Playing Hot:

Heat Illness in Sport

Playing Hot: Heat Illness in Sports
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Section One

OVERVIEW AND GOALS

Overview

This video and curriculum offer an introduction to preventing heat illness in youngsters while they participate in sport and physical activities. These materials emphasize the importance of proper hydration during physical activity, as well as alert you to the dangers that affect athletes when playing all types of sports in all kinds of weather.

Sponsored by an educational and research grant from Carl Lindner Sr., this video features an interview with Craig Lindner Jr., a collegiate tennis player who was in a coma after succumbing to heatstroke.

When the simple guidelines from this video are implemented, your athletes and students can play safely and perform at their best—in all kinds of weather.

The CD-ROM is divided into six sections. Section one contains an overview of the package. Section two instructs you, the coach or teacher, on using the package. Section three presents the key points on the videotape. Section four consists of handouts that can be photocopied and distributed to athletes and students. Section five provides further information for you to read and review before the start of the session. Section six is a resource section that includes citations of books, articles, Web sites, and other related information. These references are included to help you understand the information and important issues that are presented in the *Playing Hot* video so that you are prepared to answer questions and manage your athletes during competitions and practices in the heat.

Goals

The video and CD-ROM have two main goals:

1. To familiarize athletic directors, coaches, and physical education teachers with the research concerning proper hydration and sport participation.
2. To provide simple and clear information about proper hydration to athletes and students.

Section Two

HOW TO CONDUCT A SHORT SESSION WITH VIDEO, ACTIVITIES, AND DISCUSSION

The *Playing Hot* package was developed so that it can be used to educate athletes and students about heat-related illness during sport participation. The package can be used as a practice session before play or in a physical education health classroom.

The Resources

The *Playing Hot* package consists of an 18-minute videotape and a CD-ROM. The videotape is meant to raise awareness of heat-related illnesses that often (though not exclusively) occur in hot and humid environments. You should view the video and read the summary and handouts before showing them to students. These will provide additional facts to answer questions that arise during the class or practice session.

Options for Using the Resources

The video and accompanying handouts are *primarily* geared toward training and competing outdoors in the heat. However, most of the information presented is appropriate and useful for athletes training and competing indoors as well.

1. Have your athletes sit comfortably in a quiet area.
2. Give the short quiz orally. Your athletes can respond immediately to each question or write down the true-false answers so that all the responses can be discussed at once. Do not be particularly concerned about correct answers. The intent is to set the tone for discussion and to spark interest in watching the video. Briefly answer each question and indicate to your athletes that the video will discuss each of these points.
3. Show the video.
4. Review the key points of the video (some or all of the key points from the video summary) and answer questions.
5. Distribute and discuss the Fluid Pyramid and the Heat Index Chart, which are included in the handouts.

6. Ask your athletes to provide five tips that they can follow to prevent heat illness and optimize performance in the heat.
7. On another occasion, conduct the Body Weight, Fluid Intake, and Sweat Loss Activity (handout and directions included) with all or a selected group of your athletes.

Section Three

PLAYING HOT—KEY POINTS

Exercising in a hot environment is a challenge for any athlete. The video highlights some of the major concerns about training and competing in the heat. By watching this video and doing the activities, your athletes can reduce their risk of heat illness and increase their potential for optimal performance.

- Hot weather affects all athletes. A hot environment can make you feel uncomfortable and keep you from playing your best, and it can also be a serious threat to your health and well-being. Hot temperature combined with high humidity can increase the risk of heat illness.
- Exercise releases heat in your body, which causes your body temperature to rise. In a hot environment, this rise in core body temperature can be dramatic—especially with long-duration, high-intensity exercise.
- As core body temperature rises, performance tends to decrease due to physiological changes that reduce your capacity and desire to continue.
- Sweating is the body's primary way to get rid of heat during exercise. However, if you exercise when both the temperature and humidity are high, sweating is not very effective in removing heat. Heat and humidity combine to make the environment feel more stressful to the body and increase the risk for heat illness.
- Hydration (fluid intake and balance) is the *primary* concern for all athletes during exercise in the heat.
- Fluid losses via sweating can be extensive—1 to 2.5 liters *per hour* is common in many athletes. Some athletes sweat even more!
- Sweating can lead to significant dehydration if an athlete does not compensate by drinking enough. Dehydration leads to poorer performance and an increased risk for heat illness (heat cramps, heat exhaustion, or heat stroke).
- It is difficult—at times impossible—to match fluid intake with extensive sweating rates. Athletes should be well hydrated as they begin exercising and they should drink as much and as often as they can and are comfortable with during exercise, *especially* if they expect to sweat a lot.
- Extensive sweat loss can occur indoors as well.
- Electrolytes are also lost from sweating—primarily sodium and chloride, which together form salt.

- Sodium losses can be extensive—from 100 to more than 2,000 milligrams per liter of sweat. Some athletes with high sweating rates have been known to lose up to 5,000 milligrams of sodium each hour! Chloride losses are generally slightly less than sodium losses.
- A sodium deficit can make it difficult to rehydrate completely and may lead to heat cramps. Heat cramps can occur even when an athlete drinks a lot of water.
- Athletes who generally have high sodium and chloride losses through sweat may have to supplement their diet with salt or salty foods during competitions or while training in the heat. Tomato juice, pretzels, and salted sport drinks are some foods that can help prevent a severe progressive sodium deficit.
- Weighing yourself before and after exercise is a good way to determine your postexercise fluid deficit.
- To completely rehydrate, you need to drink about 150 percent of your postexercise fluid deficit. For example, if you weigh 1 pound less at the end of exercise, you need to drink 1.5 pounds or 24 ounces of fluid.
- You should drink fluids regularly throughout the day. These fluids can include water, milk, juice, and sport drinks. Too much caffeine can cause excessive urination and may cause dehydration before competition. Alcohol is not a good choice either.
- Drink fluids during exercise even if you don’t feel thirsty. Thirst is not a good indicator of hydration status. If you feel thirsty while exercising, then you’re probably already dehydrated.
- Sport drinks can be better than water alone, because they provide fluid, electrolytes (e.g., sodium and chloride), and carbohydrates.
- Immediately after exercise, it is important to replace water, carbohydrates, and salt before competing or exercising again.
- Adjusting (acclimatizing) to the heat helps an athlete tolerate excessive heat and can help to reduce the risk of heat injury.

Playing Hot Quiz Questions

All questions can be answered “true” or “false”

1. It’s a good idea to drink as much water as possible immediately after a long game or exercise session in the heat, especially if you have to play again soon (i.e., one to several hours later).

2. Eating a banana or an orange is an effective way to prevent or resolve muscle cramping.

3. If you eat well before you compete, water is all you will need to consume during a long match, game, or run.

4. It’s better to sweat less during exercise in the heat.

5. The video *Playing Hot* will give you a lot of important information that will help you compete safely and closer to your best in the heat.

Playing Hot Quiz Questions and Answers

Quiz for your athletes to begin the video, activities, and discussion session. (All questions can be answered “true” or “false.”)

1. It’s a good idea to drink as much water as possible immediately after a long game or exercise session in the heat, especially if you have to play again soon (i.e., one to several hours later).

   Answer: **False.** Drinking water after competition is, of course, very helpful and necessary. But, you can drink too much water too fast! This can lead to feeling sick or possibly having very severe problems. Rehydrating after sweating a lot is important; however, it is also important to replace other nutrients such as electrolytes (primarily sodium and chloride) and carbohydrates.

2. Eating a banana or an orange is an effective way to prevent or resolve muscle cramping.

   Answer: **False.** Muscle cramping during competition in the heat, when you have been sweating considerably, is often due to the excessive loss of water and salt (sodium and chloride—not potassium) from sweating. Athletes who sweat a lot and are prone to cramping in the heat may benefit from increasing their salt intake before and after competition, when sweat losses are expected to be high.

3. If you eat well before you compete, water is all you will need to consume during a long match, game, or run.

   Answer: **False.** During any activity that lasts more than an hour, if the intensity is high enough, you will probably need to ingest some carbohydrates (e.g., sport drinks or certain snacks) to maintain your best performance. Even if you ate well earlier, this rule holds true—especially in the heat. Some athletes may need to consume some salt as well.

4. It’s better to sweat less during exercise in the heat.

   Answer: **False.** Although sweating extensively causes you to lose a lot of water, which can hurt your performance and increase your risk for heat illness, sweating is a good thing! Sweating cools your body. Sweating is a very high priority during exercise in the heat—for your safety and performance. The important thing is that if you tend to sweat a lot, make sure that you are well hydrated when you begin exercise and that you drink enough as often as you can during your activity.

5. The video *Playing Hot* will give you a lot of important information that will help you compete safely and closer to your best in the heat.

   True! *Enjoy the video!*

Fluid Pyramid

Use this handy chart to learn how much water you should be drinking daily, and during exercise.

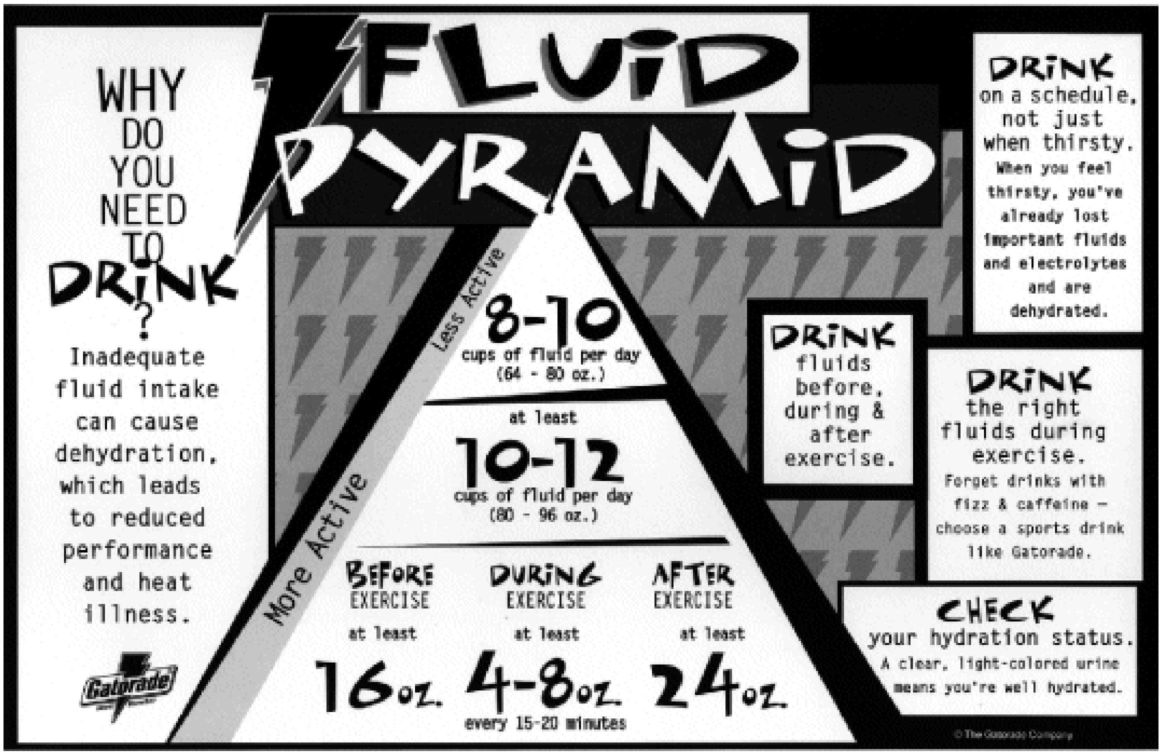

Figure 1 Fluid Pyramid.
From "Fluids 2000: Dehydration and Heat Illness." © 2000 Gatorade Sport Science Institute. Reprinted with permission. Visit the GSSI Web page at www.gssiweb.com

Heat Index Chart

This Heat Index Chart provides general guidelines for assessing the potential severity of heat stress. Individual reactions to heat will vary. Remember that heat illness can occur at lower temperatures than indicated on the chart. In addition, studies indicate that susceptibility to heat illness tends to increase with age.

How to Use the Heat Index Chart

1. Across the top of the chart, locate the environmental temperature (i.e., the air temperature).
2. Down the left side of the chart, locate the relative humidity.
3. Follow across and down to find the apparent temperature. Apparent temperature is the combined index of heat and humidity. It is the body's sensation of heat (the opposite of the wind chill factor).

Table 1 Heat Index

Relative Humidity	70°	75°	80°	85°	90°	95°	100°	105°	110°	115°	120°
	ENVIRONMENTAL TEMPERATURE (° F)										
	Apparent Temperature*										
0%	64°	69°	73°	78°	83°	87°	91°	95°	99°	103°	107°
10%	65°	70°	75°	80°	85°	90°	95°	100°	105°	111°	116°
20%	66°	72°	77°	82°	87°	93°	99°	105°	112°	120°	130°
30%	67°	73°	78°	84°	90°	96°	104°	113°	123°	135°	148°
40%	68°	74°	79°	86°	93°	101°	110°	123°	137°	151°	
50%	69°	75°	81°	88°	96°	107°	120°	135°	150°		
60%	70°	76°	82°	90°	100°	114°	132°	149°			
70%	70°	77°	85°	93°	106°	124°	144°				
80%	71°	78°	86°	97°	113°	136°					
90%	71°	79°	88°	102°	122°						
100%	72°	80°	91°	108°							

* Combined index of heat and humidity: what it feels like to the body. Source: National Oceanic and Atmospheric Administration.

Note: Exposure to full sunshine can increase heat index values by up to 15° F.

Table 2 Heat Stress Risk

Apparent Temperature	Heat Stress Risk With Physical Activity and/or Prolonged Exposure
90° - 105°	Heat cramps or heat exhaustion possible
105° - 130°	Heat cramps or heat exhaustion likely; heatstroke possible
130° and up	Heatstroke highly likely

From "Fluids 2000: Dehydration and Heat Illness." © 2000 Gatorade Sports Science Institute. Reprinted with permission. Featured on Gatorade Sports Science Institute (GSSI) Web site (www.gssiweb.com).

Note: This Heat Index Chart is designed to provide general guidelines for assessing the potential severity of heat stress. Individual reactions to heat will vary. Remember that heat illness can occur at lower temperatures than indicated on the chart. In addition, studies indicate that susceptibility to heat disorders tends to increase with age.

Heat-Related Disorders

Exposure to the combination of external heat stress and the inability to dissipate metabolically generated heat can lead to three heat-related disorders (see figure 2):

- Heat cramps
- Heat exhaustion
- Heat stroke

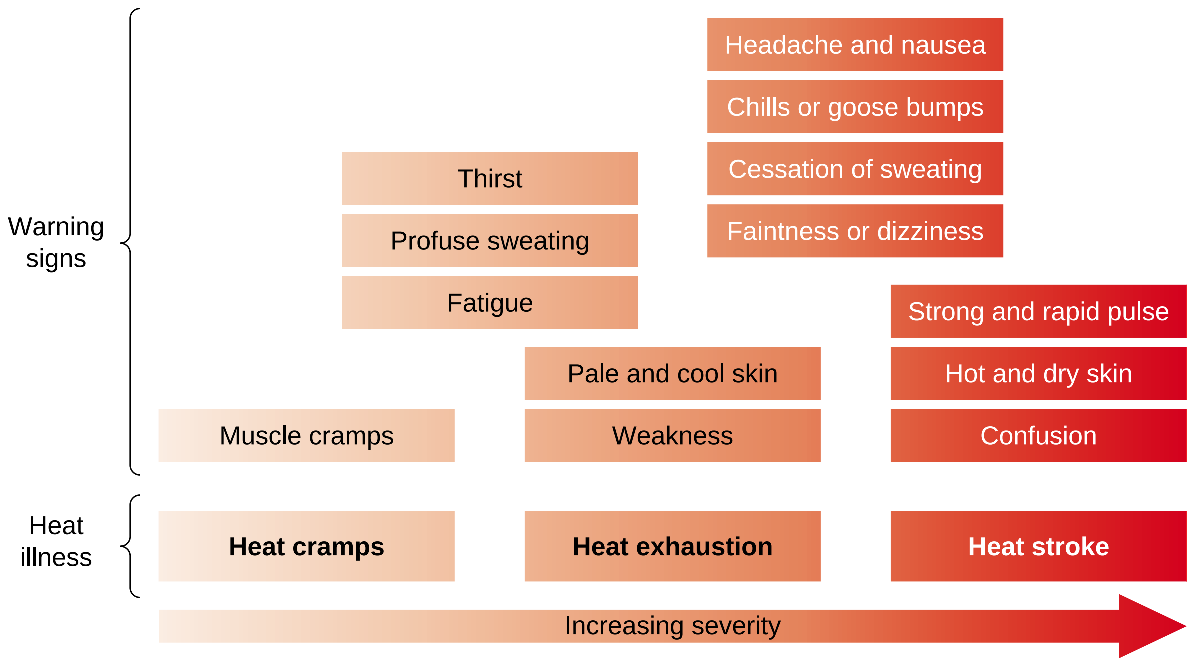

Figure 2 The warning signs of heat cramps, heat exhaustion, and heat stroke. ©PepsiCo 1995. Reprinted with permission.

Heat Cramps

Heat cramps, the least serious of the three heat disorders, is characterized by severe cramping of the skeletal muscles. It involves primarily the muscles that are most heavily used during exercise. This disorder is probably brought on by the mineral losses and dehydration that accompany high rates of sweating, but a cause-and-effect relationship has not been fully established. Heat cramps are treated by moving the stricken individual to a cooler location and administering fluids or a saline solution.

Heat Exhaustion

Heat exhaustion is typically accompanied by such symptoms as extreme fatigue, breathlessness, dizziness, vomiting, fainting, cold and clammy or hot and dry skin, hypotention (low blood pressure), and a weak, rapid pulse. It is caused by the cardiovascular system's inability to adequately meet the body's needs. Recall that during exercise in heat, your active muscles and your skin, through which excess heat is lost, compete for a share of your total blood volume. Heat exhaustion results when these simultaneous demands are not met. Heat exhaustion typically occurs when your blood volume decreases, by either excessive fluid loss or mineral loss from sweating.

With heat exhaustion, the thermoregulatory mechanisms are functioning but cannot dissipate heat quickly enough because there is insufficient blood volume to allow adequate distribution to the skin. Although the condition often occurs during mild to moderate exercise in the heat, it is not generally accompanied by a high rectal temperature. Some people who collapse from heat stress exhibit symptoms of heat exhaustion but have internal temperatures below 39 °C (102.2 °F). People who are poorly conditioned or unacclimatized to the heat are more susceptible to heat exhaustion.

Treatment for victims of heat exhaustion involves rest in a cooler environment with their feet elevated to avoid shock. If the person is conscious, administration of salt water is usually recommended. If the person is unconscious, medically supervised intravenous administration of saline solution is recommended. If allowed to progress, heat exhaustion can deteriorate to heat stroke.

Heat Stroke

Heat stroke is a life-threatening heat disorder that requires immediate medical attention. It is characterized by

- a rise in internal body temperature to a value exceeding 40 °C (104 °F),
- cessation of sweating,
- hot and dry skin,
- rapid pulse and respiration,
- usually hypertension (high blood pressure),
- confusion, and
- unconsciousness.

If left untreated, heat stroke progresses to coma, and death quickly follows. Treatment involves rapidly cooling the person's body in a bath of cold water or ice or wrapping the body in wet sheet and fanning the victim.

Heat stroke is caused by failure of the body's thermoregulatory mechanisms. Body heat production during exercise depend on exercise intensity and body weight, so heavier athletes run a higher risk of overheating than lighter athletes when exercising at the same rate and when both are about equally acclimatized to the heat.

For the athlete, heat stroke is a problem associated not only with extreme conditions. Studies have reported rectal temperatures above 40.5 ˚C (104.9 ˚F) in marathon runners who successfully completed race conducted under relatively moderate thermal conditions (e.g., 21.1 ˚C [70 ˚F] and 30% relative humidity). Even in shorter events, the body's core temperature can reach lift-threatening levels. As early as 1949, Robinson observed rectal temperatures of 41 ˚C (105.8 ˚F) in runners competing in events lasting only about 14 minutes, such as the 5-km race. Following a 10-km race conducted with an air temperature of 29.5 ˚C (85.1 ˚F), 80% relative humidity, and bright sun, one runner who collapsed had a rectal temperature of 43 ˚C (109.4 ˚F)! Without proper medical attention, such fevers can result in permanent central nervous system damage or death. Fortunately, this runner was rapidly cooled with ice and recovered without complication.

When exercising in the heat, if you suddenly feel chilled and goose bumps form on your skin, stop exercising, get into a cool environment, and drink plenty of cool fluids. The body's thermoregulatory system has become confused and think that the body temperature needs to be increased even more! Left untreated, this condition can lead to heat stroke and death.

Prevention of Hyperthermia

We can do little about environmental conditions. Thus, in threatening conditions, athletes must decrease their effort in order to reduce their heat production and their risk of developing hyperthermia (high body temperature). All athletes, coaches, and sports organizers should be able to recognize the symptoms of hyperthermia. Fortunately, our subjective sensations are well correlated with our body temperatures, as indicated on table 2 below. Although there is generally little concern when rectal temperature remains below 40 ˚C (104 ˚F) during prolonged exercise, athletes who experience throbbing pressure in their heads and chills should realize that they are rapidly approaching a dangerous situation that could prove fatal if they continue to exercise.

Subjective Symptoms Associated with Overheating

Rectal Temperature	Symptoms
40 ˚C – 40.5 ˚C (104 ˚F – 105 ˚F)	Cold sensation over stomach and back, with piloerection (goose bumps)
40.5 ˚C – 41.1 ˚C (105 ˚F – 106 ˚F)	Muscular weakness, disorientation, and loss of postural equilibrium
41.1 ˚C – 41.7 ˚C (106 ˚F – 107 ˚F)	Diminished sweating, loss of consciousness and hypothalamic control
≥42.2 ˚C (≥108 ˚F)	Death

To prevent heat disorders, several precautions should be taken. Competition and practice should not be held outdoors when the WBGT (see page 59) is over 28 ˚C (82.4 ˚F). As mentioned earlier, because WBGT reflects the humidity as well as the absolute temperature, it reflects the true physiological heat stress more accurately than does standard air temperature. Scheduling practices and contest either in the early morning or at night avoids the severe heat stress of midday. Fluids should be readily available, and athletes should be required to drink as much as they can, stopping every 10 to 20 minutes for a fluid break in warm temperatures.

Clothing is another important consideration. Obviously, the more clothing that is worn, the less body area exposed to the environment to allow heat exchange. The foolish practice of exercising in a rubberized suit to promote weight loss is an excellent illustration of how a dangerous microenvironment (the isolated environment inside the suit) can be created in which temperature and humidity can reach a sufficiently high level to block all heat loss from the body. This can rapidly lead to heat exhaustion or heat stroke. Football uniforms are another example. Areas that are covered by sweat-soaked clothing and padding are exposed to 100% humidity and higher temperatures, reducing the gradient between body surface and the environment.

Athletes should wear as little clothing as possible, when heat stress is a potential limitation to thermoregulation. The athlete should always underdress because the metabolic heat load will soon make extra clothing an unnecessary burden. When clothing is needed or required, it should be loosely woven to allow the skin to unload as much heat as possible and light colored to reflect heat back to the environment.

The American College of Sports Medicine (ACSM) has provided guidelines to help distance runners prevent heat-related injuries. A modified list of these recommendations appears in table 3 below.

Table 3 Guidelines for Distance Runners Competing Under Conditions of Heat Stress

1. Distance races should be scheduled to avoid extremely hot and humid conditions. If the WBGT index is above 28 ˚C (82 ˚F), canceling the race should be considered.
2. Summer events should be scheduled in the early morning or evening to minimize solar radiation and unusually high air temperature.
3. An adequate supply of fluid must be available before the start of the race, along the racecourse, and at the end of the event. Runners should be encouraged to replace their sweat losses or consume 150 to 300 ml (5.3 – 10.5 oz) every 15 minutes during the race.
4. Cool or cold (ice) water immersion is the most effective means of cooling a collapsed hyperthermic runner.

(continued)

Guidelines for Distance Runners
Competing Under Conditions of Heat Stress, *continued*

5. Runners should be aware of the early symptoms of hyperthermia, including
   - dizziness,
   - chilling,
   - headache or throbbing pressure in the temporal region, and
   - loss of coordination.
6. Race officials should be aware of the warning signs of an impending collapse in hot environments and should warn runners to slow down or stop if they appear to be in difficulty.
7. Organization personnel should reserve the right to stop runners who exhibit clear signs of heat stroke or heat exhaustion.

Note: These recommendations are based on the position stands published by the American College of Sports Medicine in 1987 and 1995.

Adapted, with permission, from *Physiology of Sport and Exercise,* pp. 326–328. © 1994, 1999 by Jack H. Wilmore and David L. Costill.

Keeping Your Players Hydrated

You may think that you've heard enough about the importance of drinking plenty of fluids and the benefits of staying well hydrated. After all, your players seem to drink a lot of water during exercise and most tend to avoid severe problems such as cramping or overheating. Yet many well-trained and informed tennis players continue to have hydration problems. The symptoms of inadequate or inappropriate hydration management range from simply feeling a little "off" and not quite playing at one's best to suffering painful heat cramps or heat exhaustion. These symptoms are commonly observed at many tennis tournaments, especially when it's hot.

The three primary nutritional factors related to keeping your players hydrated are **water**, **electrolytes**, and **carbohydrates**. These are also the nutrients that have the most immediate effect on performance—positive or negative, depending on management of their intake.

Water

Facts:

- Many players *begin* exercising while dehydrated.
- On-court sweat losses can be extensive—1 to 2.5 liters (~35-88 ounces) *per hour* is typical.
- *Any* water deficit can have a negative effect on a player's performance and well-being. The effects of a progressive water deficit due to inadequate fluid intake and/or excessive sweat losses include the following:

  - Increased cardiovascular strain—your heart has to work harder.
  - Decreased capacity for temperature regulation—you heat up more.
  - Decreased strength, endurance, and mental capacity—your intensity is lower, you tend to lose control, and you make inappropriate shot selections.
  - Increased rate of carbohydrate metabolism—you fatigue faster.
- Many players do not adequately *rehydrate* after play.

What you can do:

- Drink plenty of fluids (water, juice, milk, sport drinks) throughout the day.
- Don't forget to drink regularly during all practice and warm-up sessions.
- Drink another 12 to 16 ounces about one hour before you play.
- Drink at each changeover—typically, older adolescents and adults can comfortably drink up to 48 ounces or so per hour. This rate of fluid intake can prevent large fluid deficits from developing for most players.
- After play, drink about 150 percent of any fluid deficit that still remains. For example, if your weight is down 1 pound at the end of play, you will need to drink another 24 ounces.

Electrolytes

Facts:

- Players lose far more sodium and chloride (salt) from sweating than any other electrolyte.
- Sodium and chloride losses are greater with higher sweating rates.
- Players who are accustomed (acclimatized) to the heat tend to lose less sodium and chloride than players who are not acclimatized to the heat.
- Sodium deficits can lead to incomplete rehydration and muscle cramps.
- If players don't replace the salt they lose, they can't completely rehydrate.
- Excessive water consumption, combined with a large sweat-induced sodium deficit, can lead to severe hyponatremia (low blood sodium)—a very dangerous situation. Even mild hyponatremia can cause fatigue, apathy, nausea, or a headache.

What you can do:

- When you play in a hot environment (or any time you sweat a lot), add some salt to your diet, or eat certain high-salt foods, before and after you play. Salt contains 590 milligrams of sodium per 1/4 teaspoon (or 1.5 grams). Good food sources of sodium and chloride include:
  - salted pretzels,
  - many types of soups,
  - cheese,
  - salted sport drinks (or Pedialyte),
  - tomato sauce (pizza!), and
  - tomato juice.

Carbohydrates

Facts:

- Adequate carbohydrate intake is crucial to optimal tennis performance.
- Consuming carbohydrates before and after exercise can help restore some of your body water reserves.
- Playing tennis in the heat causes the body to use carbohydrates fast. So, even if you eat well before playing, after 60 to 90 minutes of intense singles play you'll probably need some supplemental carbohydrate to continue playing your best.
- Ingesting too many carbohydrates or too much of an inappropriate carbohydrate (e.g., fructose) can delay carbohydrate and fluid absorption and may cause gastrointestinal distress.

What you can do:

- Generally, 7 to 10 grams of carbohydrate per kilogram of body weight (~500 to 700 grams per day for a 155-pound player) is recommended for periods of intense training or competition.
- During exercise, 30 to 60 grams of carbohydrate per hour is most effective. Choose a sport drink whose *primary* carbohydrate is sucrose, glucose, or a glucose polymer (e.g., maltodextrin).

Adequate and well-timed water, electrolyte, and carbohydrate intake should be a priority for any athlete expecting to play well and safely. Yet athletes often overlook or underestimate the importance of these nutrients.

Adapted from Keeping Your Players Hydrated: What Are the Key Points? By Michael Bergeron, MD. From *High-Performance Coaching*, the USTA newsletter for tennis coaches, vol. 2, no. 2/2000. Used with permission of the USA Tennis Coaching Education Department.

Body Weight, Fluid Intake, and Sweat Loss Activity

The following calculations will help you find out how much fluid you lose during a training session or competition. By doing this activity, you will be able to find out how well you managed fluid intake during exercise. Your coach will help you fill in the blanks and interpret the results. You will need an accurate scale to do this activity.

Body Weight (BW)

Pre BW: ____________________ pounds

Post BW: ____________________ pounds

Total BW change (post BW – pre BW = total BW change):

____________________ pounds

% BW deficit (total BW change ÷ pre BW x 100):

____________________ percent

The change in body weight is calculated from the preplay and postplay body weight measurements. (It's best to weigh yourself both times in the same *dry* clothes, such as shorts and a T-shirt.) Any loss in body weight must be compensated for by your cardiovascular system. Notably, a decrease in body weight of even just 1 percent can have a dramatic negative effect on performance, especially in the heat.

If you weighed less at the end of play (post BW) than you did at the beginning of play (pre BW), this means that the change in body weight (total BW change) was *negative* and you had a body weight *deficit.* It also means that you did not drink enough during exercise. To find out how much more you should have drunk to avoid losing any weight, do the following:

Multiply the number of pounds lost times 16 ounces. That will give you the number of *additional* ounces that you should have drunk to avoid losing weight during exercise.

For example, with a total BW change of –1.7 pounds, 1.7 x 16 = 27.2 ounces (drop the negative sign).

In this case, you should have drunk 27.2 *more* ounces of water to avoid losing any body weight during exercise.

If you weighed the same or gained weight by the end of play (meaning post BW is greater than pre BW), the total BW change will be *0* or *positive* and you will *not* have a body weight deficit. This means that you drank as much as or more than you sweated.

Fluid Intake

Preplay water container(s) weight (WCW):

____________________ pounds

Postplay WCW:

____________________ pounds

Total WCW change (post WCW – pre WCW):

____________________ pounds

Total fluid consumed:

____________________ ounces

This difference shows how much you drank. First you calculate the amount you drank in pounds by using the scale to weigh your water container(s) before and after play. To convert pounds to ounces, simply multiply the total WCW change by 16 ounces. (You can avoid this calculation if you know exactly how many ounces you drank.)

For example, with a WCW change of –1.0 pounds, 1.0 x 16 = 16 ounces (eliminate the negative sign). In this case, you drank 16 ounces during play.

Sweat Loss

A. Total BW change (post BW – pre BW = total BW change):

____________________ pounds

B. Convert to ounces (total BW change x 16):

____________________ ounces

C. Total fluid consumed:

____________________ ounces (from fluid intake calculation above)

If the result in "B" is *negative*, then take away the negative sign and add the amount of total BW change (in ounces) to the total fluid consumed (in ounces).

Total sweat loss (in ounces) = B + C (______________ + _____________)

If the result in "B" is *positive*, then subtract the amount of total BW change from the total fluid consumed.

Total sweat loss (in ounces) = C– B (______________ – _____________)

If the result in "B" equals zero, then your total sweat loss equals your total fluid consumed—great job!

Section Five

ARTICLES

Hydration and Physical Activity: Scientific Concepts and Practical Applications

Gatorade Sports Science Exchange Roundtable # 26 / volume 7 (1996), number 4

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Introduction

Generally, research that is conducted under controlled laboratory conditions does not have an immediate impact on sports practitioners-coaches, trainers, athletes, etc., who rightly feel that the non-controlled, spontaneous, and somewhat unpredictable aspect of sport warrants field testing under less-controlled conditions. Of course, the most complete answer to a problem can be developed when the theoretical tenets of basic science can be melded with the more practical aspects of applied science.

The issue of hydration and physical performance has been studied for many years by both basic and applied scientists. In this issue of the GSSI Roundtable, we discuss a number of topics pertaining to dehydration and exercise with Gary Mack, Ph.D., a basic scientist, and Michael Bergeron, Ph.D., who has focused much of his research on the effects of dehydration in tennis players. Their responses to our questions follows.

What type of studies have you conducted regarding the effects of dehydration on physical performance?

Mack: Our studies have focused on two aspects of dehydration. First, we have examined the detrimental influence of dehydration on the body's ability to dissipate heat during a thermal load. These studies have focused on identifying the physiological mechanism by which hypovolemia and hyperosmolality, produced during dehydration, impose limitations in heat transfer from the body core to the skin, and a reduction in heat loss from the skin to the environment. Our studies have also characterized baroreflex modulation of skin blood flow and sweating in response to alterations in central blood volume, and the inhibition of thermal sweating by increases in plasma osmolality. Second, we have examined the phenomenon referred to as "involuntary dehydration." In these studies we have examined the mechanisms that contribute to a delay in complete restitution of body fluids following a reduction in total body water. Our efforts have been directed to understanding the factors that contribute to this phenomenon so that we can improve rehydration practices.

Bergeron: Most of my recent studies have been more applied in nature. Our work has been directed toward examining fluid balance in tennis. Many of the tennis players that I have worked with have experienced significant performance decrements when they haven't managed fluid balance well, and more than a few have suffered problems such as heat cramps and heat exhaustion during competition. However, with a sport such as tennis it is somewhat difficult to identify reliable and measurable outcome-related performance variables. Thus, much of my work in this area has been descriptive in nature, in an attempt to determine the extent and rate of fluid loss that players routinely encounter during competition. As a next step, we are developing projects to examine the effects of dehydration on a variety of tennis-specific psychomotor skills.

Dr. Mack, what are the physiological consequences of dehydration on one's ability to perform physical activity?

Mack: Fluid deficits imposed voluntarily (i.e., by fluid restriction) or by previous thermal and/or exercise stress will impair subsequent work performance. Water losses due to sweating can often exceed 30 g/min. (1.8 kg/h). The consequences of a progressive loss of body water are a decrease in blood volume (hypovolemia) and an increase in the concentration of electrolytes in the body fluids (hypertonicity). Both of these conditions can impair the body's ability to dissipate heat generated during exercise. The greater level of dehydration, the greater the degree of impairment.

Numerous studies have clearly demonstrated that cardiovascular strain is greater and body core temperature rises faster when a person exercises in a dehydrated condition, regardless of the environmental conditions. Of course, the decrement in performance is exaggerated when exercise is performed in a hot environment. Furthermore, the combined effects of dehydration and exercise in the heat can lead to heat-related disorders ranging from simple heat cramps to life-threatening heat stroke.

Dr. Bergeron, you have focused the majority of your research on tennis players. What is the profile of the athletes who have served as subjects in your studies?

Bergeron: Most of the players I have worked with were regionally or nationally ranked juniors, Division I collegiate players, or touring professionals. As a result of their regular training and competition schedules, which typically includes at least 2-3 hours a day on the court, these athletes generally have a high degree of cardiorespiratory fitness, a relatively low amount of body fat, and a unique blend of on-court endurance, speed, agility, and power. They usually train and compete year-round, and often play tennis in places in which they have very little time to adequately acclimatize to new environmental conditions. Their matches generally last from less than one hour to sometimes more than four hours. During tournaments, these players often play multiple, long matches on successive days. Clearly, their schedules can be grueling.

What type of sweat and electrolyte losses have you documented in the players you have studied?

Bergeron: Most of the sweat losses that we have calculated were incurred during matches in fairly hot and humid conditions. The ambient temperature was generally 90°F (32°C) or more and the relative humidity was around 60%. In general, during singles play the boys and girls (12-16 yrs.) and young women (18-22 yrs.) had sweating rates of 0.7-1.4 liters per hour; young men (18-30 yrs.) sweated at a rate of 1.2 to 2.5 liters per hour. Although the highest sweat rates that I have measured in a male and female were 3.4 liters and 2.5 liters per hour, respectively.

In heat-acclimatized young adult tennis players the sweat concentration of sodium has generally been a little above 20 mmol per liter, and sweat potassium losses have approximated 5 mmol per liter. However, in heat-acclimatized boys, the sweat sodium loss tends to be somewhat higher (approximately 40 mmol per liter). Even with a high degree of mineral conservation the on-court hourly loss of sodium for many of these players can easily exceed 1 gram. As we have observed with some players, the combination of very high sweat rates (2.5-3.4 liters per hour) coupled with moderate sweat sodium concentrations (35 to just over 60 mmol/L) can yield rather impressive on-court sweat sodium losses of 2,000 to almost 5,000 mg. per hour of play. Considering that tennis players routinely play multiple or long matches on successive days during tournaments, it is not surprising that many tournament players often begin matches in a dehydrated and sodium-deficient condition.

Dr. Mack, are these values out of line with those that you see in a laboratory setting?

Mack: Answering this question is not as clear-cut as it may seem. Several factors influence whole body sweat rate and the determination of sweat electrolyte composition. First, sweating and sweat composition is not uniform over the entire body. Second, sweat composition is dependent on the local sweat rate. Finally, progressive dehydration associated with prolonged exercise in the heat may modify regional sweat rates and thereby sweat composition. Thus, determination of an average sweat composition during exercise performed in the laboratory or field is not a simple measurement.

In our laboratory we sample sweat from five different skin sites and then use an equation which incorporates factors that account for the regional differences in sweat rate and adjusts for the relative contribution of each region to the total surface area of the body. Using this technique we have determined the average electrolyte composition of sweat in active college aged students under standard exercise protocols. Whole-body sweat rates of ~0.8 L/hr. induced with mild (40% $\dot{V}O_2$ max.) cycle ergometry in the heat (36°C; 30% RH) produces sweat with an average sodium concentration of 68 mmol/L and a potassium concentration of 4.7 mmol/L. However, these values may vary considerably with a range of 30 to 110 mmol Na/L and 2.5 to 9.3 mmol K/L. During prolonged exercise (up to six hours) in the heat, when sweat rates are maintained by simultaneous fluid replacement, individuals may lose in excess of 5 g of sodium (the equivalent of 12.5 g of table salt). At higher sweat rates (1.4 L/hr.) induced by intense treadmill exercise (70% $\dot{V}O_2$ max) we have measured an average whole body sodium concentration of 74 mmol/L (range of 40 to 104 mmol/L). Lower values of sweat sodium concentration, such as those in the tennis players described by Dr. Bergeron, are a function of the athletes' high level of fitness and degree of heat acclimatization.

Dr. Mack, the importance of sodium for rehydration purposes has been outlined in numerous articles. However, is there a downside to giving a healthy athlete "carte blanche" access to sodium?

Mack: During recovery from dehydration, electrolyte replacement ensures complete restoration of the extracellular fluid and a more complete restitution of water balance. The normal range of daily U.S. intake of sodium chloride is 2-9 grams (35-156 mmol sodium), and potassium is 2-4 grams (50-100 mmol). Electrolyte losses in these ranges are generally replenished within 24 hours following exercise if adequate fluid is consumed. In the absence of meals, more complete rehydration can be accomplished with fluids containing sodium than with plain water. The ideal salt concentration in the ingested fluid has not been determined. However, a consensus report sponsored by the National Academy of Sciences recommends that the solution should provide approximately 20-30 mmols of sodium per liter, 2 to 5 mmols of potassium per liter, and chloride as the only anion.

I don't think there is a documented downside to ad libitum sodium intake in healthy adults. Sodium intake must vary in proportion to the deficit in total body sodium content. Normal healthy adults have several sophisticated regulatory systems that act to regulate sodium intake and retention. In healthy individuals, when all these mechanisms are working properly, sodium balance is achieved without the need to restrict sodium intake.

Dr. Bergeron, are there other nutritional issues besides hydration status that you see in the athletes you work with?

Bergeron: It's clear that any time there is extensive and repetitive sweating, there is potential for developing a sodium deficit. This condition is often exacerbated when a susceptible athlete limits his or her salt intake. We are now in the process of looking more closely at other potential mineral imbalances that might develop in athletes during long periods of extensive sweating.

A tennis player's blood glucose level and carbohydrate stores are also a concern. Therefore, we always stress a high-carbohydrate diet, and we encourage players to consume a carbohydrate-electrolyte drink during and after matches, particularly if they are going to play again soon.

I also find that the daily caloric intake of many athletes is often inadequate. Unfortunately, the high dietary bulk associated with a high-calorie, high-carbohydrate diet is unappealing to some athletes. In these cases, high-carbohydrate, high-calorie drinks or snacks can be beneficial.

Do you see any carryover from your studies to other groups of athletes? To the "average" person who trains and competes in the heat?

Bergeron: Many of the college athletes that I have worked with, including swimmers, basketball players, and soccer players, tend to function in a chronically dehydrated condition, as evidenced by their high urine specific gravities or their inability to urinate prior to practices or games. I don't think that the typical athlete or the average recreational exerciser appreciates the extent of fluid and electrolyte losses that readily and routinely occur during most forms of physical activity. Generally, athletes should be able to urinate before and after they train or compete. If they are unable to do so, they likely have not consumed enough fluid. For those people who lose considerable sodium from extensive sweating, consuming more sodium-rich foods or adding salt to foods and fluids may be appropriate.

Mack: As I stated earlier, our studies have demonstrated that complete restoration of the extracellular fluid compartment (and blood volume) cannot be attained without replacement of the lost sodium. Furthermore, during prolonged exercise, a combination of sodium loss and the ingestion of large quantities of fluids with little or no electrolytes can lead to low plasma sodium. In ultra-endurance events, hyponatremia (blood sodium concentrations of less than 130 mmol/L) has been observed at the end of competition and is associated with problems of disorientation, confusion and, in some cases, grand-mal seizures. To prevent the development of hyponatremia or related conditions, sufficient electrolytes should be provided in fluid replacement beverages. This would certainly constitute a practical application of our research.

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Fluid Replacement: The American College Of Sports Medicine Position Stand

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Key Points

1. Recent scientific research has underscored the physiological and performance benefits of remaining well hydrated before, during, and following physical activity.
2. Maintaining hydration takes a concerted effort on the part of the athlete to modify drinking behavior throughout the training day.
3. The amount of fluid voluntarily ingested during physical activity is affected by the palatability of the beverage, the composition of the beverage, and by ease of use. These factors must be considered when planning a fluid-replacement regimen for athletes.
4. The goal for fluid intake during exercise should be to fully replace sweat losses. The physiological and performance benefits of doing so are well documented.
5. Rapid and complete rehydration following exercise requires the ingestion of sodium chloride to replace that which was lost in sweat and the consumption of a volume of fluid that is greater than that which was lost as sweat.

Introduction

In a book titled *Physiology of Man in the Desert,* E.F. Adolph and associates expertly described the negative impact of dehydration upon physiological function, physical performance, and health (Adolph et al., 1947). Their exhaustive research demonstrated that preventing dehydration by regular ingestion of fluids was indispensable in ensuring the physical and mental well-being of their subjects. Unfortunately, more than two decades passed before the value of regular fluid replacement during physical activity was widely recognized and practiced in the athletic setting. During this time, dozens of athletes and military recruits died from hyperthermia complicated by dehydration (Baumann, 1995). Although athletes and others continue to fall prey to exertional heat stroke, the frequency of deaths has been drastically reduced over the years (Bauman, 1995), in large part because the necessity of adequate fluid replacement has become well recognized.

Although information on fluid intake during physical activity eventually found its way into textbooks, classrooms, and onto the practice field, most of these recommendations were fairly general in nature. For example, documents published by the American College of Sports Medicine (1987), the United States military (Marriott & Rosemont, 1991), and the National Institute of Occupational Safety and Health (1986) included information on fluid replacement from which some general guidelines could be drawn. In the case of the American College of Sports Medicine (ACSM), recommendations for fluid replacement were included in a position stand entitled The Prevention of Thermal Injuries During Distance Running (ACSM, 1987). The ACSM article emphasized the need for regular fluid intake during races of 10 km and longer, and encouraged runners to ingest 100–200 ml (3–6 oz) at every aid station. The public health value of this recommendation was significant because it helped assure that race organizers included fluid stations in their events and that participants were given the opportunity to drink. However, depending upon the speed of the runner, the distance between aid stations, and the volume of fluid ingested at each station, the resulting fluid intake could vary widely, replacing a very large or very small portion of sweat loss.

This uncertainty has been addressed in the most recent position stand published the American College of Sports Medicine. The ACSM position stand on Exercise and Fluid Replacement (ACSM, 1996) provides clear and practical guidelines regarding fluid, carbohydrate, and electrolyte replenishment for athletes. In preparing the recommendations, a panel of experts in fluid homeostasis and related fields completed a comprehensive review of the scientific literature, making certain that each practical recommendation was well substantiated by research. As a result, the ACSM position stand will benefit the lay and scientific communities for years to come.

The ACSM Recommendations

The ACSM position stand contains a summary of practical recommendations supported by four pages of scientific review complemented by 92 references. The document begins by stating that, “It is the position of the American College of Sports Medicine that adequate fluid replacement helps maintain hydration and, therefore, promotes the health, safety, and optimal physical performance of individuals participating in regular physical activity.”

The purpose of this Sports Science Exchange is to further underscore the scientific and practical relevance of the ACSM recommendations so that coaches, athletic trainers, physicians, dietitians, and athletes gain an increased appreciation of the value of remaining well hydrated during physical activity. The recommendations found in the ACSM position stand are highlighted below and are supplemented with scientific and practical information related to their content.

Fluid Ingestion Before Exercise

“It is recommended that individuals consume a nutritionally balanced diet and drink adequate fluids during the 24-h period before an event, especially during the period that includes the meal prior to exercise, to promote proper hydration before exercise or competition.”

The physiological and performance benefits of entering training and competition well hydrated and with large stores of muscle and liver glycogen are widely accepted from a scientific standpoint. In terms of fluid balance, it is clear that athletes who enter competition in a dehydrated state are at a competitive disadvantage (Sawka, 1992). For example, in a study by Armstrong et al. (1985), subjects performed a 5,000-meter (~ 19 min) and 10,000-meter (~ 40 min) run in either a normally hydrated or dehydrated condition. When dehydrated by ~2% of body weight (by a diuretic given prior to exercise), their running speeds decreased significantly (by 6%–7%) in both events. To make matters worse, exercise in the heat exacerbates the performance-impairing effects of dehydration (Sawka et al., 1984).

Getting athletes to actually modify their drinking behavior during the training day is arguably a much larger challenge than convincing them about the scientific value of doing so. Dr. Ron Maughan, a sports scientist at the University of Aberdeen and an adviser to the 1996 British Olympic Team, indicated that the British athletes had to be schooled in mealtime drinking behavior during their training camps in Tallahassee, Florida. Unaccustomed to the decorum of buffet-line eating at an American university, the British athletes politely took just one beverage as they passed through the line while their American counterparts loaded up with three or four drinks. The British athletes were losing an important opportunity to rehydrate after hot-weather training. With a little prodding and some reminders, they became more aggressive mealtime drinkers. (R.J. Maughan, personal communication).

"It is recommended that individuals drink about 500 ml (about 17 ounces) of fluid about 2 h before exercise to promote adequate hydration and allow time for excretion of excess ingested water."

Laboratory subjects who ingest fluid in the hour before exercise exhibit lower core temperatures and heart rates during exercise than when no fluid is ingested (Greenleaf & Castle, 1971; Moroff & Bass, 1965). These physiological responses are undoubtedly beneficial as they reduce the strain on the body and lower the perception of exertion at a given workload (Montain & Coyle, 1992). When athletes live and train in warm environments, the value of adequate fluid intake prior to exercise cannot be overemphasized. This is apparent in the results of a study conducted on soccer players in Puerto Rico (Rico-Sanz et al., 1996). The athletes were studied during two weeks of training. When the players were allowed to drink fluids throughout the day as they wished (average intake = 2.7 L/d), their total body water at the end of one week was about 1.1 L lower than when they were mandated to drink 4.6 L of fluid per day. In other words, voluntary fluid consumption was insufficient to meet the players' daily fluid requirements, causing them to enter training and competition already dehydrated.

From a practical standpoint, the frequency of urination and the color and volume of urine can be monitored as a means of helping athletes assess their hydration status. Infrequent urination with a darkly colored urine of relatively small volume can be an indication of dehydration, a signal that the athlete should continue drinking before beginning exercise. Monitoring urine output is a common recommendation in occupational settings such as the mining industry in which the workers are constantly exposed to conditions of high heat and humidity.

Fluid Ingestion During Exercise

"During exercise, athletes should start drinking early and at regular intervals in an attempt to consume fluids at a rate sufficient to replace all the water lost through sweating, or consume the maximal amount that can be tolerated."

This is perhaps the most-significant recommendation in the position stand because it clearly identifies that the ideal goal of fluid intake during exercise is to prevent any amount of dehydration, and yet it recognizes that an optimal intake may be difficult under some circumstances. The value of maintaining full hydration is well illustrated by the studies of Montain and Coyle (1992) and Walsh et al. (1994). These researchers demonstrated that cardiovascular, thermoregulatory, and performance responses are optimized by replacing at least 80% of sweat loss during exercise. Montain and Coyle showed that larger volumes of fluid intake during exercise were associated with greater cardiac output, greater skin blood flow, lower core temperature, and a reduced rating of perceived exertion. The data of Walsh et al. reaffirmed that even low amounts of dehydration (1.8% of body weight, in this case) can impair exercise performance.

The dramatic impairment in physiological and performance response that occurs with dehydration is more easily understood when the limitations of the cardiovascular system are considered. In his text on Human Circulation: Regulation During Physical Stress, cardiovascular physiologist L.B. Rowell wrote that, "Perhaps the greatest stress ever imposed on the human cardiovascular system (except for severe hemorrhage) is the combination of exercise and hyperthermia. Together these stresses can present life-threatening challenges, especially in highly motivated athletes who drive themselves to extremes in hot environments. A long history of heat fatalities gives stark testimony to the gravity of the problem and the failure of various organizations to recognize and deal with it effectively." (Rowell, 1986). Rowell's statement is a dramatic but accurate way of explaining that both exercise and hemorrhage require the body to cope with progressively diminishing blood volume and blood pressure. Although the physiological challenge to the body occurs much more quickly and with decidedly deadlier potential in the case of hemorrhage, the slower progression of events that occurs as a result of sweat loss is no less challenging from a physiological standpoint.

It is recommended that ingested fluids be cooler than ambient temperature [between 15°and 22°C (59° and 72°F)] and flavored to enhance palatability and promote fluid replacement. Fluids should be readily available and served in containers that allow adequate volumes to be ingested with ease and with minimal interruption of exercise."

It is certainly no surprise that humans are inclined to drink more of beverages that are flavored and sweetened (Greenleaf, 1991) but the practical ramifications of this common-sense knowledge are important in the exercise setting. Any step that can be taken to increase voluntary fluid intake will help decrease the extent of dehydration and reduce the risk of health problems associated with dehydration and heat stress. In addition to having palatable beverages available for athletes to drink, a number of other practical steps should be taken. These include educating coaches, trainers, parents, and athletes about the benefits of proper hydration, making certain that fluids are easily available at all times, encouraging athletes to follow an organized regimen for fluid replacement, and weighing athletes before and after practice as a way to assess the effectiveness of their fluid intake (Broad, 1996).

The composition of beverages can also have a substantial effect on voluntary fluid intake, as illustrated by the research of Wilk and Bar-Or (1996). Young boys were studied during 3 h of intermittent exercise in the heat, during which time the subjects could drink ad libitum. The boys completed this protocol on three occasions; the beverages tested included water, a sports drink, and a flavored, artificially sweetened replica of the sports drink. The results showed that the boys ingested almost twice as much sports drink as they did water. Consumption of the placebo fell in between. Not only did flavoring and sweetness increase voluntary fluid intake, but the presence of sodium chloride in the sports drink further increased consumption (i.e., the subjects drank more sports drink than placebo).

The human thirst mechanism is sensitive to changes in plasma sodium concentration (and plasma osmolality) and to changes in blood volume (Hubbard et al., 1990). The increase in sodium concentration and the decrease in blood volume that accompany exercise result in an increased perception of thirst. Drinking plain water quickly removes the osmotic drive to drink and reduces the volume-dependent drive, causing the satiation of thirst. The resulting decrease in fluid intake occurs prematurely, occurring before adequate fluid has been ingested. The presence of low levels of sodium chloride in a beverage help maintain the osmotic drive for drinking, and assure greater fluid intake (Nose et al. 1988), a physiological certainty well understood by bartenders who make certain that their customers have easy access to salty snack foods.

“Addition of proper amounts of carbohydrates and/or electrolytes to a fluid replacement solution is recommended for exercise events of duration greater than 1 h since it does not significantly impair water delivery to the body and may enhance performance.”

The ergogenic effect of carbohydrate feeding during exercise has been extensively confirmed by research, much of which has been conducted using exercise bouts lasting from one to four-or-more hours (Coggan & Coyle, 1991). Ingestion of carbohydrate solutions containing combinations of sucrose, glucose, fructose, and maltodextrins results in improved exercise performance provided that at least 45 g of carbohydrate are ingested each hour (Coggan & Coyle, 1991). It should be noted that some researchers (Murray et al., 1991) have reported performance improvements even when subjects have ingested as little as 20–25 g/h, although a higher rate of carbohydrate intake is more advisable. However, the maximal rate at which exogenous carbohydrate can be utilized appears to be in the range of 60-75 g/h (ie, 1.0–1.5 g/min). No additional performance benefit is realized when subjects are fed greater amounts of carbohydrate (Murray et al., 1991).

The specific mechanism(s) by which performance is improved by carbohydrate feeding is still a matter of scientific inquiry, but there is general agreement that the improvement in performance is linked to an increased reliance on carbohydrate as fuel for active muscles (Coggan & Coyle, 1991). During intense physical activity, the metabolic demand for carbohydrate is high; carbohydrate ingestion satisfies part of that demand, helping assure the maintenance of carbohydrate oxidation.

"During exercise lasting less than 1 h, there is little evidence of physiological or physical performance differences between consuming a carbohydrate-electrolyte drink and plain water."

During long-duration exercise (i.e., > 1 h), carbohydrate oxidation normally declines as muscle and liver glycogen stores fall to low levels. Considering these responses, it is not surprising that exercise scientists initially relied upon bouts of long-duration cycling or running to determine if carbohydrate feeding improved performance. Not until recently have scientists turned their attention to studying shorter-duration, intermittent exercise protocols lasting one h or less to determine if carbohydrate feeding elicits a similar ergogenic effect. At the time of the 1996 ACSM position stand, very few such studies had been published. Although much more research needs to be completed, the growing body of evidence (Ball et al., 1995; Below et al., 1995; Wagenmakers et al., 1996; Walsh et al., 1994) indicates that carbohydrate ingestion may indeed benefit performance during shorter duration exercise (i.e., 1 h or less) and during intermittent exercise such as high-intensity running (Nicholas et al., 1996), cycling (Jackson et al., 1995), and tennis play (Vergauwen et al., 1996).

An excellent comparison of the benefits of ingesting water or a sports drink during shorter-duration exercise was conducted by Below et al. (1994) who had subjects cycle for 50 min at 80%VO2max and then complete a "sprint to the finish" requiring 9-12 min. The subjects experienced a 6% improvement in performance when they consumed enough water to replace about 80% of their sweat loss (1330 ml) compared to when they ingested only 200 ml of water. However, when the subjects ingested 1330 ml of a sports drink, their performance improved by 12%, leading the authors to conclude that the benefits of hydration and carbohydrate feeding were additive.

The benefits of proper hydration and carbohydrate feeding that have been illustrated by numerous laboratory studies are often echoed by the experiences of the subjects in the studies. Dr. Edward Coyle of The University of Texas noted that the competitive cyclists who participate in his experiments "know that drinking is critical to surviving the Texas heat. What they usually don't appreciate is that being well hydrated can help them thrive rather than just survive. After they learn how to fully replace fluids in our studies, they are amazed at how much better they feel as far as being cooler, having a lower heart rate, and generating more power." (E.F. Coyle, personal communication)

"During intense exercise lasting longer than 1 h, it is recommended that carbohydrates be ingested at a rate of 30–60 grams per hour to maintain oxidation of carbohydrates and delay fatigue. This rate of carbohydrate intake can be achieved without compromising fluid delivery by drinking 600–1200 ml per hour of solutions containing 4%–8% carbohydrates (grams per 100 ml). The carbohydrates can be sugars (glucose or sucrose) or starch (e.g., maltodextrin)."

As previously indicated, ingesting carbohydrate at the rate of about 60 g/h during exercise is associated with improved physical performance. Considering that most sports drinks contain 6% to 7% carbohydrate (i.e., 60–70 g carbohydrate per liter), the consumption of one L (~ one qt) of sports drink per hour will provide the needed amount of carbohydrate. However, many athletes sweat at rates substantially greater than one L/h (Broad et al., 1996) and so should drink more than 1 L/h. Consuming carbohydrate in excess of 60 g/h will not be detrimental to gastrointestinal comfort, physiological function, or performance provided that the carbohydrate concentration of the ingested beverage is not too high. Beverages containing greater than 7% carbohydrate (i.e., > 17 g carbohydrate per 236 ml [8 oz]) are associated with slower rates of intestinal absorption (Shi et al., 1995), which increases the risk of gastrointestinal distress (Davis et al., 1988; Peters et al., 1995).

Sports drinks usually contain more than one type of carbohydrate, most often combinations of sucrose, glucose, fructose, and maltodextrin. Such combinations are acceptable from both a sensory and a physiological perspective. Beverages containing mostly or solely fructose are not optimal because fructose is absorbed slowly by the intestine (Shi et al., 1995) and requires conversion to glucose by the liver before it can be metabolized by skeletal muscle, making fructose an ineffective fuel for improving performance (Murray et al., 1989). Research subjects who have had the unpleasant experience of participating in studies requiring the ingestion of fructose-only beverages can attest to the gastrointestinal limitations of fructose as the sole source of carbohydrate because vomiting and diarrhea are two common side effects when large amounts of fructose are ingested.

"Inclusion of sodium (0.5–0.7 grams per liter of water) in the rehydration solution ingested during exercise lasting longer than 1 h is recommended since it may be advantageous in enhancing palatability, promoting fluid retention, and possibly preventing hyponatremia in certain individuals who drink excessive quantities of fluid. There is little physiological basis for the presence of sodium in an oral rehydration solution for enhancing intestinal water absorption as long as sodium is sufficiently available from the previous meal."

Sweat contains more sodium and chloride than other minerals and, although sweat electrolyte values are normally substantially lower than plasma values (plasma = 138–142 mmol/L; sweat = 25–75 mmol/L), athletes who exercise in excess of two h each day can lose considerable amounts of sodium chloride. Consider, for example, a football lineman during two-a-day summer practices in which a total of 5 L of sweat is lost. If each liter of sweat contained 50 mmol sodium, the total sodium loss would be 5,750 mg, the equivalent of over 14 g of NaCl.

Food intake is usually accompanied by sodium chloride intake, and most research indicates that sodium deficits are rare among athletes or military personnel (Armstrong et al., 1987). However, there are occasions when sodium losses can present problems, as illustrated by Bergeron (1996) in a case study of a nationally ranked tennis player who suffered from frequent heat cramps. This player had both a high sweat rate (2.5 L/h) and higher-than-normal sweat sodium concentration (90 mmol/h). The muscle cramps were eliminated when he increased his daily dietary intake of sodium chloride from 5–10 g/day to 15–20 g/day, and increased his fluid intake to assure adequate hydration.

The ACSM position stand also indicates that ingesting sodium chloride in a beverage consumed during exercise can help ensure adequate fluid intake (Wilk & Bar-Or, 1996) and stimulate more-complete rehydration following exercise (Maughan et al., 1996). Both of these responses underscore the important role that sodium plays in maintaining the osmotic drive to drink and in providing an osmotic stimulus to retain fluid in the extracellular space.

It is true that the sodium content of a fluid-replacement beverage does not directly affect the rate of fluid absorption, as demonstrated by recent research (Gisolfi et al., 1995). This is because the amount of sodium that can be provided to the intestine by a beverage is miniscule compared to the amount of sodium that can be provided from the bloodstream. Plasma sodium freely diffuses into the gut following fluid intake because the concentration gradient for sodium between plasma and the contents of the intestine strongly favors sodium influx. The sodium content of the previous meal or of pancreatic secretions is of little importance in the fluid absorption process. That said, sodium chloride remains a critical ingredient in a properly formulated sports drink because it improves beverage palatability, helps maintain the osmotic drive for thirst, reduces the contribution of plasma sodium required in the gut prior to absorption, helps maintain plasma volume during exercise, and serves as the primary osmotic impetus for restoring extracellular fluid volume following exercise (Maughan et al., 1996; Nose et al., 1988).

Fluid Ingestion Following Exercise

Fluid intake following physical activity can be a critical factor in helping athletes recovery quickly between bouts of training and competition. Many athletes train more than once each day, making rapid rehydration an important consideration, particularly during training in warm weather. The ACSM position stand did not elaborate on recommendations for fluid intake after exercise, but in a recent Sports Science Exchange article, Maughan et al. (1996) provided a comprehensive review of this topic. The authors concluded that ingesting plain water is ineffective at restoring rehydration because water absorption causes plasma osmolality to fall, suppressing thirst and increasing urine output. When sodium is provided in fluids or foods, the osmotic drive to drink is maintained (Gonzalez-Alonso et al., 1992; Nose et al., 1988), and urine production is decreased. There are many occasions during training and competition when it is either difficult or unwise to ingest food, making it all the more important that athletes have access to fluid containing sodium chloride and other electrolytes.

Maughan et al. (1996) also emphasized the importance of ingesting fluid in excess of the deficit in body weight to account for obligatory urine losses. In other words, the advice normally given athletes —"drink a pint of fluid for every pound of body weight deficit"—must be amended to "drink at least a pint of fluid for every pound of body weight deficit". More-precise recommendations for how much fluid athletes should ingest to assure rapid and complete rehydration will evolve from future research; existing data indicate that ingestion of 150% or more of weight loss may be required to achieve normal hydration within six h following exercise (Shirreffs et al., 1996).

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Heat and Cold Illnesses During Distance Running

American College of Sports Medicine Position Stand

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Summary

Many recreational and elite runners participate in distance races each year. When these events are conducted in hot or cold conditions, the risk of environmental illness increases. However, exertional hyperthemia, hypothermia, dehydration, and other related problems may be minimized with pre-event education and preparation. This position stand provides recommendations for the medical director and other race officials in the following areas: scheduling; organizing personnel, facilities, supplies, equipment, and communications providing competitor education; measuring environmental stress; providing fluids; and avoiding potential legal liabilities. This document also describes the predisposing conditions, recognition, and treatment of the four most common environmental illnesses: heat exhaustion, heatstroke, hypothermia, and frostbite. The objectives of this position stand are: 1) To educate distance running event officials and participants about the most common forms of environmental illness including predisposing conditions, warning signs, susceptibility, and incidence reduction. 2) To advise race officials of their legal responsibilities and potential liability with regard to event safety and injury prevention. 3) To recommend that race officials consult local weather archives and plan events at times likely to be of low environmental stress to minimize detrimental effects on participants. 4) To encourage race officials to warm participants about environmental stress on race day and its implications for heat and cold illness. 5) To inform race officials of preventive actions that may reduce debilitation and environmental illness. 6) To describe the personnel, equipment, and supplies necessary to reduce and treat cases of collapse and environmental illness.

Introduction

This document replaces the position stand titled *The Prevention of Thermal Injuries During Distance Running* (4). It considers problems that may affect the extensive community of recreational joggers and elite athletes who participate in distance running events. It has been expanded to include heat exhaustion, heatstroke, hypothermia, and frostbite–the most common environmental illnesses during races.

Because physiological responses to exercise in stressful environments may vary among participants, and because the health status of participants varies from day to day, compliance with these recommendations will not guarantee protection from environmentally induced illnesses. Nevertheless, these recommendations should minimize the risk of exertional hyperthermia, hypothermia, dehydration, and resulting problems in distance running and other forms of continuous athletic activity such as bicycle, soccer, and triathlon competition.

Managing a large road race is a complex task that requires financial resources, a communication network, trained volunteers, and teamwork. Environmental extremes impose additional burdens on the organizational and medical systems. Therefore, it is the position of the American College of Sports Medicine that the following RECOMMENDATIONS be employed by race managers and medical directors of community events that involve prolonged or intense exercise in mild and stressful environments.

1. Race Organization

a. Distance races should be scheduled to avoid extremely hot and humid and very cold months. The local weather history should be consulted when scheduling an event. Organizers should be cautious of unseasonably hot or cold days in early spring or late fall because entrants may not be sufficiently acclimatized. The wind chill index should be used to reschedule races on cold, windy days because flesh may freeze rapidly and cold injuries may result.

b. Summer events should be scheduled in the early morning or the evening to minimize solar radiation and air temperature. Winter events should be scheduled at midday to minimize the risk of cold injury.

c. The heat stress index should be measured at the site of the race because meteorological data from a distant weather station may vary considerably from local conditions (66). The wet bulb globe temperature (WBGT) index is widely used in athletic and industrial settings [see Appendix I;(87)]. If the WBGT index is above 28 °C (82 °F), or if the ambient dry bulb temperature is below -20 °C (-4 °F), consideration should be given to canceling the race or rescheduling it until less stressful conditions prevail. If the WBGT index is below 28 °'C, participants should be alerted to the risk of heat illness by using signs posted at the start of the race and at key positions along the race course [see Appendix I;(61)]. Also, race organizers should monitor changes in weather conditions. WBGT monitors can be purchased commercially, or Figure I may be used to approximate the risk of racing in hot environments based on air temperature and relative humidity. These two measures are available from local meteorological stations and media weather reports, or can be measured with a sling psychrometer.

d. An adequate supply of fluid must be available before the start of the race, along the race course, and at the end of the event. Runners should be encouraged to replace their sweat losses or consume 150-300 ml (5.3-10.5 oz) every 15 minutes (3). Sweat loss can be derived by calculating the difference between pre and postexercise body weight.

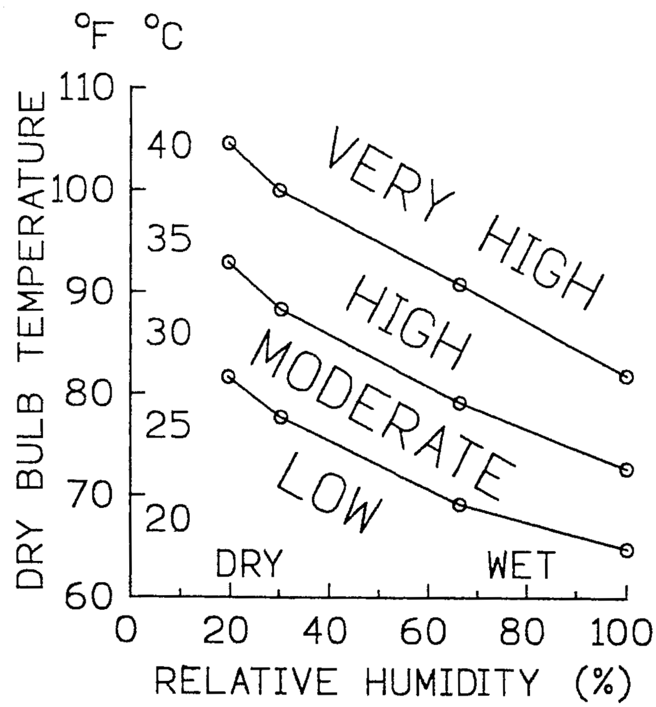

Figure 1 Risk of heat exhaustion or heatstroke while racing in hot environments. Figure drawn from data presented in American College of Sports Medicine Position stand: the prevention of thermal injuries during distance running. *Med. Sci. Sports Exerc.* 19:529-533, 1987.

e. Cool or cold (ice) water immersion is the most effective means of cooling a collapsed hyperthermic runner (25, 48, 49, 59, 88). Wetting runners externally by spraying or sponging during exercise in a hot environment is pleasurable but does not fully attenuate the rise in body core temperature (14, 88). Wetting the skin can result in effective cooling once exercise ceases.

f. Race officials should be aware of the warning signs of an impending collapse in both hot and cold environments and should warn runners to slow down or stop if they appear to be in difficulty.

g. Adequate traffic and crowd control must be maintained along the course at all times.

h. Radio communication or cellular telephones should connect various points on the course with an information processing center to coordinate emergency responses.

2. Medical Director

A sports medicine physician should work closely with the race director to enhance the safety and provide adequate medical care for all participants. The medical director should understand exercise physiology, interpretation of meteorological data, heat and cold illness prevention strategies, potential liability, and the treatment of medical problems associated with endurance events conducted in stressful environments.

3. Medical Support

a. Medical organization and responsibility: The medical director should alert local hospitals and ambulance services and make prior arrangements to care for casualties, including those with heat or cold injury. Medical personnel should have the authority to evaluate, examine, and stop runners who display signs of impending illness or collapse. Runners should be advised of this procedure prior to the event.

b. Medical facilities: Medical support staff and facilities must be available at the race site. The facilities should be staffed with personnel capable of instituting immediate and appropriate resuscitation measures. The equipment necessary to institute both cooling therapy (ice packs, child's wading pools filled with tap water or ice water, fans) and warming therapy (heaters, blankets, hot beverages) may be necessary at the same event. For example, medical personnel treated 12 cases of hyperthermia and 13 cases of hypothermia at an endurance triathlon involving 2300 competitors: air temperature was 85°F, water temperature was 58°F (92).

4. Competitor Education

The physical training and knowledge of competitive runners and joggers has increased greatly, but race organizers must not assume that all participants are well prepared or informed about safety. Distributing this position stand before registration, publicizing the event in the media, and conducting clinics or seminars before events are valuable educational procedures.

a. All participants should be advised that the following conditions may exacerbate heat illness: obesity (13, 39, 89), low degree of physical fitness (30, 63, 79, 83), dehydration (23, 34, 69, 83, 84, 95), lack of heat acclimatization (31, 51, 89), a previous history of heat stroke (82, 89), sleep deprivation (5), certain medications, including diuretics and antidepressants (31), and sweat gland dysfunction or sunburn (31). Illness 1 week prior to an event should preclude participation (32, 96), especially those involving fever, respiratory tract infections, or diarrhea (41, 46).

b. Prepubescent children sweat less than adults and have lower heat tolerance (11, 12).

c. Adequate training and fitness are important for full enjoyment of the event and will reduce the risk of heat illness and hypothermia (33, 64, 67, 85).

d. Prior training in the heat will promote heat acclimatization (6) and thereby reduce the risk of heat illness, especially if the training environment is warmer than that expected during a race (5, 51). Artificial heat acclimatization can be induced in cold conditions (6).

e. Adequate fluid consumption before and during the race can reduce the risk of heat illness, including disorientation and irrational behavior, particularly in longer events such as a marathon (23, 34, 95).

f. Excessive consumption of pure water or dilute fluid (i.e., up to 10 liters per 4 hours) during prolonged endurance events may lead to a harmful dilutional hyponatremia (60), which may involve disorientation, confusion, and seizure or coma. The possibility of hyponatremia may be the best rationale for inclusion of sodium chloride in fluid replacement beverages (3).

g. Participants should be advised of the early symptoms of heat illness, which may include clumsiness, stumbling, headache, nausea, dizziness, apathy, confusion, and impairment of consciousness (41,86).

h. Participants should be advised of the early symptoms of hypothemia (slurred speech, ataxia, stumbling gait) and frostbite (numbness, burning, pain, paresthesia) on exposed skin (36). Wet clothing, especially cotton, increases heat loss and the risk of hypothermia (68).

i. Participants should be advised to choose a comfortable running speed and not to run faster than environmental conditions or their cardiorespiratory fitness warrant (43, 71, 91).

j. It is helpful if novice runners exercise with a partner, each being responsible for the other's well-being (71).

5. Responsibilities and Potential Liability

The sponsors and directors of an endurance event are reasonably safe from liability due to injury if they avoid gross negligence and willful misconduct, carefully inform the participants of hazards, and have them sign waivers before the race (78). However, a waiver signed by a participant does not totally absolve race organizers of moral and/or legal responsibility. It is recommended that race sponsors and directors: 1) minimize hazards and make safety the first concern; 2) describe inherent hazards (i.e., potential course hazards, traffic control, weather conditions) in the race application; 3) require all entrants to sign a waiver; 4) retain waivers and records for 3 yrs; 5) warn runners of the predisposing factors and symptoms of environmental illness; 6) provide all advertised support services; 7) legally incorporate the race or organizations involved; and 8) purchase liability insurance (18, 78, 80).

Race directors should investigate local laws regarding Good Samaritan action. In some states physicians who do not accept remuneration may be classified as Good Samaritans. Race liability insurance may not cover physicians (78), therefore the malpractice insurance policy of each participating physician should be evaluated to determine if it covers services rendered at the race.

Medical and race directors should postpone, reschedule, or cancel a race if environmental conditions warrant, even though runners and trained volunteers arrive at the site and financial sponsorship has been provided. Runners may not have adequate experience to make the decision not to compete; their safety must be considered. Downgrading the race to a "fun run" does not absolve race supervisors from their responsibility or decrease the risk to participants (15, 66).

Background For This Position Stand

Dehydration is common during prolonged endurance events in both cold and hot environmental conditions because the average participant loses 0.5-1.5 quarts (0.47-1.42 liters) of sweat, and fluid replacement is usually insufficient (12, 42, 69). Runners may experience hyperthermia [body core temperature above 39°C (102.2°F)] or hypothermia [body core temperature below 35°C (95°F)], depending on the environmental conditions, caloric intake, fluid consumption, and clothing worn. Hyperthermia is a potential problem in warm and hot weather races when the body's rate of heat production is greater than its heat dissipation (2). Indeed, on extremely hot days, it is possible that up to 50% of the participants may require treatment for heat-related illnesses such as heat exhaustion and heatstroke (1, 66). Hypothermia is more likely to occur in cold or cool-windy conditions. Scanty clothing may provide inadequate protection from such environments, particularly near the end of a long race when running speed and heat production are reduced. Frostbite can occur in low air temperature and especially when combined with high wind speed. The race and medical directors should anticipate the above medical problems and be capable of responding to a large number of patients with adequate facilities, supplies, and support staff. The four most common heat and cold illnesses during distance running are heat exhaustion, heatstroke, hypothermia, and frostbite.

1. Heat Exhaustion

Body sweat loss can be significant in summer endurance races and may result in a body water deficit of 6-10% of body weight (41, 95). Such dehydration will reduce the ability to exercise in the heat because decreases in circulating blood volume, blood pressure, sweat production, and skin blood flow all inhibit heat loss (41, 81) and predispose the runner to heat exhaustion or the more dangerous hyperthermia and exertional heatstroke (41, 66).

Heat exhaustion, typically the most common heat illness among athletes, is defined as the inability to continue exercise in the heat (7). It represents a failure of the cardiovascular responses to workload, high external temperature, and dehydration (16, 41, 42). Heat exhaustion has no known chronic, harmful effects. Symptoms may include headache, extreme weakness, dizziness, vertigo, "heat sensations" on the head or neck, heat cramps, chills, "goose flesh" ("goose bumps"), vomiting, nausea, and irritability (41, 42). Hyperventilation, muscular incoordination, agitation, impaired judgment, and confusion also may be seen. Heat syncope (fainting) may or may not accompany heat exhaustion (41). The onset of heat exhaustion symptoms is usually sudden and the duration of collapse brief. During the acute stage of heat exhaustion, the patient looks ashen-gray, the blood pressure is low, and the pulse rate is elevated. Hyperthermia may add to the symptoms of heat exhaustion, even on relatively cool days (20, 22, 30, 37, 38, 43, 62, 90).

Although it is improbable that all heat exhaustion cases can be avoided, the most susceptible individuals are those who either exert themselves at or near their maximal capacities, are dehydrated, not physically fit, and not acclimatized to exercise in the heat. It is imperative that runners be adequately rested, fed, hydrated, and acclimatized (7); they should drink ample fluids before, during, and after exercise (3). Also, repeated bouts of exercise in the heat (heat acclimatization) reduce the incidence of both heat exhaustion and heat syncope. Heat acclimatization can best be accomplished by gradually increasing the duration and intensity of exercise training during the initial 10-14 d of heat exposure (6).

Oral rehydration is preferred for heat exhaustion patients who are conscious, coherent, and without vomiting or diarrhea. Intravenous (IV) fluid administration facilitates rapid recovery (42, 57). Although a variety of IV solutions have been used at races (42), a 5% dextrose sugar in either 0.45% saline (NACI) or 0.9% NaCl are the most common (1). Runners may require up to 4 1 of IV fluid if severely dehydrated (57).

2. Exertional Heatstroke

Heat production, mainly from muscles, during intense exercise is 15-20 times greater than at rest, and is sufficient to raise body core temperature by 1°C (1.8°F) each 5 minutes without thermoregulatory (heat loss) adjustments (56). When the rate of heat production exceeds that of heat loss for a sufficient period of time, severe hyperthermia occurs.

Heatstroke is the most serious of the syndromes associated with excess body heat. It is defined as a condition in which body temperature is elevated to a level that causes damage to the body's tissues, giving rise to a characteristic clinical and pathological syndrome affecting multiple organs (32, 83). After races, adult core (rectal) temperatures above 40.6°C (105.1°F) have been reported in conscious runners (24, 52, 69, 74, 77), and 42-43°C (107.6-109.4°F) in collapsed runners (72-74, 86, 90). Sweating is usually present in runners who experience exertional heatstroke (87).

Strenuous physical exercise in a hot environment has been notorious as the cause of heatstroke, but heatstroke also has been observed in cool-to-moderate [13-28°C (55-82°F)] environments (5, 32, 74), suggesting variations in individual susceptibility (5, 31, 32). Skin disease, sunburn, dehydration, alcohol or drug use/abuse, obesity, sleep loss, poor physical fitness, lack of heat acclimatization, advanced age, and a previous heat injury all have been theoretically linked to increased risk of heatstroke (5, 31, 51, 84). The risk of heatstroke is reduced if runners are well-hydrated, well-fed, rested, and acclimatized. Runners should not exercise if they have a concurrent illness, respiratory infection, diarrhea, vomiting, or fever (5, 7, 46). For example, a study of 179 heat casualties at a 14-km race showed that 23% reported a recent gastrointestinal or respiratory illness (70), whereas a study of 10 military heatstroke patients reported that three had a fever or disease and six recalled at least one warning sign of impending illness at the time of their heatstroke (5).

Appropriate fluid ingestion before and during prolonged running can minimize dehydration and reduce the rate of increase in body core temperature (24, 34). However, excessive hyperthermia may occur in the absence of significant dehydration, especially in races of less than 10 km, because the fast pace generates greater metabolic heat (90).

The mortality rate and organ damage due to heatstroke are proportional to the length of time between core temperature elevation and initiation of cooling therapy (5, 26). Therefore, prompt recognition and cooling are essential (1, 5, 22, 42, 48, 51, 62, 74, 83). A measurement of deep body temperature is vital to the diagnosis, and a rectal temperature should be measured in any casualty suspected of having heat illness or hypothermia. Ear (tympanic), oral, or axillary measurements are spuriously affected by peripheral (skin) and environmental temperatures and should not be used after exercise (8, 75, 76). When cooling is initiated rapidly, most heatstroke patients recover fully with normal psychological status (79), muscle energy metabolism (65), heat acclimatization, temperature regulation, electrolyte balance, sweat gland function, and blood constituents (5).

Many whole-body cooling techniques have been used to treat exertional heatstroke, including water immersion, application of wet towels or sheets, warm air spray, helicopter downdraft, and ice packs to the neck, underarm, and groin areas. There is disagreement as to which modality provides the most efficient cooling (7, 47, 97), because several methods have been used successfully. However, the fastest whole-body cooling rates (25, 48, 49, 59, 88) and the lowest mortality rates (25) have been observed during cool and cold water immersion. Whichever modality is utilized it should be simple and safe, provide great cooling power, and should not restrict other forms of therapy (i.e., cardiopulmonary resuscitation, defibrillation, IV cannulation). The advantages and disadvantages of various cooling techniques have been discussed (47, 75, 97).

Heatstroke is regarded as a medical emergency that might be fatal if not immediately diagnosed and properly treated. Early diagnosis is of utmost importance and time-consuming investigation should be postponed until body temperature is corrected and the patient is evacuated to a nearby medical facility that is aware of such conditions.

3. Hypothermia

Hypothermia [body core temperature below 36°C (97 °F)] occurs when heat loss is greater than metabolic heat production (94). Early signs and symptoms of hypothermia include shivering, euphoria, confusion, and behavior similar to intoxication. Lethargy, muscular weakness, disorientation, hallucinations, depression, or combative behavior may occur as core temperature continues to fall. If body core temperature falls below 31.1°C

(88°F), shivering may stop and the patient will become progressively delirious, uncoordinated, and eventually comatose if treatment is not provided (10).

During cool or cold weather marathons, the most common illnesses are hypothermia, exhaustion, and dehydration. The most common medical complaints are weakness, shivering, lethargy, slurred speech, dizziness, diarrhea, and thirst (1, 45). Runner complaints of feeling hot or cold do not always agree with changes in rectal temperature (74). Dehydration is common in cool weather (1, 45). Runners should attempt to replace fluids at a rate that matches their sweat and urine losses. Cases of hypothermia also occur in spring and fall because weather conditions change rapidly and runners wear inappropriate clothing that becomes sweat-soaked during training or competition (19).

Hypothermia may occur during races, for example when distance runners complete the second half of the event more slowly than the first half (54). Evaporative and radiative cooling increase because wet skin (from sweat, rain, or snow) and clothing are exposed to higher wind speed at a time when metabolic heat production decreases. Hypothermia also occurs after a race, when the temperature gradient between the body surface and the environment is high. Subfreezing ambient temperatures need not be present and hypothermia may develop even when the air temperature is 10-18°C (50-65°F) (19, 36, 74). A WBGT meter can be used to evaluate the risk of hypothermia (see Appendix 1). Cold wind increases heat loss in proportion to wind speed; i.e., wind chill factor. The relative degree of danger can be assessed (Fig. 2) (55). Wind speed can be estimated; if you feel the wind in your face the speed is at least 16 km per $hour^{-1}$ (kph) [10 miles per $hour^{-1}$ (mph)]; if small tree branches move or if snow and dust are raised, approximately 32 kph (20 mph); if large tree branches move, 48 kph (30 mph); if an entire tree bends, about 64 kph (40 mph) (9).

To reduce heat loss, runners should protect themselves from moisture, wind, and cold air by wearing several layers of light, loose clothing that insulate the skin with trapped air (17). An outer garment that is windproof, allows moisture to escape, and provides rain protection is useful. Lightweight nylon parkas may not offer thermal insulation but offer significant protection against severe wind chill, especially if a hood is provided. Wool and polyester fabrics retain some protective value when wet; cotton and goose down do not (10). Areas of the body that lose large amounts of heat (head, neck, legs, hands) should be covered (17).

Mild [34-36°C (93-97°F)] or moderate [30-34°C (86-93°F)] hypothermia should be treated before it progresses. Wet clothing should be replaced with dry material (sweatsuit, blanket) that is insulated from the ground and wind. Warm fluids should be consumed if patients are conscious, able to talk, and thinking clearly. Patients with moderate and severe [<30°C (86°F)] hypothermia should be insulated in a blanket and evacuated to a hospital immediately (19, 58). Although severe hypothermia should be treated in the field (27), it is widely recognized that life-threatening ventricular fibrillation is common in this state and may be initiated

Wind Chill Chart

AIR TEMPER-ATURE	ESTIMATED WIND SPEED IN MPH (KPH) 0 (0)	10 (16)	20 (32)	0 (48)	
30F (-1.l C)	30 (1.1)	16 (-8.9)	4 (-15.6)	-2 (-18.9)	LITTLE RISK
20 F (-6.7 C)	20 (-6-7)	4 (-15.6)	-10 (-23-3)	-18 (-27.8)	
10F (12.2 C)	10 (-12.2)	-9 (-22.8)	-25 (-31.7)	-33 (-36.1)	INCREASED RISK
0 F (-17.8 C)	0 (-17.8)	-24 (-31.1)	-39 (-39.4)	-48 (-44.4)	
-10 F (-23.3 C)	-10 (-23.3)	-33 (-36.1)	-53 (-47.2)	-63 (-52.8)	
-20 F (-28.9 C)	-20 (-28.9)	-46 (-43.3)	-67 (-55)	-79 (-61.7)	GREAT RISK

Figure 2 The risk of freezing exposed flesh in cold environments.
Reprinted from Milesko-Pytel, D. Helping the frostbitten patient. *Patient Care* 17:90-115, 1983.

by physical manipulation, chest compression, or intubation (10, 27, 58, 93). However, with conclusive evidence of cardiac standstill and breathlessness, emergency procedures (i.e., Basic Life Support, Advanced Cardiac Life Support) should be initiated. Life-support procedures (27) and commonly observed laboratory (i.e., electrolyte, acid-base) values (10, 58) have been described by others.

4. Frostbite

Frostbite involves crystallization of fluids in the skin or subcutaneous tissue after exposure to subfreezing temperatures [< -0.6°C (31°F)]. With low skin temperature and dehydration, cutaneous blood vessels constrict and circulation is attenuated because the viscosity of blood increases (55). Frostbite may occur within seconds or hours of exposure, depending upon air temperature, wind speed, and body insulation. Frostbitten skin can appear white, yellow-white, or purple, and is hard, cold, and insensitive to touch (55). Rewarming results in intense pain, skin reddening, and swelling. Blister formation is common and loss of extremities (fingers, toes, ears, hands, feet) is possible (36, 55). The degree of tissue damage depends on duration and severity of the freezing and effectiveness of treatment.

No data have been published regarding the incidence of frostbite among athletes during training or competition. Since winter running races are rarely postponed when environmental conditions are harsh, and frostbite is the most common cold injury in military settings (35), it is imperative that runners be aware of the dangers. Crosscountry ski races are postponed if the temperature at the coldest point of the course is less than -20 °C (-4 °F), due to the severe wind chill generated at race pace.

Runners risk frozen flesh within minutes if the air temperature and wind speed combine to present a severe wind chill. Because runners prefer to have unrestricted movement during races, and because they know that exercise results in body heating, they may not wear sufficient clothing. Runners can avoid frostbite and hypothermia in cold and windy conditions by protecting themselves by dressing adequately: wet skin or clothing will increase the risk of frostbite (21, 29).

When tissue freezes [skin temperature -2 ° -O °C, (28-32 °F)], water is drawn out of the cells and ice crystals cause mechanical destruction of skin and subcutaneous tissue (36). However, initial ice crystal formation is not as damaging to tissues as partial rethawing and refreezing (40). Therefore, the decision to treat severe frostbite in the field (versus transport to a hospital) should consider the possibility of refreezing. If there is no likelihood of refreezing, the tissue should be rapidly rewarmed (36, 40) in circulating warm water (40-43.3 °C, 104-110 °F), insulated, and the patient transported to a medical facility. Research on animals suggests that topical aloe vera and systemic ibuprofen may reduce tissue damage and speed rehabilitation in humans (9). Other aspects of hospital treatment protocols are detailed elsewhere (9, 36, 40).

Race Organization

The following suggestions constitute the ideal race medical team. They are offered for consideration, but are not intended as absolute requirements. Staff and equipment needs are unique to each race and may be revised after 1-2 yr, in light of the distinctive features of each race. Depending on the weather conditions, 2-12% of all entrants will typically enter a medical aid station (1, 45, 50, 74).

1. Medical Personnel

a. Provide medical assistance if the race is 10 km (6.2 miles) or longer.

b. Provide the following medical personnel per 1,000 runners: 1-2 physicians, 4-6 podiatrists, 1-4 emergency medical technicians, 2-4 nurses, 3-6 physical therapists, 3-6 athletic trainers, and 1-3 assistants. Approximately 75% of these personnel should be stationed at the finish area. Recruit one nurse (per 1,000 runners) trained in IV therapy.

c. Recruit emergency personnel from existing organizations (police, fire-rescue, emergency medical service).

d. One physician and 10-15 medical assistants serve as the triage team in the finish chute. Runners unable to walk are transported to the medical tent via wheelchair, litter, or two-person carry.

e. Consider one or two physicians and two to four nurses trained in the rehabilitative medical care of wheelchair athletes.

f. Medical volunteers should attend a briefing prior to the event to meet their supervisor and receive identification tags, weather forecast, instructions, and schedules. Supervisors from the following groups should be introduced: medical director; podiatry, nursing, physical therapy, athletic training, medical records, triage, wheelchair athlete care, and medical security (optional: chiropractic, massage therapy). Medical volunteers should be distinguished from other race volunteers; luminous/distinctive vests, coats, or hats work well.

2. Medical Aid Stations

a. Provide a primary medical aid station (250-1,500 ft^2 (23-139 m^2) for each 1,000 runners; see Table 1) at the finish area, with no public access. Place security guards at all entrances with instructions regarding who can enter.

b. Position secondary medical aid stations along the route at 2- to 3-km (1.2- to 1.9-mile) intervals for races over 10 km, and at the halfway point for shorter races (see Table 1). Some race directors have successfully secured equipment and medical volunteers from military reserve or national guard medical units, the American Red Cross, and the National Ski Patrol.

c. Station one ambulance per 3,000 runners at the finish area and one or more mobile emergency response vehicles on the course. Staff each vehicle with a nurse and radio person or cellular telephone. Stock each vehicle with a medical kit, automatic defibrillator, IV apparatus. blankets, towels, crushed ice, blood pressure cuffs, rehydration fluid, and cups.

d. Signs should be posted at the starting line and at each medical aid station to announce the risk of heat illness or cold injury (see Appendix 1).

e. A medical record card should be completed for each runner who receives treatment (1,74). This card provides details that can be used to plan the medical coverage of future events.

f. Provide personal protective equipment (gloves, gowns, face shields, eye protection) and hand washing facilities.

g. Provide portable latrines and containers for patients with vomiting and diarrhea.

h. Initial medical assessment must include rectal (not oral, aural, or axillary temperature; see ref. 8, 76), central nervous system function, and cardiovascular function. Rehydration and cooling or warming are the cornerstones of treatment (32, 41, 42, 50, 74, 94).

Medical aid stations

Item	Secondary Aid Station	Primary Aid Station
Stretchers (at 10 km and beyond)	2-5	4-10
Cots	10	30
Wheelchairs	0	1
Wool blankets (at 10 km and beyond)	6-10	12-20
Bath towels	5-10	10-20
High and low temperature rectal thermometers (37-43˚C; 99-110˚F) and (22-37˚C; 77-99˚F)[d]	5	10
Elastic bandages (2, 4, and 6 inch)	3 each	6 each
Gauze pads (4 x 4 inch)	1/2 case	1 case
Adhesive tape (1.5 inch)	1/2 case	1 case
Skin disinfectant	1 l	2 l
Surgical soap	1/2 case	1case
Band-aids	110	220
Moleskin	1/2 case	1 case
Petroleum jelly, ointments	1/2 case	1 case
Disposable latex gloves	80 pairs	175 pairs
Stethoscopes	1	2
Blood pressure cuffs	1	2
Intravenous (IV) stations[d]	1	2
IV fluid (D5:1/2 NS or D5:NS; 0.5 or 1l)[d]	15[e]	30[e]
Sharps and biohazard disposal containers[d]	1	2
Alcohol wipes	50	100
Small instrument kits	1	1
Athletic trainer's kit	1	1
Podiatrist's kit	1-2	2-4
Inflatable arm and leg splints	2 each	2 each
Tables for medical supplies	1	2
Hose with spray nozzle, running water[e]	1	2
Wading pool for water immersion[d]	1	2
Fans for cooling	1	2-4
Oxygen tanks with regulators and masks	0	2
Crushed ice in plastic bags	7 kg	14 kg
Rehydration fluids	50 l	100 l[e]
Cups (≥0.3l, 10 oz)	1250	2250
Eye drops	1	1
Urine dipsticksd	10	20
Glucose blood monitoring kits[d]	1	2
Inhalation therapy for asthmatics[d]	1	1
EMS ambulance or ACLS station	1	1
Injectable drugs[d]		
Oral drugs[d]		

Table 1 Suggested equipment and supplies per 1,000 runners[a].

[a] Revised from Adner, M. M., J. J. Scarlet, J. Casey, W. Robison, and 8, H. Jones. The Boston Marathon medical care team: ten years of experience. *Physician Sportsmed.* 16:99-106, 1988; Bodishbaugh, R. G. Boston marathoners get red carpet treatment in the medical tent. *Physician Sportsmed.* 16:139-143, 1988; and Noble, H. B. and D. Bachman. Medical aspects of distance race planning. *Physician Sportsmed.* 7:78-84, 1979.

[b] Increase supplies and equipment if the race course is out and back.

[c] At finish area.

[d] Supervised by a physician.

[e] Depends on environmental conditions.

3. Universal Precautions

All medical personnel may encounter blood-borne pathogens or other potentially infectious materials, and should observe the following precautions (53, 63):

a. Receive immunization against the hepatitis B virus prior to the event.

b. Recognize that blood and infectious body fluids may be encountered from needle sticks, cuts, abrasions, blisters, and clothing.

c. Reduce the likelihood of exposure by planning tasks carefully (i.e., prohibiting recapping of needles by a two-handed technique, minimizing splashing and spraying).

d. Wear personal protective equipment such as gloves, gowns, face shields and eye protection. Remove this equipment and dispose/decontaminate it prior to leaving the work area.

e. Wash hands after removing gloves or other personal protective equipment.

f. Dispose of protective coverings, needles, scalpels, and other sharp objects in approved, labeled biohazard containers.

g. Do not eat, drink, smoke, handle contact lenses, or any cosmetics/lip balm in the medical treatment area.

h. Decontaminate work surfaces, bins, pails, and cans [1/10 solution of household bleach (sodium hypochlorite) in water] after completion of procedures.

4. Fluid Stations

a. At the start and finish areas provide 0.34-0.45 1 (12-16 oz) of fluid per runner. At each fluid station on the race course (2-3 km apart), provide 0.28-0.34 1 (10-12 oz) of fluid per runner. Provide both water and a carbohydrate-electrolyte beverage in equal volumes.

b. In cool or cold weather [≤10˚C (50˚F)], an equivalent amount of warm fluid should be available.

c. Number of cups (>0.3 1, 10 oz) per fluid station on the course = number of entrants + 25% additional for spillage and double use. Double this total if the course is out and back.

d. Number of cups at start and finish area = (2 × number of entrants) + 25% additional.

e. Cups should be filled prior to the race and placed on tables to allow easy access. Runners drink larger volumes if volunteers hand them cups filled with fluid.

5. Communications/Surveillance

a. Provide two-way radio or telephone communication between the medical director, medical aid stations, mobile vans, and pick-up vehicles.

b. Arrange for radio-equipped vehicles to drive the race course (ahead and behind participants) and provide communication with the director and his/her staff. These vehicles should be stationed at regular intervals along the course to search the course for competitors who require emergency care and encourage compromised runners to stop.

c. Place radio-equipped observers along the course.

d. Notify local hospitals, police, and fire-rescue departments of the time of the event, number of participants, location of aid stations, extent of medical coverage, and the race course.

e. Use the emergency response system (telephone number 911) in urban areas.

6. Instructions to Runners

a. Advise each race participant to print name, address, telephone number, and medical problems on the back of the race number (pinned to the body). This permits emergency personnel to quickly identify unconscious runners. Inform emergency personnel that this information exists.

b. Inform race participants of potential medical problems at pre-race conferences and at the starting line. Signed registration forms should clearly state the types of heat or cold injuries that may arise from participation in this event.

c. Provide pre-event recommendations regarding training, fluid consumption, clothing selection, self-care, heat acclimatization, and signs or symptoms of heat/cold illness (88).

d. The race director should announce the following information to all participants by loudspeaker immediately prior to the race:

- Current and predicted maximum (or minimum) temperature, humidity, wind speed, and cloud cover;
- The WBGT category and the risks for hyperthermia or hypothermia (see Appendix 1);
- Location of aid stations, types of assistance, and fluid availability;
- Signs and symptoms of heat or cold illness;
- Recommended clothing;
- The need for fluid replacement before, during, and after the race;
- The policy of race monitors to stop runners who are ill;
- A request that runners seek help for impaired competitors who appear ill, who are not coherent, who run in the wrong direction, or who exhibit upper-body swaying and poor competitive posture;

- A warning to novice runners entering their first race that they should run at a comfortable pac and run with a partner;
- Warnings to runners who are taking medications or have chronic illnesses (asthma, hypertension, diabetes, cardiovascular problems).

This position stand replaces the 1987 ACSM position paper, "The Prevention of Thermal Injuries During Distance Running." This pronouncement was reviewed for the American College of Sports Medicine by members-at-large, the Pronouncements Committee, and by: Arthur E. Crago, M.D., Stafford W. Dobbin, M.D., Mary L. O'Toole, Ph.D., FACSM, LTC Katy L. Reynolds, M.D., John W. Robertson, M.D., FACSM.

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Appendix 1: Measurement of Environmental Stress

Ambient temperature is only one component of environmental heat or cold stress; others are humidity, wind speed, and radiant heat. The most widely used heat stress index is the wet bulb globe temperature (WBGT) index (96):

$$WBGT = (0.7\ T^{wb}) + (0.2\ T^{g}) + (0.\ 1\ T^{db})$$

where T^{wb} is the wet bulb temperature, T^{g} is the black globe temperature, and T^{db} is the shaded dry bulb temperature (28). T^{db} refers to air temperature measured with a standard dry bulb thermometer not in direct sunlight. T^{wb} is measured with a water-saturated cloth wick over a dry bulb thermometer (not immersed in water). T^{g} is measured by inserting a dry bulb thermometer into a standard black metal globe. Both T^{wb} and ^{T} are measured in direct sunlight.

A portable monitor that gives the WBGT index in degrees Celsius or degrees Fahrenheit has proven useful during races and in military training (28, 44, 87, 96). The measurement of air temperature alone is inadequate. The importance of humidity in total heat stress can be readily appreciated because T^{wb} accounts for 70% of the index whereas T^{db} accounts for only 10%.

The risk of heat illness (while wearing shorts, socks, shoes, and a t-shirt) due to environmental stress should be communicated to runners in four categories (see Fig. 1):

- Very high risk: WBGT above 28°C (82°F); high risk: WBGT 23-28°C (73-82°F);
- Moderate risk: WBGT 18-23°C (65-73°F);
- Low risk: WBGT below 18°C (65°F).

Large signs should be displayed, at the start of the race and at key points along the race course, to describe the risk of heat exhaustion and heatstroke (Fig. 1). When the WBGT index is above 28°C (82°F), the risk of heat exhaustion or heatstroke is very high; it is recommended that the race be postponed until less stressful conditions prevail, rescheduled, or canceled. High risk [WBGT index = 23-28°C (73-82°F)] indicates that runners should be aware that heat exhaustion or heatstroke may be experienced by any participant; anyone who is particularly sensitive to heat or humidity probably should not run. Moderate risk [WBGT index = 18-23°C (65-73°F)] reminds runners that heat and humidity will increase during the course of the race if conducted during the morning or early afternoon. Low risk [WBGT index below 18°C (65°F)] does not guarantee that heat exhaustion (even heatstroke, see ref. 5, 32) will not occur; it only indicates that the risk is low.

The risk of hypothermia (while wearing shorts, socks, shoes, and a t-shirt) also should be communicated to runners. A WBGT index below 10°C (50°F) indicates that hypothermia may occur in slow runners who run long distances, especially in wet and windy conditions. Core body temperatures as low as 92°F have been observed in 65°F conditions (74).

Section Six

REFERENCES AND WEB SITES

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For further reading, we recommend these articles.

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Web Sites

American College of Sport Medicine (ACSM)

www.acsm.org

American Sport Education Program

www.asep.com

Gatorade Sport Science Institute (GSSI)

www.gssiweb.com

Human Kinetics

www.humankinetics.com

National Athletic Trainers Association (NATA)

www.nata.org

National Strength and Conditioning Association (NSCA)

www.nsca-lift.org