Environmental Heat Illness in Children

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EDUCATIONAL GAP

After completing this article, the reader should understand both the environmental and individual risk factors that contribute to environmental heat illness in general, recognize the presentation of various heat-related illnesses, and be able to properly treat environmental heat illnesses.

OBJECTIVES *After completing this article, readers should be able to:*

1. Describe how the human body and the environment both play a role in the setting of environmental heat illness.
2. List the presenting signs and symptoms of environmental heat illnesses, including heat rash, heat exhaustion, and exertional heat stroke.
3. Explain the danger of leaving children unattended in a parked vehicle.

Environmental heat-related illness consists of a group of illnesses that can affect all individuals, including young children and exercising athletes. Environmental heat-related illness results from several conditions that all occur secondary to exposure to a hot environment. In the adult population, heat illness is known to affect laborers, athletes, soldiers, and anyone else engaged in physical exertion in hot environments. Even infants and toddlers are not immune to the effects of heat illness, in particular if they are left in a hot environment, such as a vehicle, from which they cannot escape. In general, the incidence of heat illnesses increases during the warmer months of the year, and with predicted climate change, the general rate of these illnesses is likely to increase as well. Knowledge of the risk factors is essential, as is recognizing the signs and symptoms of environmental heat illness and quickly initiating proper methods of treatment. For the purposes of this review, the term *athlete* will frequently be used to identify the patient because athletes generally form the largest pediatric/adolescent group affected by environmental heat illness; however, please recognize that any active individual is susceptible to these illnesses, and not just an athlete per se.

PRINCIPLES OF THERMOREGULATION

The same thermodynamic principles govern both hot and cold environments, as the body and its surrounding environment attempt to achieve a state of equilibrium. This occurs primarily through the mechanisms of conduction (direct

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ABBREVIATIONS

EAMC exercise-associated muscle cramp
EHS exertional heat stroke
WBGT wet bulb globe temperature

contact), convection (the fluid movement of air or water across a surface), evaporation (the conversion of a liquid to a gas), and radiation (the transfer of heat between objects not in direct physical contact with each other). Except for evaporation, which contributes only to cooling, the body can either gain or lose temperature through these mechanisms.

As body temperature rises, the body attempts to maintain a normal temperature by dissipating excess heat out into the surrounding environment. Increasing peripheral circulation coupled with the large surface area of the skin allows for more efficient heat transfer, although this mechanism of heat dissipation can only occur when the external ambient temperature is lower than the body temperature. The second and primary mechanism of heat redistribution is for the skin to produce sweat, which then evaporates to produce cooling. An insignificant amount of heat is also lost through the process of pulmonary respiration.

There are several important considerations when discussing environmental heat and the body's physiologic response. The primary issue is the gradient between body temperature and environmental temperature. The larger that temperature difference is, the more drive there will be for heat to move from the warmer area to the relatively cooler area. This means that the body will cool more rapidly as the temperature gets colder and, conversely, will heat up faster as the surrounding temperature gets warmer. A second consideration is the movement, if any, of the surrounding air. Through the process of convection, air that is moving will transfer heat more efficiently compared with still air. A third issue is the level of humidity in the surrounding environment. Higher humidity effectively limits the efficiency of the body's main cooling mechanism—the evaporation of sweat. The final consideration is the direct effect of radiant heating produced by the sun.

INDIVIDUAL RISK FACTORS FOR HEAT ILLNESS

Peripheral circulation and sweat production are the major mechanisms of dissipating excess body heat, and anything that interferes with these processes will increase the risk of heat-related illness. Appropriate levels of hydration and electrolyte balance are needed to produce sweat. Subsequently, dehydration and electrolyte depletion both increase the risk of heat-related illness. (1) Medications that influence circulation (β-blockers), sweat production (antihistamines), metabolism (stimulants), electrolyte levels (diuretics), or hydration status will also increase the risk of heat illness. (1)(2)

Underlying medical conditions, including an acute illness, may increase susceptibility to heat illness if normal physiologic mechanisms are altered. (2) Athletes with sickle cell trait have a higher rate of exertional heat illness, although the exact cause of the association is not well understood. (3)(4)

Children have a larger surface area–to-volume ratio compared with adults and will experience a more rapid increase in core temperature when exposed to a hot environment. In addition, individuals with a large body habitus may gain heat from the environment relatively slower but will also be less efficient at lowering their core temperature if overheated; they will also generate more metabolic heat during physical activity. (1)(2) Children also generate more metabolic heat with physical activity compared with adults, largely due to a lack of economy in terms of their physical motion. (5) It has been demonstrated that children produce less sweat compared with adults, and the core temperature at which sweating starts is higher. (5)(6) In general, children may take longer to acclimate to a hot environment. (7) However, after they are acclimated, their physiologic response to exercise is similar to that of an adult exercising in the same setting. (7)

Acclimation occurs after a period of repeated exposures to a hot environment. Even in athletes who are well-conditioned, the lack of heat acclimation is a risk factor for environmental heat illness. (1)(2) There is a well-documented increase in heat illnesses in adolescent athletes participating in American football (the sport with the highest incidence of heat-related illness) during their preseason, which occurs in August typically. (8)

PREVENTION OF HEAT ILLNESS

The prevention of heat-related illness involves several strategies. The first is knowing when the environmental risk for these injuries is highest, and 2 tools are commonly used for this. The wet bulb globe temperature (WBGT) and the heat index both provide helpful information in assessing environmental heat illness risk, and both have advantages and limitations. Although the WBGT provides more detailed information (ambient temperature, humidity, wind speed, and radiant sun exposure), it is often replaced by the heat index, which is more readily available. Measurement of the WBGT also requires proper equipment and training in proper use. The heat index is a chart, produced by the National Weather Service, that uses both heat and humidity levels to identify increasing levels of risk for heat illness (Fig 1). The heat index may not provide the same degree of on-sight information, however, in particular the radiant effect of sun exposure, shade, wind, and the impact of the playing surface itself, which may be more site-specific. Familiarity with these methods of assessing environmental heat

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure and/or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Figure 1. Heat index. (Image courtesy of the National Weather Service.)

risk is necessary for administrators, health-care providers, and coaches who may be involved in the planning or monitoring of athletic sporting events. (1)(2)(7)

The exercising athlete generates a large amount of internal heat through metabolism. (9) The opportunity for cooling by providing exposure to shade should be encouraged during athletic activity in hot environments. (1)(2) The importance of proper hydration and electrolyte replacement also needs to be emphasized, especially when working with children who may not understand the importance of dehydration in the setting of heat illness or of seeking out hydration opportunities on their own. (1)(2)(7) In general, taking breaks from an activity and encouraging hydration and electrolyte replacement allows the body to periodically "catch up," allowing cooling to occur.

Dressing appropriately for the activity is another important consideration. Light-colored and breathable clothing is ideal in hot and humid environments because such clothing reduces the radiant heating effect from the sun and facilitates the process of sweating. Restrictive clothing may impair the production of sweat and contribute to the presentation of several types of heat-related injuries. (1)(2) In sports in particular, the type of clothing/equipment worn may not be modifiable (ie, football helmets), so allowing the athlete to periodically remove their equipment when appropriate is a helpful strategy to promote cooling.

General physical conditioning and acclimation to the hot and humid environment is a final prevention strategy. Gradually increasing the duration and the intensity of exercise in that environment over 10 to 14 days should be sufficient to reduce the risk of heat illness, although maximum acclimation may take several weeks longer still. (1)(2)(7)

EXERCISE-ASSOCIATED MUSCLE CRAMPS

Although the term *heat cramps* is commonly used, a more accurate term would be *exercise-associated muscle cramps (EAMCs)* because these cramps are not associated with elevated body temperature. (10) The larger muscle groups of the legs are commonly affected, typically during or after bouts of prolonged exercise. (11) Heavy sweating is another commonly associated sign. (10)(12) Risk factors for EAMCs include dehydration and a general lack of conditioning and/or acclimation to the heat. The etiology of these muscle cramps is uncertain, but dehydration, sodium depletion, and muscular fatigue are felt to be possible contributors. (10)

EAMCs are treated with rest, hydration, electrolyte replacement, muscle massage, and stretching. (2)(12) Oral rehydration solutions generally have higher electrolyte concentrations compared with sports drinks, although they may be less palatable. As the etiology of EAMCs has not been firmly associated with electrolyte imbalance, there is not a specific concentration or volume of electrolyte solution that is recommended. These muscle cramps usually resolve quickly with treatment and, fortunately, long-term issues are rare, although soreness in general may persist for several days afterward. After recovery, an athlete can return to their activity, but modification may be needed to prevent recurrence, with an emphasis on general conditioning, nutrition, and hydration strategies. If EAMCs continue to be recurrent, further medical evaluation into other possible conditions, such as metabolic and mitochondrial myopathies as well as conditions that affect electrolyte balance, should be considered. (12)

MILIARIA (HEAT RASH)

Miliaria, commonly known as heat rash or prickly heat, occurs secondary to the occlusion of sweat glands, which traps sweat beneath the surface of the skin. (13) This can occur in areas of skin folds, such as the neck, groin, and axillae, or from the wearing of restrictive clothing.

The signs and symptoms of miliaria include a visible rash on the skin that is often accompanied by intense itching. The appearance of the rash can vary, depending on how deeply the sweat glands are occluded (Fig 2). Miliaria crystallina is the mildest form and affects only the top layers of skin. The rash consists of pinpoint red bumps or tiny, fluid-filled vesicles. A second variation of the rash, miliaria rubra, which is the most common form, appears as erythematous papules. (13) Occasionally, the sweat leaks out of the obstructed duct and into the surrounding tissue, which forms skin-colored papules known as miliaria profunda. (13)

Treatment of this rash is conservative, regardless of which type of rash is actually present. The primary intervention is to allow the skin to cool by removing any restrictive clothing and getting the athlete out of the hot/humid environment. A variety of topical or oral anti-itch remedies can be used to treat the itching. The rash typically responds to conservative management and does not have any long-lasting effects, although rarely anhidrosis in the affected area can occur secondary to the obstruction of the sweat glands. (13)

Activity or equipment modification is usually needed if this rash is diagnosed. Prevention strategies include modification of clothing (eg, changing to light, breathable, and/or loose-fitting clothing) as able, allowing equipment to be periodically removed as appropriate, or allowing for more frequent cooling breaks. Additional helpful strategies focus on general conditioning and acclimation, which often helps reduce the recurrence of this rash. (13)

HEAT EXHAUSTION

Heat exhaustion is an indication of impending failure of the body's cooling mechanisms. Failure to recognize and address the signs and symptoms of heat exhaustion ultimately leads to the more serious condition of heat stroke. Symptoms of heat exhaustion include nausea, fatigue, and dizziness. The physical signs of heat exhaustion can include muscle cramping, vomiting, and an elevated temperature (although $<104°F$ [$<40°C$]), tachycardia, and low blood pressure. (1)(2) The skin is often flushed and sweaty appearing. Mental status changes are not usually seen in heat exhaustion but if present may include mild confusion. Signs and symptoms of particular concern include hyperthermia and neurologic and/or mental status changes, as these are associated with exertional heat stroke (EHS). (1)(2)(7)

Treatment of heat exhaustion involves active cooling and hydration, ideally in a cooler environment. Cooling of the body can be accomplished by fanning, which will increase the efficiency of sweating/evaporation. (15) Placing cool/moist towels or ice packs in strategic locations such as the forehead, armpits, or groin is another way to produce cooling. (15) Oral rehydration, ideally with a source of glucose and electrolyte replacement, is necessary to treat dehydration and provides an internal source of cooling. Vital signs and clinical symptoms need to be closely monitored. The symptoms of heat exhaustion improve fairly rapidly in

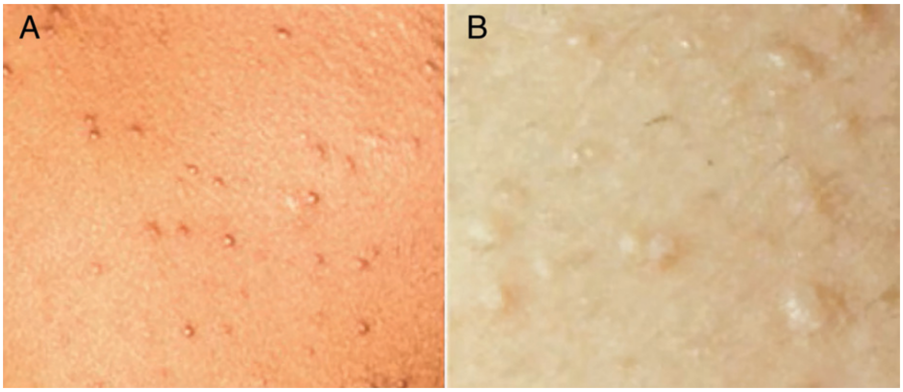

Figure 2. Miliaria. A, Miliaria rubra. B, Miliaria crystallina. (Reprinted with permission from the Mayo Foundation for Medical Education and Research. All rights reserved.)

most situations but may take several hours. A lack of clinical improvement or any deterioration of symptoms should prompt emergency referral to a health-care facility. Eventual resumption of activity requires careful consideration of the events that led to heat exhaustion in the first place. Returning to the activity on the same day is not recommended. (1)

HEAT STROKE

Heat stroke of any cause is a medical emergency and is the result of thermoregulatory failure. EHS (defined as a core temperature greater than 104°F [>40°C] combined with central nervous system changes) is associated with physical activity in hot environments, and, being preventable, it is the end result of a lack of appropriate preparation and prevention strategies and/or a lack of recognition and intervention when the signs and symptoms of heat exhaustion were present.

EHS is encountered in the setting of strenuous exercise in a hot and/or humid climate. Core temperature will be elevated (usually >104°F [>40°C]), and the athlete will usually have other clinical signs/symptoms seen with heat exhaustion. In addition to the hyperthermia, any neurologic or mental status changes, including irritability, confusion, bizarre behavior, or a loss of consciousness, are also of significant concern. Note that the symptoms of heat exhaustion and EHS exist on a spectrum; it the presence of the elevated core temperature combined with central nervous system changes that differentiates the 2 conditions. In the proper setting, hyperthermia and alteration of mental status should prompt the provider to make the diagnosis of EHS. (1)(2)

There are several pathologic mechanisms that occur in a case of heat stroke. There is denaturation of proteins and disruption of normal cell structure and function secondary to the elevated core temperature. This leads to multisystem organ damage, with most organ systems potentially being affected. Heat stroke prominently affects the cardiovascular, neurologic, gastrointestinal, renal, muscular, and hematologic systems. (16) Additional pathologic issues arise from the release of inflammatory cytokines and the creation of microemboli after activation of the coagulation cascade. (17) Some of these end-organ effects may not be evident until hours or even days after the initial injury has occurred.

EHS is a medical emergency, and as is true with all medical emergencies, rapid assessment of the airway, breathing, and circulation is needed. If possible, the athlete should be moved to a cooler environment. The athlete's temperature should be measured, and although a rectal temperature provides the most accurate core temperature measurement, it may not be practical, or even possible, depending on the setting. If EHS is diagnosed, or even suspected, treatment should not be delayed. Immediate and rapid cooling of the body is needed, which can be accomplished by several potential methods. (14)(15)(18)

In the prehospital setting, ice water immersion provides the most rapid method of cooling an athlete with EHS and, if available, is the preferred method of treatment. (14)(15)(18) However, this method may not always be readily available and comes with some risk, especially in the case of an unconscious athlete. As some degree of alteration of mental status is common in EHS, close monitoring of the airway is needed when placing the athlete into an ice water bath. (19) An alternative method to produce rapid cooling involves dousing the athlete with cold water and aggressively fanning them to increase evaporative heat losses. (14)(15)(18) Placing cooling packs in close proximity to major blood vessels (neck, axillae, groin) does produce cooling of the core, but it should be noted that this is a less efficient cooling strategy compared with the previous 2 methods. (14)(15)(18) Although it can be helpful in cases of heat exhaustion, cold packs should not be used in isolation to treat EHS unless no other methods of cooling are available. (15) Active cooling can be stopped when core temperature drops below 102°F (<38.9°C). (14) Because active cooling is the most important aspect of treatment for EHS, the principle of "cool first, transport second" should be followed. (14) In other words, cooling should not be stopped until an appropriate core temperature is reached, even if emergency medical services arrives on the scene to transport the patient to a medical facility. Active cooling cannot usually be continued while in transport, and delays in treating an elevated core temperature are associated with poorer outcomes. (14)(16)

In a hospital setting, additional treatment modalities for EHS could include placement of an intravenous catheter and administration of fluids and electrolyte replacement. Cardiac and blood pressure monitoring are necessary due to the circulatory effects of heat stroke in general. The patient will need ongoing monitoring for several days after the heat stroke is treated due to late, end-organ effects primarily involving the kidneys and liver.

After a case of EHS, the athlete will need medical clearance before returning to activity. (20) All clinical symptoms of the heat stroke should be resolved, and any abnormal laboratory tests should have returned to normal. Generally, a several-week period of gradually increasing levels of activity should be initiated, starting in an indoor (climate-controlled) environment, and progressing back to the hot environment over time. (2) Assuming that no ongoing issues are present, the athlete should be able to resume normal routines once this process is complete. Any lingering effects may require specialty consultation to aid in return-to-activity decision-making. As is true with cases of heat exhaustion, careful consideration should be given to the chain of events that lead to EHS.

VEHICULAR HEAT STROKE

Unfortunately, even young children and infants are susceptible to heat stroke, in particular if they are left inside a vehicle during hot weather. On average, 37 deaths occur yearly in children trapped in hot vehicles, and of these, 87% were younger than 3 years. (21) In some cases, children playing in a parked vehicle became trapped in it, but most children were accidently left in the vehicle by a parent or caregiver. (21) Sometimes a child is left in the car intentionally, as the parent plans on returning within a few minutes, but the parent does not realize how quickly the temperature in the car can rise.

The inside of a parked car can heat rapidly, even on days when the ambient temperature is mild. This is largely due to the trapping of radiant energy from the sun, the same phenomenon that heats a greenhouse. For example, even when the air temperature is a comfortable 72°F (22.2°C), the internal temperature of a car parked in the sun can reach 117°F (47.2°C) in less than 60 minutes, with most of that rise occurring in the first 30 minutes. (22) Even if the windows are cracked to allow for some air circulation, or the car was previously cool from running the air conditioner, McLaren and colleagues (22) found that the rate the temperature increases inside of the car was not reduced significantly. Previous studies have shown similar findings. (23)

Health-care providers should provide regular anticipatory guidance to families regarding the danger of leaving children in parked vehicles. Strategies that may help prevent this situation would be placing personal items, such as a handbag, in the back seat, which will force the driver to access the back seat before they leave the vehicle. Many newer vehicles also have a safety mechanism that senses weight in the back seat and alerts the driver to check the back seat when the vehicle is turned off.

Summary

1. An elevated core temperature above 104°F (>40°C) and changes in mental status are the primary presenting symptoms of exertional heat stroke (EHS). (2) (Level of Evidence A: consistent, high-quality, patient-oriented evidence).
2. Cold water immersion is the most effective method to reduce core temperature in a prehospital setting. (17)(18)(21) (Level of Evidence A: consistent, high-quality, patient-oriented evidence).
3. Delayed recognition and/or insufficient treatment of EHS can result in medical complications, including death. (19) (Level of Evidence A: consistent, high-quality, patient-oriented evidence).
4. Physical activity should be modified or canceled when the risk of environmental heat illness is high. (1)(2) (Level of Evidence B: inconsistent or limited patient-oriented evidence).
5. Children should never be left alone in a parked vehicle for any length of time due to the risk of heat stroke. (22) (Level of Evidence A: consistent, high-quality, patient-oriented evidence).

ADDITIONAL READING

For additional reading on heat illness in the athletic population, please reference: Environmental injury: heat. In: *The Youth Athlete: A Practitioner's Guide to Providing Comprehensive Sports Medicine Care*. 1st ed. Philadelphia, PA: Elsevier; 2023.

Take the quiz! Scan this QR code to take the quiz, access the references, and view and save images and tables (available on December 1, 2024).

PIR QUIZ

1. The principles of thermodynamics apply to hot and cold environments. These principles allow the body to achieve a state of equilibrium when impacted by environmental conditions. Which one of the following mechanisms has only a cooling effect?
   - A. Concentration.
   - B. Conduction.
   - C. Convection.
   - D. Evaporation.
   - E. Radiation.
2. A pediatrician is reviewing the risk factors for heat illness with a group of medical students. Among the individual risk factors for heat illness, certain medications may increase heat illness risk. Which one of the following classes of medications is most likely to exacerbate heat illness?
   - A. Antibiotics.
   - B. Antihistamines.
   - C. H2 blockers.
   - D. Leukotrienes.
   - E. Nonsteroidal anti-inflammatory drugs.
3. A family is planning a hiking trip to the Grand Canyon. The caregivers ask their children's pediatrician about the risks of hiking in hot weather on their children. Which one of the following is the most accurate statement about the physiologic responses of children and adults to heat exposure?
   - A. Adults experience more rapid increase in core temperature than children.
   - B. Adults take longer than children to acclimatize.
   - C. Children begin sweating at a lower core temperature than adults do.
   - D. Children generate more metabolic heat with physical activity.
   - E. Children produce more sweat than adults.
4. A 15-year-old boy develops lightheadedness, leg cramps, and mild confusion during a preseason football practice. The temperature at the beginning of practice was 86°F (30°C) with 90% humidity. The boy is removed from practice and evaluated by the team athletic trainer and has a temperature of 103°F (39.4°C) and a heart rate of 120 beats/min. Which one of the following diagnoses best explains the boy's symptoms and vital signs?
   - A. Exercise-associated muscle cramps.
   - B. Heat exhaustion.
   - C. Heat stroke.
   - D. Hyponatremia.
   - E. Myocarditis.
5. A 14-year-old girl develops signs and symptoms of heat stroke at soccer practice. Which one of the following is the most effective next step in management?
   - A. Applying ice packs to the neck, axillae, and groin.
   - B. Dousing the athlete with cold water and aggressively fanning her.
   - C. Immediate transport by emergency medical services.
   - D. Oral hydration with cold electrolyte solution.
   - E. Oral hydration with ice water.

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