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COLLAPSE IN THE ENDURANCE ATHLETE

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KEY POINTS

- Most cases of collapse are benign in nature and occur after an athlete crosses the finish line or stops exercising. Athletes who collapse before finishing are more likely to have a serious condition.
- Athletes who are awake and alert after the collapse are less likely to be seriously ill than those who have a diminished level of consciousness.
- In evaluating the collapsed athlete, it is essential to check vital signs (especially rectal temperature if heat stroke is suspected), assess fluid status (dehydrated vs. fluid overload), and perform laboratory tests (blood sodium and glucose) when needed.
- The most common benign cause of collapse is low blood pressure due to blood pooling in the legs after cessation of exercise (as in postural hypotension, heat exhaustion, or syncope). This condition is treated by elevating the feet and pelvis until symptoms improve.
- The most common serious cause of collapse is low blood sodium (hyponatremia), which is usually associated with excessive replacement of sweat with fluid containing little or no sodium. Hyponatremic athletes who appear fluid overloaded should not receive intravenous fluid.
- Heat stroke is a rare cause of collapse but can be fatal if not diagnosed early and treated with ice-water immersion to achieve rapid cooling.

INTRODUCTION

Collapse is perhaps the most dramatic of all medical problems affecting athletes. Though collapse can be seen in any athletic event requiring maximal exertion, it is most common in endurance events, such as marathons and triathlons. The incidence seems to increase as the race distance, temperature, and humidity increase (O'Conner et al., 2003).

In endurance events, about 85% of the cases of collapse occur after the athlete crosses the finish line (Holtzhausen & Noakes, 1997). Most of these cases are benign and the athlete suffers no lasting deleterious effects, but in some circumstances collapse can be severe and life threatening. For this reason, medical personnel attending endurance events or caring for these athletes should be aware of the proper evaluation and management of the collapsed athlete, which can sometimes be the difference between life and death.

RESEARCH REVIEW

Defining Exercise-Associated Collapse

Exercise-associated collapse can be defined as the inability to walk unassisted, with or without exhaustion, nausea, vomiting, or cramps (Holtzhausen & Noakes, 1997; O'Conner et al., 2003). An athlete who collapses may have a body temperature that is normal, high, or low. For the purposes of this article, exercise-associated collapse excludes orthopedic conditions such as knee or ankle injuries that could potentially prevent an athlete from walking unassisted but can be easily distinguished from the more traditional causes of collapse.

The conditions that usually cause exercise-associated collapse are relatively few in number and can generally be grouped into benign and serious conditions. The most common benign causes of collapse include exhaustion, postural hypotension, dehydration, and muscle cramps. Serious causes include hyponatremia, heatstroke, hypoglycemia, hypothermia, cardiac arrest, and various other medical conditions.

Evaluation of the Collapsed Athlete in the Field

Initial assessment of the collapsed athlete in the field should begin with a quick evaluation of the athlete's level of consciousness. If the athlete is awake and alert, the cause of collapse is more likely to be benign. Those with a diminished level of consciousness should be assessed as to whether advanced cardiac life support is needed. Restoration of airway, breathing, and circulation is the first priority. Vital signs, including rectal temperature, heart rate, and blood pressure should be measured as soon as possible. The location of the athlete's collapse is a clue to possible severity; collapse

occurring after an athlete finishes a race is much less of a concern than when the athlete collapses before the finish line.

History. Coaches, trainers, parents, fellow athletes, and other observers often can provide important information to assist in the evaluation of the collapsed athlete. Important questions include the following:

1. How much and what type of fluid was ingested during the race? The answer to this question can be a clue to dehydration, hyponatremia, or hypoglycemia.
2. How much urine was passed during the race? Athletes who are significantly dehydrated most likely will not be urinating.
3. Was there any vomiting or diarrhea during the race? If so, it would contribute to dehydration.
4. How much carbohydrate was ingested before and during the race? Inadequate carbohydrate intake can lead to low blood sugar (hypoglycemia), especially in diabetic athletes.
5. Was there recent illness or medications (Table 1) that may have impaired heat tolerance or fluid balance?
6. Was the athlete well trained and prepared for the competition? Inadequate preparation makes collapse more likely.
7. Did the athlete have any symptoms, such as chest pain, palpitations, nausea, or wheezing, that could be clues to an underlying medical condition causing collapse?

Class of Drug	Examples of Drugs in Class
Anticholinergics	Atrovent, Pro-Banthine, Bentyl
Antihistamines	Allegra, Benadryl, Chlor-Trimeton
Beta-blockers	Inderol, Lopressor, Corgard
Diuretics	Lasix, Aldactone, Diuril
Methyldopa	Aldoclor, Aldoril
Monoamine oxidase (MAO) inhibitors	Nardil, Parnate, Marplan
Phenothiazines	Thorazine, Compazine, Trilafon
Tricyclic antidepressants	Imipramine, Amitriptyline, Nortriptyline
Drugs of abuse	Cocaine, amphetamines
Alcohol	Beer, wine, hard liquor

TABLE 1. Drugs that can adversely affect thermoregulation

Examination. Examination of the collapsed athlete should include continued monitoring of the athlete's vital signs. Heart rate and blood pressure should be measured in both supine and erect postures. When the athlete stands, if heart rate increases by 20 beats per minute or systolic blood pressure falls by 20 mm Hg or diastolic blood pressure falls by 10 mm Hg, these changes suggest significant depletion of blood volume and probable dehydration. Keep in mind that most endurance athletes have very low resting hearts rates, and a resting pulse of 80 beats per minute may actually represent tachycardia (Mayers & Noakes, 2000; O'Conner et al., 2003). Athletes with diminished mental function should have their rectal temperatures measured to rule out heat stroke. (Measuring temperature in the ear or mouth does not give an accurate measure of core body temperature). A rectal temperature above 104°F (40°C) demands immediate cooling measures.

The athlete's state of hydration can be assessed by asking about thirst and the ability to spit (Holtzhausen & Noakes, 1997; O'Conner et al., 2003). Athletes who are dehydrated will be thirsty, and they will have a difficult time producing spit if they are seriously dehydrated. Also, skin turgor may be diminished in seriously dehydrated athletes, i.e., their skin may seem loose, may feel doughy, and may resemble a miniature tent after being pinched (the "tenting" phenomenon).

Conversely, athletes who are over-hydrated may look and feel puffy. They may state that rings, watches, shoes, and race wristbands fit more tightly than before the race. In severe cases of fluid overload, pitting edema (swelling) in the legs may be noted. This is often associated with low levels of blood sodium (hyponatremia). Measuring body weight before and after competition is a helpful gauge of fluid status. A 2-5% loss of body weight indicates dehydration, whereas weight gain suggests fluid overload.

Laboratory Tests. Important laboratory evaluations in the collapsed athlete include measurements of blood sodium and glucose concentrations. Hyponatremia is the most common serious cause of collapse in the endurance athlete. The ability to quickly measure sodium levels is critical in diagnosing this condition and helping to guide appropriate treatment. Hypoglycemia, while less common, can produce dramatic alterations in the level of consciousness and even coma, which can be promptly corrected by administering oral or intravenous glucose.

Severity Classification for the Collapsed Athlete

The vast majority of athletes who collapse do so for benign reasons (Holtzhausen & Noakes, 1997; Mayers & Noakes, 2000; Sandell et al., 1988). According to Bently (1996) and O'Conner et al. (2003), findings suggestive of a benign cause of collapse include:

1. Athlete is conscious and alert.
2. Rectal temperature is greater than 95°F (35°C) but less than 104°F (40°C).
3. Systolic blood pressure is greater than 100 mmHg, and heart rate is less than100 beats per minute.
4. Blood glucose concentration is 70-180 mg/dl, and plasma sodium concentration is 135-148 mEq/L.
5. Weight loss is less than 5%.

The most common serious causes of collapse in the athlete include hyponatremia, hypoglycemia, heatstroke, cardiac arrest, and various other serious medical conditions, such as seizures, brain hemorrhage, or diabetic coma. Bently (1996)

and O'Connor et al. (2003) list the following findings suggestive of a more serious cause of collapse:

1. Unconscious or diminished mental status (confused, disoriented, or aggressive).
2. Rectal temperature greater than 104°F (40°C) or less than 95°F (35°C).
3. Systolic blood pressure less than 100 mm Hg and heart rate greater than 100 beats per minute.
4. Blood glucose concentration less than 70 mg/dl or greater than 180 mg/dl; serum sodium concentration less than 130 mEq/L or greater than 148 mEq/L.
5. Weight loss or gain greater than 5% of body weight. (Weight loss indicates dehydration, and weight gain suggests fluid overload and risk for hyponatremia.)

Causes of Collapse in the Endurance Athlete

Postural Hypotension (Heat Exhaustion or Syncope). Postural hypotension (low blood pressure while standing) has been referred to as heat exhaustion or heat syncope and is one of the most common causes of collapse. The collapse typically occurs after the finish line and is rarely serious enough to warrant hospital admission. It is likely caused by blood pooling in dilated vessels of the skin and limbs, especially the legs, and loss of the muscle pumping action from the lower legs after cessation of exercise (Holtzhausen & Noakes, 1997; O'Conner et al., 2003; Sandell et al., 1988).

Dehydration and a resultant decrease in circulating blood volume increase the risk for postural hypotension, but there is no evidence that postural hypotension will progress to heat stroke. Postural hypotension is the likely culprit if the rectal temperature is less than 104°F (40°C), the heart rate is less than 100 beats per minute, and the systolic blood pressure is greater than 100 mm Hg once the athlete has assumed the supine position.

Treatment involves elevating the feet and pelvis for 10-20 minutes until normal circulation has been re-established. Athletes should be given oral fluids as tolerated. Oral rehydration solutions or sports drinks that replace electrolytes and replenish carbohydrates are usually better than water. Some athletes may need intravenous fluid if they are unable to tolerate oral fluids or if there are signs of severe dehydration.

Muscle Cramps. Muscle cramps are common in virtually all strenuous sports activities. They can occur during or after repetitive exercise performed in the heat, cold, or in water. Cramps tend to be more common and severe when intense exercise is done in hot and humid environments. In certain individuals, severe and recurrent cramps are associated with sickle-cell trait and suggest a risk for exercise-related sudden death.

Current evidence supports two common etiologies for sports-related muscle cramping, i.e., muscle fatigue caused by overuse, and sodium depletion (Bently, 1996; Miles & Clarkson, 1994). Overuse-induced muscle fatigue usually causes less severe and more localized cramping. Salt loss, on the other hand, often causes more severe total-body cramping.

The initial treatment for sports-related muscle cramps is to keep the affected muscles in a stretched position. The application of ice and/or massage can be helpful in lessening the symptoms of an acute cramp. Cramps due to muscle fatigue tend to occur early in the competitive season when athletes are less physically fit or when they are involved in unusually strenuous activities. Increased salt intake can be very helpful in preventing cramps that are severe, involve the whole body, and recur frequently.

Dehydration. Dehydration can have a variety of deleterious effects on the athlete, all of which may impair performance and increase the likelihood of collapse (American College of Sports Medicine, 1996; Casa et al., 2000). Dehydration leads to a reduced blood volume, making the athlete more susceptible to postural hypotension and collapse. Low blood volume is also associated with a decreased cardiac stroke volume that results in a decreased blood flow to the skin, which in turn adversely affects heat dissipation. Dehydrated athletes have higher rectal temperatures than normally hydrated athletes, and dehydration reduces the time that exercise can be sustained before heat-induced fatigue and eventual collapse. Signs and symptoms of serious dehydration include severe thirst, dry mouth, and difficulty producing spit. Findings on physical exam consistent with dehydration include increased heart rate, decreased blood pressure, weight loss, dry mouth, and poor skin turgor (loose skin with tenting).

Treatment of the dehydrated athlete should begin with oral rehydration solutions or sports drinks if the athlete is not vomiting and has lost less than 5% of body weight. Intravenous fluid should be given if athletes cannot tolerate oral fluids or the level of dehydration is greater than 5%.

Hyponatremia of Exercise. Hyponatremia is the most common serious cause of exercise-associated collapse. It is usually caused by replacement of relatively hypertonic sweat with a hypotonic fluid that contains little or no sodium. It is most often seen in longer endurance races and is more common in females, slower runners, and those drinking water rather than sports drinks containing sodium (Noakes, 1998; Sandell et al., 1988; Speedy et al., 1999). Symptoms of hyponatremia depend on the severity of the sodium deficit. The normal range of sodium concentration in blood serum is between 135 and 145 mEq/L, and the severity of hyponatremia can be graded as mild to severe:

- **Mild** (sodium = 131-134 mEq/L) Generally causes no symptoms.
- **Moderate** (sodium = 126-130 mEq/L) Can result in malaise, nausea, fatigue, confusion and "phantom

running" (persistent and involuntary leg movement at rest).

- **Severe** (sodium <126 mEq/L) Can cause coma, seizures, and even death.

Examination of an athlete with hyponatremia (as determined from a blood draw) generally reveals a rectal temperature of less than 103°F (39°C) along with stable blood pressure and heart rate. There is often a diminished level of consciousness when the hyponatremia is moderate to severe. Hyponatremia due to fluid overload may cause the athlete to look puffy, and rings, watches, shoes, and race wristbands are often tight. These athletes have often gained significant body weight during the competition. However, athletes with hyponatremia can sometimes be dehydrated and have a low blood volume, probably due to only partial replacement of sweat loss with hypotonic fluid. This hypovolemic type of hyponatremia seems to be more common in the faster finishers.

Experience suggests that one should assume hyponatremia if rectal temperature, blood pressure, and heart rate are normal in the collapsed athlete who exhibits a diminished level of consciousness (Holtzhausen & Noakes, 1997, 1998; Mayers & Noakes, 2000). In athletes who appear fluid overloaded, administration of large volumes of intravenous fluid should be avoided because this treatment can lead to congestive heart failure and even death. In athletes who appear dehydrated and are suspected of having a low blood volume, intravenous administration of normal saline can replace both salt and water. In very severe cases, hypertonic saline (3-5%) can be infused at a slow rate (less than 50 ml/h) while closely monitoring the athlete's condition. Most athletes with even severe hyponatremia of exercise recover spontaneously after 1-3 hours of rest and supportive care. The voiding of copious amounts of clear urine often precedes their recovery.

Heatstroke. Heatstroke is caused by failure of the body to regulate its temperature in the heat. It is a rare event and is easily treated when diagnosed early, but it has a very high morbidity and mortality when improperly managed or when the diagnosis is delayed. The hallmark symptom of heat stroke is a marked change in mental function, i.e., a loss or diminished level of consciousness or mental stimulation (Holtzhausen & Noakes, 1997; Noakes, 1998). Athletes with heat stroke often collapse or act inappropriately. Eventually, they lapse into a coma and often develop rhabdomyolysis (breakdown of muscle tissue) and renal failure leading to death.

Athletes suffering heatstroke usually collapse prior to the finish of an event, often shorter races run at faster speeds. Heavier athletes are at greater risk. Because athletes competing in long endurance events run at slower speeds, they usually store less body heat (if the humidity is relatively low) so heat stroke is less common. Predisposing factors include high heat and especially humidity, faster running speed, history of heat illness, greater body weight, and possibly dehydration with blood volume depletion. Vomiting and diarrhea are often symptomatic of the onset of heatstroke.

The hallmark exam finding with heatstroke is a rectal temp above 104°F (40°C). In addition, athletes with heatstroke usually have high heart rates, rapid breathing, and low blood pressure. With classic heatstroke, sweating often stops and the victim appears hot and dry, but in heat stroke associated with athletic activity, the victim is usually sweating profusely.

The treatment for heatstroke is active cooling as soon as possible. The survival rate is 90-95% when cooling is done rapidly. However, if cooling is delayed and the temperature rises above 108°F (42°C), the mortality approaches 80% (Holtzhausen & Noakes, 1997, 1998; Noakes, 1988). Heatstroke is a true emergency and can be thought of as a "heat attack," in which every minute of delay in treatment significantly reduces the chance of a good outcome for the athlete.

The most effective measure to achieve rapid cooling of an overheated athlete is immersion in ice water. This is most easily accomplished using a small plastic tub or pool filled with ice and water. Typically, immersion for 5-10 minutes is long enough to cool an athlete with heatstroke. Cooling should continue until the rectal temperature is below 101°F (38°C) or the athlete begins to shiver.

A less effective cooling alternative is to apply ice packs to neck, groin and underarms of the heatstroke victim. Applying a cold-water mist using spray bottles, combined with fanning, can be a useful adjunct. Additionally, cold intravenous fluids can help cool a heat-stroke victim.

Hypoglycemia. Hypoglycemia is a less frequent cause of exercise-associated collapse and can occur when the liver production of glucose decreases as liver glycogen stores are depleted (Holtzhausen & Noakes, 1997; Sandell et al., 1988). This is most commonly seen in distance events lasting more than four hours. Athletes who fail to eat and drink sufficient carbohydrate before and during an event are at risk. Hypoglycemia is most often seen in diabetic athletes and in those with eating disorders.

Symptoms of hypoglycemia include weakness, nausea, anxiety, sweating, slurred speech, and eventually coma. Treatment is the administration of glucose (sports drinks, juice, hard candy, or glucose tablets), which gives immediate relief of symptoms. Hypoglycemic athletes who are unconscious or unresponsive should be given an intravenous glucose solution (D50) or a glucagon injection to immediately raise blood sugar levels.

Hypothermia. Hypothermia is an unusual cause of collapse but can occur when an athlete remains too long in a cold environment and does not generate enough body heat to compensate for heat loss to the environment. Most cases are seen when the swim portion of a triathlon is done in cold water, when endurance events are held during cold and wet weather, or in cold-weather sports such as cross-country skiing.

The severity of hypothermia is gauged by rectal temperature. Mild hypothermia is defined as a rectal temperature between 90-95°F (32-35°C) and is often accompanied by mild confusion and intense shivering. Treatment should include protecting the athlete from the environment and removing wet clothing, followed by passive warming with blankets and drinking of hot liquids. When the rectal temperature drops below 90° F, shivering (which generates body heat) usually stops; if this happens, the athlete must be immediately transferred to a hospital for more active warming measures such as administration of warm intravenous fluids, warm oxygen, or peritoneal dialysis using warm fluids. Severely hypothermic athletes, i.e., rectal temperature less than 82°F, may appear dead, only to survive after re-warming.

SUMMARY

Exercise-associated collapse is a relatively common occurrence in endurance athletes, especially those competing in high heat and humidity. The cause is most often benign in athletes who collapse after finishing exercise with no loss of consciousness, with normal vital signs, and with normal mental status. A more serious cause should be suspected in athletes who collapse while exercising, have unstable vital signs, or an altered level of consciousness. Appropriate and early diagnosis is essential in athletes who collapse so that proper treatment can be initiated. Most cases can be managed with rest and oral fluids. On the other hand, more serious causes of collapse, e.g., when associated with hyponatremia and heatstroke, can lead to serious organ damage and even death if not treated quickly and appropriately. It is essential that those providing medical care at endurance events or caring for these athletes be familiar with the appropriate management of the collapsed athlete to prevent a possible tragic outcome.

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Information herein is intended for professional audiences, including scientists, coaches, medical professionals, athletic trainers, nutritionists, and other sports health professionals who have a fundamental understanding of human physiology.

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ENDURANCE ATHLETES WHO COLLAPSE

It is relatively common to witness the collapse of athletes in endurance events, especially when the heat and humidity are high. If an athlete collapses after finishing an event and remains conscious with normal heart rate, blood pressure, breathing, and mental status, the condition is usually not serious and is probably brought on by exhaustion, moderate dehydration that contributes to a moderate fall in blood pressure while the athlete is standing, or muscle cramps.

A more dangerous cause should be suspected in athletes who collapse during competition or training, have unstable vital signs, and/or become unconscious or exhibit inappropriate behaviors (Table S1).

Non-Serious Causes	Serious Causes
■ Exhaustion ■ Dehydration ■ Low blood pressure while standing ■ Muscle cramps	■ Low blood sodium (hyponatremia) ■ Heatstroke ■ Low blood sugar (hypoglycemia) ■ Low body temperature (hypothermia) ■ Cardiac arrest ■ Various other medical conditions, including seizures, brain hemorrhage, and diabetic coma

TABLE S1. Common causes of collapse during exercise.

Appropriate and early diagnosis is essential in athletes who collapse so that proper treatment can be initiated. Table S2 illustrates the common features of non-serious or benign collapse and potentially dangerous collapse. It is especially important that medical personnel be able to obtain quick laboratory reports on concentrations of blood glucose and serum sodium. Depending on the serum sodium concentrations, severe outcomes can result (Table S3).

Benign Collapse	Severe Collapse
Appearance: Conscious and alert	*Appearance:* Unconscious or altered mental status
Physical examination results: Rectal temperature <104° F (40° C) Systolic blood pressure >100 Heart rate <100 beats per minute Weight loss 0-5%	*Physical examination results:* Rectal temperature >104° F (40° C) Systolic blood pressure <100 Heart rate >100 beats per minute Weight gain or loss >5%
Laboratory test results: Blood glucose = 70-180 mg/dl Serum sodium = 135-145 mEq/L	*Laboratory test results:* Blood glucose = <70 or >180 mg/dl Serum sodium <130 or >148 mEq/L

TABLE S2. Severity classification for the collapsed athlete.

Symptoms of Hyponatremia	
Mild (Na 131-135 mEq/L):	Usually no symptoms
Moderate (Na 126-130 mEq/L):	Malaise, nausea, fatigue, confusion, “phantom running”
Severe (Na <126 mEq/L):	Seizures, coma, death

TABLE S3. Symptoms of hyponatremia.

Most cases of collapse can be managed with rest, elevation of the legs and pelvis, and administration of oral fluids, especially oral rehydration solutions or sports drinks that contain carbohydrate and sodium. On the other hand, more serious causes of collapse, e.g., when associated with hyponatremia and heatstroke, can lead to serious organ damage and even death if not treated quickly and appropriately.

COMMON CAUSES OF COLLAPSE AND THEIR APPROPRIATE TREATMENT

Postural Hypotension (Heat Exhaustion or Syncope) - blood pools in the skin and legs after stopping exercise because of the loss of the muscle pump action in the legs. This in turn steals blood from the central circulation and brain, causing the athlete to feel light-headed or even to faint. Dehydration can amplify these symptoms by decreasing blood volume. The treatment is simply elevating the feet and pelvis for 10-20 minutes until symptoms are normalized.

Hyponatremia - should be suspected if rectal temperature, blood pressure, and heart rate are normal in the collapsed athlete who exhibits a diminished level of consciousness. In athletes who appear fluid overloaded, administration of large volumes of intravenous fluid should be avoided because this treatment can lead to congestive heart failure and even death. In athletes who appear dehydrated and are suspected of having a low blood volume, intravenous administration of normal saline can replace both salt and water. In very severe cases, hypertonic saline (3-5%) can be infused at a slow rate (less than 50 ml/h) while closely monitoring the athlete's condition.

Heatstroke - should be assumed if the athlete has a rectal temp above104°F (40°C). In addition, athletes with heatstroke usually have high heart rates, fast breathing, and low blood pressure. In heat stroke associated with athletic activity, the victim is usually sweating profusely.

The treatment for heatstroke is active cooling by immersion in a tub of ice water as soon as possible. Immersion should last for 5-10 minutes until the rectal temperature is below 101°F (38°C) or the athlete begins to shiver. If cooling is delayed and the temperature rises above108°F (42°C), the mortality approaches 80%. Heatstroke is a true emergency and can be thought of as a "heat attack," in which every minute of delay in treatment significantly reduces the chance of a good outcome for the athlete.

Hypoglycemia - symptoms include body tremors, weakness, anxiety, sweating, nausea, slurred speech, and eventually coma. Treatment is the administration of glucose (sports drinks, juice, hard candy, or glucose tablets), which gives immediate relief of symptoms. Athletes who are unconscious or unresponsive should be given an intravenous glucose solution (D50) or a glucagon injection to immediately raise blood sugar levels.

Hypothermia - is considered mild if the athlete's rectal temperature is 90-95°F (32-35°C). The hypothermic athlete often exhibits mild confusion and intense shivering. Treatment should include protecting the athlete from the environment and removing wet clothing, followed by passive warming with blankets and drinking of hot liquids. When the rectal temperature drops below 90°F, shivering (which generates body heat) usually stops; if this happens, the athlete must be immediately transferred to a hospital for more active warming measures.

CONCLUSION

It is essential that those providing medical care at endurance events or caring for these athletes be familiar with the appropriate management of the collapsed athlete to prevent a possible tragic outcome.

SUGGESTED ADDITIONAL RESOURCES

Holtzhause, L.M., and T.D. Noakes (1998). Planning emergency care for an ultra-endurance event. *Trauma Emergency Med.* June/July: 19-26.

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