JAMA Insights

Heat-Related Illness in Athletes

Francis G. O'Connor, MD, MPH; David W. DeGroot, PhD

Heat is a well-studied stressor to athletic performance. At the 2020 Olympic men's marathon in Sapporo, Japan, there was an ambient temperature of 28 °C (82.4 °F) and relative humidity of 72% at the 7:00 AM start, and nearly 30% of participants (30 of 106) were unable to finish.[1] Serious exertional heat illness (EHI) at its extreme causes exertional heat stroke (EHS), with a core temperature generally greater than 40 °C (104 °F) and altered mental status (confusion, delirium, stupor, or unconsciousness), which can cause organ failure and death.[2]

Multimedia

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Symptoms

Before developing EHS, athletes may have heat-related signs and symptoms, including cramping, confusion, ataxia, and collapse. Clinical evaluation reveals elevated core temperature that may be associated with tachycardia, hypotension, heavy sweating, clammy skin, weakness, vomiting, and headaches.[2]

Epidemiology

The incidence of EHI increases as ambient temperature and humidity increase.[2] A systematic review of 62 epidemiological studies reported the incidence of EHI in American football as 4.19 events per 1000 athlete-exposures (1 practice session or competition defines an exposure), and the highest rates occurred in running (pooled mean, 6.74% during competition), cycling, and adventure races.[3] EHI hospitalizations associated with marathon running (26.2 mi [42.16 km]) ranged from 3.0 to 12.9 cases per 10 000 athlete-exposures.[2] Running distances shorter than a marathon may also result in EHS; in 18 consecutive years of the 7-mile (11.3-km) Falmouth Road Race, the mean (SD) EHS rate was 21.3 (16.2) cases per 10 000 athletes.[4]

Risk Factors

Risk factors associated with EHI are shown in the **Table**.[5] Athletes with certain health conditions (eg, diabetes, cardiovascular disease) should consult their physician prior to endurance training. In addition, acute disorders (eg, diarrheal, viral illness) adversely affect heat tolerance and increase EHI risk.

Prevention

During recreational activities or training, slowing down is often sufficient to mitigate heat stress, while avoiding exercise may be required in severe heat and/or humidity. Athletes should alert medical staff or coaches immediately if severe exhaustion, lightheadedness, or other concerning symptoms develop in themselves or another athlete. Coaches and event staff should monitor athletes for signs and symptoms suggestive of EHI, particularly altered mental status and ataxia.

In athletic competition, the intensity of effort might approach the limits of heat tolerance, so additional measures to mitigate EHI are needed. Leadership and organizational planning are increasingly recognized as important factors in risk mitigation.[6] Organization plans may include moving a sporting event to a cooler location, changing the event to cooler early-morning times, providing rest and hydration breaks, educating staff and athletes about how to avoid and treat EHI, and having an emergency action plan that includes preparation and supplies for rapid cooling of athletes along with activation of the emergency medical system.[6] The wet-bulb globe temperature (WBGT) index assesses heat stress risk by combining the effect of air temperature, humidity, wind speed, and solar radiation. The index can guide rest and fluid replacement needs, with a WBGT of 65 °F (18.3 °C) considered generally safe for all individuals, including those who are not acclimatized; at WBGT greater than or equal to 32.2 °C (90 °F), training should preferentially be suspended and competition requires mandatory breaks.[2] Real-time WBGT, heat stress category, and recommendations are available online.

Acclimatization is the most important strategy to prevent EHI in athletes.[2] Heat acclimatization requires 7 to 14 days with training under a heat stress comparable with the target competition.[2,6,7] At the 2019 World Athletics Championships, acclimated marathon and racewalker athletes had better final standing than those who were not acclimated (mean, 18th vs 28th place [$P = .01$]) and lower peak core temperatures (mean, 39.4 °C vs 39.8 °C [$P = .04$]).[7] Acclimatization results in increased total body water (TBW) and plasma volume, mediated by increased plasma colloid and crystalloid osmotic pressures, secondary to an upregulation of the renin-angiotensin-aldosterone system. Increased TBW with acclimatization facilitates improved sweating efficiency (earlier onset, greater sweat volume, and more hypotonic sweat). Change in TBW, which may approach 2 L to 3 L,

Table. Factors That Contribute to Development of Exertional Heat Illness

Environmental	Individual	Medications	Health conditions	Behavioral
• Warm-hot weather • Heat wave, defined as >3 d of temperature >32 °C (90 °F) • Heavy clothes, equipment, or uniforms	• Age (infants, older adults) • Overweight or obesity • Poor physical fitness • High work to rest ratios • Inadequate acclimatization • Heat stress in prior 1-3 d • Poor hydration (before and during activity) • History of exertional heat illness	• Diuretics • Anticholinergics • β-Blockers • Antihistamines • Antidepressants • Laxatives • Stimulants (amphetamines, cocaine, ecstasy, ephedra)	• Viral or bacterial infections • Fever • Diarrhea • Vomiting • Skin disorders (rash, large area of burned skin, eczema, psoriasis) • Diabetes • Cystic fibrosis • Cardiovascular disease	• Self-imposed motivation to excel • Leadership or organizational structure that do not prioritize athlete well-being • Peer or coach pressure to excel

requires an increase in fluid intake to maintain euhydration during the acclimatization process. Training sessions for acclimatization should last at least 60 minutes per day and induce an increase in core and skin temperatures, as well as stimulate sweating.[2,6,7]

Prevention of EHI includes attention to individualized hydration strategies with the goal of beginning exercise in a euhydrated state. A 2017 National Athletic Trainers' Association position statement recommended that individuals engaging in physical activity lasting less than 1 hour can drink only water; for sessions lasting longer than 1 hour, carbohydrates or electrolytes (or both) may be added to rehydration fluids, especially in extreme heat environments.[8] Three validated estimates of hydration status are first morning urine color assessed with a dehydration urine color chart, thirst sensation, and body weight.[8] Body weight is ideally based on 3 consecutive days of a euhydrated baseline mean; postexercise body weight losses generally require replacement with 100% to 150% of fluid losses, particularly when fluid recovery time is limited (<4 hours before the next practice or competition). Symptomatic exercise-associated hyponatremia, typically due to overhydration with hypotonic fluids, occurs in up to 7% of marathon runners, highlighting the need for education and personalized hydration strategies.[9]

Prevention of EHI also includes use of appropriate clothing, which should be adjusted for individual sports; generally, lightweight, loose-fitting, moisture-wicking fabrics are preferred to enable sweat evaporation. Athletes with higher body weights have proportionally smaller surface area to mass ratios and higher body mass index than athletes with lower body weights, both of which are associated with increased EHI risk.

Management

The cornerstone of EHI management is rapid recognition and cooling, which reduces organ and tissue temperatures and supports tissue perfusion by vasoconstricting blood vessels in the skin and superficial tissues to facilitate the movement of intravascular volume from the peripheral to the central circulation.[2] Early, preferably on-site, and rapid whole-body cooling minimizes morbidity and mortality.[2] A 2020 systematic review analyzing 521 persons with EHS demonstrated 100% survival in those who received rapid cooling (n = 378; >0.15 °C/min) vs 84% survival in those cooled at slower rates (n = 143; <0.15 °C/min).[10] Cold water immersion (2-20 °C) is the best practice with the fastest cooling rates (0.13-0.35 °C/min), though dousing with cold water or applying rotating ice-soaked sheets can also be effective.[2] Although EHS is the most severe form of EHI, the 2023 American College of Sports Medicine's consensus statement includes the identification and management of milder forms of EHI (eg, heat exhaustion).[2]

Conclusion

Elevated WBGT increases the risk of EHI, which can cause organ dysfunction and death. Athletes should prepare for competition by appropriately acclimatizing and having an individualized plan for hydration to ensure both pre-event euhydration and rehydration during and after exercise to optimize performance and recovery. Coaches and competition event staff should have a management plan that identifies dangerous heat stress days, recognizes athletes with EHI, and provides rapid cooling on site to decrease morbidity and mortality from EHS.

ARTICLE INFORMATION

Author Affiliations: Uniformed Services University of the Health Sciences, Bethesda, Maryland (O'Connor); Army Heat Center, Martin Army Community Hospital, Fort Moore, Georgia (DeGroot).

Corresponding Author: Francis G. O'Connor, MD, MPH, Consortium for Health and Military Performance, Military and Emergency Medicine, Uniformed Services University of the Health Sciences, 4301 Jones Bridge Rd, Bethesda, MD 20814 (Francis.oconnor@usuhs.edu).

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