Exertional heat illness in adolescents and adults: Management and prevention

Authors: Francis G O'Connor, MD, MPH, FACSM, FAMSSM, Douglas J Casa, PhD, ATC, FNAK, FACSM, FNATA
Section Editors: Daniel F Danzl, MD, Karl B Fields, MD
Deputy Editor: Jonathan Grayzel, MD, FAAEM

All topics are updated as new evidence becomes available and our peer review process is complete.

Literature review current through: Mar 2023. | **This topic last updated:** Jan 25, 2023.

INTRODUCTION

Exertional heat illness (EHI) is among the leading causes of death in young athletes each year [1-3]. A report by the United States Centers for Disease Control (CDC) found that EHI occurs both during practice and competition and noted a disturbing trend of increasing incidence [4]; in addition, despite prevention efforts exertional heat stroke in the military continues to climb [5]. Clinicians who care for athletes, both young and old, and for others who exert themselves in the heat (eg, firefighters, soldiers, construction workers) need to be aware of the basic physiologic principles of thermoregulation, the spectrum of heat illness, strategies for prevention and treatment, and current guidelines for determining safe return to play or work.

The management and prevention of exertional heat illness are reviewed here. Assessment of the collapsed athlete, thermoregulation, and the clinical presentation and diagnosis of exertional heat illness are discussed separately, as are exercise-associated hyponatremia, nonexertional heat stroke, malignant hyperthermia, and heat illness in children:

- Collapsed athlete and related conditions (see "Evaluation of the collapsed adult athlete" and "Exercise-associated hyponatremia")
- Exertional heat illness (see "Exertional heat illness in adolescents and adults:

Epidemiology, thermoregulation, risk factors, and diagnosis" and "Heat illness (other than heat stroke) in children")

- Non-exertional heat illness (see "Severe nonexertional hyperthermia (classic heat stroke) in adults" and "Malignant hyperthermia: Diagnosis and management of acute crisis" and "Neuroleptic malignant syndrome" and "Heat stroke in children" and "Heat illness (other than heat stroke) in children")

GUIDING PRINCIPLES

Two critical observations inform the management of exertional heat stroke (EHS) and all types of severe heat illness [6-8]:

- The severity of a heat illness may not be apparent during the initial presentation.
- Morbidity and mortality are directly related to the duration of core temperature elevation.

Accordingly, effective management of any severe heat illness requires careful evaluation at the field and hospital, and treatment of EHS with rapid cooling is paramount. It may help to think of EHS as a "heat attack" [8,9].

Clinicians caring for patients with severe heat illness must remain vigilant for late developing complications, possibly including rhabdomyolysis, acute kidney injury, disseminated intravascular coagulation, and acute liver failure. For patients with high rectal temperatures (≥105°F, 40.5°C) and concerning symptoms but no clear signs of end-organ damage, clinical suspicion needs to remain high. In most such cases, it is prudent to observe or admit the patient and reevaluate with serial clinical examinations and laboratory studies. (See 'Complications' below and 'Disposition and admission criteria' below.)

MANAGEMENT OF EXERTIONAL HEAT STROKE

Prehospital assessment and initial interventions — Resuscitation of the athlete with possible severe heat illness begins by evaluating and stabilizing as necessary the patient’s airway, breathing, and circulation, in accordance with standard life support protocols (see "Basic airway management in adults" and "Adult basic life support (BLS) for health care providers"). The consensus statements in the reference that follows outline important elements in prehospital care [10,11].

Vital signs, including a rectal temperature, should be obtained quickly and appropriate treatment initiated rapidly. Blood (ie, fingerstick) glucose and serum sodium concentration should be measured depending on the patient presentation. Treatment tents at major endurance events often have the capacity to measure a serum sodium concentration to rule out exercise-associated hyponatremia, but emergency medical services (EMS) units typically do not. Elevated temperature (≥105°F, 40.5°C) in the setting of altered mental status is consistent with a diagnosis of exertional heat stroke and is treated with rapid cooling. (See "Exertional heat illness in adolescents and adults: Epidemiology, thermoregulation, risk factors, and diagnosis", section on 'Exertional heat stroke'.)

If appropriate medical staff is available on-site (eg, team physician, athletic trainer), materials needed for aggressive cooling are readily available (ie, cold water immersion, ice/wet towel rotation, high flow cold water dousing), and no other emergency medical treatment is needed other than rapid lowering of the body temperature, it is usually best to follow the "cool-first, transport second" guideline. Once cooling to a reasonable temperature (eg, approximately 39°C or 102.2°F) is achieved, the patient is rapidly transported to the closest emergency department [12].

If the conditions for on-site cooling are not met, particularly if the patient has additional problems (eg, seizure) requiring medical intervention, the patient should be transferred immediately to the closest emergency department. Cooling can be initiated during transport in the most effective manner possible.

Rapid cooling — Rapid cooling is the most effective strategy for minimizing morbidity and mortality from exertional heat stroke (EHS) and should be initiated as soon as possible, and within 30 minutes of presentation [13-19].

Key steps in cooling the athlete at the field include:

- Activate emergency medical system immediately; if appropriate medical staff is on-site and no medical emergencies other than EHS are present, cool first and transport second whenever possible.
- Remove all equipment and excess clothing. Cooling should not be delayed in order to remove all clothing; this can be done simultaneously with cooling efforts [20].
- If ice water immersion is to be performed, immerse the athlete in a tub of cold water (the colder the better); water temperature should be between 35 to 60°F (2 to 15°C); ice water is ideal, but even tepid water is helpful; maintain an appropriately cool water

temperature; stir the water vigorously during cooling.

- If ice water immersion is not feasible or possible, rapidly initiate an alternative method of cooling. These are described immediately below.
- Monitor vital signs (rectal temperature, heart rate, respiratory rate, blood pressure) and mental status continually. Maintain patient safety at all times.
- Cease cooling when rectal temperature reaches approximately 102.2°F (38.3 to 39°C).

A detailed guide to field-side cooling is provided in the accompanying table (table 1). Note that cooling rates are slower initially, but increase the longer the patient is treated.

If immersion is not possible in the field (equipment is unavailable), alternative cooling methods should be used. Such measures include putting the athlete in a cold shower, dousing them with cold water from a hose, or moving them to a cool shaded area and applying cold, wet towels to as much of the body surface as possible. For the last method, towels should be replaced as soon as they are no longer cool or every two to three minutes otherwise. If ice is available but no tub, the patient can be placed in a tarp or sheet, covered with a large amount of ice, and then the tarp or sheet can be wrapped around them. Ice should be replenished as soon as a moderate degree of melting occurs.

Cooling should not be delayed in order to remove all clothing, uniforms, or equipment. The cooling process should be initiated as quickly as possible; clothing and equipment can be removed while cooling is initiated, or when practical [20,21].

Few controlled studies are available to determine the best method for achieving rapid cooling of patients with EHS and other forms of severe EHI. Based upon largely low quality evidence, several systematic reviews have concluded that ice water immersion is the most effective method available [22-25]. When appropriate conditions are met, the authors strongly prefer this approach; however, in some circumstances, treatment with ice water immersion is not feasible, particularly if the patient has complications requiring aggressive medical intervention (eg, compromised airway, seizure). If clinicians are actively managing or anticipate the need to manage such complications, alternative methods of cooling should be used that allow for necessary interventions (eg, tracheal intubation, administration of medication or IV fluid) and close patient monitoring. In the emergency department, one reasonable approach is to undress the patient and apply ice packs to the neck, axillae, and inguinal regions (areas adjacent to large blood vessels), while simultaneously spraying tepid water over the patient's body and using fans to blow air over the moist skin (ie, evaporative cooling). Water should be continually reapplied as needed and fanning performed continuously.

There is little evidence to guide the use of chilled intravenous fluids or gastric, peritoneal, or bladder cooling with cold lavage fluids; cooling blankets have not been found to be effective [26,27].

One area of active research is the use of intravenous cooling as either a primary or adjunctive therapy to facilitate a rapid reduction in core temperature. While this strategy is employed in the acute management of cardiac arrest and other conditions, there are no published clinical trials concerning this intervention in the setting of exertional heat stroke nor are published practice guidelines available. Case reports show the potential utility of endovascular cooling in extreme situations, but clinical criteria have yet to be defined [28]. Intravenous cooling may be useful in scenarios such as ambulance transport or when a cooling tub is unavailable but further research is needed [29].

Temperature measurement and monitoring — Do **not** use alternative methods to determine body temperature (eg, oral, aural canal, tympanic, axillary, temporal, skin, forehead sticker) [30-33], even if a rectal thermometer is not available. Alternative methods do **not** provide accurate measurements of core temperature in athletes who have been exercising intensely in the heat and can be misleading. If a rectal temperature is not available when treating EHS, we suggest one of two options:

- Cool until the patient begins to shiver.

  or

- Treat with cold water immersion for 15 to 20 minutes. This would cool most patients 3 to 4°C (5 to 7°F), which would make removal from an ice tub prudent in most cases.

  The latter approach assumes a typical cooling rate with cold water immersion of about 0.21°C per minute (0.37°F per minute), and that nearly all patients are between 41 and 43.5°C at the time of the incident (106 and 110°F). In such cases, the patient would cool 1°C every five minutes or 1°F every three minutes. This approach does **not** account for patients who are exceptionally hot at the start of treatment or those who cool slower than average. Continuous monitoring with a rectal thermistor (flexible thermometer) remains the best approach.

Clinical assessment at the hospital — Assessment of the patient with exertional heat stroke (EHS) begins with careful evaluation of the patient's airway, breathing, and circulation

(ABC's). A protected airway, adequate oxygenation and ventilation, and adequate circulation must be ensured. Regular reassessment of the ABC's is important. (See "The decision to intubate" and "Overview of advanced airway management in adults for emergency medicine and critical care" and "Severe nonexertional hyperthermia (classic heat stroke) in adults", section on 'Management'.)

If rapid cooling was initiated in the field but the temperature has not yet been sufficiently lowered (goal temperature is 101 to 102°F, or 38.3 to 38.9°C), cooling measures are continued in the hospital. Rapid cooling is initiated as quickly as possible for patients diagnosed with EHS who could not be treated in the field. (See 'Rapid cooling' above.)

The most effective method for cooling patients with EHS is cold water immersion, regardless of the patient's location. However, many facilities are not equipped to implement this strategy, and in some cases this approach is not feasible. Effective alternative cooling methods are described above. (See 'Rapid cooling' above.)

Frequent vital sign measurements combined with pulse oximetry, cardiac and other monitoring provide immediate insight into respiratory and hemodynamic status. A bladder (eg, Foley) catheter allows for monitoring of fluid status and renal function. In some cases, in particular when urine output may not be reliable, central venous pressure monitoring may be needed to guide fluid resuscitation.

Continuous temperature measurement is invaluable during the initial resuscitation of the patient with EHS. If available, a rectal thermistor (flexible thermometer) that provides continuous temperature readings is preferred to episodic measurements performed with a standard rectal thermometer. If a rectal thermistor is not available during cold water immersion, or evaporative cooling, a rectal temperature should be measured approximately every 10 minutes using a rectal thermometer.

The secondary survey must include a careful assessment of mental status, evaluation of muscle compartments for evidence of acute compartment syndrome, and examination of all orifices for possible bleeding. Patients with severe EHS typically demonstrate muscle flaccidity; rigidity should prompt consideration for malignant hyperthermia or neuroleptic malignant syndrome [34,35]. (See "Malignant hyperthermia: Diagnosis and management of acute crisis" and "Acute compartment syndrome of the extremities".)

The clinician should inquire about the nature of the precipitating event, interventions at the scene, medical history (eg, sickle cell trait, recent infection, malignant hyperthermia, cardiovascular disease), medications, supplements, and drugs of abuse.

There is evidence that many of the complications of EHS (eg rhabdomyolysis, acute kidney injury, disseminated intravascular coagulation) result from the systemic inflammatory response syndrome (SIRS) [6,36]. Accordingly, SIRS criteria should be followed during the course of the hospitalization. (See "Sepsis syndromes in adults: Epidemiology, definitions, clinical presentation, diagnosis, and prognosis", section on 'Definitions'.)

Laboratory testing and diagnostic imaging — Targeted laboratory and radiographic studies are important for identifying early and late complications of severe EHI [37]. Initial laboratory studies to be performed include:

- Complete blood count (hemoglobin, platelet and white blood cell counts)
- Basic serum electrolytes (Na, K, Cl, HCO_3), including calcium
- Renal function studies (BUN, creatinine)
- Urinalysis
- Creatine kinase (CK)
- Liver function tests (AST, ALT)
- Coagulation studies (PT, INR, aPTT)

Additional studies are obtained based upon the clinical presentation and potential complications, and may include: urine myoglobin, electrocardiogram, cardiac biomarkers, arterial and/or venous blood gas, serum lactate, toxicology screening tests, chest radiograph, CT of the head. (See 'Complications' below.)

Supportive therapy — Aggressive and appropriate supportive care, particularly rapid cooling, is critical for reducing the risk of severe morbidity and mortality associated with EHS [24,38]. Important interventions early during hospitalization include:

- Treatment of hyperthermia with rapid cooling (see 'Rapid cooling' above)

- Fluid resuscitation, as determined by the patient's volume status, urine output, and cardiopulmonary function

- Correction of electrolyte abnormalities

- Diagnosis and treatment of complications (eg, central nervous system dysfunction, rhabdomyolysis, acute kidney injury, acute liver failure, disseminated intravascular coagulation)

Patients with classic (ie, nonexertional) heat stroke can manifest significant cardiac dysfunction. The combination of a hyperdynamic heart and peripheral vasodilation can lead to high output cardiac failure [39,40]. Although generally less common among patients with EHS, clinicians should be aware of this complication and the potential need for aggressive fluid resuscitation with isotonic crystalloid, despite possible signs of pulmonary edema. Use of a therapeutic hypothermia treatment protocol can be helpful, particularly for patients with severe complications [41].

EHS management in patients who develop complications can be complex and we suggest early consultation with appropriate specialists as needed, including critical care and possibly nephrology, neurology, and gastroenterology. Potential complications and links to topics describing the management of these entities are provided. (See 'Complications' below.)

Pharmacologic therapy — There is no specific pharmacologic treatment for EHS. In addition, there is no role for antipyretic therapy, as the pathogenesis of EHS does not involve a change in the hypothalamic set-point, as is seen in patients with fever. Moreover, drugs used to reduce fever, such as acetaminophen and nonsteroidal anti-inflammatory medications (eg, ibuprofen), can exacerbate complications of EHS, such as acute kidney injury, hepatic failure, and disseminated intravascular coagulation. Pharmacologic interventions may be needed to treat complications of EHS.

There is interest among some researchers in a potential relationship between malignant hyperthermia (MH) and exertional heat stroke, and dantrolene, a standard treatment for MH, is being studied as a potential adjunctive therapy for exertional heat stroke [42,43]. However, pending further study, there is no role for routine treatment of exertional heat stroke with dantrolene. Treatment of severe exertional heat illness with immune modulators is also a subject of on-going research [6].

Complications — EHS can lead to a number of complications during resuscitation and subsequent hospitalization [16,44]. These complications can result directly from heat-related injury or from associated conditions, such as fluid and electrolyte abnormalities and a protracted systemic inflammatory response [45].

Important complications to look for in patients with EHS include the conditions listed below. Information about the diagnosis and management of these conditions is found in the accompanying UpToDate topics.

- Electrolyte and other metabolic abnormalities (eg, hypo- and hyperkalemia, hypo- and hypernatremia, hypoglycemia, hypophosphatemia, hypomagnesemia, and hypocalcemia). (See "Clinical manifestations and treatment of hypokalemia in adults" and "Treatment and prevention of hyperkalemia in adults" and "Overview of the treatment of hyponatremia in adults" and "Exercise-associated hyponatremia" and "Hypophosphatemia: Evaluation and treatment" and "Clinical manifestations of hypocalcemia" and "Treatment of hypocalcemia" and "Hypomagnesemia: Evaluation and treatment".)

- Seizure (may be secondary to electrolyte abnormalities that require correction, hypoglycemia, brain trauma, inadequate cerebral perfusion pressure, or other causes). While investigating the underlying cause, clinicians provide initial treatment with benzodiazepines (eg, lorazepam 4 mg IV or diazepam 5 mg IV). (See "Evaluation and management of the first seizure in adults", section on 'Causes of seizures' and "Exercise-associated hyponatremia" and "Convulsive status epilepticus in adults: Management", section on 'First therapy: Benzodiazepines'.)

- Agitated delirium (most often is transient from the effects of hyperthermia but may be secondary to hypoglycemia, inadequate cerebral perfusion pressure, brain injury, or other causes). Short-acting benzodiazepines can be used for treatment (eg, midazolam 2.5 to 5 mg IV or IM).

- Respiratory failure; acute respiratory distress syndrome. (See "Basic airway management in adults" and "Overview of advanced airway management in adults for emergency medicine and critical care" and "Acute respiratory distress syndrome: Clinical features, diagnosis, and complications in adults" and "Acute respiratory distress syndrome: Fluid management, pharmacotherapy, and supportive care in adults".)

- Rhabdomyolysis. (See "Rhabdomyolysis: Clinical manifestations and diagnosis" and "Prevention and treatment of heme pigment-induced acute kidney injury (including rhabdomyolysis)".)

- Acute kidney injury (usually associated with rhabdomyolysis; see above; nephrology consultation for renal replacement therapy (eg, hemodialysis) should be obtained as soon as a potential need arises).

- Hepatic injury. (See "Acute liver failure in adults: Management and prognosis".)

- Disseminated intravascular coagulation. (See "Evaluation and management of disseminated intravascular coagulation (DIC) in adults".)

- Gastrointestinal bleeding and ischemic bowel injury (possibly sustained during a period of myocardial depression). (See "Approach to acute upper gastrointestinal bleeding in adults" and "Approach to acute lower gastrointestinal bleeding in adults".)

- Myocardial injury (generally resolves with rapid cooling, fluid resuscitation, and correction of electrolyte abnormalities; cardiology consultation is prudent for patients with persistent hypotension or arrhythmias). Electrical cardioversion and antiarrhythmic medications are generally ineffective in severe hyperthermia, until the patient is sufficiently cooled.

The risk of multiorgan failure and mortality from EHS depends upon how fast it is diagnosed and rapid cooling implemented [16,44]. With rapid treatment, cardiovascular injury from EHS usually resolves within hours [46-49]. Biomarkers of hepatic injury (eg, elevated transaminase concentrations) may remain elevated for 24 to 48 hours before returning to a normal range, which may require weeks to months depending upon the severity of the episode [50,51]. Renal injury may require weeks to resolve [6]. Biomarkers of muscle injury associated with rhabdomyolysis (creatine kinase, myoglobin) may increase for 24 to 96 hours before starting to decline; a return to normal concentrations may require weeks depending upon the severity of the injury [52]. Although cognitive function improves quickly in most survivors of EHS who are rapidly cooled, some evidence suggests that severe episodes can cause permanent neurologic sequelae [53,54]. In the absence of early and effective intervention in EHS, multiorgan failure can result in permanent residual injury, require organ transplantation, or result in death [1,6,50,54-56].

Disposition and admission criteria — Nearly all patients who develop EHS, including all of those at risk or with signs of complications, are hospitalized for a period of observation and monitoring for complications. Indications for admission include the following:

- Difficulty correcting hypotension
- Seizure
- Severe encephalopathy
- Moderate encephalopathy (eg, confusion) that is not clearing rapidly
- Persistent oliguria
- Persistent myalgia suggesting evolving rhabdomyolysis
- Persistent electrolyte abnormalities
- Persistent creatinine above 2 mg/dL (180 µmol/L)
- Evidence of acute kidney injury or myoglobinuria

- Evidence of disseminated intravascular coagulation
- Exertional hypoglycemia
- Persistent substantial diarrhea
- Significant gastrointestinal bleeding

In general, patients should be admitted to a monitored setting if they manifest persistent vital sign abnormalities or alterations in mental status despite appropriate treatment, or appear to be at increased risk for severe complications (eg, rhabdomyolysis, disseminated intravascular coagulation), as determined by clinical signs or laboratory studies. Patients with signs of multiorgan dysfunction are admitted to an intensive care setting.

Although it is best to err on the side of caution and hospitalize patients with EHS, some patients may be amenable to discharge after a period of close observation. Common practice at many major endurance events with appropriate on-site medical coverage that includes experienced physicians has been to observe and monitor carefully a minority of athletes who are healthy at baseline (ie, no comorbidities), recover rapidly and completely from EHS with cooling, and have no subsequent symptoms or signs of complications. Such individuals can generally be discharged after an appropriate period of observation with arrangements for proper follow-up. There are no studies on which to base a recommendation, but a six-hour period of observation seems reasonable. A thorough reexamination of the patient should be performed prior to discharge. The patient should be admitted if this reexamination reveals any concerning findings or if the patient develops recurrent or new symptoms during the observation period. A responsible adult should remain with the patient for approximately the first 24 hours following discharge in case complications arise and the patient needs medical attention.

MANAGEMENT OF OTHER TYPES OF EXERTIONAL HEAT ILLNESS

"Heat cramps" — So-called "heat cramps" (which do not appear to be caused by increased ambient temperatures) are muscle cramps that occur during exercise. Current terminology more correctly refers to heat cramps as exercise-associated muscle cramps (EAMC). The etiology and diagnosis of heat cramps are discussed separately. (See "Exertional heat illness in adolescents and adults: Epidemiology, thermoregulation, risk factors, and diagnosis", section on '"Heat cramps" (exercise associated muscle cramps)'.)

Treatment — We suggest the following treatment measures for suspected heat, or exercise-associated, muscle cramps:

- Hydrate the athlete and replace sodium losses with a sports drink or other source of salt.

  Oral hydration should be encouraged. This approach helps instruct the athlete about their role in preventing heat illness and prevents them from relying upon intravenous (IV) hydration. IV hydration with isotonic saline is faster and can provide large volumes of fluid that are easily tolerated in most patients. However, oral rehydration has consistently been shown to be as effective as IV rehydration when equal amounts of fluids are given.

- Relax, stretch, and massage the involved muscle to reduce acute discomfort.

Neuroinhibition techniques to relax the muscle and prolonged stretching (30 to 60 seconds at a time) may also help to relieve symptoms. While some clinicians use intravenous diazepam and magnesium sulfate to treat exertional muscle cramping, there is no evidence to support these interventions [57-59].

Persistent or systemic cramping should prompt an assessment of the serum sodium to evaluate for exertional hyponatremia and raise the possibility of sickle cell crisis due to exertion.

Research suggests that the transient receptor potential (TRP) channel plays a role in the modulation of EAMC, and that ingestion of TRP agonists is associated with attenuated EAMC characteristics [60]. Further research is needed to determine whether TRP agonists are effective therapy.

Prevention — Although evidence is limited mainly to expert opinion, muscle cramps are thought to be prevented best through adequate conditioning, acclimatization, hydration, electrolyte replacement, and appropriate dietary practices [58,61]. Athletic trainers and possibly others who work closely with athletes may have insight into which individuals are relatively heavy “salt losers” based on such findings as white streaks on clothing used for exercise and expressions of salt cravings.

Additional sodium may be needed prior to activity to prevent cramps, particularly in those with a history of heat cramps. Extra sodium can be easily administered by diluting about one-half teaspoon of table salt (approximately 1200 mg sodium) in a typical sports drink. Commercial sports drinks generally contain between 25 and 200 mg of sodium per 8 ounces

(240 mL).

Heat syncope and exercise associated collapse — Heat syncope is a transient loss or near-loss of consciousness due to the indirect effects of high ambient temperature that generally occurs during the first few days that someone is exposed to high environmental temperatures, before acclimatization is complete.

Exercise associated collapse (EAC) occurs when an athlete is unable to stand or walk as a result of lightheadedness or syncope [62]. EAC usually occurs immediately after completing a race or workout and is commonly observed at endurance events (eg, marathon). The clinical presentation and diagnosis of heat syncope and exercise associated collapse are discussed separately. (See "Exertional heat illness in adolescents and adults: Epidemiology, thermoregulation, risk factors, and diagnosis", section on 'Heat syncope and exercise associated collapse'.)

Particularly in older athletes and those with preexisting cardiac disease, heat-related syncope of either type must be distinguished from other causes. (See "Approach to the adult patient with syncope in the emergency department" and "Syncope in adults: Clinical manifestations and initial diagnostic evaluation".)

For heat syncope and EAC, we suggest the following treatment:

- Move the person to a shaded area
- Have the person lay supine
- Elevate the person's feet above the level of their head (ie, raise their legs)
- Give fluids to drink
- The person should avoid sudden or prolonged standing until fully recovered

An athlete should recover within 15 to 20 minutes with these maneuvers; failure to improve should prompt further evaluation, including a rectal temperature. Patients at higher risk for dangerous causes or adverse outcomes and those who do not completely recover within 20 minutes should be evaluated in the emergency department using the approach for any patient with syncope.

Heat exhaustion — Heat exhaustion is characterized by the inability to maintain adequate cardiac output due to strenuous physical exercise and environmental heat stress. Most often this manifests as physical collapse during exercise. Body temperature elevation is milder than with EHS or heat injury and the central nervous system is not affected. The clinical presentation and diagnosis of heat exhaustion is discussed separately. (See "Exertional heat illness in adolescents and adults: Epidemiology, thermoregulation, risk factors, and diagnosis", section on 'Heat exhaustion'.)

We suggest the following treatment for heat exhaustion:

- Remove any athlete from play and move them to a shaded or air-conditioned area.
- Place the patient supine with their feet elevated above the level of their head (ie, raise their legs).
- Remove excess clothing and equipment.
- Cool the patient until their rectal temperature is approximately 101ºF (38.3ºC).
- The mode of cooling is less important for heat exhaustion than heat stroke since the cooling is primarily for comfort rather than life-saving. Any technique used to treat heat stroke may be used, including immersing the athlete in a tub of cool water, running cool water over them using a shower or hose, or using evaporative cooling measures. The time needed to reach the goal temperature will be much shorter than with heat stroke. (See 'Rapid cooling' above.)
- Rehydrate the patient with chilled water or a sports drink if they are not nauseated, vomiting, or manifesting a depressed mental status; give IV fluid if the athlete is unable to drink (one reasonable approach is to give a rapid IV bolus of one liter isotonic saline followed by an infusion at a maintenance or 1.5 times maintenance rate, and titrated to response).
- Continuously observe and frequently monitor heart rate, blood pressure, respiratory rate, rectal temperature, and mental status.
- Transport the patient to an emergency department if rapid improvement does not occur despite appropriate treatment.

Athletes who recover completely with the treatments described here within one or two hours of presentation and have no other symptom or sign of illness may be discharged with a responsible adult. Patients who fail to improve within a few hours despite these measures may be developing late complications consistent with possible heat injury, such as rhabdomyolysis, acute kidney injury, disseminated intravascular coagulation, or acute liver failure and should be admitted for observation and diagnostic testing [35]. (See 'Complications' above and 'Laboratory testing and diagnostic imaging' above and

'Disposition and admission criteria' above.)

Heat injury — Exertional heat injury is defined as a progressive multisystem disorder with hyperthermia following vigorous activity that is associated with end-organ damage (eg, kidney, liver, muscle) in the absence of significant neurologic injury. Unlike EHS, core body temperature does not have to exceed 104 to 105°F (40 to 40.5°C), and unlike heat exhaustion, there is clear evidence of end-organ injury. The diagnosis and clinical presentation of heat injury are discussed separately. (See "Exertional heat illness in adolescents and adults: Epidemiology, thermoregulation, risk factors, and diagnosis", section on 'Heat injury'.)

If there is **any** suspicion of exertional heat stroke (EHS), in other words, any suggestion of neurologic abnormality (eg, abnormal behavior or mood), clinicians should assume that EHS is present and appropriate steps, including rapid cooling, should be initiated as soon as possible. (See 'Management of exertional heat stroke' above.)

For patients suspected to have heat injury, we recommend immediate rapid cooling using any of the methods used for EHS. Additional resuscitative measures are provided as necessary; initial care is largely supportive. Although the rate of cooling is less critical in the absence of neurologic dysfunction, patients with heat injury should still be cooled quickly and monitored closely. Treatment for EHS is described in detail separately (table 1). (See 'Management of exertional heat stroke' above.)

The clinical distinction between heat injury and EHS is made based upon a careful assessment of central nervous system dysfunction (eg, seizure, altered mental status, abnormal behavior). In practice, this distinction is often made after the initial treatment of the patient and is based on a careful review of the event with the patient, witnesses, and other treating clinicians.

Subsequent treatment of heat injury following cooling requires careful risk stratification based upon the clinical presentation and the results of diagnostic studies. All patients with signs of heat injury are closely followed to insure the resolution of any end-organ damage prior to returning to play or vigorous activity [7]. In addition to vital signs and urine output, monitoring should include the following studies: liver function tests (serum aminotransferases (AST, ALT), prothrombin time), urinalysis including urine myoglobin, BUN and creatinine, and creatine kinase. The indications for hospital admission are identical to those for EHS. (See 'Disposition and admission criteria' above.)

The specific management plan is determined individually on the basis of the patient's presentation. As examples, patients with diffuse myalgias and an elevated creatine kinase at risk for developing rhabdomyolysis or patients with signs and abnormal laboratory values suggestive of acute kidney or liver injury should be admitted and managed appropriately. (See "Rhabdomyolysis: Clinical manifestations and diagnosis" and "Prevention and treatment of heme pigment-induced acute kidney injury (including rhabdomyolysis)" and "Overview of the management of acute kidney injury (AKI) in adults" and "Acute liver failure in adults: Management and prognosis".)

Organ damage does not always manifest with laboratory abnormalities early in the course of illness and clinicians should monitor patients with possible heat injury closely. For patients without severe symptoms or signs and no grossly abnormal initial laboratory results, a reasonable approach is to reexamine the patient and recheck the relevant studies on an outpatient basis every 24 to 48 hours to assess organ function. Once symptoms and signs have resolved and two successive sets of normal laboratory values have been obtained, surveillance may be discontinued, and the patient may gradually return to normal activity. (See 'Determining return to play' below.)

DETERMINING RETURN TO PLAY

Recovery from exertional heat stroke (EHS) and heat injury is related to the duration of core temperature elevation above the critical level (approximately 105°F, 40.5°C): The longer that a patient's core temperature remained above this level, the greater the risk of severe morbidity and mortality, and the longer the period needed for recovery. Any guidelines used to determine the approach and time frame for an athlete's recovery must be modified based upon the severity of illness.

Guidelines for return to activity following full recovery from EHS or heat injury differ among experts and institutions [63-65]. At a minimum, athletes should not begin **any** significant physical activity until they are asymptomatic and all blood tests have returned to a normal range. Beyond these requirements, guidelines generally consist of "common sense" recommendations, including a gradual, cautious reintroduction of physical activity to ensure adequate fitness and full acclimatization [52].

The recommendations of the American College of Sports Medicine for returning an athlete to training and competition following an episode of EHS represent one reasonable approach [66]:

- No exercise permitted for at least seven days following release from medical care.

- Follow-up with the medical team approximately one week after release for physical examination and any necessary laboratory testing and diagnostic imaging based upon the organs affected during the EHS episode.
- Once cleared for a return to activity, the athlete begins exercise in a cool environment and gradually increases the duration, intensity, and heat exposure over two weeks to demonstrate heat tolerance and initiate acclimatization.
- Athletes who cannot resume vigorous activity over four weeks because of recurrent symptoms (eg, excessive fatigue) should be reevaluated. Laboratory exercise-heat tolerance testing may be useful in this setting.
- The athlete may resume full competition once he or she is able to participate in full training in the heat for two to four weeks without adverse effects.

HEAT TOLERANCE TESTING

Heat tolerance testing can be useful when clinicians must decide if an athlete is ready to return to play following exertional heat stroke (EHS), particularly in more complex cases (eg, history of multiple episodes of EHS, difficulty with initial reacclimatization, or EHS complicated by significant end organ injury) [64]. In its simplest form, a positive test indicates a failure to compensate to a given heat challenge in a controlled environment, suggesting that the athlete is not ready to resume full activity in the heat. Such failure prompts the clinician and athlete to develop and follow an appropriate plan for acclimatizing to activity in the heat and reestablishing fitness. A follow-up heat tolerance test can be used to gauge progress. Positive repeat testing suggests persistent problems with heat intolerance and the need to monitor the athlete more closely as activities in the heat are gradually resumed.

As an example, the Israeli Defense Force (IDF) uses a heat tolerance test (HTT) to evaluate soldiers following an episode of EHS and guide decision-making about return to duty [67,68]. The IDF HTT assumes that tolerance to heat stress varies among individuals. Individuals who are unable to tolerate a specific heat challenge, as indicated by increases in body temperature that occur sooner and at a faster rate than normal responders, under identical environmental and exercise conditions, are defined as "heat intolerant" [67]. While the IDF has used this test for over 30 years, it remains unclear whether heat intolerance, as defined by the HTT, predicts who will experience subsequent episodes of EHS [69].

PREVENTION OF EXERTIONAL HEAT ILLNESS

Exertional heat illness (EHI) is often preventable. Important principles for developing a prevention program for exertional heat illness and specific measures for reducing risk, including several recommendations included in consensus statements, are described below and in the accompanying table (table 2) [70-75].

Measures that can be taken to reduce the risk of EHI include the following:

Long-term institutional measures:

- Institute prevention policies, including an emergency action plan (table 3).
- Educate staff and athletes about heat illness.

Long-term and preparatory measures for athletes:

- Maintain a high level of fitness.
- Acclimatize gradually to exercising in hot and/or humid conditions. The process of heat acclimatization generally requires 7 to 14 days, but ideally, athletes should train for two weeks under a heat stress comparable to the target competition. Most adaptations occur during the first week.
- Training sessions for heat acclimatization should last at least 60 minutes per day, and induce an increase in core and skin temperatures, as well as stimulate sweating.

Institutional/coaching measures during activity:

- Provide frequent breaks for hydration and cooling.
- Avoid activity during severe heat and/or humidity (use WBGT as a guide (table 3)); practicing when the WBGT is lower (ie, night, early morning) or in a cooler indoor facility may be a reasonable alternative. (See "Exertional heat illness in adolescents and adults: Epidemiology, thermoregulation, risk factors, and diagnosis", section on 'Wet bulb globe temperature (WBGT) and other heat indices'.)
- Pay careful attention to athletes with large mass to skin surface ratios (eg, obese athletes) during workouts in hot or humid conditions.
- Carefully monitor those athletes with any history suggestive of prior heat illness.

- Minimize equipment and clothing that hinder heat loss in hot or humid conditions.

Athlete measures immediately before and during activity:

- Hydrate before activity and keep well hydrated throughout activity. Before training and competition in the heat, athletes should drink 6 mL of fluid per kg of body mass every two to three hours in order to begin exercise properly hydrated. We begin this process approximately four to six hours prior to the start of training or competition. Of note, unless an athlete is deficient in sodium and other electrolytes, increased salt intake before and during exercise is unlikely to help prevent exertional heat illness.

- Avoid exercise in severe heat and/or humidity when ill.

- Stop exercising and notify medical staff immediately if severe exhaustion, lightheadedness, or other concerning symptoms develop in yourself or a teammate.

- "Precooling" (ie, implementing cooling measures before or especially during play) may benefit athletes whose sport involves sustained exercise (eg, middle and long distance running, cycling, tennis, and team sports) in hot environments [76,77]. Precooling strategies can include both internal methods (eg, ice slurry) and external methods (eg, cooling vests). In addition to precooling, athletes can use cooling strategies during exercise. Athletes who participate in sports with regular breaks in play (eg, American football, tennis) can implement cooling methods during such breaks. In addition to drinking an ice slurry, such cooling methods may include donning an ice vest or ice hat, draping an ice towel around the neck or over the head, or immersing arms or hands in an ice chest. Precooling and intra-event cooling methods affect some athletes differently than others, and thus it is important to experiment or practice with these strategies before they are used in competition.

- Wear athletic clothing that ventilates well and allows for evaporative cooling when exercising in the heat. Clothing should be changed when it becomes saturated with sweat, which limits evaporative cooling.

COMMON MISCONCEPTIONS

Misconceptions about the causes and management of exertional heat illness are common among clinicians, athletes, and the population at large. Important misconceptions are described in the accompanying table (table 4).

SOCIETY GUIDELINE LINKS

Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Exertional heat illness".)

INFORMATION FOR PATIENTS

UpToDate offers two types of patient education materials, "The Basics" and "Beyond the Basics." The Basics patient education pieces are written in plain language, at the 5th to 6th grade reading level, and they answer the four or five key questions a patient might have about a given condition. These articles are best for patients who want a general overview and who prefer short, easy-to-read materials. Beyond the Basics patient education pieces are longer, more sophisticated, and more detailed. These articles are written at the 10th to 12th grade reading level and are best for patients who want in-depth information and are comfortable with some medical jargon.

Here are the patient education articles that are relevant to this topic. We encourage you to print or e-mail these topics to your patients. (You can also locate patient education articles on a variety of subjects by searching on "patient info" and the keyword(s) of interest.)

- Basics topic (see "Patient education: Heat stroke (The Basics)")

SUMMARY AND RECOMMENDATIONS

- **Core principles** – Two critical observations inform the management of exertional heat stroke (EHS) and all types of severe heat illness:
  - The severity of a heat illness may not be apparent during the initial presentation.
  - Morbidity and mortality are directly related to the duration of core temperature elevation. (See 'Guiding principles' above.)

- **Initial resuscitation and core temperature measurement** – Resuscitation of the athlete with possible severe exertional heat illness (including heat stroke and heat injury) begins by evaluating and securing the airway, breathing, and circulation, in accordance with standard life support protocols. Measurements of vital signs, including a rectal temperature, blood (ie, fingerstick) glucose, and serum sodium concentration, should be obtained quickly and appropriate treatment initiated rapidly. Do **not** use alternative methods to determine body temperature (eg, oral, tympanic, axillary, temporal, forehead sticker). If a rectal thermistor or rectal thermometer is not available, one reasonable approach is to cool the patient with a severe heat illness until they begin to shiver. (See 'Prehospital assessment and initial interventions' above and 'Rapid cooling' above.)

Elevated core body temperature (above 105°F, 40.5°C) associated with altered mental status following exertion in high heat and humidity is consistent with a diagnosis of EHS. If appropriate medical staff is available on-site (eg, team physician), tools to implement aggressive cooling are readily available, and **no other emergency medical treatment is needed** other than rapid lowering of the body temperature, it is generally best to follow the "cool-first, transport second" guideline. Once initial cooling is achieved (eg, 38.9°C, 102°F), the patient with EHS or other severe heat illness is rapidly transported to the closest emergency department.

- **Rapid cooling is critical** – We recommend that adults with EHS be treated as quickly as possible with rapid cooling (**Grade 1B**). Cold water immersion therapy is highly effective and the authors' preferred treatment if appropriate conditions are met and suitable equipment is available. In circumstances when ice water immersion is not feasible, particularly if the patient has complications requiring aggressive medical intervention (eg, compromised airway, seizure), alternative methods of cooling should be used. In the emergency department, one reasonable approach is to apply ice packs to the neck, axillae, and inguinal regions (areas adjacent to large blood vessels), while simultaneously spraying tepid water over the patient's body and using fans to blow air over the moist skin (ie, evaporative cooling). A detailed guide to field-side cooling is provided in the accompanying table (table 1). The goal temperature is 101 to 102°F or 38.3 to 38.9°C. Continuous monitoring of the patient is mandatory. (See 'Rapid cooling' above.)

- **Hospital management of EHS** – Once at the hospital, patients with EHS or other severe heat illness receive a diagnostic evaluation while rapid cooling and other interventions (eg, fluid resuscitation, correction of electrolyte abnormalities) are performed as needed. Studies to be obtained are listed above. Potential complications of EHS include respiratory failure, seizure, rhabdomyolysis, acute kidney injury, electrolyte abnormalities, hepatic injury, coagulopathy, gastrointestinal bleeding, and myocardial injury. (See 'Clinical assessment at the hospital' above and 'Laboratory testing and diagnostic imaging' above and 'Supportive therapy' above and 'Complications' above.)

- **Exertional heat injury** – Exertional heat injury is similar to EHS, but the patient's central nervous system is not affected. For patients with suspected heat injury, we recommend immediate treatment with rapid cooling using any of the methods suitable for EHS (**Grade 1B**). Additional resuscitative measures are provided as necessary and a hospital evaluation similar to that for patients with EHS should be performed. (See 'Heat injury' above.)

- **Heat exhaustion and heat syncope** – Heat exhaustion is characterized by the inability to maintain adequate cardiac output (usually manifested as physical collapse during exercise) due to strenuous physical activity and environmental heat stress. Elevations in body temperature are less extreme than with EHS, and the central nervous system is not affected. Treatment includes moving the patient to a cool environment, with additional cooling methods used as needed, rehydration (usually with oral fluids), and careful monitoring. Evaluation in an emergency department is necessary if rapid improvement (within one or two hours) does not occur with appropriate management. Similar management is provided to patients with heat-related syncope and exercise-associated collapse. (See 'Heat exhaustion' above and 'Heat syncope and exercise associated collapse' above.)

- The treatment of heat cramps consists of hydration, replacement of sodium losses, and stretching and massage of the affected muscles. (See '"Heat cramps"' above.)

- **Prevention** – Measures for preventing exertional heat illness are presented in the text (table 2 and table 3). (See 'Prevention of exertional heat illness' above.)

REFERENCES

1. Maron BJ, Doerer JJ, Haas TS, et al. Sudden deaths in young competitive athletes: analysis of 1866 deaths in the United States, 1980-2006. Circulation 2009; 119:1085.
2. Mueller FO, Cantu RC. Catastrophic sports injury research: 26th Annual Report Fall 1982-Spring 2008. University of North Carolina, Chapel Hill 2008. http://www.unc.edu/depts/nccsi/AllSport.pdf (Accessed on July 09, 2012).
3. Kerr ZY, Yeargin SW, Hosokawa Y, et al. The Epidemiology and Management of Exertional Heat Illnesses in High School Sports During the 2012/2013–2016/2017 Academic Years. J Sport Rehabil 2020; 29:332.
4. Centers for Disease Control and Prevention (CDC). Heat illness among high school athletes --- United States, 2005-2009. MMWR Morb Mortal Wkly Rep 2010; 59:1009.
5. Update: Heat injuries, active component, U.S. Armed Forces, 2009. MSMR 2010; 17:6. htt

p://www.afhsc.mil/viewMSMR?file=2010/v17_n03.pdf#Page=06 (Accessed on June 05, 2012).

6. Bouchama A, Knochel JP. Heat stroke. N Engl J Med 2002; 346:1978.
7. Gardner JW, JA K. Clinical diagnosis, management, and surveillance of exertional heat illness. In: Textbook of Military Medicine, Zajitchuk R (Ed), Army Medical Center Borden Institute, Washington, DC 2001.
8. Heled Y, Rav-Acha M, Shani Y, et al. The "golden hour" for heatstroke treatment. Mil Med 2004; 169:184.
9. Stearns RL, O'Connor FG, Casa DJ, Kenny GP. Exertional heat stroke. In: Preventing Sudden Death in Sport and Physical Activity, Casa DJ (Ed), Jones & Bartlett Learning, Sudbury 2011. p.53.
10. Belval LN, Casa DJ, Adams WM, et al. Consensus Statement- Prehospital Care of Exertional Heat Stroke. Prehosp Emerg Care 2018; 22:392.
11. Hosokawa Y, Racinais S, Akama T, et al. Prehospital management of exertional heat stroke at sports competitions: International Olympic Committee Adverse Weather Impact Expert Working Group for the Olympic Games Tokyo 2020. Br J Sports Med 2021; 55:1405.
12. Casa DJ, DeMartini JK, Bergeron MF, et al. National Athletic Trainers' Association Position Statement: Exertional Heat Illnesses. J Athl Train 2015; 50:986.
13. Casa DJ, Kenny GP, Taylor NA. Immersion treatment for exertional hyperthermia: cold or temperate water? Med Sci Sports Exerc 2010; 42:1246.
14. Casa DJ, McDermott BP, Lee EC, et al. Cold water immersion: the gold standard for exertional heatstroke treatment. Exerc Sport Sci Rev 2007; 35:141.
15. Proulx CI, Ducharme MB, Kenny GP. Effect of water temperature on cooling efficiency during hyperthermia in humans. J Appl Physiol (1985) 2003; 94:1317.
16. Sithinamsuwan P, Piyavechviratana K, Kitthaweesin T, et al. Exertional heatstroke: early recognition and outcome with aggressive combined cooling--a 12-year experience. Mil Med 2009; 174:496.
17. Bouchama A, Dehbi M, Chaves-Carballo E. Cooling and hemodynamic management in heatstroke: practical recommendations. Crit Care 2007; 11:R54.
18. Smith JE. Cooling methods used in the treatment of exertional heat illness. Br J Sports Med 2005; 39:503.
19. Demartini JK, Casa DJ, Stearns R, et al. Effectiveness of cold water immersion in the

treatment of exertional heat stroke at the Falmouth Road Race. Med Sci Sports Exerc 2015; 47:240.

20. Miller KC, Long BC, Edwards J. Necessity of Removing American Football Uniforms From Humans With Hyperthermia Before Cold-Water Immersion. J Athl Train 2015; 50:1240.
21. Miller KC, Truxton T, Long B. Temperate-Water Immersion as a Treatment for Hyperthermic Humans Wearing American Football Uniforms. J Athl Train 2017; 52:747.
22. McDermott BP, Casa DJ, Ganio MS, et al. Acute whole-body cooling for exercise-induced hyperthermia: a systematic review. J Athl Train 2009; 44:84.
23. Newport M, Grayson A. Towards evidence-based emergency medicine: best BETs from the Manchester Royal Infirmary. BET 3: In patients with heatstroke is whole-body ice-water immersion the best cooling method? Emerg Med J 2012; 29:855.
24. Lipman GS, Eifling KP, Ellis MA, et al. Wilderness Medical Society practice guidelines for the prevention and treatment of heat-related illness. Wilderness Environ Med 2013; 24:351.
25. Douma MJ, Aves T, Allan KS, et al. First aid cooling techniques for heat stroke and exertional hyperthermia: A systematic review and meta-analysis. Resuscitation 2020; 148:173.
26. Atha WF. Heat-related illness. Emerg Med Clin North Am 2013; 31:1097.
27. Gaudio FG, Grissom CK. Cooling Methods in Heat Stroke. J Emerg Med 2016; 50:607.
28. Bursey MM, Galer M, Oh RC, Weathers BK. Successful Management of Severe Exertional Heat Stroke with Endovascular Cooling After Failure of Standard Cooling Measures. J Emerg Med 2019; 57:e53.
29. Morrison KE, Desai N, McGuigan C, et al. Effects of Intravenous Cold Saline on Hyperthermic Athletes Representative of Large Football Players and Small Endurance Runners. Clin J Sport Med 2018; 28:493.
30. Casa DJ, Becker SM, Ganio MS, et al. Validity of devices that assess body temperature during outdoor exercise in the heat. J Athl Train 2007; 42:333.
31. Ganio MS, Brown CM, Casa DJ, et al. Validity and reliability of devices that assess body temperature during indoor exercise in the heat. J Athl Train 2009; 44:124.
32. Mazerolle SM, Scruggs IC, Casa DJ, et al. Current knowledge, attitudes, and practices of certified athletic trainers regarding recognition and treatment of exertional heat stroke. J Athl Train 2010; 45:170.
33. Ronneberg K, Roberts WO, McBean AD, Center BA. Temporal artery temperature

measurements do not detect hyperthermic marathon runners. Med Sci Sports Exerc 2008; 40:1373.

34. Capacchione JF, Muldoon SM. The relationship between exertional heat illness, exertional rhabdomyolysis, and malignant hyperthermia. Anesth Analg 2009; 109:1065.
35. O'Brien KK, Leon LR, Kenefick RW. Clinical management of heat-related illnesses. In: Wild nerness Medicine, 6th ed, Auerbach PS (Ed), Elsevier, Philadelphia 2012. p.232.
36. Zeller L, Novack V, Barski L, et al. Exertional heatstroke: clinical characteristics, diagnostic and therapeutic considerations. Eur J Intern Med 2011; 22:296.
37. Hashim IA. Clinical biochemistry of hyperthermia. Ann Clin Biochem 2010; 47:516.
38. Marom T, Itskoviz D, Lavon H, Ostfeld I. Acute care for exercise-induced hyperthermia to avoid adverse outcome from exertional heat stroke. J Sport Rehabil 2011; 20:219.
39. Shahid MS, Hatle L, Mansour H, Mimish L. Echocardiographic and Doppler study of patients with heatstroke and heat exhaustion. Int J Card Imaging 1999; 15:279.
40. Atar S, Rozner E, Rosenfeld T. Transient cardiac dysfunction and pulmonary edema in exertional heat stroke. Mil Med 2003; 168:671.
41. Hong JY, Lai YC, Chang CY, et al. Successful treatment of severe heatstroke with therapeutic hypothermia by a noninvasive external cooling system. Ann Emerg Med 2012; 59:491.
42. Hosokawa Y, Casa DJ, Rosenberg H, et al. Round Table on Malignant Hyperthermia in Physically Active Populations: Meeting Proceedings. J Athl Train 2017; 52:377.
43. Hadad E, Cohen-Sivan Y, Heled Y, Epstein Y. Clinical review: Treatment of heat stroke: should dantrolene be considered? Crit Care 2005; 9:86.
44. Varghese GM, John G, Thomas K, et al. Predictors of multi-organ dysfunction in heatstroke. Emerg Med J 2005; 22:185.
45. Leon LR, Helwig BG. Heat stroke: role of the systemic inflammatory response. J Appl Physiol (1985) 2010; 109:1980.
46. Costrini AM, Pitt HA, Gustafson AB, Uddin DE. Cardiovascular and metabolic manifestations of heat stroke and severe heat exhaustion. Am J Med 1979; 66:296.
47. Kew MC, Tucker RB, Bersohn I, Seftel HC. The heart in heatstroke. Am Heart J 1969; 77:324.
48. Wilson TE, Crandall CG. Effect of thermal stress on cardiac function. Exerc Sport Sci Rev 2011; 39:12.
49. Whiticar R, Laba D, Smith S. Exertional heat stroke in a young man with a documented

rise in troponin I. Emerg Med J 2008; 25:283.

50. Bianchi L, Ohnacker H, Beck K, Zimmerli-Ning M. Liver damage in heatstroke and its regression. A biopsy study. Hum Pathol 1972; 3:237.
51. Shibolet S, Coll R, Gilat T, Sohar E. Heatstroke: its clinical picture and mechanism in 36 cases. Q J Med 1967; 36:525.
52. McDermott BP, Casa DJ, Yeargin SW, et al. Recovery and return to activity following exertional heat stroke: considerations for the sports medicine staff. J Sport Rehabil 2007; 16:163.
53. Mehta AC, Baker RN. Persistent neurological deficits in heat stroke. Neurology 1970; 20:336.
54. Romero JJ, Clement PF, Belden C. Neuropsychological sequelae of heat stroke: report of three cases and discussion. Mil Med 2000; 165:500.
55. Wallace RF, Kriebel D, Punnett L, et al. Prior heat illness hospitalization and risk of early death. Environ Res 2007; 104:290.
56. Garcin JM, Bronstein JA, Cremades S, et al. Acute liver failure is frequent during heat stroke. World J Gastroenterol 2008; 14:158.
57. Maquirriain J, Merello M. The athlete with muscular cramps: clinical approach. J Am Acad Orthop Surg 2007; 15:425.
58. Schwellnus MP, Drew N, Collins M. Muscle cramping in athletes--risk factors, clinical assessment, and management. Clin Sports Med 2008; 27:183.
59. Garrison SR, Korownyk CS, Kolber MR, et al. Magnesium for skeletal muscle cramps. Cochrane Database Syst Rev 2020; 9:CD009402.
60. Craighead DH, Shank SW, Gottschall JS, et al. Ingestion of transient receptor potential channel agonists attenuates exercise-induced muscle cramps. Muscle Nerve 2017; 56:379.
61. Bergeron MF. Exertional heat cramps: recovery and return to play. J Sport Rehabil 2007; 16:190.
62. Asplund CA, O'Connor FG, Noakes TD. Exercise-associated collapse: an evidence-based review and primer for clinicians. Br J Sports Med 2011; 45:1157.
63. Binkley HM, Beckett J, Casa DJ, et al. National Athletic Trainers' Association Position Statement: Exertional Heat Illnesses. J Athl Train 2002; 37:329.
64. O'Connor FG, Casa DJ, Bergeron MF, et al. American College of Sports Medicine Roundtable on exertional heat stroke--return to duty/return to play: conference

proceedings. Curr Sports Med Rep 2010; 9:314.

65. O'Connor FG, Williams AD, Blivin S, et al. Guidelines for return to duty (play) after heat illness: a military perspective. J Sport Rehabil 2007; 16:227.
66. American College of Sports Medicine, Armstrong LE, Casa DJ, et al. American College of Sports Medicine position stand. Exertional heat illness during training and competition. Med Sci Sports Exerc 2007; 39:556.
67. Moran DS, Erlich T, Epstein Y. The heat tolerance test: an efficient screening tool for evaluating susceptibility to heat. J Sport Rehabil 2007; 16:215.
68. Moran DS, Heled Y, Still L, et al. Assessment of heat tolerance for post exertional heat stroke individuals. Med Sci Monit 2004; 10:CR252.
69. Laitano O, Leon LR, Roberts WO, Sawka MN. Controversies in exertional heat stroke diagnosis, prevention, and treatment. J Appl Physiol (1985) 2019; 127:1338.
70. Racinais S, Alonso JM, Coutts AJ, et al. Consensus recommendations on training and competing in the heat. Br J Sports Med 2015; 49:1164.
71. Grundstein AJ, Hosokawa Y, Casa DJ. Fatal Exertional Heat Stroke and American Football Players: The Need for Regional Heat-Safety Guidelines. J Athl Train 2018; 53:43.
72. Hosokawa Y, Casa DJ, Trtanj JM, et al. Activity modification in heat: critical assessment of guidelines across athletic, occupational, and military settings in the USA. Int J Biometeorol 2019; 63:405.
73. Kerr ZY, Register-Mihalik JK, Pryor RR, et al. The Association between Mandated Preseason Heat Acclimatization Guidelines and Exertional Heat Illness during Preseason High School American Football Practices. Environ Health Perspect 2019; 127:47003.
74. Parsons JT, Anderson SA, Casa DJ, Hainline B. Preventing catastrophic injury and death in collegiate athletes: interassociation recommendations endorsed by 13 medical and sports medicine organisations. Br J Sports Med 2020; 54:208.
75. Racinais S, Hosokawa Y, Akama T, et al. IOC consensus statement on recommendations and regulations for sport events in the heat. Br J Sports Med 2023; 57:8.
76. Wegmann M, Faude O, Poppendieck W, et al. Pre-cooling and sports performance: a meta-analytical review. Sports Med 2012; 42:545.
77. Tyler CJ, Sunderland C, Cheung SS. The effect of cooling prior to and during exercise on exercise performance and capacity in the heat: a meta-analysis. Br J Sports Med 2015; 49:7.

Topic 17235 Version 22.0

GRAPHICS

Guidelines for cold water immersion treatment of exertional heat illness

Contact emergency medical services (EMS) immediately.
Assess airway, breathing, circulation, and mental status; measure vital signs before immersing the patient.
If appropriate medical staff is present on-site (eg, team physician), equipment for aggressive cooling is readily available (eg, cold water immersion, ice/wet towel rotation, high-flow cold water dousing), and **no other emergency medical treatment is needed** other than rapid lowering of the body temperature, follow the "cool-first, transport second" guideline.
For patients to be treated with ice water immersion, prepare as follows:
Get help.
Move patient to a shaded area.
Half fill a tub or wading pool with water and ice. Ice should cover the surface of the water at all times.
A whirlpool tub filled with ice water may be used if the athlete collapses near an athletic training room.
During ice water immersion treatment, assess the patient's core body temperature with a rectal thermistor continuously (a thermistor is a flexible thermometer that remains in place throughout the cooling and treatment process).
Obtain necessary assistance and cool the patient as follows:
Place the athlete in the ice water immersion tub.
Cover as much of the body as possible with ice water. If complete coverage is not possible, cover the torso as much as possible.
Keep the athlete's head and neck above water. An assistant or two can do so by holding the victim under the axillae with a towel or sheet wrapped across the chest and under the arms.
Place a towel soaked in ice water over the head and neck while the body is being cooled.
Keep water temperature under 15°C (60°F).
Vigorously circulate water throughout the cooling process.
Monitor vital signs approximately every 10 minutes and mental status continually during cooling.
Have several additional assistants immediately nearby in case the athlete becomes combative or must be lifted or rolled because of vomiting.
Continue cooling until the patient's rectal temperature reaches 39°C (102°F). If the rectal temperature cannot be measured and on-site ice water immersion is indicated, cool for 10 to 15 minutes and then transport to the emergency department. Cooling via ice water immersion occurs

at a rate of approximately 1°C for every five minutes (or 1°F every three minutes), if the water is aggressively stirred.
Remove the patient from the immersion tub and transfer to the nearest emergency department or hospital after the rectal temperature reaches 39°C (102°F).
If ice water immersion is not feasible given the constraints of the environment, and on-site cooling is appropriate, then cool the patient using the best available means. These may include any of the following three methods:
Fill a cooler with ice, water, and 12 towels. Place six icy wet towels all over the patient's body. Leave them in place for two to three minutes, then place those back in cooler and replace them with the six others. Continue this rotation every two to three minutes.
Douse the patient continuously with cold water using a shower or hose.
If ice is available but no tub, place the patient in a tarp or sheet, cover the patient with a large amount of ice, and then wrap the tarp or sheet around them. Replenish the ice as soon as a moderate degree of melting occurs.

Adapted from: The Korey Stringer Institute (ksi.uconn.edu) and Casa DJ, McDermott BM, Lee EC, et al. Cold-water immersion: The gold standard for exertional heat stroke treatment. Exerc Sport Sci Rev 2007; 35:141.

Graphic 54492 Version 5.0

Principles of prevention for exertional heat illness

Ensure that appropriate medical care and equipment, including a cold water immersion tub or other effective tools for rapid cooling, are available at practices and games.
Review and update emergency plans for exertional heat illness (EHI) annually with athletic directors, coaches, athletes, and medical personnel.
Educate the medical staff, emergency personnel, athletes, coaches, and parents about EHI and proper acclimatization and hydration strategies.
Include questions about EHI on pre-participation questionnaires and during examinations to identify "high-risk" individuals.
Establish and follow heat acclimatization guidelines: These should allow individuals to acclimatize over the course of 10 to 14 days, progressively increasing the intensity and duration of activity and the amount of equipment.
Establish and follow hot and humid weather activity guidelines that incorporate Wet Bulb Globe Temperature (WBGT) readings, time of day for activity, intensity and duration of activity, equipment, and rest and water breaks.
Establish and follow clear policies to ensure proper hydration: Use appropriate rest to work ratios, weigh-ins before and after activity, and encourage drinking both water and sodium-containing fluids during activity.

Graphic 83028 Version 3.0

WBGT activities chart

WBGT (°C)	WBGT (°F)	Risks and permitted activities		
		Intermittent activites		**Continuous activities**
		Non-acclimatized, unfit, or high-risk individuals	**Acclimatized, fit, low-risk individuals**	
18.4 to 22.2	65.1 to 72	Increase the rest:work ratio; monitor fluid intake	Normal activity	Risk of heat stress and other heat illnesses begin to rise; high-risk individuals should be monitored or not compete
22.3 to 25.5	72.1 to 78	Increase the rest:work ratio; decrease total duration of activity	Monitor fluid intake	Risk for all competitors is increased
25.6 to 27.7	78.1 to 82	Decrease intensity and total duration of activity	Monitor fluid intake	Risk of unfit, non-acclimatized individuals is high
27.8 to 30	82.1 to 86	Increase the rest:work ratio to 1:1; limit intense exercise; watch at-risk individuals carefully	Plan intense/prolonged activity with discretion. Watch at-risk individuals carefully	Cancel activity/competition
30.1 to 32.2	86.1 to 90	Cancel or stop practice and competition	Limit intense exercise and total exposure to heat and humidity; watch for early signs/symptoms of heat stress	
>32.2	>90	Cancel exercise	Cancel exercise; heat stress exists for all athletes	

WBGT: wet bulb globe temperature.

Based on guidance from the American College of Sports Medicine. Adapted from: Wet Bulb Globe Temperature. National Weather Service. Available at: https://www.weather.gov/arx/wbgt (Accessed on August 25, 2021).

Graphic 133128 Version 1.0

Myths about exertional heat illness[1,2]

Misconception	Explanation
Athletes stop sweating when they develop exertional heat stroke (EHS)	Since EHS occurs during intense exercise in the heat, athletes are almost always sweating profusely when they collapse. This widely held but completely **inaccurate** belief about EHS can delay diagnosis and is dangerous.
Athletes must be severely dehydrated to develop EHS	While dehydration may predispose athletes to exertional heat illness and can exacerbate EHS, it is **not** a necessary precondition. EHS can occur in as little as 20 minutes after the beginning of exercise, before severe fluid loss has occurred. Exercise intensity and environmental conditions (ie, heat and humidity) are the primary factors associated with EHS.
Body temperature can be accurately determined using external means	No external temperature assessment devices currently available have been proven accurate in athletes exercising in intense heat with a significant degree of hyperthermia. External temperature devices, including oral, tympanic, temporal, forehead sticker, and axillary devices, should **never** be used to diagnose EHS. The only device that is practical and accurate under these conditions is the rectal thermistor.
Lucid mental status in a patient with severe heat illness means everything is okay	Many patients with impending EHS appear lucid initially, only to progress to more severe disease. This initial period of normal mental function can mislead the clinician and obscure or delay the diagnosis. The lucid interval often coincides with minor central nervous system (CNS) dysfunction that is difficult to recognize.
Shivering delays cooling	Shivering does occur when a normothermic individual is placed in a cold water bath. However, this is seldom the case with hyperthermic individuals and rapid cooling occurs even in the few patients who manifest a shivering response.
The onset of exertional heat stroke (EHS) is unpredictable	Several predisposing factors for EHS are well documented. They include: environmental conditions (high temperature and/or high humidity), high intensity exercise, lack of acclimatization, poor physical fitness, equipment preventing heat loss, large mass to surface area ratio (eg, obesity), sleep deprivation, dehydration, and fever.
Cold water immersion puts the patient at risk of drowning	With proper precautions, there is almost no risk of drowning. Precautions include: supervising the patient at **all** times, obtaining adequate help from teammates and colleagues, and placing a sheet under the patient's armpits and across their chest to hold them upright and prevent their head from falling under water.

Cold water immersion is unsanitary	While unsanitary conditions may be present due to vomiting or diarrhea, an unsanitary tub is an acceptable tradeoff when providing a life-saving intervention. A dirty tub is easily cleaned.
Hypothermic afterdrop (continued cooling following immersion) can occur	Hypothermic afterdrop may be a concern if the athlete is cooled too long. However, if a proper measurement device (ie, rectal thermistor or rectal thermometer) is used, core body temperature can be closely monitored during treatment to prevent such an afterdrop.
Peripheral vasoconstriction (PVC) delays cooling	Although PVC may occur during cold water immersion, it has little impact compared to the large conductive and convective thermal transfer that rapidly cools the body. While initially PVC may increase core body temperature slightly even in an EHS patient, a rapid decrease in body temperature immediately follows.
Ice water immersion is uncomfortable for the patient	The physical comfort of the patient and staff is a secondary concern in the face of a life-threatening illness like EHS. No significant harm is sustained by the patient during appropriately managed ice water immersion therapy.

References:

1. *The Korey Stringer Institute (ksi.uconn.edu).*
2. *Casa DJ, McDermott BM, Lee EC, et al. "Cold-water immersion: The gold standard for exertional heat stroke treatment," Exercise and Sports Science Reviews 2007; 35:141.*

Graphic 83041 Version 3.0

Contributor Disclosures

Francis G O'Connor, MD, MPH, FACSM, FAMSSM No relevant financial relationship(s) with ineligible companies to disclose. **Douglas J Casa, PhD, ATC, FNAK, FACSM, FNATA** Grant/Research/Clinical Trial Support: AMP [Exercise in the heat and preventing sudden death in sport/physical activity]; BHSAI [Exercise in the heat and preventing sudden death in sport/physical activity]; Brainscope [Exercise in the heat and preventing sudden death in sport/physical activity]; CamelBak [Exercise in the heat and preventing sudden death in sport/physical activity]; Defibtech [Exercise in the heat and preventing sudden death in sport/physical activity]; Department of Defense [Exercise in the heat and preventing sudden death in sport/physical activity]; Eagle [Exercise in the heat and preventing sudden death in sport/physical activity]; Falmouth Road Race [Exercise in the heat and preventing sudden death in sport/physical activity]; First Line [Exercise in the heat and preventing sudden death in sport/physical activity]; Flashback [Exercise in the heat and preventing sudden death in sport/physical activity]; Gatorade [Exercise in the heat and preventing sudden death in sport/physical activity]; Heartsmart [Exercise in the heat and preventing sudden death in sport/physical activity]; Kelvi [Exercise in the heat and preventing sudden death in sport/physical activity]; Kestrel [Exercise in the heat and preventing sudden death in sport/physical activity]; Kraft-Heinz [Exercise in the heat and preventing sudden death in sport/physical activity]; Magid [Exercise in the heat and preventing sudden death in sport/physical activity]; Mission [Exercise in the heat and preventing sudden death in sport/physical activity]; MPUSA [Exercise in the heat and preventing sudden death in sport/physical activity]; NATA [Exercise in the heat and preventing sudden death in sport/physical activity]; NCAA [Exercise in the heat and preventing sudden death in sport/physical activity]; Neurorescue [Exercise in the heat and preventing sudden death in sport/physical activity]; NFL Foundation [Exercise in the heat and preventing sudden death in sport/physical activity]; NIOSH [Exercise in the heat and preventing sudden death in sport/physical activity]; Polar [Exercise in the heat and preventing sudden death in sport/physical activity]; UNC (NCCSIR) [Exercise in the heat and preventing sudden death in sport/physical activity]; US Air Force [Exercise in the heat and preventing sudden death in sport/physical activity]; US Army [Exercise in the heat and preventing sudden death in sport/physical activity]; WHOOP [Exercise in the heat and preventing sudden death in sport/physical activity]. Consultant/Advisory Boards: NFL [Exercise in the heat and preventing sudden death in sport/physical activity]; Sports Innovation labs [Exercise in the heat and preventing sudden death in sport/physical activity]. Speaker's Bureau: Gatorade [Exercise in the heat and preventing sudden death in sport/physical activity]. Other Financial Interest: Expert witness on legal cases [Heat stroke, exertional sickening, dehydration]. All of the relevant financial relationships listed have been mitigated. **Daniel F Danzl, MD** No relevant financial relationship(s) with ineligible companies to disclose. **Karl B Fields, MD** No relevant financial relationship(s) with ineligible companies to disclose. **Jonathan Grayzel, MD, FAAEM** No relevant financial relationship(s) with ineligible companies to disclose.

Contributor disclosures are reviewed for conflicts of interest by the editorial group. When found, these are addressed by vetting through a multi-level review process, and through requirements for references to be provided to support the content. Appropriately referenced content is required of all authors and must conform to UpToDate standards of evidence.

Conflict of interest policy

→