Basic Athletic Training
Course Pack D

CHAPTER

29

Environmental Conditions

STUDENT OUTCOMES

1. Describe the activation of heat-regulating mechanisms in the body, including the methods used to generate heat via internal and external sources.
2. Demonstrate measurement of the heat stress index using a sling psychrometer.
3. Explain the methods used to prevent heat illness.
4. Identify the signs and symptoms of heat-related conditions.
5. Describe the appropriate management of heat-related conditions.
6. Describe the body's production of internal heat during

cold ambient temperatures.

7. Differentiate between frostbite and systemic cooling and describe the appropriate management of each condition.
8. Explain the impact of high altitude and poor air quality on exercise and sport performance.
9. Explain the dangers of lightning and list the lightning safety guidelines for sport and exercise participation.

INTRODUCTION

Environmental conditions affect even the best conditioned individuals. Athletic practices and contests can be held on hot, humid days or on cold, windy days, which predisposes individuals to hyperthermia and hypothermia, respectively. In addition, exercising during thunderstorms that produce lightning can be extremely dangerous. These environmental conditions as well as altitude and air quality are discussed in this chapter.

HEAT-RELATED CONDITIONS

? Field hockey practice is scheduled for this afternoon. The U.S. Weather Bureau is forecasting 90°F (air temperature), with a relative humidity of 80% during the practice time. Based on this information, what measures should be taken to reduce the risk of heat-related illness?

The process by which the body maintains body temperature is called **thermoregulation**. It is controlled primarily by the **hypothalamus**, which is a region of the diencephalon forming the floor of the third ventricle of the brain. **Hyperthermia**, or elevated body temperature, occurs when internal heat production exceeds external heat loss (Fig. 29.1). The hypothalamus is a gland that maintains **homeostasis**, or a state of equilibrium within the body, by initiating cooling or heat-retention mechanisms to achieve a relatively constant body core temperature between 36.1° and 37.8°C (97° and 100°F). The body core encompasses the skull, thoracic, and abdominal area. Heat-regulating mechanisms, such as perspiring or shivering, are activated by two means:

1. Stimulation of peripheral thermal receptors in the skin
2. Changes in blood temperature as it flows through the hypothalamus

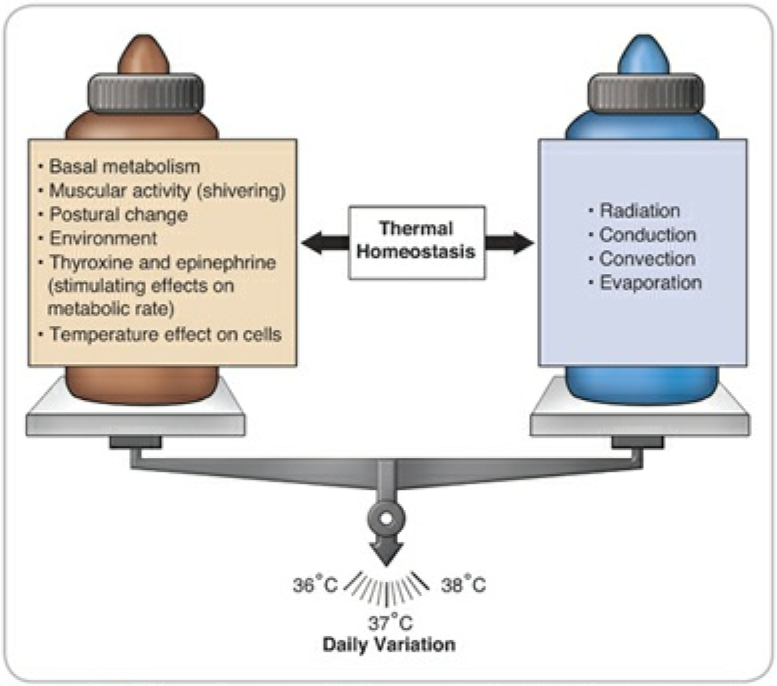

Figure 29.1. Thermal homeostasis. Homeostasis is achieved when internal heat production and heat loss are properly balanced to maintain a relatively constant body core temperature.

Internal Heat Regulation

During exercise, the body gains heat either from external sources (i.e., environmental temperatures) or from internal processes (Fig. 29.2). Much of the internal heat is generated during muscular activity through energy metabolism. The act of shivering can increase the total metabolic rate by threefold to fivefold. During sustained, vigorous exercise, the metabolic rate can increase by 20- to 25-fold above the resting level. Theoretically, such a rate can increase core temperature by approximately 1°C (1.8°F) every 5 to 7 minutes.

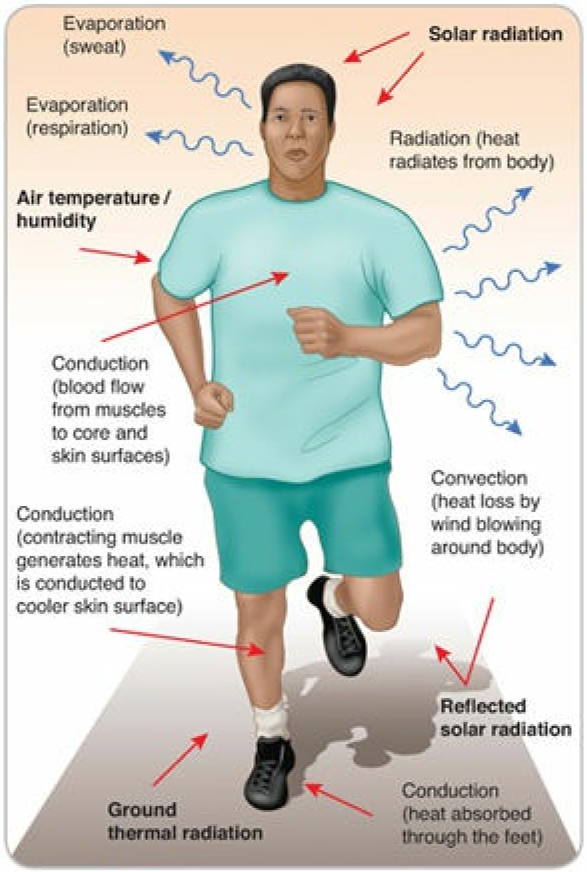

Figure 29.2. Heat gain and loss. Heat produced within working muscles is transferred to the body's core and skin. During exercise, body heat is dissipated into the surrounding environment by radiation, conduction, convection, and evaporation. *Straight lines* represent heat gain, and *wavy lines* indicate heat loss.

During exercise, the circulatory system must deliver oxygen to the working muscles and heated blood from deep tissues (i.e., core) to the periphery (i.e., shell) for dissipation. The increased blood flow to the muscles and skin is made possible by increasing cardiac output and redistributing regional blood flow (i.e., blood flow to the visceral organs is reduced). As exercise begins, heart rate and cardiac output increase while superficial venous and arterial blood vessels dilate to divert warm blood to the skin surface. Heat is dissipated when the warm blood flushes into skin capillaries. This is evident when the face becomes flushed and reddened on a hot day or after exercise. When the individual is in a resting state and the air temperature is less than 30.6°C (87°F), approximately two-thirds of the body's normal heat loss results from conduction, convection, and radiation. As air temperature approaches skin temperature and exceeds 30.6°C (87°F), evaporation becomes the predominant means of heat dissipation.

Radiation

Radiation is the loss of heat from a warmer object to a cooler object in the form of infrared waves (i.e., thermal energy) without physical contact. Usually, body temperature is warmer than the environment, and radiant heat is dissipated through the air to surrounding solid, cooler objects. When the temperatures of surrounding objects, such as hot artificial turf, exceed skin temperature, radiant heat is absorbed. Participating in a shaded area is one means of reducing the effects of radiant heat during activity.

Conduction

Conduction is the direct transfer of heat through a liquid, solid, or gas from a warm to a cooler object. For example, a football player can absorb heat through the feet simply by standing on hot artificial turf. The rate of conductive heat loss depends on the temperature gradient (i.e., difference) between the skin and surrounding surfaces and on the thermal qualities of both surfaces. For example, heat loss in water can be considerable.

Convection

Convection depends on conduction from the skin to the water or the air next to it. The effectiveness of heat loss by convection is dependent on the speed at which the air (or water) next to the body is exchanged. If air movement is slow, air molecules next to the skin are warmed and act as insulation. In contrast, if warmer air molecules are continually replaced by cooler air molecules, as occurs on a breezy day or in a room with a fan, heat loss increases as the air currents carry heat away. Convection cools the body as air currents pass by while the individual is running or cycling. For example, air currents at 4 miles per hour are approximately twice as effective for cooling as air currents moving at 1 mile per hour. This is the basis of the wind-chill index (**Fig. 29.4**), which shows the equivalent still-air temperature for a particular ambient temperature at different wind velocities. In water, the body loses heat more rapidly by convection while swimming than lying motionless in the water.

Evaporation

Evaporation is the most effective heat loss mechanism for cooling the body. During rest, sweat glands assist thermoregulation by secreting unnoticeable amounts of sweat (i.e., ~500 mL per day). Sweat is a weak saline solution, largely composed of water (99%), which evaporates when molecules in the water absorb heat from the environment and become energetic enough to escape as a gas. As core temperature rises during exercise or illness, peripheral blood vessels dilate and sweat glands are stimulated to produce noticeable amounts of sweat. On a hot, dry day, sweating is responsible for more than 80% of heat loss. Sweating, however, does not cool the body; the evaporation of the sweat is what cools the body. The total sweat that is vaporized from the skin depends on three factors:

1. The skin surface exposed to the environment
2. The temperature and relative humidity of the ambient air
3. The convective air currents around the body

Relative humidity is the most important factor in determining the effectiveness of evaporative heat loss. Relative humidity is the ratio of water in the ambient air to the total quantity of moisture that can be carried in air at a particular ambient temperature. It is expressed as a percentage. For example, 65% relative humidity means that ambient air contains 65% of the air's moisture-carrying capability at the specific temperature. When humidity is high, the ambient vapor pressure approaches that of the moist skin, and evaporation is greatly reduced. Therefore, this avenue for heat loss is closed, even though large quantities of sweat bead on the skin and, eventually, roll off. In this form, sweating represents a useless water loss that can lead to a dangerous state of dehydration and overheating.

In addition to heat loss through sweating, a basal level of body heat loss exists because of the continuous evaporation of water from the lungs, from the mucosa of the mouth, and through the skin. This averages approximately 350 mL of water as it seeps through the skin every day, as well as another 300 mL of water vaporized from mucous membranes in the respiratory passages and mouth. The latter is illustrated when you "see your breath" in very cold weather.

In total, it is not uncommon for an individual to lose 1.5 to 2.5 L per hour of water during exercise. This translates into a loss of 3 to 6 lb of body weight per hour. During a 2- to 3-hour workout, an individual can become dehydrated by losing 1% to 2% of body weight, which could compromise physiological function and negatively influence performance. Dehydration of >3% of body weight further compromises physiological function and increases the risk of developing an exertional heat illness (i.e., heat cramps, heat exhaustion, or heat stroke).[1,2] Although an individual may continually drink water throughout an exercise bout, less than 50% of the fluid lost is replenished. This "voluntary dehydration" was recognized long ago and continues to be characterized by researchers. Accordingly, a physically active individual should drink as much fluid as possible before exercise and before thirst is perceived during exercise. It is critical to drink beyond the perception of satisfying one's thirst to **hyperhydrate** the body to prevent voluntary dehydration.

Measuring the Heat-Stress Index

The heat-stress index is a measure of ambient air temperature, humidity, and solar radiant energy. The most commonly used heat-stress index, the Wet-Bulb-Globe Temperature (WBGT) Index, consists of the measurement of ambient temperature (T_a), wet-bulb temperature (T_w), and black globe temperature (T_g) as follows:

1. For outdoor use,

$$\mathrm{WBGT} = (0.1 \times \mathrm{T}_a) + (0.7 \times \mathrm{T}_w) + (0.2 \times \mathrm{T}_g)$$

2. For indoor use,

$$WBGT = (0.3 \times T_a) + (0.7 \times T_w)$$

Currently, the WBGT is the most widely used index of determining heat stress for indoor and outdoor use. It is used in military and industrial settings to determine safe limits for physical activity. The index is limited, however, in that it fails to take into account the impact of wearing clothing. Clothing that is impermeable or semipermeable can impede or prevent sweat evaporation, and as such, a higher heat stress level is generated.

T_w is the temperature recorded by a thermometer with the mercury bulb surrounded by a wet wick. T_g is the temperature recorded by a thermometer with a mercury bulb encased in a sphere that is painted black. The black globe absorbs radiant energy from the environment to obtain a measure that is not available using dry- and wet-bulb thermometers.

See **Application Strategy: Using a Sling Psychrometer to Determine Relative Humidity**, available on the companion Web site at thePoint, for further information on use of a sling psychrometer.

A sling psychrometer measures heat stress by exposing dry- and wet-bulb thermometers to rapid airflow. One thermometer is ordinary (i.e., a dry-bulb thermometer); the other thermometer has a cloth wick over its bulb (i.e., a wet-bulb thermometer). After whirling the instrument in the air for several minutes, the temperatures of both thermometers are read. If the surrounding air is holding as much moisture as possible (i.e., relative humidity of 100%), no difference exists between the two temperatures. In contrast, greater differences in the recorded temperatures indicate a high rate of evaporation and low humidity.

In 2002, the National Athletic Trainers' Association (NATA) published a position statement on exertional heat illnesses.[3] This statement served as a basis for an additional document in 2003 released by the Inter-Association Task Force on Exertional Heat Illness,[4] a group that convened at the request of the NATA to develop universal guidelines for reducing the risk of heat illness. The document from the Inter-Association Task Force received the support of the American Academy of Pediatrics, the American College of Emergency Physicians, the American Orthopaedic Society for Sports Medicine, and the American College of Sports Medicine, among other prestigious organizations. Because of the inception of these documents, these organizations including the Korey Stringer Institute are continuously providing updated evidence to promote the prevention of sudden death in sport through health and safety initiatives. The NATA provides the public with position and consensus statements providing various recommendations for ensuring a safe exercise environment for sport participants. For example, in certain geographic locations, such as the Southeastern United States, the WBGT is routinely high, extreme, or hazardous throughout a large portion of the year; as such, appropriate steps should be taken to reduce increased risk of heat illness. Table 29.1 lists recommendations for activities when temperature, humidity, and radiation are measured using the WBGT index.

TABLE 29.1 Wet-Bulb-Globe Temperature Risk Chart

WET-BULB-GLOBE TEMPERATURE	FLAG COLOR	LEVEL OF RISK	COMMENTS
<65°F (<18°C)	Green	Low	Risk is low but still exists on the basis of risk factors.
65°–73°F (18°–23°C)	Yellow	Moderate	Risk increases as the event progresses through the day.
73°–82°F (23°–28°C)	Red	High	Everyone should be aware of injury potential; individuals at risk should not participate in physical activity.
>82°F (28°C)	Black	Extreme or hazardous	Consider rescheduling or delaying the event until safer conditions prevail; if the event must take place, a high alert condition exists.

Factors That Modify Heat Tolerance

Several factors can affect an individual's tolerance to heat. Acclimatization and proper hydration are among the most critical in preventing heat illness.

Acclimatization

Exercising moderately during repeated heat exposures can result in physiological adaptation to a hot environment, which can improve performance and heat tolerance (Box 29.1). In general, the major acclimatization occurs during the first week of heat exposure and is complete after 14 days. Only 2 to 4 hours of daily heat exposure is required. The first several exercise sessions should be light and last approximately 15 to 20 minutes. Thereafter, exercise sessions can progressively increase in duration and intensity. Well-acclimatized individuals should train for 1 to 2 hours under the same heat conditions that will be present during their competitive event.[3] Proper hydration is essential for the acclimatization process to be effective. In 2009, the NATA released the preseason heat-acclimatization guidelines for secondary school athletics. This guideline provides several recommendations for a 14-day heat-acclimatization period.[5]

BOX 29.1 Physiological Changes Seen After 10 Days of Heat Exposure

- Heart rate and body temperature decrease.
- Sweat becomes more diluted (i.e., less salt is lost).
- Peripheral blood flow and plasma volume increase.
- Sweat is distributed more evenly over the skin surface.
- The increased perspiration rate is sustained over a longer period of time.
- Sweating capacity nearly doubles.

Heat acclimatization is lost rapidly, however. As a general rule, 1 day of heat acclimatization is lost over 2 to 3 days without heat exposure, with the major benefits being lost within 2 to 3 weeks after returning to a more temperate environment.

Fluid Rehydration

The primary objective of fluid replacement is to maintain plasma volume so that circulation and sweating occur at optimal levels. Dehydration progressively decreases plasma volume, peripheral blood flow, sweating, and stroke volume (i.e., the quantity of blood ejected with each heartbeat), and it leads to a compensatory increase in heart rate. The general deterioration in circulatory and thermoregulatory efficiency increases the risk of heat illness, impairs physiological functions, and decreases physical performance.

Thirst is not an adequate indicator of water needs during exercise. Physically active individuals may not become thirsty until systemic water loss equals 2% of body weight.[6] Rather, thirst develops in response to increases in osmolality and blood sodium concentrations and decreases in plasma volume caused by dehydration.

It is essential that physically active individuals begin an exercise session when they are well hydrated and have ready access to adequate water replacement throughout the exercise session to prevent dehydration. Cold beverages of 10° to 15°C (50° to 59°F) are recommended because cooler drinks, especially water, empty from the stomach and small intestine significantly faster than warm fluids.[1] Fluid replacement guidelines include the following[1]:

- Preexercise hydration: 500 to 600 mL (17 to 20 fl oz) of water or a sports drink 2 to 3 hours before exercise and 200 to 300 mL (7 to 10 fl oz) of water or a sports drink 10 to 20 minutes before exercise
- Exercise hydration: 200 to 300 mL (7 to 10 fl oz) of water or a sports drink every 10 to 20 minutes
- Postexercise hydration: Within 2 hours of exercise, rehydrate with water to restore hydration status, CHOs to replenish glycogen stores, and electrolytes to speed rehydration. Ingestion equal to 150% of weight loss can result in optimal rehydration 6 hours after exercise.

See **Recommended Fluid Intake for a Strenuous 90-Minute Exercise Bout**, found on the companion Web site at thePoint.

Several steps can be taken to ensure adequate hydration before, during, and after exercise (Box 29.2).

BOX 29.2 Strategies to Reduce the Risk of Dehydration

Healthy population

- Have unlimited fluid available during exercise.
- When exercising for 1 hour or more, drink at least 7–10 oz of fluid every 10–20 minutes. Drink beyond thirst.
- Drink cool fluids containing less than 8% CHOs.
- Use individual water bottles to accurately measure fluid consumption.
- Freeze fluid in plastic bottles before exercise; the bottles will thaw and stay cool during exercise sessions.
- Record preexercise and postexercise weight to determine if excessive and unsafe weight loss has occurred.
- Replenish lost fluid with at least 24 oz of fluid for every pound of body weight lost.
- Avoid caffeine, alcohol, and carbonated beverages.

Children (in addition to previous)

- Allow 10–14 days of acclimatization.
- Reduce intensity of prolonged exercise.

To prevent dehydration, fluids must be ingested and absorbed by the body. Running through sprinklers or pouring water over the head may feel cool and satisfying, but it does not prevent dehydration. A standard rule is to drink until thirst is quenched—and then drink a few more ounces.

An easy method to determine if enough fluids are being consumed is to monitor the color and volume of the urine. An average adult's urine amounts to 1.2 quarts in a 24-hour period. Urination of a full bladder usually occurs four times each day. Within 60 minutes of exercise, passing light-colored urine of normal to above-normal volume is a good indicator of adequate hydration. If the urine is dark yellow in color, of a small volume, and of strong odor, the individual needs to continue drinking. Ingesting vitamin supplements often can result in a dark-yellow urine; as such, urine color, volume, and odor must all be considered when determining hydration status.[4,6]

Carbohydrate Replacement

Consuming carbohydrates (CHOs) during the preexercise hydration session along with a healthy daily diet can increase glycogen stores and benefit optimal performance. If exercise is intense, additional CHOs should be consumed 30 minutes before exercise and after exercise. During exercise, 1 L of a 6% CHO drink per hour of exercise is recommended.[1] CHO concentrations greater than 8% may compromise the rate of fluid emptying from the stomach and absorbed from the intestine. Fruit juices, CHO gels, sodas, and some sport drinks have CHO concentrations greater than 8% and are not recommended during an exercise session as the sole beverage.[1] While maintaining hydration, the participant should avoid diuretics, such as excessive amounts of protein, caffeinated drinks (e.g., soda, tea, and coffee), chocolate, and alcoholic beverages.

Clothing

Light-colored, lightweight, and porous clothing is preferred to dark, heavy weight, and nonporous material. Clothing made of 100% cotton is not recommended, especially in hot climates, because moisture in sweat-soaked cotton does not evaporate easily. Evaporative heat loss occurs only when clothing is thoroughly wet and perspiration can evaporate. Changing into a dry shirt simply prolongs the time between sweating and cooling. Heavy sweat suits or rubberized plastic suits produce high relative humidity close to the skin and retard evaporation, severely increasing the risk of heat illness. Even when wearing only football helmets and loose-fitting, porous jerseys and shorts, 50% of the body surface of football players can be sealed and evaporative cooling is limited. The increased metabolic rate that is needed to carry the weight of the equipment and the increased temperature on artificial surfaces also can increase the risk of heat illness. As such, football players should initially practice in t-shirts, shorts, and low-cut socks. On hot, humid days, uniforms should not be worn, and if possible, shoulder pads and helmets should be removed often to allow radiation and evaporative cooling. Because much of the body’s heat escapes through the head, helmets used in noncontact sports (e.g., cycling) should allow adequate airflow and evaporation.

Age

Children have a lower sweating capacity and a higher core temperature during exposure to heat as compared to adolescents and adults. This occurs even though children have a higher number of heat-activated sweat glands per unit of skin. Sweat composition in children also differs. Children excrete higher concentrations of sodium and chlorine and lower concentrations of lactate and potassium. Therefore, children do not benefit from electrolyte beverages and should use only cool water for fluid replacement.[7] In addition, children require a longer time to acclimatize to heat as compared to adolescents and young adults.

In general, middle-aged and older men and women are less tolerant to exercising in heat. When compared to younger men and women, older men and women develop higher heart rates, higher skin and core temperatures, and lower sweat rates during exercise in heat. Aging can lead to a limited peripheral vascular response that can impair local vasodilation. The onset of sweating also appears to be delayed with advancing age, and the sweating response appears to be blunted. This may result from either a limitation in sweat gland output or a dehydration-limited sweat output if fluid replacement is insufficient. In addition, older individuals do not recover from dehydration as effectively as younger individuals do, which may be related to a blunted thirst drive. This may make older individuals more prone to dehydration that could adversely affect the thermoregulatory capacity.

Sex

The general consensus is that women can tolerate the physiological and thermal stress of exercise at least as well as men of comparable fitness and level of acclimatization. Both sexes can acclimatize to a similar degree; however, sweating does differ. Although women possess more heat-activated sweat glands per unit of skin area as compared to men, women sweat less than men do. Compared with men, women begin to sweat at higher skin and core temperatures, produce less sweat for a comparable heat-exercise load, and yet show an equivalent heat tolerance. Women probably rely more on circulatory mechanisms for heat dissipation, whereas men rely on evaporative cooling.

The production of less sweat to maintain thermal balance can provide women with significant protection from dehydration during exercise at a high ambient temperature.

Diuretics, Supplements, and Medications

Individuals taking diuretics or laxatives should be carefully observed for dehydration. These agents increase fluid loss, reduce plasma volume, and may adversely affect thermoregulation and cardiovascular function. Substances used to induce vomiting and diarrhea also lead to dehydration and may cause excessive electrolyte loss with accompanying muscle weakness. Some nutritional supplements, such as creatine phosphate, require additional fluids to decrease the risk of heat cramps and other associated heat illnesses. Medications, such as β-adrenergics, anticholinergics, antihistamines, β-blockers, calcium channel blockers, and tricyclic antidepressants, can impair the body's normal mechanisms of dissipating heat, which may result in a dangerously high core temperature.[8] Before taking supplements or medications, an individual should be fully informed regarding the proper use and possible side effects of the substances.

Practice Schedules

On hot, humid days, workouts, practices, and competitions should be scheduled during early morning or evening hours to avoid the worst heat of the day (i.e., 11:00 a.m. to 3:00 p.m.). It also may be necessary to allow frequent water breaks (i.e., 10 minutes every half an hour), shorten practices, and lessen the exercise intensity. Whenever possible, participants should be moved out of direct sunlight (e.g., shade trees and tents), and restrictive equipment (e.g., pads and helmets) should be removed frequently.

Weight Charts

Measuring pre- and postexercise weight can decrease the risk of heat illness. Measurement of the athlete's sweat rate (sweating rate = preexercise body weight − postexercise body weight + fluid intake − urine volume / exercise time in hours) should be a representative range of environmental conditions, practices, and competitive events. Begin by weighing a large number of athletes prior to an intense 1-hour practice session and then reweigh them at the end of the 1-hour practice. Do not allow any rehydration or urination during the 1-hour postpractice session when the sweat rate is being calculated. When water loss reaches 3% of body mass, a definite impairment is noted in physical work capacity, physiological function, and thermoregulation. A rule of thumb is that for every pound of water lost, 24 oz (i.e., 3 cups) of fluid should be ingested, meaning that 150% of the fluid loss during exercise is replenished.

Identifying Individuals at Risk

Healthy individuals at risk for heat illness include those who are poorly acclimated or conditioned, those who are inexperienced with heat illness, those with large muscle mass, children, wheelchair athletes, Special Olympians, and elderly people. Others who are at risk are listed in Box 29.3.

BOX 29.3 Individuals at Risk for Heat Illness

Healthy individuals

- Age extremes (children, elderly persons)
- Excessive muscle mass, large, or obese
- Poorly acclimatized or conditioned
- Previous history of heat illness
- Salt or water depletion
- Sleep deprived

Those with acute illnesses

- Illnesses that involve fever
- Gastrointestinal illnesses

Those with chronic illnesses

- Alcoholism and substance abuse (e.g., amphetamines, cocaine, hallucinogens, laxatives, diuretics, narcotics)

- Cardiac disease
- Certain nutritional supplements (e.g., creatine phosphate)
- Cystic fibrosis
- Eating disorders
- Medications (e.g., anticholinergics, antidepressants, antihistamines, diuretics, neuroleptics, β-blockers)
- Skin problems with impaired sweating (e.g., miliaria rubra or miliaria profunda)
- Uncontrolled diabetes mellitus or hypertension
- Using oil- or gel-based sunscreens that block evaporative cooling

Wheelchair athletes who

- Have a spinal cord injury (alters thermoregulation)
- Limit water intake to avoid going to the bathroom

Heat Illnesses

If the signs and symptoms of heat stress (e.g., thirst, fatigue, lethargy, flushed skin, headache, and visual disturbances) are not treated, cardiovascular compensation begins to fail, and a series of progressive complications, termed heat illness, can result. The various forms of heat illness, in order of severity, include exercise-associated muscle (heat) cramps, exercise (heat) exhaustion, and exertional heat stroke. Although symptoms often overlap between the conditions, failure to take immediate action can result in severe dehydration and possible death.

Exercise-Associated Muscle (Heat) Cramps

Etiology

Heat cramps are painful, involuntary muscle spasms caused by excessive water and electrolyte loss during and after intense exercise in the heat.

Paradoxically, the condition most frequently occurs in well-conditioned, acclimatized, physically active individuals who have overexerted themselves in hot weather and rehydrated only with water. Predisposing factors include lack of acclimatization, use of diuretics or laxatives, neuromuscular fatigue, and sodium depletion in the normal diet. The condition can be prevented by ingesting copious amounts of water and increasing the daily intake of salt through a normal diet several days before the period of heat stress.[9]

Signs and Symptoms

Exercise-associated muscle cramps commonly occur in the calf and abdominal muscles, but they also may involve the muscles of the upper extremity. Signs and symptoms mimic dehydration and include thirst, sweating, transient muscle cramps, and fatigue. Body temperature is not usually elevated, and the skin remains moist and cool. Pulse and respiration may be normal or slightly elevated. Dizziness may be present.

Management

The patient should stop activity, replace lost fluids with sodium-containing fluids, and begin mild, passive stretching of the involved muscle(s) and ice massage over the affected area. The patient should ingest enough cool CHO fluids to drink beyond the point of satisfying thirst. A recumbent position may allow more rapid redistribution of blood flow to cramping leg muscles.[3] The patient should be watched carefully, because this condition may precipitate heat exhaustion or heat stroke.

Exercise (Heat) Exhaustion

Etiology

Exercise (heat) exhaustion usually occurs in individuals who are not acclimatized during the first few intense exercise sessions on a hot day. Those who wear protective equipment or heavy uniforms also are at greater risk, because evaporation through the material may be retarded. It is a “functional” illness and is not associated with organ damage. Heat exhaustion is caused by ineffective circulatory adjustments compounded by a depletion of extracellular fluid, especially plasma volume, as a result of excessive sweating. Blood pools in the dilated peripheral vessels, which dramatically reduces the central blood volume necessary to maintain cardiac output.

Signs and Symptoms

Thirst, headache, dizziness, light-headedness, mild anxiety, fatigue, profuse sweating, weak and rapid pulse, and low blood pressure in the upright position are common signs and symptoms (Fig. 29.3A). The patient may appear to be ashen and gray, with cool, clammy skin. An uncoordinated gait often is present. Urine output may be small. Sweating may be reduced if the person is dehydrated, but body temperature generally does not exceed 40°C (104°F).[9] The patient may have an urge to defecate or may experience diarrhea. Significant neurological impairment is absent.

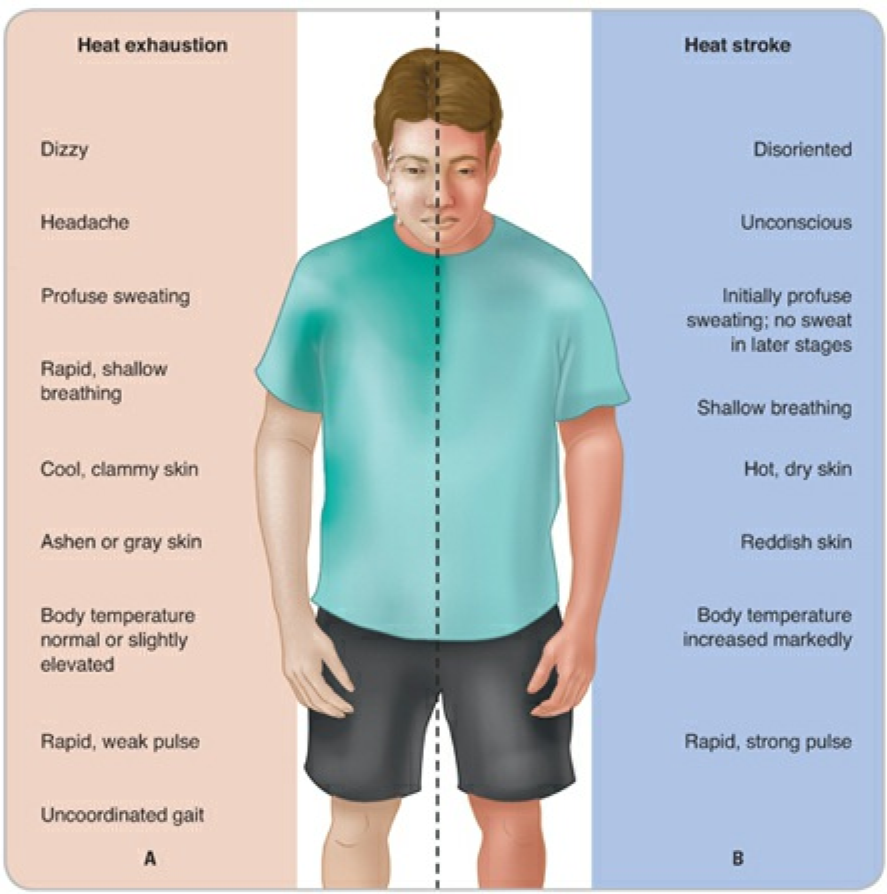

Figure 29.3. Signs and symptoms of heat exhaustion and heat stroke. A, Heat exhaustion. **B,** Heat stroke.

Management

The patient should be moved immediately to a cool place. All equipment and unnecessary clothing should be removed. Rapid cooling of the body should be initiated. Two effective cooling methods are evaporative cooling and ice immersion. Evaporative cooling involves spraying copious amounts of tap water over the patient's skin with air fanning. The average cooling rate through this technique is 0.14°C per minute.[10] Ice immersion involves placing the patient into a pool or tub of cold water (~1° to 15°C [35° to 59°F]). Circulation of the water may enhance cooling. If immersion in ice water is not available, other cooling methods should be used. These may include wrapping in cool, wet, iced towels; using fans; and applying crushed ice packs to the neck, axilla, and groin. Fans and cool-mist machines, however, have limited use during humid conditions. It is essential to administer copious amounts of cool fluids with a diluted electrolyte solution as quickly as possible. Elevating the legs to reduce postural hypotension also can be effective. If recovery is not rapid and uneventful, the patient should be transported to the closest medical facility; intravenous fluids may need to be administered. Some patients, particularly endurance athletes exercising in the heat, may require as much as 4 L of fluid replacement.[11] Physical activity should not be resumed until the patient has returned to the predehydrated state and been cleared by a physician.

Exertional Heat Stroke

Etiology

Exertional heat stroke is the least common, but most serious, heat-related illness. In football, heat stroke is second only to head injuries as the most frequent cause of death. The condition also is seen in dehydrated distance runners and wrestlers. Unlike classic heat stroke, which involves prolonged heat exposure in infants, elders, or unhealthy sedentary adults in whom body heat-regulation mechanisms are inefficient, exertional heat stroke occurs during physical activity.[3]

During exercise, metabolic heat continues to rise. Decreased blood plasma volume causes the heart to beat faster and work harder to pump blood through the circulatory system. The thermoregulatory system is overloaded, and the body's cooling mechanisms fail to dissipate the rising core temperature. The hypothalamus shuts down all heat-control mechanisms, including the sweat glands, in an effort to conserve water loss. A vicious circle is created in which, as temperature increases, the metabolic rate increases, which in turn increases heat production. The skin becomes hot and dry. As the temperature continues to rise, permanent brain damage may occur. Core temperature can rise to 40.6°C (105°F), and it has been known to reach 41.7° to 42.2°C (107° to 108°F). If untreated, death is imminent. Mortality is directly related to the magnitude and duration of the hyperthermia.

Signs and Symptoms

By definition, the condition occurs when body temperature is elevated to a level that causes characteristic clinical and pathological damage to body tissues and affects multiple organs. Initial symptoms include a feeling of burning up, confusion, disorientation, irrational behavior, agitation, profuse sweating, and an unsteady gait. As the condition deteriorates, sweating ceases. The skin is hot and dry and appears to be reddened or flushed (**Fig. 29.3B**). The patient hyperventilates or breathes deeply and has dilated pupils, giving the appearance of a glassy stare. As core temperature rises, the pulse becomes rapid and strong (as high as 150 to 170 beats per minute). The patient may become hysterical or delirious. Tissue damage by excessive body heat leads to vasomotor collapse, shallow breathing, decreased blood pressure, and a rapid pulse. Muscle twitching, vomiting, or seizures may occur just before the patient lapses into a coma.[9]

Management

Mortality and organ damage appear to be directly proportional to the length of time between elevation of core body temperature and initiation of cooling therapy.

> The emergency medical plan, including summoning emergency medical services (EMS), should be activated.

The patient should be moved immediately to a cool place. All equipment and unnecessary clothing should be removed, and rapid cooling of the body should be initiated. Core temperature should be measured every 5 to 10 minutes and, to avoid hypothermia, should not fall below 38°C (100.4°F).[3] Victims of exertional heat stroke usually require airway management, intravenous fluids, and in severe cases, circulatory support. Physical activity should not be resumed until the patient has returned to the predehydrated state and been cleared by a physician.

Other Heat Conditions

Four other common conditions may result from exercising in the heat. These include heat syncope, exertional hyponatremia, miliaria rubra, and miliaria profunda. Although not usually life threatening, they can be bothersome to a competitive individual. Table 29.2 lists the signs, symptoms, and immediate care for all heat-related conditions.

TABLE 29.2 Management of Heat-Related Conditions

CONDITION	SIGNS/SYMPTOMS	TREATMENT
Heat cramps	Involuntary muscle spasms or cramps, normal pulse and respirations, profuse sweating and dizziness	Rest in cool place; massage the cramp with ice and passive stretching; drink cool water with diluted electrolyte solution.
Heat syncope	Weakness, fatigue, hypotension, blurred vision, fainting, elevated skin and core temperature	Place supine in cool place; elevate legs; give oral saline if conscious; record blood pressure and body temperature.
Miliaria rubra and miliaria profunda	Pruritic, inflamed skin eruptions	Cool and dry the affected skin; control infection; avoid reexposure until lesions have healed.
Heat exhaustion	Thirst; headache; weakness; confusion; profuse sweating; skin is wet, cool, and clammy and may appear ashen; breathing is rapid and shallow; pulse is weak.	Rest in cool place; remove equipment and clothing; execute rapid cooling of body; sponge or towel with cool water, or use a fan; intravenous fluids; discontinue activity until thoroughly recovered and cleared by a physician.
Heat stroke	Sweating ceases; irritability progresses to confusion and hysteria; unsteady gait; pulse is rapid and strong; skin is hot, dry, red, or flushed; blood pressure falls; convulsions; seizures; coma	Activate the emergency medical plan, including summoning EMS; rapidly cool body with immersion in ice water, or place crushed ice packs on the neck, axilla, and groin.

Heat Syncope

Etiology

Heat syncope, or orthostatic dizziness, can occur when a person is exposed to high environmental temperatures, or it can be seen at the end of a race in individuals who are not acclimatized who may or may not be under heat stress. The condition is usually attributed to vasodilation, postural pooling of blood, diminished venous return, dehydration, reduction in cardiac output, and cerebral ischemia.[3,9] The condition is often seen during the first 5 days of acclimatization or in individuals with heart disease or those taking diuretics. Predisposing factors include dehydration, lack of acclimatization, ending the exercise bout without a cooldown, or moving quickly from the cold (e.g., a cold bath) into a hot sauna or whirlpool.

Signs and Symptoms

Signs and symptoms include dizziness, low blood pressure (hypotension), blurred or tunnel vision, pale or sweaty skin, weakness or fatigue, reduced pulse rate, and elevated skin temperature. Core temperature may not be elevated.[3]

Management

Treatment involves placing the patient in a supine position in a shaded or cool area, elevating the legs above the level of the head, monitoring vital signs, and replacing any water deficit.

Exertional Hyponatremia

Etiology

Exercising for long periods may cause low blood sodium (i.e., **hyponatremia**), which is a potentially fatal condition. Low blood sodium occurs when an individual drinks excessive amounts of water, thus diluting the sodium content of blood. Inadequate sodium intake also may play a role; however, low blood sodium is most likely to occur during prolonged exercise in dehydrated individuals who lose large amounts of sodium through sweating.

Signs and Symptoms

Hyponatremia is characterized by headache, confusion, nausea, cramping, bloated stomach, altered consciousness, significant mental compromise, swelling in the extremities (e.g., fingers and ankles), and seizures. In severe cases, the individual may experience respiratory changes as a result of cerebral and/or pulmonary edema.[4]

The emergency medical plan, including summoning EMS, should be activated. Blood sodium levels need to be monitored. Use of certain diuretics or intravenous solutions may be necessary.

Management

The patient should not resume activity until cleared by a physician and instructed in an individual-specific hydration protocol to ensure that the proper level and type of beverages and meals are consumed before, during, and after exercise.[4]

Miliaria Rubra and Miliaria Profunda

Etiology

Miliaria rubra and miliaria profunda are seen in humid climates or with skin that is totally covered by clothing, resulting in a highly humid environment. The sweat glands are occluded with organic debris and can no longer produce sweat for evaporation, which may predispose the individual to heat conditions. If the resulting heat rash is localized, it is called miliaria rubra; if the condition becomes generalized and prolonged, it is called miliaria profunda.

Signs and Symptoms

Miliaria rubra (i.e., heat rash or prickly heat) is an inflamed, itchy (i.e., **pruritic**) skin eruption that arises when active sweat glands are blocked. The lesions are truncal, noninflamed, and **papular**. Individuals with profunda are less heat tolerant than the general population due to the prolonged suppression of heat loss; therefore, they are at a higher risk for heat illnesses.

Management

Treatment involves cooling and drying the skin and relieving the itching. Cool baths and topical antipruritics, such as pramoxine and calamine lotion, can provide relief. The rash usually subsides if a person avoids sweating for 1 or 2 days.

Because the U.S. Weather Bureau is forecasting 90°F (air temperature) with a relative humidity of 80% during the scheduled time for field hockey practice, the following measures should be taken to reduce the risk of heat-related illness: Practice should be shortened and the intensity of some activities reduced; water should be available at any time throughout practice; and scheduled water breaks should take place every 20 minutes.

COLD-RELATED CONDITIONS

The weather for a scheduled soccer game is forecasted to be in the low 40s, with winds gusting up to 25 miles per hour. What measures can be taken to prevent cold-related conditions?

Hypothermia, or reduced body temperature, occurs when the body is unable to maintain a constant core temperature. In cold weather, three primary heat-promoting mechanisms attempt to maintain or increase core temperature. The initial response is cutaneous vasoconstriction to prevent blood from shunting to the skin. Because the skin is insulated with a layer of subcutaneous fat, heat loss is reduced. The second response is to increase metabolic heat production by shivering, which is an involuntary contraction of skeletal muscle, or to increase physical activity. During vigorous exercise, skeletal muscles can produce 30- to 40-fold the amount of heat produced at rest. During gradual, seasonal changes, an increased amount of the hormone thyroxine is released by the thyroid gland, which serves as the third avenue to increase metabolic rate.

Because of their larger ratio of surface area to body mass and smaller amount of subcutaneous fat, children are more prone to heat loss during cold exposure than adults are. Cold exposure also increases the risk for exercise-induced bronchospasm, which is being seen increasingly in children. Women are less able to produce heat through exercise or shivering because of their lower percentage of lean body mass, although the additional subcutaneous fat does provide more tissue insulation. Men tend to maintain lower heart rate, higher stroke volume, and higher mean arterial blood pressure than women do, but no distinct differences are seen in cold tolerance when genders are matched for aerobic fitness at the same relative workload. Elderly people, however, have a decreased capacity for metabolic heat production and vasoconstriction. Alcohol dulls mental awareness of cold and inhibits shivering, perhaps by causing hypoglycemia.[12]

Preventing Cold-Related Injuries

During cold weather, body heat is lost through respiration, radiation, conduction, convection, and evaporation. Although the body attempts to generate heat through heat-producing mechanisms, this may be inadequate to maintain a constant core temperature. **Box 29.4** lists predisposing factors that contribute to cold-related injuries.

BOX 29.4 Predisposing Factors for Cold-Related Injuries

- Inadequate insulation from cold and/or wind
- Restrictive clothing or arterial disease that prevents peripheral circulation, especially in the feet
- Diet lacking adequate CHOs or fat
- Presence of chronic metabolic disorders
- Spinal cord injury (cannot vasoconstrict peripheral arterioles in the skin and has a blunted shivering response to cold)
- Preexisting fatigue or general weakness
- Use of alcohol, tobacco products (especially smoking tobacco), and other medications, such as barbiturates, phenothiazines, reserpine, and narcotics
- Age (very young or old)
- Decreased circulation

Several steps that can be taken to prevent heat loss are summarized in Box 29.5. The "layered principle" of clothing allows several (i.e., three or more) thin layers of insulation rather than one or two thick ones. Fabrics should be light yet porous enough to allow free exchange of perspiration, and they should not restrict movement. Fabrics may include wool, wool/synthetic blends, polypropylene, treated polyesters (e.g., Capilene), and hollow polyesters (e.g., ThermoStat).[13] Cotton has poor insulating ability that is markedly decreased when saturated with perspiration. Pile garments that contain down (e.g., Dacron, Hollofil, Thinsulate, or Quallofil) are more useful when worn during warm-up, time-outs, or cooldown periods following exercise. Jackets with a hood and drawstring as well as pants made of wind-resistant material (e.g., Gore-Tex, nylon, or 60/40 cloth) can protect against the wind.

BOX 29.5 Reducing the Risk of Cold-Related Injuries

- Check weather conditions and consider possible deterioration.
- Identify individuals who may be susceptible to cold and observe closely.
- Dress in several light layers.
- Wear windproof, dry, well-insulated clothing that allows water evaporation; wool, polypropylene, or polyesters (e.g., Capilene, ThermoStat) are recommended.
- Carry windproof pants and jacket if conditions warrant; keep the back to the wind.
- Wear well-insulated, windproof mittens, gloves, hats, and scarves.
- Wear well-insulated footwear that keeps the feet dry.
- Avoid dehydration. Do not drink alcoholic beverages or eat snow because these worsen hypothermia.
- Carry nutritious snacks that contain predominantly CHOs.
- Eat small amounts of food frequently.

- Do not stand in one position for extended periods of time. Wiggle the toes and keep moving to bring warm blood to various areas of the body.
- Stay dry by wearing appropriate rain gear or protective clothing. If wet, change into dry clothing as soon as possible.
- Breathe through the nose, rather than the mouth, to minimize heat and fluid loss.
- Watch the face, ears, and fingers for signs of frostbite.

A ski cap, face mask, and neck warmer can protect the face and ears from frostbite. Ski goggles can protect the eyes; goggles must be well ventilated to prevent fogging and be treated with antifog preparations. Polypropylene gloves or, in extreme temperatures, woolen mittens can be worn with windproof outer mittens of Gore-Tex or nylon. Athletic shoes should be large enough to accommodate an outer pair of heavy wool socks. It is important to avoid getting wet, because heat loss can be increased by evaporation. The insulating ability of clothing can be decreased by as much as 90% when saturated either with external moisture or condensation from perspiration. If weather conditions are bad enough, it is better to cancel the practice or event for the day.

Cold Conditions

People tend to adapt less readily to cold than to heat. Even inhabitants of cold regions show only limited evidence of adaptation, such as a higher metabolic rate. Like heat illness, cold-related injuries range from minor problems, such as Raynaud syndrome, cold-induced bronchospasm, or frostbite, to the more severe, general systemic cooling, or hypothermia, which can be life threatening. Cold emergencies occur in two ways. In one, the core temperature remains relatively constant, but the shell temperature decreases. This results in localized injuries from frostbite. In the other, both core temperature and shell temperature decrease, leading to general body cooling. All body processes slow down, and systemic hypothermia results. If left unabated, death is imminent.

Raynaud Syndrome

Etiology

Raynaud syndrome is seen in young individuals, especially females. It can be caused by an underlying disease or anatomical abnormality, and it can be a long-term complication of frostbite. Usually, however, its source is unknown.

Signs and Symptoms

The condition is characterized by bilateral episodes of spasms of the digital blood vessels in response to emotion or cold exposure. Initially, during the ischemic phase, the affected digits (usually the fingers) become cold, pale, and numb. This is followed by hyperemia with redness, throbbing pain, and swelling.

Management

Treatment involves warming the affected extremity. A physician should evaluate the patient to rule out an underlying condition. Cigarette smoking should be avoided, because it compromises circulation.

Cold-Induced Bronchospasm

Etiology

Cold-induced bronchospasm is also a condition seen frequently in young people. It is brought on by exposure to cold, dry air during cold-weather sports.

Signs and Symptoms

Linked to exercise-induced bronchospasm, the patient experiences difficulty breathing, as manifested by shortness of breath, coughing, chest tightness, and wheezing.

Management

Attacks can be prevented by the use of bronchodilators or cromolyn sodium. Salmeterol, a more recent, long-acting bronchodilator, administered 30 to 60 minutes before exercise appears to protect many individuals for up to 12 hours. Chapter 26 provides information on exercise-induced bronchospasm.

Frostbite Injuries

Etiology

Frostbite is caused by the freezing of soft tissue. Individuals who have cold urticaria (cold allergy) or Raynaud syndrome are at higher risk for frostbite. Frostbite is classified on a continuum of three degrees (**Table 29.3**). First-degree, or superficial, frostbite involves the skin and underlying tissues, but the deeper tissues are soft and pliable. If damage extends into the subcutaneous tissues, it is classified as second-degree frostbite. Third-degree, or deep, frostbite involves the tissues deep to the subcutaneous layers and may result in complete destruction of the injured tissue, including damage to bones, joints, and tendons.[14] Damage depends on the depth of cold penetration that results from the duration of exposure, temperature, and wind velocity. Areas commonly affected are the fingertips, toes (especially when wearing constricting footwear), earlobes, and tip of the nose.

TABLE 29.3 Signs and Symptoms of Frostbite

First degree	Skin is soft to the touch and appears initially red, then white, and usually is painless. The condition typically is noticed by others first.
Second degree	Skin is firm to the touch, but tissue beneath is soft and initially appears red and swollen. Diffuse numbness may be preceded by an itchy or prickly sensation. White or waxy skin color may appear later.
Third degree	Skin is hard to the touch, totally numb, and appears blotchy white to yellow-gray or blue-gray.

Signs and Symptoms

In superficial frostbite, the area may feel firm to the touch, but the tissue beneath is soft and resilient. The skin initially appears red and swollen, and the patient complains of diffuse numbness, transient tingling, or burning. If the frostbite extends into the subcutaneous or deep layers, the skin feels hard, because it actually is frozen tissue. The area then turns white, with a yellow or blue tint that looks waxy.

Management

A person with superficial frostbite should be removed from the cold and taken indoors immediately and then treated with careful, slow warming of the area. Clothing and jewelry should be removed and the injured area immersed in water heated to between 37° and 40°C (98° and 104°F) for 15 to 30 minutes.[15] A whirlpool is ideal, but if one is unavailable, a basin large enough to prevent the skin from touching the sides of the container should be used. Hot water should be avoided, because it may cause burns. If frostbite is superficial, rewarmed skin may have clear blisters, whereas with deep frostbite, the rewarmed skin has hemorrhagic blisters.[14] The involved area should be dried and a sterile dressing applied. If fingers or toes are involved, sterile dressings should be placed between the digits before covering. The entire area can be covered with towels or a blanket to keep it warm, and the patient should be transported to the nearest medical center, with the affected limb slightly elevated.

If the frostbite is severe, hemorrhagic blisters may form over the area, and gangrene may develop within 2 to 3 weeks. Throbbing, aching pain as well as burning sensations may last for weeks. The skin may remain permanently red, tender, and sensitive to reexposure to cold.

Deep frostbite is best rewarmed under controlled conditions in a hospital. The emergency medical plan, including summoning EMS, should be activated. During transport, the patient should be kept warm, but active rewarming of the frozen part should not occur.

Systemic Body Cooling (Hypothermia)

Hypothermia is more of a danger to individuals who are exposed to cold for long periods of time, such as long distance runners and Nordic ski racers, especially those who are slowing down late in a race because of fatigue or injury. Any injured or ill individual who has been exposed to cold weather or cold water should be suspected of having hypothermia until proved otherwise.

Etiology

Most of the body heat is lost through radiation involving the exposed surfaces on the hands, face, head, and neck. When the temperature is 4.4°C (40°F), more than half the body's generated heat can be lost from an uncovered head. If the temperature is −15°C (5°F), up to 75% of the body's heat is lost through the head. Air movement coupled with cold produces a wind-chill factor that causes heat loss from the body much faster than occurs in still air. The faster the wind, the higher the wind-chill factor (**Fig. 29.4**).

Temperature (˚F)

Wind (mph) / Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Wind Chill (˚F) = 35.74 + 0.6215 T - 35.75 ($V^{0.16}$) + 0.4275 T ($V^{0.16}$)

Where, T = Air Temperature (˚F); V = Wind Speed (mph)

Little Danger Frostbite Times: 30 minutes 10 minutes 5 minutes

Figure 29.4. **Wind-chill index.**

When core temperature falls below 35°C (95°F), essential biochemical processes begin to slow. Heart and respiration rates slow, cardiac output and blood pressure fall, and as the skin and muscles cool, shivering increases violently. Numbness sets in, and even the simplest task becomes difficult to perform. If core temperature continues to drop below 32°C (90°F), shivering ceases, and muscles become cold and stiff. Cold diuresis (i.e., polyuria) occurs as blood is shunted away from the shell to the core in an effort to maintain vascular volume. This leads to excessive excretion of urine by the kidneys. If intervention is not initiated, death is imminent.

See **Signs and Symptoms of Hypothermia**, available on the companion Web site at thePoint,

for highlights of the stages of systemic hypothermia.

Signs and Symptoms

Patients with hypothermia are divided into those with mild hypothermia (rectal temperature between 37° and 35°C [98.6° and 95°F]) and those with moderate-to-severe hypothermia (rectal temperature between 34° and 32°C [93.2° and 90°F]). Rectal temperatures obtained through either a digital or mercury thermometer that can read below 34° (93.2°F) are preferred over using a tympanic, axillary, or oral temperature due to environmental concerns, such as exposure to air temperatures.[15]

In mild hypothermia, the patient is vigorously shivering. The patient may appear to be clumsy, apathetic, or confused and have slurred speech, stumble, and drop things. Blood pressure is within normal limits. A patient with moderate-to-severe hypothermia does not feel any sensation or pain, is not shivering, and presents with depressed respiration and pulse. The patient's movements will become jerky, and the patient becomes unaware of the surroundings. Blood pressure will be decreased and difficult to measure. Cardiac arrhythmias, dilated pupils, and muscle rigidity may lead to bradycardia, severely depressed respirations, and hypotension; pulmonary edema progresses to a comatose state and eventually cardiac arrest.[15]

Management

In cases of mild hypothermia, the patient should be moved carefully into a warm shelter. Any wet or damp clothing should be removed. Rewarming can be accomplished by insulating the patient with dry clothes (remember to cover the head) and allowing the patient to shiver inside a blanket or sleeping bag or by using external rewarming devices, such as hot-water bottles or heating pads. Apply external heat only to the trunk and other areas of heat transfer, such as the axilla, chest wall, and groin. Warm drinks (preferably nonalcoholic and noncaffeinated) and foods containing 6% to 8% CHOs to sustain metabolic heat production may be useful after the patient is partly rewarmed and able to swallow. The patient should continue to be rewarmed en route to the nearest medical facility.

The emergency medical plan, including summoning EMS, should be activated.

If hypothermia is moderate to severe, on-site rewarming should not be attempted. Once rewarming begins, serious electrolyte, metabolic, and cardiovascular changes occur that cannot be treated in the field. As such, while waiting for EMS to arrive, treatment involves preventing any further cooling and monitoring and treating for shock as necessary. As in mild hypothermia, remove any wet or damp clothing; insulate the patient with warm, dry clothing or blankets; and apply heat to the trunk, axilla, chest wall, and groin. Continue to monitor vital signs and be prepared for airway management.[15]

The effects of cold can be minimized by dressing in several layers of insulating clothing under the uniforms. Jackets with a hood and drawstring as well as pants made of wind-resistant material can protect against the wind. Wool socks and gloves also may keep the player warm.

OTHER ENVIRONMENTAL CONDITIONS

The threat exists for thunderstorms to pass through the area during a scheduled afternoon lacrosse game. Based on this information, what actions should be taken before the game, and how should a decision to suspend the game be determined?

The ever-changing environment presents a unique challenge for individuals participating in sport and physical activity. Individuals must cope with heat, humidity, cold, rain, lightning, altitude, and air pollution. A basic understanding of these situations can help to facilitate the performance of participants.

Altitude Disorders

The percentage of oxygen in the atmosphere at an altitude of 10,000 ft is exactly the same as that at sea level. The density of air, however, decreases progressively with ascension above sea level. The decreased partial pressure of ambient oxygen, or density of oxygen molecules, makes it more difficult to deliver oxygen to working muscles of the body. This leads to a reduction in work capacity that is directly proportional to altitude. This factor has little, if any, effect on short bursts of energy, but it can have significant impact on sustained aerobic activities. In some cases, individuals are unaware of the impact that altitude exposure can have on their performance and, in compensating for the decrease in maximum oxygen uptake, experience hyperventilation or tachycardia. As a result, stroke volume is reduced, and fewer red blood cells are available to transport needed oxygen.

High-altitude illness is a collective term for the syndromes that affect individuals who are not acclimatized shortly after their ascent to high altitude. The term encompasses the primary cerebral syndromes of acute mountain sickness (AMS) and high-altitude cerebral edema (HACE) as well as the pulmonary syndrome high-altitude pulmonary edema (HAPE). Both HACE and HAPE occur much less frequently than AMS, but these two syndromes are potentially fatal. Risk factors for developing high-altitude illness include the rate of ascent, the altitude reached, and the individual’s susceptibility.[16]

Acute Mountain Sickness

Etiology

Altitude sickness is a disorder related to **hypoxia** at high altitudes. Predisposing factors include cold temperatures, strenuous exercise, use of cigarettes or alcohol, respiratory infections or a blunted ventilatory response, the water-retaining phase of the menstrual cycle, and a family history of AMS. The mildest form of altitude sickness, AMS arises after rapid ascent (i.e., <24 hours) to altitudes above 8,200 ft (2,500 m). A time lag of 8 or more hours occurs between arrival at the altitude and onset of symptoms.[17]

Signs and Symptoms

Signs and symptoms are directly proportional to the rapidity of the ascent and both the duration and degree of physical exertion, and they are inversely proportional to acclimatization and physical conditioning. Symptoms usually start 4 to 8 hours after arrival at high altitude. Headache is the cardinal symptom but may not be sufficiently distinctive to differentiate it from other causes of headache. Other symptoms include dizziness, fatigue, nausea, vomiting, suppressed appetite, insomnia, dyspnea, decreased urine output, and tachycardia during physical exertion. Appetite suppression can be severe during the onset of a high-altitude stay, and this suppression can result in an average reduction of energy intake by approximately 40%, with an accompanying loss of body mass. The nonspecific symptoms of AMS can result in diagnostic confusion with those of other disorders, such as exhaustion, dehydration, hypothermia, alcohol hangover, and migraine headache.[16]

Management

Acclimatization and physical conditioning can enhance altitude tolerance, reduce the severity of AMS, and decrease the physical performance decrements that occur during the early stages of altitude sickness. In addition, diets that are high in CHOs (i.e., >70% of total kilocalories) and low in salt can lessen the impact of AMS. If AMS occurs, treatment involves a reduction in altitude, physical rest, eating frequent small meals, avoiding alcohol, and taking acetaminophen for the headache. Recovery normally is seen within a few days, with no residual effects.

High-Altitude Cerebral Edema

Etiology

HACE, often thought of as the end stage of AMS, rarely occurs below 10,000 ft. It usually happens in people who ascend rapidly to significant altitudes.

Signs and Symptoms

Several days after the onset of mild AMS, increased brain cell volume leads to a severe headache, nausea and vomiting, ataxia, impaired judgment, inability to make decisions, irrational behavior, and in some cases, altered consciousness. Without treatment, coma usually develops within 1 to 2 days, and death occurs rapidly because of brain herniation.[17]

Management

An immediate descent is mandatory. High-flow supplemental oxygen or a portable hyperbaric bag should be used while descending or if descent is delayed.

High-Altitude Pulmonary Edema

Etiology

For unknown reasons, some individuals experience a severe aspect of AMS at altitudes greater than 9,000 ft. The condition is referred to as HAPE. Individuals at greatest risk include those who ascend rapidly, perform strenuous exercise on arrival, are obese, are male, and have a previous history of pulmonary edema.[17] HAPE may develop during the first exposure but often develops after descent and reascent or occurs during the second night after ascent. The lungs accumulate fluid within the alveolar walls that may progress to pulmonary edema.

Signs and Symptoms

Initial signs and symptoms include shortness of breath (**dyspnea**), decreased performance, cough, and reduced exercise tolerance greater than expected for the altitude.[16,17] A dry cough with substernal chest pains becomes productive, with blood-stained sputum, later in the illness. During rest, headache, decreased concentration, fatigue, **tachycardia**, and abnormal breath sounds (i.e., **rales**) in the middle right lobe also may be present. Later, **cyanosis**; extreme weakness; mild fever (rarely exceeding 38.3°C [101°F]); productive cough with bloody, frothy sputum; irrational behavior; and coma may occur.

Management

A rapid return to a lower altitude is imperative. The patient should be given oxygen as soon as possible. Exertion should be kept to a minimum. If oxygen is unavailable and descent impossible, treatment in a portable hyperbaric chamber may be lifesaving, although the recumbent position that is necessary for operation of the chamber may not be tolerated by the patient. The condition resolves rapidly.

Preventing Altitude Illness

Acclimatization is the single most important factor in preventing the onset of altitude sickness. In general, the length of the acclimatization period depends on the altitude. Individuals who are native to areas of high altitude have a larger chest capacity, more alveoli, more capillaries that transport blood to tissues, and a higher red blood cell level. As a result, these individuals have an advantage in endurance activities at higher altitudes. Training for aerobic activities (i.e., events lasting longer than 3 or 4 minutes) at altitudes above 6,800 ft (2,000 m) requires acclimatization for 10 to 20 days for maximal performance. Highly anaerobic activities at intermediate altitudes do not require arrival in advance of the event. The benefits of acclimatization probably are lost within 2 to 3 weeks after returning to sea level.

Air Pollution and Exercise

Chemicals that make up air pollution typically are classified as either primary pollutants (i.e., those emitted directly into the environment) or secondary pollutants (i.e., those that develop from the interactions of the primary pollutants). Most primary pollutants essentially come from the combustion of petroleum-based fuels, including carbon monoxide, sulfur oxides, nitrogen oxides, hydrocarbons, and particulates. Secondary pollutants include ozone, peroxyacetyl nitrate, sulfuric acid, aldehydes, and sulfates. Smog usually contains both primary and secondary pollutants. Certain individuals are more susceptible to the adverse effects of air pollution. Even what would be subthreshold concentrations of air pollutants for healthy adults can compromise respiratory and cardiovascular function in children and elderly people. Others who are more affected by air pollution include individuals with respiratory disorders (e.g., asthma or chronic obstructive pulmonary disease) and heart disease.

Carbon Monoxide

The most frequent air pollutant is carbon monoxide. It is a colorless, odorless gas that reduces the ability of hemoglobin to transport oxygen and restricts the release of oxygen at the cellular level. In an individual who smokes cigarettes, carbon monoxide reduces both aerobic power and the ability to sustain strenuous, submaximal exercise. It not only interferes with maximal performance during exercise but also can impair attentiveness; decision making; and psychomotor, behavioral, or attention-related tasks, and it may result in higher core temperatures during prolonged exercise. The major group at risk from carbon monoxide exposure includes individuals with cardiovascular disorders (e.g., angina pectoris, ischemic cardiovascular disease, and intermittent **claudication**), pulmonary diseases (e.g., chronic bronchitis and emphysema), or anemia.

Sulfur Oxides

Sulfur oxides are produced from burning coal or petroleum products. They include sulfur dioxide, sulfuric acid, and sulfate, with 98% of the sulfur released into the atmosphere being in the form of sulfur dioxide. By itself, sulfur dioxide has little effect on lung function in normal individuals, but it can be a potent bronchoconstrictor in those with asthma. Exposure to just a trace amount of the gas during brief periods of strenuous exercise (i.e., 10 minutes) can produce a marked decrease in airway conductance in people with asthma. Individuals with asthma can prevent problems in breathing by using disodium cromoglycate before exposure or by breathing through the nose.

Nitrogen Oxides

Nitrogen oxide is a combination of nitrogen and oxygen that develops from high-temperature combustion. It is seen in several forms—namely, nitrous oxide, nitric oxide, nitrogen dioxide (NO_2), dinitrogen dioxide, dinitrogen pentoxide, and nitrate ions. Oxide levels in the air are particularly high during peak traffic periods, at airports, and in the smoke associated with cigarette smoking and firefighting. High NO_2 levels (i.e., 200 to 4,000 ppm) can cause severe pulmonary edema and even death. In lower concentrations (i.e., 2 to 5 ppm), NO_2 increases airway resistance and reduces pulmonary diffusion capacity.

Ozone

Ozone (i.e., triatomic oxygen) is a complex union of oxygen, nitrogen oxides, hydrocarbons, and sunlight and is therefore designated a photochemical oxidant. Ozone is classified as either ground level or atmospheric. Atmospheric ozone is produced naturally and protects the earth from the sun's ultraviolet waves. The ozone that interferes with functional capacity is ground level, which stays close to the earth's surface and originates in automobile and factory emissions. Ground-level ozone is an irritant that can exacerbate existing respiratory conditions, such as emphysema and asthma. The effects of ground-level ozone normally are short term, but they can diminish work production and may produce shortness of breath and early fatigue. When maximal exertion is required, ozone may lead to coughing, chest tightness, shortness of breath, pain during deep breaths, nausea, eye irritation, fatigue, and lowered resistance to lung infections.

Ozone levels are indexed as low, moderate, or high (**Table 29.4**). The ozone index can be found on the weather page of most newspapers or on the Web (e.g., https://weather.com/). Individuals who reside in regions of high ozone levels may become desensitized to the irritating effects after repeated exposures and, as such, do not develop symptoms or changes in functional abilities.

TABLE 29.4 Ozone Level

LEVEL	ACTIVITY PRECAUTIONS
Low	No precautions are necessary.
Moderate	Individuals with respiratory conditions should minimize outdoor exposure and decrease prolonged exercise or work.
High	Individuals with respiratory conditions should stay indoors. Individual without respiratory conditions should minimize outdoor exposure.

Primary Particulates

Primary particulates, which include dust, soot, and smoke, can impair pulmonary function when inhaled into the lungs. The fine dust from charcoal and cigarette smoke increases airway resistance and reduces forced expiratory volume. The ability of fine dust to infiltrate the lungs depends on the particle size, amount of air inspired and expired in a single breath (i.e., **tidal volume**), frequency of breathing, and whether the particle was inhaled nasally or orally. During strenuous exercise, the breathing rate significantly increases, and breathing tends to be oral. Therefore, exercise likely increases the impact of these pollutants on breathing effectiveness.

Exercising in Thunderstorms

Another environmental threat is inclement weather conditions, such as rain, lightning, and thunderstorms. Most organized outdoor sport practices and competitions are held between 3:00 p.m. and 9:00 p.m., which are peak periods for the development of thunderstorms and lightning. If the lightning (flash) to thunder (bang) occurs within 30 seconds, all outdoor activities should end, and all participants should seek shelter, preferably in a sturdy building.

Lightning Injuries

Etiology

Lightning poses a triple threat of injury—namely, burns from the high temperature of the lightning strike, injury caused by the elicited mechanical forces activated by the intense levels of electricity (electromechanical forces), and the resulting concussive forces that can propel objects through the air, causing blunt trauma (e.g., fracture and concussion). Lightning injuries usually are the result of five different mechanisms[18]:

1. Direct strike
2. Contact injury
3. Side flash (splash)

4. Ground current (step voltage)
5. Blunt trauma

> If a patient is not breathing and is in cardiac arrest, the emergency medical plan, including summoning EMS, should be activated. Rescue breathing and cardiopulmonary resuscitation should be initiated. Unless ruled out, a cervical spine injury should always be suspected, and treatment should proceed accordingly. Any person struck by lightning should be immediately transported to the nearest medical facility.

Signs and Symptoms

The most common burn from lightning is a Lichtenberg figure, which resembles a feathering pattern on the skin. A Lichtenberg figure is not actually a burn; rather, it is a pattern on the skin from the electron avalanche that strikes the body hit by lightning, which causes an inflammatory dermal response. The pattern is transient and fades after 24 hours.

Direct strikes are the most deadly, particularly when the person is in contact with metal (e.g., golf club, shoe cleats, belt buckle, bra clips, watch band, or metal bleachers), with the burn normally appearing where the person's body is in contact with that metal object. Additional symptoms are cardiac asystole (cardiac standstill) and respiratory arrest. Fortunately, the heart is likely to restart spontaneously if the victim is not experiencing respiratory arrest. The most critical factor in determining morbidity and mortality associated with a lightning strike is the duration of apnea rather than cardiac asystole. It is not uncommon for a person to become unconscious or confused or to develop amnesia following a lightning strike. Other medical conditions that have been reported include blunt trauma, including fractures and internal organ damage; brain lesions because of hypoxia caused by cardiac asystole; ruptured tympanic membranes; ocular problems, including hyphema as well as fixed and dilated pupils; seizures; subdural and epidural hematomas; anterior compartment syndromes; and transitory lower extremity paralysis.[19]

Management

Lightning strikes claim the lives of approximately 100 people each year. Prior to moving into action, survey the scene and determine if it is safe to respond to the situation. Activate the EMS plan. Move the victim to a safer location, if available. The priority is to assess and treat for apnea and asystole. If the person is conscious and has normal cardiorespiratory function, a secondary assessment should be conducted to assess and treat any burns, fractures, or other trauma that may have been sustained.

Lightning Safety Policy

As mentioned, most organized outdoor sport practices and competitions are conducted between the hours of 3:00 p.m. and 9:00 p.m. Most lightning casualties occur between May and September, with July having the greatest number of casualties. There are 45% of deaths and 80% of casualties occurred in these months between 10:00 a.m. and 7:00 p.m.[19,20] Thunderstorms can become threatening within 30 minutes of the first sign of thunder. All athletic and recreational facilities should have a formalized emergency action plan specific to lightning safety prior to the start of the thunderstorm season. This plan should include the following[19]:

See **Lightning Safety Policy for All Outdoor Activities, Including Swimming**, available on the companion Web site at thePoint.

- Specific chain of command to identify an individual with the authority to remove participants from athletic venues or activities
- Weather watcher to actively look for signs of developing local thunderstorms, such as high winds, darkening clouds, and any lightning or thunder
- Specific plan to monitor local weather forecasts from either local weather radio stations or the National Weather Service
- Clearly defined and listed safe structures or locations to evacuate to in the event of lightning. Ideally, this structure should have plumbing, electric wiring, and telephone service. If unavailable, an alternative is the use of a fully enclosed vehicle with a metal roof and the windows completely

closed.

- Specific criteria for suspension and resumption of activities. (By the time the flash-to-bang count approaches 30 seconds or less, all individuals should be inside or should immediately seek a safe structure or location. To determine distance of the storm, begin counting at the first sight of the flash. Stop counting when the associated bang [thunder] is heard. Divide by 5 to determine the distance in miles. For example, a flash-to-bang count of 30 seconds equates to a distance of 6 miles.) Wait at least 30 minutes after the last sound of thunder or lightning flash before resuming the activity.
- Recommended lightning safety strategies. If caught outside, assume the lightning-safe position (i.e., crouched on the ground, weight on the balls of the feet, feet together, head lowered, and ears covered). Do not lie flat on the ground.

All coaches, athletic trainers, athletic directors, athletic supervisors, managers, and physically active individuals should understand the development of thunderstorms and lightning strikes. This lightning safety policy can decrease the risk of injury and death as well as protect the organization or institution from litigation if the policy is referred to and heeded.

> Before the start of the lacrosse game, the athletic trainer should review the school's lightning safety emergency plan, determine who will serve as the designated weather watcher, and meet with the game officials and visiting team's athletic trainer (or coach) to explain the lightning safety plan. The game should be suspended if the "flash-to-bang" is within 30 seconds or if a thunderstorm appears imminent.

SUMMARY

1. The body generates heat by cutaneous vasoconstriction, increasing the metabolic heat production by shivering or physical activity, and the increase of the hormone thyroxine during gradual, seasonal changes. The

body loses heat through respiration, radiation, conduction, convection, and evaporation.

2. During exercise, the body gains heat from external sources (e.g., environmental temperatures) or internal processes (e.g., muscle activity).
3. During rest, approximately two-thirds of the body's normal heat loss results from conduction, convection, and radiation. As air temperature approaches skin temperature and exceeds 30.6°C (87°F), evaporation becomes the primary means of heat dissipation.
4. Sweating places a high demand on the body's fluid reserves and can create a relative state of dehydration. If sweating is excessive and fluids are not continually replaced, plasma volume falls, and core temperature may rise to lethal levels.
5. Acclimatization and proper hydration are among the most critical factors in preventing heat illness. Minerals lost through sweating generally can be replaced through the diet. During prolonged exercise, drinking a small amount of electrolytes added to a rehydration beverage replaces fluids more effectively than drinking plain water.
6. To prevent dehydration, fluids must be ingested and absorbed by the body. Cold liquids, especially water, empty from the stomach and small intestines faster than warm fluids do.
7. Exercise-associated muscle (heat) cramps are caused by excessive loss of water and electrolytes during and after intense exercise in the heat. Treatment involves passive stretching of the involved muscles and ice massage over the affected area. The patient also should drink fluids containing an electrolyte solution to beyond the point of satisfying thirst.
8. Exercise (heat) exhaustion is a functional illness and is not associated with organ damage. Treatment involves moving the patient to a cool place and rapidly cooling the body. The patient also should drink fluids containing an electrolyte solution to beyond the point of satisfying thirst. Intravenous fluids may need to be administered if the dehydrated state is

moderate to severe.

9. Exertional heat stroke signifies a significantly elevated core temperature and dehydration. The emergency medical plan, including summoning EMS, should be activated, because the patient may require airway management, intravenous fluids, and in severe cases, circulatory support. While waiting for EMS to arrive, the patient should be moved to a cool place, and efforts should be made to rapidly cool the body. Immersion in ice water is the most effective method to cool the body; however, to avoid hypothermia, the core temperature should not fall below 38°C (100.4°F). If conscious, the patient should drink copious amounts of fluid.
10. In the prevention of cold-related injuries, the principle of layering clothing has proven to be effective through providing several thin layers of insulation. In addition, a ski cap, face mask, and neck warmer can protect the face and ears from frostbite.
11. Frostbite occurs when the core temperature remains relatively constant but the shell temperature decreases. Superficial frostbite is treated by moving the patient indoors, removing any wet or damp clothing, and rapidly rewarming the involved body part in water heated to between 39° and 42°C (102.2° and 107.6°F) for 30 to 45 minutes. Deep frostbite is best rewarmed under controlled conditions in a hospital. The emergency medical plan should be activated.
12. Hypothermia occurs when both core and shell temperatures decrease, leading to general body cooling. If hypothermia is mild, the patient can be rewarmed; if hypothermia is moderate to severe, on-site rewarming should not be attempted. The emergency medical plan, including summoning EMS, should be activated.
13. Altitude sickness may involve AMS, HAPE, or HACE. The latter two conditions can lead quickly to death; therefore, oxygen therapy and immediate descent are mandatory.
14. Carbon monoxide, the most frequent air pollutant, interferes with the

ability of hemoglobin to transport oxygen to the cells. Other air pollutants that can affect sport performance include sulfur oxides, nitrogen oxides, ozone, and primary particulates.

15. Lightning poses a double threat of injury—namely, burns from the high temperature of the lightning strike and concussive injuries caused by the elicited electromechanical forces.
16. Most thunderstorms occur between 10:00 a.m. and 7:00 p.m. during the months of May through September. Schools and sport organizations should have a detailed lightning safety policy to prevent injury or death from storms.

APPLICATION QUESTIONS

1. A new soccer coach has joined the athletic staff at your high school. What guidelines should be provided to the coach to prevent heat illness during preseason practice sessions?
2. The WGBT in the wrestling room is 85°F. A wrestler leaves the mat during the match complaining of dizziness. Assessment indicates rapid and weak pulse; ashen, cool, and clammy skin; and dizziness. What condition should be suspected? How might his condition be managed?
3. Although it is not raining, the rumble of thunder can be heard in the distance during a softball game. Should the umpires be advised to suspend the game, or is it better to wait and see if any lightning is associated with the storm? What criteria would indicate that the game should be suspended?
4. You have been asked to speak to a group of hikers in an outdoor pursuits class who are going backpacking in the Smokey Mountains in January. What suggestions might you provide to help the hikers prevent hypothermia during their trip?
5. A cross-country skier complains of pain and numbness in the fingers and

toes. Observation reveals red and swollen toes and fingers, but palpation finds the areas to be cold and firm to the touch. What condition should be suspected? What is the management for this condition?

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