Return to Exercise Training After Heat Exhaustion

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Context: Exertional heat exhaustion (HEX) is the most common form of heat illness experienced by athletes, laborers, and military personnel. Both dehydration stemming from a water and/or salt deficiency and a high ambient temperature must exist for HEX to occur. In the field, appropriate therapy can reduce recovery time. Objective: This manuscript provides clinical guidance regarding return to activity. The primary focus of this paper is to describe the evaluation of residual effects and the underlying personal characteristics that initially predispose the athlete to HEX. Attention to these factors will reduce the risk of future episodes.

Exhaustion (E), the inability to continue exercise or work, is complex because different types of exercise induce exhaustion via different mechanisms. A marathon runner, for example, may experience devastating exhaustion, often termed “hitting the wall” at the 40-km point of a race because of depleted liver and muscle glycogen stores. A sprinter may encounter exhaustion during a 400 m track event due to intramuscular lactacidosis. But anyone can experience exertional heat exhaustion (HEX) during prolonged exercise-heat stress if substantial dehydration exists.

The non-specific signs and symptoms of exercise- or labor-induced E, in all climates, are difficult to distinguish from HEX, the most common heat-related disorder of athletes, soldiers, and civilians. However, research shows that mild exercise (40 to 50 %VO2max) in mild ambient conditions (34 to 39°C, 93 to 102°F) does not induce HEX unless significant fluid-electrolyte loss and cardiovascular stress exist; further, research also shows that exercise performed in a cool environment does not induce HEX. Thus, both dehydration and a high ambient temperature must exist for HEX to occur.

Field reports of HEX prior to 1947 recount the experiences of laborers and military personnel in desert and jungle environments. Virtually all of these cases, and the present World Health Organization taxonomy of heat illnesses, recognize two distinct forms of HEX. First, water-depletion heat exhaustion is an acute condition that is caused by insufficient fluid intake during exercise in a hot environment; humans consume less water than they lose in sweat. Second, salt-depletion heat exhaustion is a chronic condition attributed to inadequate replacement of sweat and urinary salt losses in a hot environment, leading to a whole-body deficit of sodium and dehydration. These two forms of HEX may be distinguished in the field by evaluating thirst and muscle cramps, which often appear with salt-depletion but rarely with water depletion.

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Whether due to water or salt depletion, HEX involves a reduced extracellular (eg, blood) volume and insufficient cardiac output to meet the simultaneous blood flow demands of muscle (for exercise) and skin (for heat dissipation). These physiological responses appear clinically as orthostatic intolerance, syncope, or a shock-like state in severe cases. In most cases, a HEX patient feels faint and nauseous; skin appears ashen, cool, and wet; the pulse is rapid and weak; and blood pressure is low. This explains why cardiovascular insufficiency precipitated by strenuous exercise in a hot environment is recognized as the primary mechanism of HEX by the U.S. Army and the Occupational Safety & Health Administration of the U.S. Government.

In the field, appropriate therapy can reduce recovery time. An athlete with HEX should be removed to a cool, shaded area or air-conditioned building. Excess clothing and gear should be removed and his/her legs elevated to encourage venous return to the heart. These steps reduce cardiovascular strain. If the athlete is free of nausea, vomiting, and confusion, chilled oral fluids should be consumed to enhance blood volume. Intravenous fluids are recommended only if the athlete is moderately-to-severely dehydrated and unable to drink. Rectal temperature, heart rate, blood pressure, and CNS status are used to disprove heatstroke and monitor the athlete's improvement.

Severe Heat Exhaustion

When HEX patients collapse and/or exhibit altered mental status, the condition is termed "severe HEX" because hyperthermia adds additional stress to the existing cardiovascular insufficiency. Although this makes the condition difficult to distinguish from exertional heatstroke, severe HEX can be verified in most cases by three characteristics: a rectal temperature below 40ºC, consciousness, and normal serum enzyme levels. In cases of exertional heatstroke, which is defined as a medical emergency, the definitive serum enzyme concentrations peak between 1 and 5 days after the event 452 ± 294 to reach levels equal to alanine aminotransferase, 452 ± 294 U·L⁻¹; aspartate aminotransferase, 908 ± 553 U·L⁻¹; lactate dehydrogenase, 575 ± 132 U·L⁻¹; creatine phosphokinase, 5664 ± 2133 U·L⁻¹. In HEX patients and healthy adults, values for these enzymes range from 33 to 213, 92 to 186, 7 to 32, and 2 to 45 U·L⁻¹, respectively. Thus, if field diagnosis cannot incorporate laboratory values, and a patient exhibits symptoms of both severe HEX and exertional heatstroke, whole-body cooling should be instituted immediately after hyperthermia is discovered or if rectal temperature cannot be measured promptly. Cold or ice water immersion provides the most rapid cooling rate and the most effective therapy for hyperthermia.

Return to Training

Most athletes with HEX recover on site and, when clinically stable, are discharged in the company of a friend or relative. Serious complications are very rare. Prognosis after HEX is best when mental acuity was not altered and the athlete becomes alert quickly, following rest and fluids. Neither rest nor body cooling allows heat exhaustion patients to recover to full exercise capacity on the same day.
exemplified by the data set of 77 underground miners who experienced HEX but returned to work on the following day.\textsuperscript{21,22} Thirty of these miners had persistent mild symptoms of headache and fatigue and were not allowed to return to normal duties that day; 22 of the 30 were restricted to an air conditioned environment. All workers returned to their normal work duties by the third day without further medical treatment.

Before receiving clearance to resume exercise, the athlete should have no symptoms of HEX and exhibit normal hydration status as evaluated via urine specific gravity, urine color, and body weight change if a daily baseline weight is known. When the environmental temperature is harsh, protective equipment should be limited until the athlete demonstrates adequate heat tolerance.

Athletes and individuals who experience mild HEX and possess a high level of fitness may return to exercise within 24 to 48 hours, observing instructions to gradually increase the intensity and volume of training over several days. During these days, it is wise for the recovering athlete to train with a partner, sharing observations regarding appearance and ability to continue exercise. An athlete with severe heat exhaustion (Figure 1) should follow up with a sports medicine physician, after the initial day of training, to discuss unusual sensations or symptoms.\textsuperscript{19} To determine the time before returning to training and to reduce the risk of HEX reoccurrence, the attending physician should evaluate the residual effects of the HEX and consider factors to reduce reoccurrence.

**Evaluation of Residual Effects**

The time course of an athlete’s recovery will depend on the degree of injury that occurred and his/her status upon discharge. Four questions are relevant.

1. Is the patient dehydrated? While the patient stabilizes in the hospital setting, fluids should be replaced until urine osmolality, urine specific gravity, body weight, or plasma osmolality indicate a normal hydration status. If the patient is mildly dehydrated at the time of discharge, prescribe a fluid regimen to allow the athlete to regain normal hydration status. During the 48 hours after discharge, the athlete can monitor his/her urine volume (> 1 liter/day) and color (ie, a pale yellow or straw colored urine indicates euhydration) to gauge recovery.\textsuperscript{23} Also, as fluid-electrolyte balance is restored, thirst will diminish and gradually disappear; the absence of thirst indicates that the patient is within 1% of normal body weight.

2. Is plasma sodium concentration normal? Salt-depletion HEX (see above) is due to a small dietary sodium (eg, NaCl) intake, large NaCl loss, or both.\textsuperscript{12,24} A NaCl deficit usually requires 3 to 5 days to develop. Three clinical grades have been identified. Early salt depletion involves a whole-body Na\textsuperscript{+} loss of 0.5 g/kg body weight and is associated with fatigue, negligible urinary Na\textsuperscript{+}, and reduced plasma volume. Moderately severe salt depletion (0.5 to 0.75 g Na\textsuperscript{+}/kg) involves the onset of pallor, nausea, muscle cramps, hemoconcentration, and possible vomiting. Very severe salt depletion involves sodium loss of > 0.75 g/kg body weight; it is associated with all of the above characteristics plus collapse, systolic hypotension, and shock in severe cases.\textsuperscript{12} While the patient stabilizes in the hospital, sodium and other electrolytes should be replaced via intravenous fluid or diet until plasma osmolality and sodium levels are normal.
If the patient is discharged with a mild sodium deficit, increased dietary salt intake can be recommended. Suggest that patients consume canned soup or other salty foods such as pretzels for a few days.

3. What is the relationship between elapsed time after cessation of exercise and rectal temperature? When the elapsed time (minutes) after collapse or cessation of exercise (horizontal axis) is plotted against rectal temperature (vertical axis), what is the “area under the curve” in degree-minutes? This is important because hyperthermic injury to tissues and organs is directly related to the severity and duration of rectal temperature elevation. In general, hyperthermic athletes who are recognized and cooled immediately tolerate about 60 degree-minutes (area under the cooling curve) above approximately 40°C without lasting sequelae. Conversely, athletes with severe HEX who are not cooled quickly (and have more than about 60 degree-minutes of temperature elevation above approximately 40°C) tend to experience increased morbidity and poor prognosis. In some instances, the patient actually may experience exertional heat stroke; in this event, whole-body immersion cooling plus monitoring provides the best therapeutic intervention.
4. Do serum enzymes rise within 3 to 5 days after the event? In severe HEX cases, serum enzyme concentration that is tracked for 1 to 5 days may increase. Because the serum enzyme levels during HEX and most febrile states are normal, they verify whether hyperthermic tissue injury occurred. Whole-body immersions cooling plus monitoring are important. Cold-water immersion restrains serum enzyme elevations because it reduces tissue damage.

**Reduction of the Risk of Reoccurrence**

Once the athlete has been evaluated and deemed “recovered,” the attending physician should consider the causes underlying HEX to rule out underlying conditions that initially predisposed the athlete and to reduce the risk of future events.16

1. Is the patient overweight or obese? Excess body weight reduces exercise efficiency resulting in increased oxygen consumption and heat production at mild or moderate exercise intensity. One study of underground miners determined that HEX was more common when male laborers had a body mass index (BMI) greater than 27 kg·m$^{-2}$.21 Similarly, male and female Marine recruits, whose BMI was > 26 kg·m$^{-2}$, were three times more likely to experience heat illness during basic training than soldiers whose BMI was < 22 kg·m$^{-2}$.25 Loss of adipose tissue and gain of muscle mass will enhance the patient’s exercise efficiency and reduce heat storage.

2. Has exertional heat exhaustion occurred more than once? It is important to determine if there are common factors between events and if behavioral factors were involved. Often, a patient displays a chronic unwillingness, disregard, or ignorance of the basic principles of rehydration and nutrition. Also, the internal motivation of athletes to succeed at all costs is a part of HEX etiology.19 In these cases, behavioral modification will reduce the likelihood of HEX.

3. Which acquired characteristics can be modified to enhance heat tolerance? Table 1 summarizes the acquired predisposing factors of HEX. The most significant reduction of risks involves seeking to improve fitness and heat acclimatization status.

4. Has the patient acclimatized to exercise in a hot environment? Heat acclimatization reduces the risk of HEX. It is recommended that exercise intensity and duration be gradually increased for 10 to 14 days. Table 2 shows

**Table 1**  **Factors That Predispose to Exertional Heat Exhaustion**

<table>
<thead>
<tr>
<th>Hereditary</th>
<th>Acute</th>
<th>Acquired</th>
<th>Chronic</th>
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<tbody>
<tr>
<td>Age$^a$</td>
<td>Inadequate heat acclimatization</td>
<td>Inadequate cardiorespiratory fitness</td>
<td></td>
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<tr>
<td>High sweat rate$^b$</td>
<td>Dehydration</td>
<td>Fluid-electrolyte imbalance</td>
<td></td>
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<tr>
<td>Cystic fibrosis$^c$</td>
<td>Low salt diet, Gastrointestinal illness</td>
<td>History of heat exhaustion</td>
<td></td>
</tr>
</tbody>
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$^a$Older adults (> 60 yr) have a reduced thirst drive and reduced kidney function that increase their risk of HEX. $^b$Sweat losses of some individuals may exceed the maximal gastric emptying rate per hour; this predisposes them to dehydration. $^c$A high sweat chloride and sodium content predisposes some individuals to a sodium imbalance, depending on dietary intake.
that exercise-heat acclimatization improves cardiovascular responses beyond the benefits gained from physical training in a cool environment.\textsuperscript{26}

5. What is his/her aerobic fitness capacity? HEX results from cardiovascular insufficiency. Enhanced cardiovascular fitness will improve cardiovascular function and reduce the risk of HEX.\textsuperscript{27} Table 2 summarizes the physiological benefits of exercise training in a cool environment.

6. Does the patient sweat excessively? Is his/her clothing caked with a white, salty pattern that indicates a high salt concentration in sweat? If yes, the patient may benefit from referral to a dietician who is trained in sports nutrition. Counseling regarding a possible sodium imbalance and adequate fluid and dietary salt intake will optimize blood volume and cardiovascular responses during exercise in the heat. The patient’s sweat rate can be used to make fluid replacement recommendations as well as salt supplementations, if needed. Salt replacement can be made in the form of salty snacks (ie, pretzels, canned soup) or the dilution of salt in a sports drink in a way that is still palatable. For example, depending on an individual’s needs, \( \frac{1}{4} \) teaspoon of salt (590 mg of sodium) could be added to a 32 oz sports drink to replace lost sodium.

7. Will the patient be required to exercise or work in a hot environment again? The incidence of HEX increases among laborers\textsuperscript{28} when the air temperature rises above 33ºC (92ºF).

### Conclusion

Before receiving clearance to resume exercise, the athlete should have no symptoms of HEX and should be normally hydrated. Athletes and individuals who experience mild HEX and possess a high level of fitness may return to exercise within 24 to

<table>
<thead>
<tr>
<th>Physiological adaptations after 14 days</th>
<th>Training in a cool environment</th>
<th>Training in a hot environment (heat acclimatization)</th>
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</thead>
<tbody>
<tr>
<td>Decreased heart rate</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Earlier onset of sweating (evaporative cooling)</td>
<td>+</td>
<td>++</td>
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<tr>
<td>Increased skin blood flow (radiative and convective cooling)</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Decreased core body temperature</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Decreased skin temperature</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Increased blood volume</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Enhanced ability to exercise in a cool environment</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Enhanced ability to exercise in a hot environment</td>
<td>+</td>
<td>++</td>
</tr>
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Symbols. + = mild or moderate effect; ++ = major effect.
48 hours by observing instructions to gradually increase the intensity and volume of training over several days. To determine the time before retuning to training and to reduce the risk of HEX reoccurrence, the attending physician should assess the level of dehydration, plasma sodium concentration, extent of hyperthermia, and elevation of serum enzyme levels. To reduce the risk of HEX reoccurrence, the clinician should consider history of heat exhaustion, heat acclimatization and physical fitness status, BMI, excessive sweating, and the future requirement for work in the heat.

References


