to exercise, but not without consequences for some athletes. Carbohydrates in juice can help top off glycogen stores for use during exercise. Because juice is a liquid source of carbohydrates, it is digested and absorbed more quickly than are solid foods, making for a speedy delivery of nutrients to the muscles. Potassium, which is found in both fruit and vegetable juices, as well as sodium, found mainly in vegetable juices, are electrolytes that are lost in sweat and therefore beneficial to consume prior to exercise. Seemingly an ideal choice, some athletes swear by juice before training and competitions, whereas others find juices disagreeable to their gastrointestinal systems immediately prior to exercise. The high fructose content of full-strength juices, if consumed immediately before exercise (or within 15 to 30 minutes) may delay gastric emptying, causing gastrointestinal upset in some athletes. Individual preference and tolerance should guide the choice of whether to include juice in the preexercise hydration plan.

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Water, juice, and milk are excellent choices for preexercise hydration.

Milk provides another seemingly ideal beverage to the lineup of hydration choices. Milk helps athletes meet carbohydrate and protein requirements prior to exercise, in addition to providing fluid. A little protein in the preexercise meal or snack slows the release of nutrients into the bloodstream and thereby allows for a more even supply of energy to the muscles during exercise. Therefore, milk is an excellent preexercise fluid choice; however, many athletes find it difficult to digest, causing stomach upset, bloating, or diarrhea prior to training or competitions. Obviously these effects are undesirable, so milk consumption prior to exercise should be based on individual preference and tolerance.

Coffee and tea are often used as a precompetition beverage because of the claims that caffeine enhances endurance performance. The general consensus in the research is that caffeine does provide an ergogenic benefit by improving endurance time to exhaustion in prolonged events.[14,15] Some of the controversy that exists surrounding caffeine is the balance between an ergogenic benefit and potentially detrimental effects resulting from subsequent dehydration. However, as mentioned earlier in this chapter, the diuretic effects of caffeine do not completely negate the fluid contribution of these beverages. Therefore, coffee and tea do count toward fluid goals prior to exercise. The deciding factor on inclusion of coffee or tea before exercise is an athlete's

Figure 8.8 Variety of beverages for daily hydration. All beverages consumed count toward daily hydration needs. Limit the use of sodas and other carbonated beverages, which may decrease the effectiveness of overall hydration and nutrition status.

individual tolerance and familiarity with the effects of caffeine. For those who are accustomed to caffeine on a daily basis, coffee or tea should be consumed to avoid headaches or lethargy caused by sudden caffeine withdrawal. For those who do not consume caffeine regularly, coffee and tea should probably be avoided because of the potential side effects of nervousness, tremors, and gastrointestinal distress.

Sports drinks are frequently used by athletes prior to training sessions and competitions. Sports drinks are specifically formulated as a fluid replacement beverage for use during exercise. Athletes should therefore reserve the consumption of these drinks mainly for training sessions and competitions and not necessarily as a refreshment beverage during the day or in the hours leading up to exercise. A small amount of a sports beverage can be appropriately used immediately prior to exercise, with the intention of supplying a small amount of carbohydrates, sodium, and fluids for the initiation of exercise. However, the focus of preexercise fluids should be on more nutritionally concentrated beverages. An additional concern is that, for those embarking on long-duration activities, sports drinks should be consumed during the activity in copious amounts. If sports drinks are consumed before exercise, there is the possibility that the athlete will tire of the flavor of the sports drink before the end of the endurance training session, potentially lowering overall fluid intake and possibly affecting performance.

Sodas are not appropriate for consumption prior to exercise. In general, sodas should be minimized in an athlete's diet because of their large contribution of refined sugars. Besides fluid and simple sugars, sodas are devoid of vitamins and minerals and thus do not have nutritional value. The carbonation in soft drinks tends to cause individuals to drink less because of a feeling of fullness, potentially leading to dehydration at the initiation of exercise. Sodas should not be consumed prior to exercise and in general should be consumed only occasionally.

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An athlete can drink a variety of fluids prior to competition. However, it is important to experiment with the various drinks to determine taste preference and tolerance before actually using them prior to competition.

Methods to enhance preexercise hydration by supersaturating the body with water have been investigated recently. One such method is consuming fluids containing glycerol. The results from well-controlled studies concerning hyperhydration with glycerol have been equivocal.[16–19] Some studies have revealed a thermoregulatory benefit, whereas others have shown no effect. However, it appears that even in cases where glycerol intake has been shown to be positive, the benefits have been somewhat negated when hydration status is maintained during exercise.[20] Therefore, at this time there is not enough evidence to endorse the use of glycerol-containing beverages before exercise. It should also be noted that the side effects of glycerol ingestion include nausea, headaches, and gastrointestinal distress—all of which are undesirable and unfavorable conditions for optimal athletic performance.

What are practical guidelines for consuming fluids before exercise?

The goal of fluid consumption before exercise is to ensure that athletes begin training sessions and competitive events hydrated and fueled to perform at their best and maintain health. To achieve these goals, athletes and coaches should consider the following hydration factors:

- *Drink according to established preexercise hydration guidelines.* Consuming adequate fluids prior to exercise is critical to performance. However, more is not necessarily better.
- *Athletes and coaches should determine a method for assessing hydration status prior to training sessions and competitions to avoid the adverse effects of dehydration.* Urine color, concentration, and odor, as well as body weight, are the most commonly used methods for assessment.
- *Water, juices, and milk are excellent choices for preexercise hydration and can easily be included in the preexercise meal or snack*. Caffeinated coffee and tea should be consumed in moderation. Sodas should be avoided.

What is the role of hydration during exercise?

The goals of hydration during exercise are to maintain plasma volume and electrolyte balance. Through optimal hydration, athletes can avoid abnormal increases in heart rate and core temperature that can potentially lead to health issues, as well as premature fatigue that will zap performance. Both dehydration (insufficient fluids) and water intoxication (excessive fluids) can negatively affect performance.

A water loss of merely 2–3% of total body weight can decrease performance by reducing cardiac output and increasing an athlete's risk for heat

gaining the performance edge

Athletes cannot "train" their bodies to increase performance when in a dehydrated state. Proper hydration protocols should be used in all practices and competitions to ensure optimal health and sport performance.

illnesses.[8] Fluid replacement sustains the process of sweating, which cools the body through evaporation. If fluid replacement is suboptimal, blood flow to the skin is decreased, which impairs heat dissipation and elevates body core temperature. Losing 2–3% of total body weight is very common and can happen relatively quickly to athletes during training and competitions. Athletes should note that fluid replacement means *consuming* fluids—not pouring fluids over their heads. Pouring a cold cup of water or ice over the body can provide an immediate sense of relief from the heat but does not elicit the same benefit as consuming the fluids. The most effective way to keep body temperature in check and enhance performance is to actually ingest the cold fluids.

What is the magnitude of water and electrolyte losses during exercise?

Water and electrolyte losses during exercise can vary greatly depending on several factors, including body size, exercise intensity, ambient temperature, humidity, clothing choices, and acclimation.[21] For slow-paced, low-intensity efforts conducted in low to moderate temperatures, fluid losses might not exceed 500 milliliters per hour (~16–20 oz).[22] In hot and humid environments, some athletes can lose up to 2–3 liters of water per hour (~68–102 oz). Considering the size of a 2-liter bottle, consuming upward of one and a half of those bottles during 1 hour of exercise can be daunting! However, each athlete's needs are different, and therefore individual sweat losses should be calculated and hydration protocols developed to replace fluids at a similar rate. Electrolytes lost in sweat include mainly sodium, some potassium, and small amounts of calcium. Sodium losses have been estimated at 50 mmol per liter of sweat, or 1 gram per liter, during exercise, with a range of 20–80 mmol per liter (400–1600 milligrams per liter). Potassium losses are typically 4–8 mmol per liter (76–152 milligrams per liter) during exercise.[23] For short-duration activities, normal daily intake of electrolytes may be adequate to replenish losses in sweat. For athletes training and competing for longer durations, at higher intensities, or in hot, humid environments, electrolyte replacement during exercise will be critical for sport performance and prevention of hyponatremia.

As mentioned, individual sweat rates vary dramatically. To prevent dehydration, while also avoiding water intoxication, athletes need to know the current water and electrolyte intake recommendations for during exercise, their individual sweat rates, and how to translate the information into a fluid plan for training sessions and competitions.

How much fluid should be consumed during exercise?

Many national organizations, including the ACSM, NATA, and AND, have issued position statements regarding their recommendations on the ideal quantity of fluid to ingest during exercise for health and peak performance.[1,5,13,24] The consensus is that athletes should aim for matching their sweat and urine output with fluid consumption to maintain hydration at less than a 2% reduction in body weight. For most individuals, consuming approximately 200–300 milliliters, or 7–10 fluid ounces, every 10 to 20 minutes during exercise will achieve this goal. However, this recommendation must be confirmed by calculating individual sweat losses through a "sweat trial" to ensure proper hydration based on the factors that contribute to individual variability.

Several studies have revealed no change in performance with varying volumes of fluid ingested during cycling lasting less than 60 minutes in a neutral environment.[25,26] Although consuming fluids may not have a huge impact on short-duration exercise, it does have a large impact on long-duration exercise (~60 minutes), especially in hot, humid environments.[2,27,28] Any athlete engaging in exercise lasting longer than an hour should measure his or her sweat rate and implement a hydration plan.

How can an athlete calculate his or her individual sweat rate?

Athletes can estimate their individual sweat rate by gathering information from a sweat trial. After collecting the data from the trial, the athlete will be able to estimate his or her individual fluid needs per hour through a series of short calculations. Sweat trials should be performed multiple times during training to provide the most accurate estimation of the quantity of fluid needed on competition day, enabling the athlete to perform at his or her best.

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Although consuming 200–300 milliliters (7–10 oz) of fluid about every 15 minutes will help maintain hydration during exercise for most athletes, sweat trials should be performed to learn individual hydration needs.

Sweat trials should be conducted in several different environments to gain as much information as possible so that there are no surprises or guesses on competition day. Differences should be compared between indoor and outdoor workouts, summer and winter training sessions, and easy and hard effort days. The data to collect during a sweat trial include the following:

- Body weight (BW), in pounds, before exercise.
- BW after exercise (without wearing sweaty clothes).
- Volume of fluid consumed (in ounces) during the workout.
- Urine output during exercise.
- Total workout/competition time (in hours).[5]

Most of these measurements can be collected easily, with the exception of urine output. To make the calculation more feasible, athletes should exercise for 1 to 2 hours without urinating, thus negating the need for the urine output data. After collecting the other pieces of data indicated, the sweat rate can be calculated using the following steps:

1. *Determine body weight lost during exercise.* By subtracting the total body weight after exercise from the total body weight before exercise, an athlete can determine the amount of water lost, expressed in pounds:

> BW before exercise − BW after exercise = pounds of water weight lost

2. *Determine the fluid equivalent, in ounces, of the total weight lost during exercise.* Every pound of body weight lost during exercise equals approximately 2–3 cups or 16–24 ounces of fluid (1 cup = 8 oz).[5] The weight loss that occurs during exercise can translate into the number of ounces of fluid the athlete should have consumed, in addition to the fluid actually consumed during the training session or competition, to maintain fluid balance. To determine the number of ounces of fluid lost during exercise, multiply the pounds of water weight lost by 16–24 ounces:

> pounds of water weight lost during exercise × 16–24 oz = number of ounces of additional fluid that should have been consumed to maintain fluid balance during the exercise session

3. *Determine the actual fluid needs of the athlete during an identical workout.* Add the quantity of fluid consumed during the workout to the fluid equivalent of the weight lost during exercise to determine the total actual fluid needs of the athlete:

> ounces of fluid consumed + ounces of additional fluid needed to establish fluid balance = total fluid needs

4. *Determine the number of fluid ounces needed per hour of exercise.* For practical purposes, divide the total fluid needs by the duration of the sweat trial, in hours. This final calculation will provide the athlete with an estimation of his or her hourly fluid needs, which can then be used to plan accordingly for training sessions, and ultimately for competitions of varying lengths.

> total fluid needs/total workout time in hours = fluid ounces per hour of exercise

For example, Alex weighs in before tennis practice at 145 pounds. After 2 hours of playing tennis outdoors on a mild summer day, he weighs in at 143 pounds. During his practice, Alex consumed 20 ounces of fluid. What are Alex's total fluid needs per hour? Following the steps listed previously:

1. Weight loss = 145 lb – 143 lb = 2 lb of water weight loss.
2. Additional fluid needed = 2 lb × 16–24 oz = 32–48 oz of additional fluid that should have been consumed to maintain fluid balance during the practice session.
3. Total fluid needs = 20 oz + 32–48 oz = 52–68 oz.
4. Fluid needs per hour = 52–68 oz/2 hr of practice = 26–34 oz/hr.

From this sweat trial, Alex would estimate his total fluid needs per hour of training or competition to be 26–34 ounces. Therefore, he can plan accordingly for his next practice and bring two 20-ounce water bottles filled with a sports drink.

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An athlete should not gain weight during an exercise session. Weight gain indicates overhydration and can increase the risk for hyponatremia.

Food for Thought 8.1

Determine Your Fluid Needs During Exercise

Perform your own sweat trial to determine your fluid needs.

How does the volume of fluid ingested during exercise affect gastric emptying and intestinal absorption?

The goal of determining individual sweat rates is to establish a fluid plan that would closely match fluid intake with fluid losses. This state of fluid balance, or **euhydration**, is not always possible for athletes to achieve. In some cases, athletes' sweat rates exceed maximal gastric emptying rates, which, in turn, limit the intestinal absorption of fluids. For these athletes, fluid recommendations are set at a volume that matches sweat losses as closely as possible without exceeding gastric emptying rates, thus avoiding stomach cramping and bloating. Using a carbohydrate-containing sports beverage during exercise can enhance absorptive capacity. The section entitled "How much and what types of carbohydrates should be included in a fluid replacement beverage?" later in the chapter describes this in more detail.

euhydration A state of fluid balance in which water loss has been replaced by adequate water intake.

However, a majority of athletes are consuming fluids at a rate and volume much lower than their maximal gastric emptying rate. Many athletes consume less than 500 milliliters of fluid per hour during training or competition. For most individuals, gastric emptying rates of 1 liter or more per hour are possible.[21] Therefore, athletes are not reaching their hydration potentials and would benefit from increasing fluid intake during exercise.

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By increasing the volume of fluid ingested, athletes will not only more closely match their fluid losses, thus preventing the detrimental effects of dehydration, but also will actually facilitate euhydration by stimulating gastric emptying. Larger volumes in the stomach stimulate the release of fluids into the intestines, leading to a faster delivery of fluids from ingestion to absorption during exercise. If an athlete becomes dehydrated by as little as 2–3% body weight, gastric emptying rates begin to decline, leading to dehydration and often times stomach discomfort.[29]

How does heat acclimatization affect hydration requirements?

Physiological changes occur as an athlete adjusts to warmer environments during exercise. Adjustments are made for both short- and long-term exposure to heat. An example of a short-term exposure scenario is when athletes are forced to train indoors for several days because of icy winter conditions or heavy snowfall. In this scenario, the indoor temperature and humidity are much higher than the athletes are accustomed to. As a result, they sweat more than usual and thus require a short-term adjustment in their hydration requirements. Once the athletes return to the colder outdoor environment, water requirements quickly return to their previous outdoor training levels. An example of a long-term situation occurs with the change in seasons. As the weather changes from the cool temperatures of spring to the hot, humid conditions of summer, athletes' sweat rates will be altered. Sweat rates will increase initially for 10 to 14 days. After approximately 2 weeks, an athlete's sweat rate should be reassessed and the hydration plan modified accordingly.

Athletes' hydration status should be monitored closely during acclimatization. Typically, athletes will not replace all lost fluids voluntarily in the heat. As heat acclimatization progresses, voluntary intake usually increases to more closely match losses.[30] One study has reported an opposite trend in fluid intake.[31] Five untrained, unacclimated women performed 3 days of exercise in the heat over a period of 6 weeks. The researchers found that fluid intake actually decreased over time. This study had several methodological pitfalls, however, including the lack of sweat volume measurements to compare to intake to evaluate fluid balance. The study did confirm previous findings that thirst may not always drive an athlete to drink sufficient amounts of fluids, and thus the recommendation for monitoring hydration status during heat acclimation.

How does altitude affect hydration requirements? Exposure to high altitude increases the risk for athletes becoming dehydrated. Physiologically, several issues can affect the hydration status of athletes training or competing at higher altitudes, in particular altitudes above 1.6 kilometers (5280 feet). First, temperatures tend to become progressively colder with increasing altitude (1.8° F for every 500 feet), and colder air is drier air. As altitude increases above 5280 feet, there is less air pressure driving oxygen into the blood. As a result, the body adjusts to the decreased oxygen availability by noticeably increasing breathing rate. The increased volume of dry air coursing through the respiratory passageways, even at rest, leads to increased water loss as the air is humidified on its way to the lungs. When taken in combination, 24-hour exposure to colder, drier air leads to a reduction of body water via dramatic increases in insensible water loss through the skin and respiratory tract. As a result, dehydration can result independent of whether the athlete is training or not. During training, sweat losses are added to the increased water loss via insensible avenues to make fluid turnover even greater. Therefore, athletes need to be particularly conscious about increasing fluid intake at higher altitudes and monitoring urine color and/or body weight fluctuations to help maintain their water balance.

What types of fluids should be consumed during exercise?

The type of fluid consumed during exercise can have a major impact on the athlete's hydration status. The inclusion of macronutrients, vitamins, and minerals can supply the dietary components to enhance endurance performance and/or muscle building. The temperature of a beverage can affect palatability and digestibility, affecting the volume of fluid an athlete ingests and absorbs. These components and characteristics of fluid replacement beverages have been recognized, studied, and integrated into what most athletes know of as "sports drinks."

How much and what types of carbohydrates should be included in a fluid replacement beverage? Exogenous carbohydrates are extremely beneficial during exercise, especially if the activity is of high intensity or long duration (> 45 minutes). In terms of fluids, a carbohydrate-containing beverage has been shown to increase athletic performance versus consuming water alone.[28,32,33] It is recommended that athletes consume 60–66 grams of carbohydrates per hour, or 1.0–1.1 grams of carbohydrates per minute, during exercise to maintain energy and power output while preventing gastrointestinal upset. Sixty to 66 grams of carbohydrates per hour equate to approximately 1 liter of a 6–8% carbohydrate drink. Consuming beverages supplying greater than an 8% solution will increase the ingestion of carbohydrates; however, it will also decrease the gastric emptying and intestinal absorption rates.[29,34,35] Higher concentrations in the intestines can cause a reverse osmotic effect, pulling fluids into the intestinal lumen, potentially leading to bloating, cramping, and diarrhea. Therefore, fluids with a higher concentration of carbohydrates, such as fruit juices, sodas, and some sports beverages, are not recommended as the sole beverage during exercise.[5] These fluids can be used appropriately in small amounts during ultra-endurance events when flavor fatigue is of concern.

gaining the performance edge

Ingesting sports drinks containing a 6–8% carbohydrate concentration can enhance performance during long-duration (> 45 minutes) exercise.

The carbohydrate concentration, or % carbohydrate, can be determined by looking at the Nutrition or Supplement Facts label on a product. Look for the number of grams of carbohydrates in 240 milliliters, or 8 ounces, of the product. To determine the carbohydrate concentration, divide the grams of carbohydrates by 240 milliliters, and then multiply the result by 100:

$$(\text{grams of carbohydrates}/240\ \text{milliliters}) \times 100 = \%\ \text{carbohydrate solution}$$

For example, a sports beverage may have 15 grams of carbohydrates in one 8-ounce serving. By using the preceding calculation, it is determined that the sports beverage is a 6% carbohydrate solution:

$$(15\ \text{g of carbohydrates}/240\ \text{mL}) \times 100 = 6\%\ \text{carbohydrate solution}$$

Conversely, a fruit juice might have 35 grams of carbohydrates in one 8-ounce serving. The fruit juice is a 15% carbohydrate solution:

$$(35\ \text{g of carbohydrates}/240\ \text{mL}) \times 100 = 15\%\ \text{carbohydrate solution}$$

By using this calculation, athletes can evaluate the appropriateness of new or existing products on the market for use during training sessions or competitions.

The type of carbohydrates in a fluid replacement beverage is also of importance. Glucose, sucrose, and glucose polymers are appropriate types of carbohydrates that digest well for most individuals and are absorbed readily through the intestines. Sports drinks are typically composed of a combination of these sugars. The absorption of carbohydrates is actually maximized when several forms of carbohydrates are used simultaneously, which is the reason why glucose, sucrose, and glucose polymers are included in one product.[36–38] Sources of fructose, such as fruit juice, should be limited because fructose has been shown to increase gastrointestinal distress when consumed during exercise.[36,39] Athletes should note that fructose is sometimes included in small amounts in sports beverages to increase the palatability of the beverage and possibly enhance gastric emptying. A few studies have shown gastric emptying to increase when a beverage contains both glucose and fructose, versus glucose alone.[40] In general, the small amounts of fructose added to some sports beverages can be tolerated without consequence. Each athlete should determine his or her individual preferences and tolerances to evaluate the usage of products that contain fructose.

Taste can affect the amount of fluid consumed during exercise. A flavored beverage has been found to encourage higher fluid consumption during exercise than plain water.[41–43] Some athletes have specific flavor preferences and may consume less total fluid if they are presented with beverages in flavors they dislike. If a team or coaching staff supplies flavored sports drinks to players, providing several different flavors may be helpful to meet specific player preferences. Athletes should be encouraged to try different flavors during their sport activity practices and use the most palatable flavors during competition and training.

Exercise intensity and environmental conditions also dictate what is considered the ideal carbohydrate concentration of a fluid replacement beverage. As the need for fluids during exercise increases, the ideal level of carbohydrate concentration decreases. For example, in hot, humid environments where sweat rates are high and therefore fluid requirements are great, the level of carbohydrates in a replacement beverage should be below 7% to optimize the rate at which carbohydrates are digested and absorbed. When conditions are mild and the exercise intensity is low, carbohydrate concentrations of greater than 7% may be tolerated.[5] Once again, individual variances will ultimately determine the ideal level of carbohydrate concentration and thus fluid choices.

gaining the performance edge

Having athletes drink flavored beverages of their liking during exercise may encourage higher fluid consumption.

How much and what types of electrolytes should be included in a fluid replacement beverage?

Sweat is composed mainly of water, along with various electrolytes, such as sodium, chloride, potassium, magnesium, and calcium. However, the concentration of electrolytes in sweat can vary greatly based on the rate of sweating, the state of training, and the state of heat acclimatization. Generally speaking, the better the state of conditioning and the more acclimatized the athlete is to hot, humid environments, the lower the concentration of electrolytes found in the sweat. However, considering that sweat rates can be upward of 2–3 liters per hour, the loss of sodium and other electrolytes can be significant. To maintain proper bodily function as well as peak performance, drinks containing electrolytes are appropriate for consumption during exercise, especially prolonged endurance activities. The main electrolytes lost in sweat are sodium and chloride. For exercise durations less than 3 to 4 hours in length, sodium and chloride replacement does not appear to be physiologically necessary. However, even for short-duration activities, the presence of sodium in a beverage provides an extra bonus in the quest for optimal hydration—sodium typically makes beverages more palatable and stimulates the drive to drink. Therefore, even though the depletion of sodium during short-duration activities does not necessitate concurrent replacement, it can motivate athletes to drink more fluids and thus optimize hydration levels.

In several situations sodium and chloride consumption during exercise is critical. For athletes engaging in exercise sessions lasting longer than 4 hours, the gradual loss of sodium in sweat over time can lead to depletion and low blood sodium concentrations. Also, within the initial days of heat acclimatization, athletes will lose a larger percentage of sodium in sweat and thus require sodium replacement. In addition to consuming sodium during exercise, athletes acclimatizing to the heat should also consider a temporary increase in their daily intake of sodium, possibly as high as 4–10 grams of sodium per day.[44] This level can be easily consumed by eating salty foods and adding a small amount of table salt to foods during meals. Finally, individuals who are restricting sodium intake or who have not consumed a well-balanced meal prior to exercise should consider choosing a beverage containing sodium during exercise. Therefore, under these conditions, the NATA has recommended adding sodium to fluid replacement beverages in quantities of 0.3–0.7 grams per liter. For most athletes the sodium content of sports beverages is sufficient to meet their needs during exercise. However, in some cases additional salt tablets may be indicated.

Other minerals in sweat, though present in small quantities, include potassium, magnesium, calcium, copper, iron, and zinc. These minerals are not universally found in sports beverages but can be found in other sports performance products. Most sports beverages contain a small amount of potassium, which will meet the needs of most athletes during exercise. Potassium tablets should not be taken—excessive amounts of potassium can disrupt the electrical rhythm of the heart. Athletes can easily, and inexpensively, increase their daily food intake of these minerals to compensate for any losses in sweat.

If electrolytes lost in sweat are not replaced, problems can occur. An electrolyte deficiency can occur after one bout of long-duration exercise and/or excessive sweating or from a low daily intake of electrolytes coupled with consistent depletion of electrolytes through regular physical activity. One of the most common symptoms of electrolyte deficiencies is muscle cramping. Muscle cramps are uncomfortable, distracting, and can halt athletes in their tracks, thus affecting sport performance. In some cases, an electrolyte deficiency not only affects athletic performance but also endangers health. One of the increasingly common health issues associated with electrolyte deficiency is exercise-induced hyponatremia.

Hyponatremia is a disorder of fluid-electrolyte balance that results in abnormally low sodium concentrations (> 130–135 mmol/L) in the blood, typically occurring during endurance duration activities lasting longer than 4 hours. If sustained, hyponatremia can lead to a variety of neurological dysfunctions that, left untreated, can escalate into seizures, coma, and/or death. The signs and symptoms of hyponatremia include headache, nausea, dizziness, vomiting, or seizures. Hyponatremia can be caused by several factors:

- Drinking too much prior to a workout or event.
- Following a salt-free or very low salt diet.
- Consuming fluid in excess of individual sweat losses.
- Drinking only water, versus a sports beverage containing sodium, during long-duration exercise.
- Exercising for longer than 4 hours.
- Taking diuretic medications, typically prescribed for hypertension.
- Taking NSAIDs (nonsteroidal anti-inflammatory drugs) such as Advil or Aleve before or during exercise.

By following the preexercise hydration guidelines, discovering individual sweat rates, relying on mainly sports beverages during long-duration exercise, and eating sodium in pre- and postexercise meals, a majority of hyponatremia cases can be averted. Special precautions need to be taken for athletes participating in marathons, Ironman distance triathlons, and other ultra-endurance events.

Does the osmolality of the fluid consumed during exercise make a difference?

The effects of osmolality on both gastric emptying and intestinal absorption have been studied. The osmolality of a beverage depends mainly on the carbohydrate and electrolyte content of a product. In general, as osmolality increases, gastric emptying decreases. In recent years, to decrease the osmolality of their products, sports drink manufacturers have started using glucose polymers or maltodextrins, which have less of an effect on osmolality than simple sugars do. Although important, the osmolality of beverages seems to be secondary to other factors in regard to gastric emptying. Gisolfi et al.[45] found that beverages ranging as high as 400 mOsm/kg did not inhibit gastric emptying. Therefore, the osmolality of sports beverages does not appear to be as influential as the volume and calorie content of fluids for gastric emptying.

osmolality An indicator of the concentration of dissolved particles per kilogram of solvent (mOsm/kg). Osmolality affects the movement of water across membranes when the concentrations on either side of the membrane are different. A beverage with a high osmolality tends to draw water to it rather than be absorbed.

However, the osmolality of sports beverages has been shown to greatly affect the intestinal absorption of fluids. Some research has shown that solutions that are hypertonic to plasma (< 280 mOsm/kg) stimulate less fluid absorption through the intestines and actually draw water into the intestinal lumen, potentially leading to dehydration and intestinal cramping.[46] Hypotonic and isotonic solutions (< 280 mOsm/kg) have been suggested to enhance fluid absorption through the intestinal wall, facilitating hydration.[19,47] However, some studies have challenged the notion of an upper limit of 280 mOsm/kg for optimal intestinal absorption.[45] More research is needed in this area to determine an ideal osmolality for intestinal absorption at varying levels of exercise intensities. For now, a general recommendation, attempting to optimize both gastric emptying and intestinal absorption, is to choose a fluid replacement beverage with an osmolality close to 280 mOsm/kg. The amount and type of carbohydrates in a beverage have the greatest effect on osmolality; therefore, continuing to use commercially prepared sports drinks of less than or equal to a 6–8% solution (14–18 grams carbohydrates per 8 fluid ounces) is still the best recommendation.

Does the temperature of fluids consumed during exercise matter?

The temperature of fluids consumed during exercise can either encourage or discourage consumption. Most athletes prefer a cool beverage, claiming the lower temperatures make the fluid more appealing and refreshing. Individual preferences vary; however, beverages at 50–59° F are typically recommended.[5]

Should protein be included in fluid replacement beverages?

The inclusion of protein in carbohydrate–electrolyte replacement beverages has recently been explored. The theory is that consuming protein during exercise will increase the body's insulin response to ingested nutrients during exercise, thus sparing glycogen stored in the muscle and liver, and, in turn, enhancing endurance performance. In several studies, the addition of protein to a carbohydrate beverage enhanced the insulin response postexercise.[48–50] It has therefore been theorized that adding protein to a beverage during exercise would have the same effect. However, the results from studies performed during exercise have been inconsistent, with some researchers reporting increased performance without an enhanced insulin response.[51] Therefore, an ergogenic effect may be caused by a mechanism other than insulin. More research is needed in this area to define the advantages of a protein–carbohydrate–electrolyte beverage over a traditional sports drink, as well as the ideal quantity of protein to consume through a beverage during exercise.

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During exercise, drinking chilled fluids is refreshing and may encourage greater fluid consumption.

For a summary of factors affecting fluid consumption and absorption during exercise, refer to **Table 8.4**.

Why are commercial sports beverages beneficial for athletes?

In the 1960s, the University of Florida Gators were frustrated by the performance of their football team. The players were strong in the first half of a game but faded quickly near the end of the third and beginning of the fourth quarters because of dehydration. Dr. Robert Cade and Dr. Dana Shires developed a beverage that replaced the nutrients lost during exercise and heavy sweating, specifically carbohydrates and electrolytes. Cade and Shires's beverage became known as Gatorade—the original sports beverage. After drinking this new beverage, the athletes felt rejuvenated and therefore played strong throughout their games. The Gators had a record of 7–4 in their first year of drinking Gatorade in 1965 and then improved to a 9–2 record in 1966. Opponents were flabbergasted and intrigued. As the Gators went on to win the Orange Bowl for the first time in their history, the athletes swore that drinking Gatorade was the reason they felt stronger for longer. Although its introduction was not monitored through a controlled study, Gatorade is now one of the most well-researched products in the sports nutrition arena. However, the "ideal" sports beverage for all durations, intensities, and types of sports has not been defined or formulated. To learn more about Gatorade and research on sports beverages, consult the website of the Gatorade Sports Science Institute at www.gssiweb.com.

Gatorade currently has many competitors in the sports beverage market, with formulas varying slightly from product to product. The commonality among most sports beverages is the inclusion of fluid, carbohydrates, and electrolytes. The profile of electrolytes, vitamins, and carbohydrate sources as well as the quantity of each of these nutrients create a majority of the differences. Formulas also vary by flavor, sweetness, carbonation, and viscosity in attempts to cater to varying personal preferences. The "optimal" formulation of a sports beverage has not necessarily been proven through comparison

TABLE 8.4 Factors Affecting Fluid Consumption and Absorption During Exercise

Factor	Recommendation	Additional Considerations
Amount of carbohydrate	1.0–1.1 g carbohydrates/minute or 60–66 g carbohydrates/hour	Helps provide energy during exercise.
Carbohydrate concentration	6–8% carbohydrate solution is the best for beverages used during exercise	>8% solution can cause delayed gastric emptying and gastric upset.
Type of carbohydrate	Glucose, sucrose, and glucose polymers	High levels of fructose in sports drinks may cause delayed gastric emptying and gastric upset.
Flavor	Flavored beverages increase fluid intake during exercise versus plain water or unflavored sports beverages	Athletes have varied flavor preferences and should taste test a variety of flavors to find a favorite.
Exercise intensity	8% or lower carbohydrate solution is best tolerated at higher exercise intensity levels	Either sports drinks or water can be used during high-intensity exercise.
Environmental conditions	High heat and humidity increase fluid needs; 8% or lower carbohydrate solution is best tolerated in these conditions	More frequent hydration breaks during exercise and competition are needed.
Electrolytes	0.3–0.7 g sodium per liter of fluid consumed	Other electrolytes such as potassium, magnesium, or calcium may be added in small amounts.
Osmolality	~280 mOsm/kg	As osmolality increases, intestinal absorption tends to decrease.
Temperature of the beverage	Cool is best, typically between 50° F and 59° F is best tolerated	Individual preferences will vary.
Protein	No recommendations at this time for the inclusion of protein in sports beverages	More research is needed to fully evaluate the need for protein during exercise.

research; therefore, individual preferences are a major determinant of consumption and thus success with a sports beverage. Overall, the benefit of sports beverages versus water is the inclusion of carbohydrates for sustaining energy levels and electrolytes to prevent conditions such as hyponatremia.

Athletes need to look closely at the Nutrition Facts or Supplement Facts label on beverages to evaluate the type and quantity of carbohydrates, electrolytes, and other nutrients contained in the beverage to determine the appropriateness for their individual sport, the duration of their activities, and individual preferences. The following are some items to look for when reading sports beverage labels:

- *Type of carbohydrate:* Each formula is slightly different. Look for glucose, sucrose, or glucose polymers listed on the ingredients label. Some brands promote their product as a source of "complex carbohydrates," claiming to sustain energy longer. Most of these products use glucose polymers as the carbohydrate source; these are strings of linked glucose molecules versus a single or "simple" carbohydrate. These products can certainly be beneficial in enhancing performance because they provide carbohydrates, but they may or may not necessarily be more effective than other sports beverages that include a mix of carbohydrate sources. In general, avoid products that contain solely or mainly fructose as the source of carbohydrates. "Natural" sports beverages often contain fructose because fruit juice is used as the sweetening agent versus other sugars. Some athletes may be able to consume fructose without adverse side effects of stomach and intestinal upset and cramping; however, it is better to be safe than sorry and make it a rule to watch out for fructose.
- *Artificial sweeteners:* Some brands of sports beverages include artificial sweeteners. The artificial sweeteners are added to enhance the flavor and palatability of the beverage while keeping the carbohydrate concentration within the guidelines of 6–8%. However, if an athlete is consuming large quantities of fluid during workouts or

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During exercise, consuming sports beverages containing 6–8% carbohydrate can help sustain performance; however, be cautious using drinks containing fructose, artificial sweeteners, and/or stimulants.

competitions to match sweat losses, the athlete's intake of artificial sweeteners can rise dramatically with these products. Some athletes experience adverse side effects or possibly allergic reactions to artificial sweeteners. Therefore, products containing artificial sweeteners such as aspartame, saccharin, and acesulfame potassium are not recommended. Look for these sweeteners in the ingredient listing on the label.

- *Stimulants such as caffeine or herbal products:* Beverages labeled as "energy" drinks are often marketed for use during exercise. These drinks often contain caffeine and/or a variety of herbal stimulants, such as guarana, as their major source of "energy." Sugar can be included but is often in concentrations above the recommended 6–8%. Other formulas are sweetened by artificial sweeteners, which provide no carbohydrates. In general, these energy drinks should be avoided during exercise. Look for kola nut, guarana, caffeine, and artificial sweeteners in the ingredients listing.
- *High doses of vitamins and minerals:* To make their formula different, some beverages contain a variety of B vitamins, antioxidant vitamins, or minerals. Sodium, chloride, and potassium are the minerals that are beneficial to include in a sports drink and should be included in sufficient quantities. However, other vitamins or minerals can cause gastrointestinal distress, especially when the beverage is consumed in large quantities to match sweat rates. Look on the Supplement Facts label for the %DV for each vitamin and mineral in one serving of the product. Multiply the percentage by the number of servings that will be consumed in one exercise session. If the total amount consumed—for nutrients other than carbohydrates, sodium, or potassium—is reaching 200% or more, then reconsider using the product. For example, magnesium is promoted as a mineral that can help prevent cramping. For athletes consuming a well-balanced diet, sufficient daily magnesium can be helpful for the prevention of muscle cramps. However, if an athlete who suffers from muscle cramping chooses a sports beverage containing significant amounts of magnesium, problems can result. Assuming the athlete will need to drink 4 to 8 servings of the sports beverage (assuming an 8 oz serving, with the athlete requiring 32–64 oz for a practice lasting 1 to 2 hours), the total magnesium consumed may exceed the RDA by several times, possibly resulting in gastrointestinal upset and diarrhea—a side effect of excessive intake of magnesium. Therefore, look for the electrolyte basics in a sports beverage—sodium, chloride, and potassium—and avoid products containing large quantities (> 10–20% DV in one serving) of other vitamins or minerals.
- *Carbonation:* The vast majority of commercial sports beverages are not carbonated. However, athletes should check the label and avoid carbonated beverages before, during, and immediately after exercise. The effervescent bubbles in these beverages take up space in the stomach, causing a full or bloated feeling. This will decrease the amount of fluid consumed because there is a false sense of fullness. Athletes should limit carbonated beverages as part of their regular fluid intake during the day for the same reason.
- *Specialty formulas:* Sports beverage producers may have an entire line of hydration products. Typically the products will fall into several categories: preexercise, during physical activity, ultraendurance events, and recovery beverages. The preexercise beverages are generally higher in carbohydrates to help athletes maximize glycogen stores before a training session or competition. These beverages may not be necessary; well-balanced meals and fluids from water, milk, and juice are sufficient for providing carbohydrates and fluids prior to activity. Formulas for during activity focus on carbohydrates and electrolytes. Follow the previously mentioned guidelines when reviewing these products. The endurance formulas are typically higher in sodium and other electrolytes. These beverages can be useful and appropriate for exercise lasting longer than 4 hours. Evaluate each product for the appropriateness of the types of carbohydrates and quantities of various vitamins and minerals. Recovery beverages generally contain carbohydrates, protein, and antioxidant vitamins and minerals. These beverages can be

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During exercise, sports drinks containing small amounts of sodium, potassium, and chloride can help sustain performance; however, avoid drinks containing large quantities (> 10% DV) of other vitamins and minerals.

useful for situations when athletes do not have immediate access to food after exercise. However, if food and beverages are easily accessible, then recovery beverages may not be necessary. For a comparison of sports beverages commonly used during exercise, refer to **Table 8.5**.

What are some practical guidelines for consuming fluids during exercise?

The goal of fluid consumption during exercise is to keep athletes hydrated so that they can perform at their best and maintain health. To achieve these goals, athletes and coaches should consider the following hydration factors:

- *Fluids should be readily available*. Athletes need to take personal responsibility for having fluids on hand at all times during training sessions and competitions. Athletes should have plenty of water bottles to keep in gym bags, in lockers, at home, and in training rooms. Measured water bottles can also help athletes determine whether they are meeting their hydration needs.
- *Fluids should taste good based on personal preference*. If the beverage does not taste good to an athlete, he or she will not drink it. Therefore, allow athletes to choose their fluid replacement beverage, within the guidelines stated in this chapter.
- *Coaches should allow for regular refreshment breaks during training and competitions*. Not only should fluids be on-site and available, but regular breaks should be taken in order for consumption to occur. Breaks will depend on the nature of the sport, such as timeouts in basketball or in between sets in swimming.

Fortifying *Your Nutrition Knowledge*

Determine Don's Hydration Needs

Don, an Ironman triathlete, performed a sweat trial to determine his fluid needs per hour. He cycled 50 miles at a 20 mph pace, and then ran 10 miles at a 9-minute-per-mile pace. During the workout, he drank four 24-ounce bottles of a sports beverage on the bike, and then drank another 24 ounces of water during the run. He lost 6 pounds during his workout.

What are Don's fluid needs?

Answer:

- *Determine body weight lost during exercise*. Don lost 6 pounds during his exercise session.
- *Determine the fluid equivalent, in ounces, of the total weight lost during exercise*. Don lost 6 pounds, so 6 lb × 16–24 oz/lb = 96–144 oz.
- *Determine the actual fluid needs of the athlete during an identical workout*. Don consumed 96 ounces on the bike (4 × 24 oz/bottle) plus 24 ounces on the run, for a total of 120 ounces. Adding the fluid consumed during exercise to the fluid equivalent of body weight lost during exercise equals 216–264 oz (120 + [96–144]).
- *Determine the number of fluid ounces needed per hour of exercise*. Don's total fluid needs are 216–264 oz. Because he was on the bike for 2.5 hours (50 miles ÷ 20 mph = 2½ hr) and 1.5 hours on the run (10 miles × 9 min/mile pace = 90 min = 1½ hr), the total exercise time was 4 hours. Dividing the total fluid needs by the total exercise time equals 54–66 oz/hr ([216–264 oz] ÷ 4 hr).

Don is a "big sweater," losing 54–66 ounces of sweat per hour of exercise. This volume of fluid can be challenging to consume while exercising. Currently, Don is only consuming 30 ounces of fluid per hour (120 oz consumed ÷ 4 hours of exercise = 30 oz/hour). Therefore, Don can start to gradually increase the volume of fluid he ingests each hour during exercise, approaching 54–66 ounces per hour, monitoring for any gastric and/or intestinal discomfort. He may or may not reach the ultimate goal; however, he can strive for it. To maximize the fluid retained, he should focus on the inclusion of sports beverages versus solely water.

TABLE 8.5 Sports Beverage Comparison (per 8 oz of product)

Product	Purpose	Quantity of CHO* (g)	% CHO*	Type of CHO*	Sodium (mg)	K** (mg)	Vitamins and Minerals	Other Ingredients	Comments
Ideal sports beverage composition	Hydration during short- and long-duration exercise	14–20	6–8%	Glucose, sucrose, and glucose polymers (maltodextrin)	70–200	30–75	If added, only small amounts (0.5–2% of DV) of calcium and magnesium	None	Beverage needs to taste good to encourage consumption. Athletes should be able to consume large quantities of the beverage without risk of reaching toxic levels of any vitamin or mineral.
Accelerade	Hydration during exercise	14	6%	Sucrose, fructose, trehalose (Ascenda)	127	43	67% of DV for vitamin C and E	3.3 grams of protein	Unique product containing protein. Levels of vitamin C and E are too high if consuming large quantities.
All Sport Body Quencher	Hydration during exercise	16	7%	High fructose corn syrup	55	60	40% of DV for vitamin C	None	High fructose corn syrup may cause upset stomach and intestinal cramping.
Carbo-Pro	Hydration during exercise	19	8%	Glucose polymers	0	0	None	None	Neutral flavor may be appealing to athletes who dislike the sweet taste of beverages. Does not contain electrolytes; therefore, it is not appropriate for long-duration activity unless combined with other products.
Gatorade Endurance (G Series Pro, 02 Perform)	Hydration for long-duration events	14	6%	Sucrose, fructose	200	90	None	None	Higher sodium and potassium content is beneficial for exercise lasting longer than 3 to 4 hours. The quantities of calcium and magnesium are kept low and therefore the risk of adverse side effects is also low.
Gatorade Thirst Quencher (G Natural, 02 Perform)	Hydration during exercise	14	6%	Sucrose, dextrose	110	30	None	None	The original sports beverage. Contains the basics for replenishment during exercise: carbohydrates, sodium, and potassium.

(continued)

TABLE 8.5 Sports Beverage Comparison (per 8 oz of product) *(Continued)*

Product	Purpose	Quantity of CHO* (g)	% CHO*	Type of CHO*	Sodium (mg)	K** (mg)	Vitamins and Minerals	Other Ingredients	Comments
Heed Sports Drink	Hydration during exercise	9.5	4%	Maltodextrin, zylitol, stevia	14.5	9	Added magnesium, vitamin B_6, manganese, calcium, chloride, and chromium	None	Low sodium and potassium as well as high levels of vitamin B_6 and manganese. The sugar alcohol, zylitol, could cause gastric upset.
Heed Perpetuem	Hydration during exercise	20	8%	Maltodextrin, fructose, stevia	80	44	Added magnesium, vitamin B_6, manganese, calcium, chloride, and chromium	2.5 g of protein	High level of chromium, moderate level of manganese. Higher sodium and potassium content is beneficial for exercise lasting longer than 3 to 4 hours.
High 5 Isotonic Sachets	Hydration during exercise	23	10%	Maltodextrin, fructose	240	70	None	None	Higher sodium and potassium content is beneficial for exercise lasting longer than 3 to 4 hours.
Ironman Perform	Hydration during exercise	17	8%	Maltodextrin, dextrose, fructose	190	10	Added magnesium	None	Higher content of sodium versus most sports drinks but low potassium. Magnesium content is low and should not cause problems for most athletes.
Powerade Isotonic	Hydration during exercise	19	8%	Sucrose, maltodextrin	67	34	None	None	Should not cause problems for most athletes.
Shaklee Performance	Hydration during exercise	25	10%	Maltodextrin, fructose, glucose	130	50	Added calcium, magnesium, chloride, and phosphorus	None	Concentration of carbohydrates is high for consumption during exercise. Added minerals are in small quantities and unlikely to cause problems unless very large volumes are consumed at once.

* CHO = Carbohydrate

** K = Potassium

- *Consumption of fluids should begin early in an exercise session.* It takes approximately 10 to 20 minutes for ingested fluids to reach the bloodstream; by initiating the consumption of fluid replacement beverages early in a training session, athletes can stay ahead of the game in hydration. By consuming fluids gradually during practices and competitions, athletes not only will maintain euhydration to a greater degree, but also will generally tolerate fluids better than in bolus feedings.

Food for Thought 8.2

Importance of Water Intake for Athletes

Review information on types of fluids, intake and output quantities, and other pertinent hydration information.

- *Use sports beverages for sessions lasting longer than 60 to 90 minutes.* As the duration of exercise increases, the need for carbohydrate and electrolyte replacement during exercise also escalates. Drinking solely water during long-duration exercise can increase the risk of hyponatremia because of the lack of electrolyte consumption. It should be noted that sports beverages may also enhance performance during slightly shorter duration activities (i.e., 45 to 60 minutes) if they are of high intensity.
- *Consider "hydration training" equal to "physical training" for competition.* Athletes must practice their hydration protocol during training to minimize the risk of gastric and intestinal discomfort during competitions caused by unfamiliar conditions. Hydration training should be considered as seriously as physical training.

What is the role of postexercise hydration?

After exercise, the body is thirsty and hungry for replenishment. Replacing water, as well as electrolytes and carbohydrates lost during exercise, as quickly as possible aids in the recovery of a variety of body processes, including cardiovascular, thermoregulatory, and metabolic activities. Unfortunately, many athletes fail to drink enough to fully restore euhydration and replenish their glycogen and electrolyte stores. Athletes need to be educated on the importance of proper hydration after exercise, current guidelines, and practical tips and hints to put the recommendations into practice.

How much fluid should be consumed?

Ideally, athletes will estimate their sweat losses and then aim to match sweat losses with fluid intake during exercise. However, this situation rarely exists, and therefore lost fluids need to be replaced after training sessions or competitions. If pre- and postexercise weight measurements were taken, then the rehydration volume can be calculated. Sweat losses should be matched 100–150% because the kidneys continually produce urine, thus increasing total water excretion.[52] Therefore, for every pound that is lost during exercise, approximately 16–24 ounces of fluid should be consumed. Fluids should be consumed as soon as possible to accelerate recovery, especially if athletes are performing multiple workouts in one day.

Regardless of whether body weight was measured, athletes should begin hydrating immediately, drinking slowly and consistently. Typically, athletes are encouraged to drink until their urine returns to a clear or pale color. If so, then it is estimated that the athlete will be within 1% of his or her baseline body weight.[53] However, the notion of urine color providing an accurate measure of hydration status has been questioned by some researchers. Kovacs et al.[54] found that urine color, specific electrical conductance, and osmolality were all poor indicators of hydration status in the 6 hours postexercise. More research is needed in this area to fully define the ideal measures of hydration postexercise.

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Two to 3 cups of water should be consumed for every pound that is lost during exercise. Fluids should be consumed as soon as possible to accelerate recovery.

Athletes should be cautioned to avoid drinking very large quantities of water in a short period of time immediately following exercise because this can potentially lead to delayed rehydration or, more seriously, hyponatremia. Large quantities of water are absorbed readily into the bloodstream. The rapid influx of water dilutes the concentration of sodium, causing a decreased plasma osmolality. The body responds to the lower osmolality by increasing urine production and blunting the normal sodium-dependent stimulation of the thirst mechanism. If plain water continues to be consumed, sodium concentrations will continue to plummet, and hyponatremia ensues. Postexercise beverages should ideally contain carbohydrates and electrolytes to replenish stores as well as to assist in optimizing rehydration. Therefore, beverages such as fruit and vegetable juices, milk, soups, or sports drinks are preferred over water after exercise.

What types of fluids should be consumed?

Many athletes' rehydration plans consist of guzzling down plain water. Although water will supply fluid

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Athletes should consider consuming drinks containing carbohydrates and sodium for rehydration after training to help speed replenishment of fluid and energy reserves as well as replace sodium lost as a result of sweating.

to the body, it may not be the ideal beverage for postexercise replenishment. By consuming carbohydrates and sodium along with water, euhydration, muscle glycogen, and electrolyte balance can be restored more readily.

As mentioned previously, most athletes do not drink enough fluids voluntarily. Therefore, any method of encouraging fluid consumption after exercise will be beneficial. Part of the concern with consuming only water is that it generally does not stimulate the drive to drink and also can increase urine output, causing both decreased intake and increased losses. The presence of carbohydrates and sodium in either a postexercise beverage or a meal consumed concurrently with water can remedy the situation. Sodium will enhance fluid retention and the drive to drink.[52,55] Carbohydrates can increase the rate of intestinal absorption of both water and sodium.[56–58] Because sodium is lost in sweat and carbohydrate stores are depleted during exercise, it is beneficial to consume these nutrients not only for rehydration purposes, but also for electrolyte and glycogen replenishment.

Potassium, another electrolyte lost in sweat, can easily be replaced by consuming whole foods and juices after exercise. In a 2-hour workout session, an average athlete will lose approximately 180 milligrams of potassium. One banana contains ~500 milligrams—more than twice what is lost in 2 hours of exercise. A variety of whole fruits and vegetables and their juices are rich sources of potassium and are ideal to consume after exercise.

Refer to **Table 8.6** for a summary of the daily and exercise-specific fluid recommendations for athletes.

Are supplements beneficial after exercise?

Many fluid replacement products are marketed to athletes to help facilitate hydration while also replacing electrolytes and glycogen stores after exercise. Before reaching for one of these products, athletes should consider the following:

- *How filling is the product?* Many of the products come in a powdered form that is mixed with 8–24 ounces of plain water. If an athlete loses 2 pounds during a workout (the equivalent of 32–48 fluid ounces), but only drinks 8–24 ounces, then he or she is falling short on water replenish-

TABLE 8.6 Daily and Exercise-Specific Fluid Recommendations for Athletes

	Daily Recommendation	2–4 Hours Prior to Exercise	10–20 Minutes Prior to Exercise	During Exercise	After Exercise
Amount	AI = 3.7 L/day (males); 2.7 L/day (females) 1 mL/calorie consumed	13–20 oz	7–10 oz	7–10 oz every 10 to 20 minutes	16–24 oz per pound of body weight lost, consumed within 2 hours
Type of Beverage	Water, 100% juices, milk, or other beverages	Water or sports drink; juices or milk if tolerated	Water or sports drink	Sports drink preferable or water	Water, sports drink, juices, milk, or other beverages

ment. Recovery products typically contain 120–320 calories and thus can be filling, causing an athlete to voluntarily stop drinking. Although added carbohydrates, sodium, and other nutrients are important to have immediately following exercise, if they prevent an athlete from also consuming the fluid he or she needs, then the supplement should be avoided. If the product tastes good and therefore the athlete drinks more, then the supplement may be beneficial.

- *How much carbohydrate and sodium are present in the supplement?* As mentioned previously, carbohydrates and sodium are beneficial for replenishment and rehydration. However, some products fall short of the recommended doses of each of these nutrients, potentially hindering recovery if no other food or fluid is consumed. Athletes should consume carbohydrates at a rate of 1.0–1.5 grams per kilogram of body weight per hour for 3 to 4 hours postexercise. For every liter of fluid lost in sweat (1 L = 34 oz = ~1.5–2 pounds of weight loss), 300–700 milligrams of sodium should be consumed after exercise. Based on body weight and sweat losses, athletes should examine the Supplement Facts label on the supplement to determine whether it contains sufficient quantities of carbohydrates and sodium, in addition to fluid.
- *How expensive is the product?* Supplements can cost a fortune! Water, juices, and soups as well as sodium- and carbohydrate-rich foods can deliver equal nutrition, often at a much lower price. However, some athletes prefer using the recovery drink supplements because they require little to no preparation, may not require refrigeration, and can taste good. Athletes should weigh the pros and cons of using a supplement versus "real" food to determine whether it is worth the cost.
- *Are there a lot of "extras" in the supplement?* Some supplements can pack a huge dose of one or several vitamins and minerals in one serving of the product. Keep in mind that the recovery drink is only one item consumed throughout the day. If the supplement, in addition to other foods and beverages, provides mega-doses of nutrients, toxic levels may be reached over time. Look closely at the Supplement Facts label to ensure that none of the nutrients are supplied in doses above 100% DV.

What are some practical guidelines for consuming fluids after exercise?

The goal of fluid consumption after exercise is to restore the body to euhydration status in preparation for the next training or competitive session. To achieve this goal, athletes and coaches should consider the following:

- *Rehydration should begin as soon as possible.* Athletes need to begin drinking water and other fluids within 2 hours of the cessation of activity, but preferably immediately following exercise. Encourage athletes who tend to avoid intake of fluids altogether after exercise to sip on fluids gradually until their stomach is ready to handle more volume.
- *Beverages and/or foods consumed after exercise should contain carbohydrates and sodium.* The addition of these nutrients facilitates fluid absorption and retention while also replacing nutrients lost during exercise. Examples of salty, carbohydrate-rich beverages and foods include vegetable juices, soups, cheeses, luncheon meats, pizza, pretzels, and condiments (such as mustard, ketchup, barbeque sauce, and steak sauce) on sandwiches and burgers.
- *Plan ahead.* Often, athletes will not refuel and rehydrate properly after exercise as a result of limited access to refreshments. Athletes need to take responsibility for ensuring that fluids and foods will be available immediately after exercise to begin the replenishment process. Planning options include packing items before heading to the gym or playing field, purchasing fluids and foods at a nearby grocery or convenience store, and returning home quickly and drinking/eating as soon as possible.
- *Plan for easy-to-prepare snacks and meals.* After hard workouts and competitions, athletes are fatigued and can lack the motivation to prepare a snack or meal in a timely fashion. Athletes should develop a rehydration plan that is easy to follow and easily accessible.
- *Use supplements wisely and sparingly.* Supplements can have a place in an athlete's rehydration plan, if used intelligently. Reserve supplement use for times when other beverages and foods are not available. Read Supplement Facts labels and look for adequate quantities of carbohydrates and sodium and moderate quantities of other vitamins, minerals, and nutrients.

Food for Thought 8.3

You Are the Nutrition Coach

Apply the concepts from this chapter to several case studies.

The Box Score

Key Points of Chapter

- Water is arguably the most essential of all the nutrients despite the fact that it does not provide the body with energy. Two-thirds of the body's water is found inside the cells and is referred to as intracellular water. Muscle tissue, which is of obvious importance to athletes, is 70% water. The remaining one-third of the body's water is found outside of cells and is known as extracellular water. Most of the extracellular water is found in the spaces between cells, in lymph, and in blood plasma.
- Water provides structural integrity to cells, serves as the body's delivery and waste removal medium, aids in thermoregulation, helps in the regulation of acid–base balance, and is critical to the maintenance of blood volume. All of these functions have a direct impact on not only athletic performance but also survival. Dehydration resulting in weight loss of as little as 2–3% of body weight begins to compromise cardiovascular function, which has a direct impact on sport performance.
- Approximately 80% of our daily water needs are supplied in the form of fluids. The remainder (20%) comes from water found in fruits, vegetables, other foods, and metabolic water.
- Water is lost via insensible perspiration, urine, feces, and sweat. The amount lost via sweat is highly variable depending on the environmental conditions as well as the intensity and duration of the exercise training or sport activity. Balancing water intake with water loss is critical for optimal performance, particularly during long-duration activities.
- One easy way to determine the achievement of water balance is to monitor body weight. Daily weight fluctuations are caused primarily by changes in water status.
- Although rare, it is possible to drink too much water, which can result in what is known as "water intoxication." Water intoxication leads to very low blood sodium levels (i.e., hyponatremia), thereby causing muscle weakness, disorientation, and/or coma. Endurance and ultra-endurance athletes are at greatest risk for hyponatremia because of their repeated exposure to long training bouts in which water intake is very high and/or sodium intake inadequate.
- For men and women 19 years and older, the recommended intake for water is 3.7 liters and 2.7 liters per day, respectively. These daily quantities reflect total water intake from drinking water as well as from other beverages containing water and from solid foods.
- Proper hydration before exercising sets the stage for optimal sports performance. Generous, but not excessive, amounts of fluids should be consumed in the 24 hours before exercise. Drinking enough fluids to meet the daily recommendations will allow an athlete to start an exercise session well hydrated. Drinking approximately 13–20 ounces of fluid 2 to 4 hours prior to competition and 7–10 ounces of fluid 10 to 20 minutes prior will ensure that athletes are properly hydrated.
- The goals of hydration during exercise are to maintain plasma volume and electrolyte balance. Water and electrolyte losses during exercise can vary greatly depending on several factors, including body size, exercise intensity, ambient temperature, humidity, clothing choices, and acclimation. For most individuals, consuming approximately 200–300 milliliters, or 7–10 fluid ounces, every 10 to 20 minutes during exercise will achieve this goal.
- Replacing water, as well as electrolytes and carbohydrates, should begin as quickly as possible after exercise. Two to 3 cups of water or replacement beverage should be consumed for every pound that is lost during exercise.

Study Questions

1. Discuss why the statement "you are what you drink" is appropriate in regard to water's role as a nutrient.
2. What is "water balance"? Which condition, a positive balance or a negative balance, poses the greatest risk to athletes? Defend your answer.
3. Explain why the statement "bottled water is a better source of fluid than tap water" is not necessarily accurate.
4. An athlete concerned about drinking municipal water because of the impurities comes to you to find out where she can buy distilled water. What do you tell the athlete? In other words, what are some of the pros and cons of drinking distilled water?
5. What is the difference between sweat and insensible perspiration? Which is a greater avenue of fluid loss in the athlete?
6. As a sports nutritionist, how can you determine whether your athletes are hydrating well enough during daily training sessions? If they are not taking in enough fluid during training, how do you know how much to tell them to drink to rehydrate before the next practice?
7. What is the AI for daily fluid intake? What are the body's sources for fluids throughout the day?
8. How much and what types of beverages can be consumed in the hours and minutes leading up to competition? Discuss why fluid intake prior to competition is advantageous.

9. What is a "sweat trial"? What data need to be collected when performing a sweat trial? What are the potential risks associated with not performing a sweat trial on an athlete?
10. What factors can affect how quickly fluids are absorbed by the intestines during training or sport performance?
11. What is hyponatremia? Under what conditions and in which sports might it pose the greatest risk?
12. As a sports nutritionist, what practical guidelines would you give your athletes to help ensure adequate hydration during competition?
13. After competition or training, rehydration is very important. What are the pros and cons of drinking just plain water during recovery?

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