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CARE OF THE WILDERNESS ATHLETE

Medical Evaluation for Exposure Extremes: Heat

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Exertional heat illness can be a serious consequence of sports or exercise in hot environments. Participants can possess intrinsic or face extrinsic risk factors that may increase their risk for heat-related illness. Knowledge of the physiology and pathology of heat illness, identification of risk factors, and strategies to combat heat accumulation will aid both the practitioner and the participant in preparing for activities that occur in hot environments. Through preparation and mitigation of risk, safe and enjoyable wilderness adventure can be pursued.

Key words: heat illness, heat stroke, WBGT, preparticipation examination

Introduction

The ultimate goal of the preparticipation examination is to allow for safe participation in sport and exercise and to screen for predisposing factors that could place individuals at further risk. The preparticipation exam for wilderness and adventure athletes should include specific questions regarding exposure to hot ambient conditions. Of particular interest is history of exertional heat illnesses (EHI), as this is a strong predictor of future EHI. Asking encompassing questions regarding a variety of wilderness athlete-specific circumstances is crucial in ensuring safe athletic participation.

Physical activity and exercise can typically be performed in hot environments without injury; however, individuals who participate in wilderness and outdoor adventure sports are often exposed to variable and prolonged extreme weather conditions, including heat. Individuals exposed to hot ambient conditions for extended periods of time, such as ultraendurance athletes and wilderness hikers, have an increased likelihood of suffering heat-related injuries due to extended periods of time with high internal body temperature. These injuries can range from benign conditions such as heat edema and heat cramps to potentially fatal conditions such as exertional heat stroke (EHS). Definitions[1,2] are as follows:

1. Heat edema: extremity swelling caused by peripheral vasodilation and interstitial pooling
2. Heat cramps: exercise-associated muscle spasms during or immediately after exercise
3. Heat syncope: a transient loss of consciousness due to pooling of blood in the extremities usually after ending exercise suddenly
4. Heat exhaustion: the inability to continue exercise in heat due to exertional heat stress and low central blood volume impairing heat dissipation
5. Exertional heat stroke: extreme exercise-induced hyperthermia, thermoregulatory failure, and profound central nervous system dysfunction

The majority of EHI can be prevented with education, preparation, and purposeful adjustment to hot conditions. Identifying modifiable factors that contribute to heat injuries such as hydration status, wearing improper, excessive or heavy clothing, and sleep loss can assist with prevention. Athletes should be educated to recognize early signs and symptoms of heat illnesses such as fatigue, cramps, nausea, and dizziness so that they may

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take steps to prevent worsening such as increasing rest intervals, seeking shade, ensuring proper hydration, and decreasing activity intensity.

Methods

Multiagency position statements, consensus guidelines, and textbooks as well as the references cited in those documents/texts were reviewed for use in this article. Where possible, the best available evidence was used.

PHYSIOLOGY

Although the human body has remarkable resilience against cold, it can tolerate only minor temperature elevations (9°F) before developing systemic dysfunction, which eventually leads to multiorgan failure and death if body temperature cannot be lowered. The human body has multiple mechanisms to dissipate heat[3]:

1. Evaporation occurs when water vaporizes from the skin and respiratory tract. This is the body's most effective mechanism for dissipating excess heat and is the primary means for athletes exercising in hot environments.
2. Radiation is the emission of electromagnetic heat waves. This energy transfer does not require direct contact or air motion.
3. Convection is the transfer of heat to a gas or liquid moving over the body. Heat dissipation occurs when the gas or liquid is cooler than the body and is especially important to athletes through circulating air, the speed of air circulation, and the amount of body surface area exposed.
4. Conduction is direct heat transfer to an adjacent cooler object.

During exercise, the human body dissipates excess heat generated by the skeletal muscle. This requires an intact cardiovascular system that uses blood to transfer heat from the body core to the skin, where the mechanisms for dissipating heat can take effect. However, when the ambient temperature is higher than the body's internal temperature, convection, conduction, and radiation are no longer effective. Environmental conditions also can affect evaporative cooling. A water vapor pressure gradient must exist for sweat to evaporate and release heat into the environment. In high humidity (relative humidity $>75\%$), evaporation becomes ineffective for transferring heat. Thus, in hot and humid conditions, athletes become susceptible to EHI.

Limitations of heat dissipation in hot and humid weather are exacerbated during intense exercise by a finite supply of blood that must fulfill multiple functions, including meeting metabolic demands of active skeletal muscle and transporting heat to the skin surface for cooling. Dehydration that develops in individuals during intense exercise in the heat further complicates matters by decreasing plasma volume. Studies suggest that during intense exercise in the heat, for every 1 percent of body mass lost from dehydration, there is a concomitant increase in core body temperature of 0.21°C (0.4°F).[4–7] A number of additional factors influence the rate at which a person's internal body temperature rises during vigorous activity including fitness level, hydration status, degree of heat acclimatization, clothing/equipment, and physiologic responses (eg, degree of tachycardia).[8]

Heat stress refers to the environmental and host conditions that increase body temperature, whereas heat strain is the physiological and psychological consequence of heat stress. Heat stress is further categorized as compensable or uncompensable. During exercise, body temperature elevates in response to an increase in metabolic heat production. A modest rise in temperature is thought to represent a favorable adjustment that optimizes physiologic functions to mobilize cooling mechanisms. With compensable heat stress, the body achieves a new steady-state internal temperature that is proportional to the increased metabolic rate and available means for dissipating heat. Uncompensable heat stress results when cooling capacity is exceeded and the athlete cannot maintain a steady temperature.[8] Continued exertion in the setting of uncompensable heat stress increases heat retention, causing a progressive rise in internal body temperature and increasing the risk for severe heat illnesses.

Acclimatization is the body's ability to improve its response and tolerance of heat stress over time, and it is the most important factor that determines how well an athlete withstands extreme heat.[2] Thus, allowing sufficient time and using optimal training strategies that enable athletes to acclimatize are critical for improving performance and mitigating the risk for EHI. Observational studies have found that the first week of athletic practice in high heat and humidity is the period of greatest risk for developing EHI.[9] Full acclimatization requires at least 10 to 14 days of exercise at an intensity that raises body temperature to at least 38.5°C for at least 60 minutes.[10] This can be accomplished in either hot environmental conditions or cooler conditions if clothing or equipment is worn and exercise intensity is high. However, any improved tolerance of heat stress generally dissipates within 2 to 3 weeks of returning to a more temperate environment.[10,11] The major physiologic adjustments that occur during heat and humidity acclimatization include[10]

1. Plasma volume expansion
2. Improved cutaneous blood flow