Osteopathic Family Physician (2013) 5, 200–207

ELSEVIER

acofp Osteopathic Family Physician

Exposure injury: Examining heat- and cold-related illnesses and injuries

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KEYWORDS:
Exposure injury;
Cold-related illness;
Heat-related illness;
Heat exhaustion;
Heat stroke;
Hypothermia;
Frostbite;
Miliaria;
Pernio;
Chilblains

Abstract Heat- and cold-related illnesses represent a broad spectrum of preventable common conditions affecting diverse populations every year. Clinicians treating patients near areas of outdoor recreation and nursing homes or who potentially see critical pediatric, indigent, or intoxicated patients can benefit from a better understanding of exposure injuries. Heat-related illnesses include the continuum of heat rash, heat cramps, heat exhaustion, and the potentially deadly heat stroke. Cold-related illnesses encompass a broad array of conditions ranging from soft tissue injuries like pernio, trench foot, and frostnip to the more severe effects of frostbite and hypothermia. The majority of patients with severe environmental exposure would usually present to an emergency or urgent care center; however, milder acute cases and more subtle chronic presentations would generally first be seen by a primary care physician. With any temperature-related illness, the family physician's role should most importantly include identification of at-risk populations and promotion of proper preventative strategies allowing early symptom recognition and rapid treatment.

Thermoregulation

Heat exchange between the body and the environment is accomplished in 5 ways—evaporation, conduction, radiation, convection, and respiration. Ambient features such as humidity and temperature, as well as heat index and wind chill, create a contrast with the body temperature, thus greatly influencing to what extent and velocity heat is lost or gained. Additionally, medications may predispose a patient to significant temperature alterations (Table 1). Evaporation is the most effective method by which humans dissipate heat via perspiration. In optimal conditions, the average individual can dissipate 600 kcal/h and produce up to 1-2 L of sweat per hour.[1,2] Conduction relates to the direct transfer of heat from a warmer surface to a cooler surface. The amount of heat exchanged is directly proportional to the temperature gradient and surface area contacted. For example, the larger the surface area submerged during cold-water immersion, the more the heat dissipated. Similarly, radiation is the direct transfer of heat into the environment. It is the second most effective method of dissipating heat; however, it is largely dependent on the ambient temperature being below body temperature. Because children have a greater relative surface area-to-mass ratio, more heat is absorbed via radiation than any other source.[1] This becomes particularly important in preventing heat-related illness, especially in children and adolescents, as light-colored clothing reflects more radiant energy thus absorbing less heat. Convection depends on air flow around the body to produce a heat gradient. This can be generated from movement through the environment as with cycling or running or can be dependent on wind current. Air-conditioning, fans, and loose-fitting clothing contribute to increased heat loss via convection.[3] In a better-protected

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http://dx.doi.org/10.1016/j.osfp.2013.04.002

Table 1 Medications that interfere with thermoregulation

Increase heat production
α-Adrenergic agents
Amphetamines
Beta blockers
Calcium channel blockers
Dietary supplements (ie, ephedra and diet pills)
Diuretics
Illicit drugs (ie, cocaine, heroin, LSD, and PCP)
Monoamine oxidase inhibitors
Thyroid Agonists
Tricyclic Antidepressants
Decrease sweating
Anticholinergics
Antihistamines
Benztropine mesylate
Typical antipsychotics (phenothiazines, thioxanthines, and butyrophenones)
Decrease thirst
Haloperidol

LSD = lysergic acid diethylamide; PCP = phencyclidine.
Adapted from Howe and Boden,[2] Becker and Stewart, and [3] Moran and Gaffin.[9]

individual, such as those in a well-planned mountain expedition, the effects of respiratory heat loss initially dominate, in most cases, because of high altitude air that is typically colder, more windy, and dry. By understanding the various methods through which heat is lost or gained, the family physician can work with athletes, coaches, and trainers, as well as specific populations like environmental workers, caregivers, and the elderly, to provide better education on proper strategies, for example appropriate attire, hydration, and weather conditions, to prevent exposure injury.

The physiological regulation of body temperature involves a complex array of mechanisms controlled by the hypothalamus in response to factors such as heat production, absorption, and dissipation. Increases in the core temperature of less than 1°C (33.8°F) can activate the hypothalamic thermoregulatory response between the spinal cord and peripheral centers in the skin and organs to help maintain core body temperature between 36°C (96.8°F) and 37.5°C (99.5°F).[1,3,4] The primary response to the increased core temperature is peripheral vasodilation, which promotes heat loss and reduces environmental heat gain. The increased epidermal blood flow causes a compensatory drop in splanchnic blood flow to maintain blood pressure.[5] When the core body temperature approaches 40°C (104°F), this physiological response creates an ischemic environment that promotes the release of gut and renal endotoxins, thereby leading to systemic inflammatory cytokine release, coagulopathies, and multiorgan system dysfunction. If not promptly treated, this inflammatory cascade can result in death.[6]

Similarly, yet on the opposite end of the temperature spectrum, prolonged cold exposure causes peripheral vasoconstriction and direct tissue-freeze injury. Under ischemic conditions induced by vasoconstriction, ice crystals form intracellularly (in rapid freezing) or extracellularly (in gradual freezing), causing derangement of cellular proteins, lipids, electrolytes, and hydration, which leads to cytolysis and tissue necrosis.[7] If thawing and refreezing occurs, tissue integrity rapidly deteriorates from ischemia, extravasation of fluids, inflammatory mediator cascade spikes, and thrombi showers.[7] As shivering proceeds, with tissue hypoxia and freeze injury, lactic acid production and muscle-breakdown products develop a metabolic acidosis with impending renal failure with associated hyperkalemia. Furthermore, as the core temperature decreases along the continuum of hypothermia, a hypercoagulable state ensues secondary to direct inhibition of enzymes of the clotting cascade and the temperature-dependent production of thromboxane B_2, thus impairing platelet function and leading to thromboembolism.[8] To further complicate the situation, there is a sequestration of platelets in the splanchnic vasculature, liver, and spleen. As the body temperature falls, blood buffering systems also lose effectiveness. Eventually, muscle fatigue and metabolic dysfunction along with glycogen depletion lead to multiorgan decompensation and extreme temperature drop. Without proper treatment, neurologic decline, cardiopulmonary arrest, and mortality soon occur.

Acclimatization to extreme heat or cold can prevent such reactions from occurring, but typically take several weeks. A gradual increase in physical activity over 8-10 days should provide optimal acclimatization. Children need a longer period of 10-14 days to achieve a similar response.[9] Physiological adaptations to higher ambient temperatures include improved renal function—increased sodium retention and glomerular filtration rate—and enhanced cardiovascular performance.[10] Because of these changes, persons can work, live, and play in more extreme environments than what would normally be tolerated.

Heat-related illness

Heat-related illness is a spectrum of common conditions caused by tissue and physiological changes to higher temperatures, which is largely preventable by simple measures. These conditions range from relatively minor ailments like heat rash or heat cramps, to more serious illnesses like heat exhaustion and life-threatening heat stroke. Currently, heat is the leading cause of weather-related deaths in the United States.[11] Because of physiological differences, access to hydration or air-conditioning, or prolonged environmental stress, at-risk populations for heat-related illness include the elderly, children, athletes, military recruits, and environmental workers. Individuals with heart and lung conditions, mental illness, and those who take medications that may blunt cardiovascular compensation are also at risk. Of the deaths that occur because of heat-related illness, the largest percentage occurred amongst environmental workers, particularly