

Exertional Heat Stroke in Athletes

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Abstract

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Exercising in hot and especially humid environment can cause rise in body core temperature to such a critical level that it does not only reduce performance, but also may ultimately lead to exertional heat stroke (EHS). This illness is true medical emergency that can result in significant morbidity and mortality, if not early recognized and promptly treated. Diagnostic criteria for EHS are body core temperature above 40°C and central nerve system dysfunction. Any athlete experiencing such symptoms should be immediately exposed to aggressive cooling treatment aimed to lower the elevated core temperature to near normal as quickly as possible. Ice water immersion is highly recommended as a cooling method because it provides the fastest cooling rates and is associated with lowest mortality rates. Athletes cooled rapidly soon after the onset of EHS usually recover without complications and are able to return to normal training in hot environment within a few weeks. EHS is also a preventable condition, and its occurrence can be minimized by implementing a few simple measures.

Introduction

The human body is equipped with well developed thermoregulation mechanisms that regulate its internal temperature at about 37°C for optimal function of organ systems. Nevertheless, it is not uncommon for athletes who train and compete in hot and humid environment to experience thermoregulation problems with the consequences ranging from premature fatigue to serious heat illness, such as exertional heat stroke (EHS) [1, 2]. This illness is a true medical emergency that can result in significant morbidity and mortality, if not early recognized and promptly treated [3-6]. In fact, EHS is reported to be the third leading cause of death among athletes [7], with American-type football players and distance runners being the most commonly affected [3]. Considering this, and especially since we are experiencing a period of global warming which can be expected to increase the incidence of EHS, education in recognition, treatment and prevention of this illness is essential, if heat-related deaths in athletic fields are to be avoided in the future.

Definition of Heat-Related Illnesses

In general, heat exposure can result in a variety of heat disorders including heat edema, heat syncope, heat cramps, heat exhaustion and heat stroke [8-10]. *Heat edema* is the mildest form of heat illness, which appears as a swelling of hands and feet, usually in unacclimatized individuals. *Heat syncope* is fainting that is usually associated with prolonged standing or sudden rising from a lying position. *Heat cramps* are involuntary, painful, spasmodic contractions of muscles, which tend to occur in settings of heavy sweating coupled with inadequate fluid and sodium intake [11, 12]. *Heat exhaustion* is the most common form of heat illness defined as the inability to continue the activity in the heat [13]. It is caused by the inability of the body to sustain the rate of cardiac output necessary to simultaneously meet the demands of blood flow for exercising muscle, skin and vital organs. Dehydration-induced plasma volume depletion is thought to be the primary factor for the development of this condition [11, 13]. *Heat stroke*, defined by a body core temperature above 40°C and

central nerve system dysfunction, occurs when body's thermoregulation system fails to remove the excess heat accumulated from metabolic processes and external environment [13-15]. Traditionally, heat stroke has been described in two forms: classic heat stroke (CHS) and exertional heat stroke (EHS). CHS occurs during the summer heat waves, affecting primarily the vulnerable population such as elderly, young children, those with pre-existing diseases, alcoholics, and drug abusers, while the EHS occurs in previously healthy young individuals involved in strenuous physical activities, usually in the heat.

Thermoregulation

During intense exercise, athlete's metabolic rate can increase 15-20 times above resting level. However, only 20-25% of the energy produced is used for muscle work, with the remaining 75-80% released as heat. As a consequence of this process body heat content might be markedly increased. To prevent elevation of core temperature to dangerous level most of the generated heat must be transferred from body's core to the skin surface via circulatory system, and subsequently dissipated to the surrounding environment by means of radiation, convection, conduction and evaporation [9]. Radiation is direct transfer of heat from body into the environment by infrared waves. Convection involves heat loss by air circulating around the body. Conduction refers to heat loss by direct contact with a cooler surface. Evaporation is dissipation of heat through vaporization of sweat from the skin surface.

Of these four heat dissipation mechanisms, the most important during exercise in the heat is evaporation of sweat. In fact, on a hot day, when the temperature of the air exceeds that of the skin surface, evaporation becomes the only heat loss avenue available [9, 16]. However, the ability to dissipate heat through sweating is determined by the water vapor pressure gradient between the skin and the air. At a given ambient temperature when the relative humidity of the air is low, the water vapor pressure gradient between the skin and the air will be large and sweat will evaporate relatively fast, enabling efficient body cooling. High relative humidity at the same ambient temperature, on the other hand, creates lower vapor pressure gradient between the skin and the air which impairs evaporation of sweat from the skin [4, 16]. Thus, although an athlete may experience profuse sweating, a large percent of the sweat will merely drip off the body without any heat loss. At this point, therefore, body's ability to thermoregulate effectively will be significantly compromised. Consequently, exercising under these environmental conditions may result in body heat production in excess of heat loss, a situation which if persists for sufficient period of time can cause core temperature to reach such a critical level that it does not only reduce performance, but also may ultimately

lead to EHS [1, 2, 9, 17].

Predisposing factors for EHS

Although EHS poses a threat to virtually all athletes exercising in the heat, it appears that certain athletes are particularly at risk of becoming heat casualties. Those are athletes who have some medical or physiological condition that can provoke heat intolerance [18, 19]. A comprehensive list of predisposing factors for EHS is shown in Table 1. These factors exert their negative effects mainly through disruption of body's thermoregulation by either impairing heat dissipation process or increasing endogenous heat production [17].

Table 1: Predisposing factors for EHS.

Physiological conditions
Lack of acclimatization
Poor fitness level
Obesity
Dehydration
Sleep deprivation
Generalized fatigue
Glycogen depletion
Medical conditions
Upper respiratory infection
Fever
Diarrhea
Vomiting
Diabetes
Anorexia
Cardiovascular disease
Cystic fibrosis
Hypertension
Previous history of EHS
Healed Burns
Chronic idiopathic anhidrosis
Miliaria rubra
Psoriasis
Scleroderma
Sunburn
Medications and drugs
Alcohol
Anticholinergics
Antihistamines
Beta-blockers
Calcium channel blockers
Diuretics
Laxatives
Salicylates
Stimulants
Sympathomimetics
Monoamine oxidase inhibitors
Neuroleptics
Phenothiazines
Tricyclic antidepressant

Lack of heat acclimation, poor fitness level, obesity, dehydration and current or recent illness are considered to be the most significant predisposing factors for EHS [18, 20]. Sleep loss and generalized fatigue are acknowledged as predisposing factors, and have been implicated in several EHS cases [21]. Skin disorders can seriously compromise evaporative heat loss because of the diminished ability of sweat glands for sweat secretion, and thus lead to EHS [22]. Prior EHS injury can cause heat intolerance for a variable period of time after an incident, and as a result it may increase the risk for recurrence of this illness [4, 23, 24]. Various types of drugs and medications can also contribute to the development of dangerous hyperthermia [5, 7, 13]. Notably, commonly

used performance enhancing substance Ephedra has been associated with a number of adverse health events, one of which is EHS [25].

Recognition of EHS

Any change in athletes' mental status such as confusion, inappropriate behavior or impaired judgment during or shortly after exercise in the heat may indicate the presence of EHS [3, 6, 7], as the brain is especially sensitive to hyperthermia [11]. However, in majority of the cases the onset of EHS is accompanied by a physical collapse and manifestations of central nervous system dysfunction ranging from disorientation to delirium and coma [6, 16, 26, 27]. Other common signs and symptoms include profuse sweating, tachycardia, hyperventilation, hypotension, convulsion, dehydration, vomiting and diarrhea [1, 3, 6].

To confirm the diagnosis of EHS, core temperature must be measured as soon as possible post-incident, and this has to be done via the rectal route [1, 3-7, 26-28]. Skin, oral, aural and axillary routes do not accurately reflect core temperature under the field settings [29, 30], and therefore they should never be used when evaluating the athlete suspected to have suffered from EHS [3]. Rectal temperature reading above 40°C coupled with altered mental status is accepted as diagnostic criteria for EHS [3-7, 27, 31].

Table 2: Differential diagnosis of EHS.

Hyponatremia
Hypoglycemia
Cerebrovascular accident
Heat syncope
Heat exhaustion
Severe dehydration
Drug intoxication
Cerebral injury
Epilepsy
Meningitis
Hysterical reaction
Hypothalamic hemorrhage
Coagulopathies

Apart from EHS, there are a few other medical conditions (Table 2) that can also cause athlete to collapse or present with changes in mental status [1, 7, 26-28], but none of these are associated with extreme hyperthermia, and as such they can be distinguished from EHS by a rectal temperature <40°C. For instance, one such condition that can be initially mistaken for EHS is hyponatremia of exercise [31-33], which is defined as a serum sodium concentration less than 130 mmol/L, and occurs most commonly during the marathon races and ultra-endurance-type events [34]. Misdiagnosis of EHS will result in improper management, which in turn increases the likelihood of a tragic outcome [35].

Treatment of EHS

Once a diagnosis of EHS has been established treatment must follow immediately, focusing on whole-body cooling. Lowering the core temperature to near normal as quickly as possible is crucial, because the damage caused by EHS is directly related to the magnitude and duration of hyperthermia [5, 7, 28, 36, 37]. Thus, for the best medical outcome and in the absence of other life-threatening complications, it is recommended cooling to be achieved on-site prior transferring the athlete to a medical facility [3, 5, 26].

Initially, the affected athlete should be moved in the shade or cooler area and get undressed while preparing for cooling to be initiated. Several whole-body cooling methods have been described in the literature and much debate exists regarding which one is the most effective as well as practical to be employed in the treatment of heat stroke [16, 36, 38]. Nevertheless, so far, the most rapid cooling and the lowest mortality rates have been observed with cold and ice water immersion [1, 3-5, 39]. In the athletic field, this can be done by immersing the athlete's torso and upper legs in a small plastic tub or pool filled with water and ice [40]. In this way, a cooling rate of 0.20°C/min can be achieved, resulting in lowering the core temperature below 39°C within 10-40 minutes [41]. Alternatively, when water immersion is not feasible, athlete should be treated with rapid rotation of ice water soaked towels or by dousing a large amount of tap water on the skin combined with fanning. These forms of cooling have also been shown to be very effective, providing a cooling power comparable to that of water immersion [6, 42]. Along with the cooling treatment 500-1000 ml of intravenous fluid of normal saline should be given [1]. Cooling should be discontinued when core temperature falls to 38°C or the athlete begins to shiver, to prevent hypothermia [1, 4, 27, 28]. Following the initial treatment athlete must immediately be transferred to the appropriate medical facility for further evaluation and monitoring.

Recovery from EHS and return to training

Following an episode of EHS, even with a timely treatment, athlete may experience some organ damage and temporary heat intolerance, which as has been mentioned above, may increase the risk for subsequent EHS incident [4, 23, 24]. Thus, it is essential to ensure that full recovery from EHS takes place before athlete returns to normal training in hot environment [5]. For that purpose, the following guidelines [1, 3, 5, 24, 43] are recommended. First, it is advised that no exercise should take place for at least 1 week following post-hospital treatment, after which athlete should undergo full medical examination. Second, once asymptomatic and all laboratory tests have normalized, athlete may begin exercising in climate-controlled environment while

being closely monitored for potential signs and symptoms of heat illness. Over the course of next 2 weeks the intensity and duration of training sessions as well as heat exposure should be gradually increased in order to re-establish heat acclimatization and fitness level. Third, about 3 to 4 weeks after the EHS episode, athlete should undergo heat tolerance test to assess his/her heat tolerance ability. If the test results are normal, athlete can be cleared for exercising without restriction; otherwise the test should be repeated 4 to 8 weeks later. In general, athletes cooled rapidly soon after the collapse, usually recover completely within a few weeks [5].

Prevention of EHS

The risk of EHS in hot weather can be reduced by scheduling the sporting events during the early morning or evening to avoid the hottest hours of the day. In addition, it is important that athlete is well rested and adequately nourished prior to event and avoids heavy exertion until he/she becomes acclimatized to the surrounding environment. Achieving heat acclimatization, which usually requires 10-14 days of moderate exercise in the heat, is crucial as it helps to counteract the adverse effects of heat stress [3, 4]. Yet this does not make athlete immune to EHS, especially when exercising under the conditions of severe heat and high humidity. In such cases, lowering the exercise intensity, increasing the number or duration of rest breaks and frequently changing the players in team sports are effective measures to limit the body heat gain. Pre-cooling and proper hydration are other strategies that can also provide some protection against hyperthermia by reducing the rate of core temperature elevation [44-46]. Similarly, exercising in clothing that is made of lightweight, breathable and light-colored material allows efficient elimination of heat from the body and reduces solar heat load [9]. Finally, athletes who experience some of the predisposing factors listed in Table 1 should not take part in strenuous exercises.

Conclusion

Exercising in hot and especially humid environment places unusual demand on the mechanisms that regulate body temperature and significantly increase the risk for EHS. Thus, whenever a sporting event is planned to take place under such environmental conditions, adequate measures must be taken to prevent EHS from occurring, and if it does occur, to avoid serious injury and death. Early recognition and rapid cooling are the key factors for a satisfactory outcome.

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