

Chapter 22

ENVIRONMENTAL EXTREMES: HEAT AND COLD

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INTRODUCTION

Service members on today's battlefield confront a variety of environmental challenges, particularly with the emergence of unconventional, asymmetric, and hybrid warfare. Knowledge of these environmental challenges, as well as strategies to mitigate against the stressors that impact optimal performance and provide an advantage against enemy combatants, are essential for the military medical officer (MMO). This chapter specifically addresses the environmental challenges

of heat and cold exposures as applied to today's warfighter; the focus is on enhancing performance in these settings. Specifically discussed are core definitions applied to these stressors, relevant military history and epidemiology, applicable applied physiology, and detailed prevention strategies. Specific guidance and resources are provided to assist the MMO in identifying and preventing the consequences of environmental stress experienced by combatants.

DEFINITIONS

Common terminologies related to thermal challenges (heat and cold) that confront service members are presented in Exhibits 22-1 and 22-2. First, basic and specific applied physiologic definitions are provided to assist

the MMO in interpreting relevant literature and established military doctrinal guidance. These definitions are followed by terms associated with common medical conditions and injuries in that particular environment.

MILITARY HISTORY AND EPIDEMIOLOGY

Extremes of both heat and cold have always plagued soldiers.¹⁻³ Old Testament authors documented the health risks of wearing heavy body armor in the heat, noting, "when the sun stands still in the heavens," it helps the Hebrews fight the more heavily armored Canaanites. In 400 BCE, in one of the first reliable reports on the effect of heat in military operations, Herodotus described the effects of load carriage, protective clothing, and heat stress during an Athenian and Spartan conflict as both armies were worn out by the "thirst of the sun." In 325 BCE, while returning home from his conquests, Alexander the Great and 40,000 troops were exposed to 2 months of extreme heat and inadequate water. The army arrived home with only 5,000 soldiers remaining. Hannibal lost nearly half his army from cold injury while crossing the Alps from Spain in 153 BCE. The Roman legionary had knowledge of heat illness and associated risk factors, including load carriage, and instituted mitigation strategies: headgear included the capability to insert rushes in the helmet, which were kept wet with water, and noncombatant auxiliaries were utilized to carry supplies and weapons to preserve the legionnaires' strength for fighting.

The principal of heat acclimatization became apparent during the Middle Ages when English King Edward's heavily armored crusaders were defeated by lighter Arab horsemen in one of the final battles of the Crusades; the English loss was attributed to the advantage the native Arabs had by living regularly in the heat.¹ Military environmental casualties and loss of troop effectiveness have remained significant operational concerns in modern warfare; it is estimated that in the early period of World War II in the Pacific theater

of operations, there were over 100 casualties from heat or illness for every combat casualty. In the European theater, between autumn 1944 and spring 1945, 46,000 cases of cold weather injury were reported, and nearly 10% of all injuries were secondary to cold exposure.^{1,2}

Currently, the Armed Forces Health Surveillance Center publishes the Medical Surveillance Monthly Report, an important document for all MMOs to be familiar with. The report regularly provides critical insight into disease trends in the US military. Table 22-1 presents patterns of heat and cold injuries from 2010 through 2014. Clearly, cold injuries were less common than heat injuries during these years.^{4,5}

Unfortunately, recent efforts to mitigate exertional heat stroke casualties have not reduced injury rates. The annual rate (unadjusted) of cases of heat stroke in 2014 was slightly higher than in 2013 and similar to rates in 2011 and 2012. In 2014, the incidence of heat stroke was highest among males and service members younger than 20 years of age, Asian/Pacific Islanders, Marine Corps and Army members, recruit trainees, and combat-specific occupations. Heat stroke rates in the Marine Corps were 50% higher than in the Army, and Army heat injury rates were more than 9-fold those in the other two services. The incidence was 86% higher among males than females.

The rate of cold injuries was higher in 2014 than previous years, despite robust training, doctrine, procedures, and protective equipment and clothing to counter the threat from cold exposure. The Army and Marine Corps accounted for most of the increase in cold injuries from the year before, and like heat injury, the rate was highest among those under 20 years of

EXHIBIT 22-1

HEAT AND COLD APPLIED PHYSIOLOGY TERMINOLOGY

General Thermoregulation Terms

- **Acclimation.** Physiological adaptations to environmental stress that occurs through experimentally induced stressors, eg, exercising in a hot or cold chamber.
- **Acclimatization.** Physiological adaptations to the environmental stress that occur from natural environmental stressors, eg, exercising in a hot and humid, or cold and wet, environment.
- **Habituation.** The diminishing of a physiological response to a frequently repeated stimulus, eg, repeated cold exposure leads to blunted shivering and decreased cold-induced vasoconstriction.
- **Conduction.** Direct heat transfer to an adjacent, cooler object.
- **Convection.** Transfer of heat to a gas or liquid moving over the body. Heat transfer occurs when the gas or liquid is colder than the body. Convective heat loss by water can be large because the convective heat transfer coefficient of water is 25 times more than air.
- **Evaporation.** Occurs when water from eccrine sweat glands vaporizes from the skin. Evaporation is an effective mechanism for dissipating excess heat, associated with a heat loss of 580 kcals/L of sweat.
- **Radiation.** Emission of electromagnetic heat waves; does not require direct contact or air motion.
- **Thermal balance equation.** $S = M - (\pm W) \pm (R + C) \pm K - E$, where S = rate of body heat storage, M = rate of metabolic energy production, W = mechanical work of exercise, R + C = rate of radiant and convective energy exchange, K = rate of conduction, and E = rate of evaporative loss.

Heat Terms

- **Thermotolerance.** Ability to compensate for heat stress and sustain work. Individuals who are unable to sustain heat and whose body temperatures rise faster than others in comparable conditions are heat intolerant. Heat intolerance can be congenital (eg, ectodermal dysplasia); functional (eg, lack of acclimatization); or acquired (eg, infection, prior heat stroke).
- **Heat stress and strain (compensated and uncompensated).** Heat stress refers to the environmental and host conditions that increase body temperature; heat strain is the physiological and psychological consequence of heat stress. Compensated heat stress occurs when heat gain and loss are balanced so that a steady state is reached and work can be maintained; uncompensated heat stress occurs when cooling requirements are exceeded, a steady state cannot be maintained, and physiologic fatigue results.
- **Wet bulb globe temperature (WBGT).** An index developed by the military to calculate overall environmental heat load. The WBGT integrates radiant heat, ambient temperature, and relative humidity.

$$\text{WBGT} = 0.1 \times \text{dry bulb temperature (ambient air temperature)} + 0.7 \times \text{wet bulb temperature (relative humidity)} + 0.2 \times \text{globe temperature (radiant heat)}$$

Cold Terms

- **Cold stress.** Environmental and/or personal conditions that tend to remove body heat and decrease body temperature. Cold stress is frequently measured by the wind chill temperature.
- **Cold strain.** Physiologic and/or psychological consequences of cold stress.
- **Wind chill temperature.** A quantity expressing the effective lowering of the air temperature caused by the wind, especially as it affects the rate of heat loss from an object or human body or as it is perceived by an exposed person.
- **Hypothermia.** A decline of 2°C or 3.6°F in normal human core temperature (37°C or 98.6°F).
- **Rewarming (passive and active).** Passive rewarming is preventing further heat loss. Active rewarming is applying an external or internal (core) source of heat.
- **Rewarming shock.** Vascular collapse during rewarming, secondary to depressed myocardium, vasodilation, and hypovolemia.
- **After-drop.** Further cooling of the body core after removal from cool environment; caused by cool blood from the periphery returning to the core.

EXHIBIT 22-2

HEAT AND COLD INJURY TERMINOLOGY

Exertional Heat Illness

- **Heat exhaustion.** Characterized by the inability to maintain adequate cardiac output due to strenuous physical exercise and environmental heat stress. Other symptoms generally include difficulty continuing with exercise, core body temperature between 101° and 104°F (38.3°–40.0°C), possible dehydration, but no significant dysfunction of the central nervous system (eg, seizure, altered consciousness, persistent delirium).
- **Heat injury.** Characterized by evidence of hyperthermia and possible end organ damage, but without significant neurologic manifestations. Other symptoms generally include a core temperature from 104° to 105°F (40.0°–40.5°C); clinical and laboratory manifestations of metabolic acidosis, rhabdomyolysis, acute kidney injury, and liver failure; and the absence of neurologic findings.
- **Exertional heat stroke.** A multisystem illness characterized by central nervous system dysfunction (encephalopathy) and additional organ and tissue damage (eg, acute kidney injury, liver injury, rhabdomyolysis), as well as a core temperature above 104°F (40°C) measured immediately following collapse during strenuous activity. Central nervous system dysfunction can manifest as a wide range of possible symptoms and signs, including disorientation, headache, irrational behavior, irritability, emotional instability, confusion, altered consciousness, coma, or seizure.

Cold Injury

- **Hypothermia.** Defined as a body core temperature below 35.0°C (95.0°F). Symptoms depend on the temperature. In mild hypothermia, there is shivering and mental confusion. In moderate hypothermia, shivering stops and confusion increases. In severe hypothermia there may be paradoxical undressing, where a person removes their clothing, as well as an increased risk of the heart stopping.
 - Mild hypothermia: 90°F (32°C) – 95°F (35°C)
 - Moderate hypothermia: 82°F (28°C) – < 90°F (32°C)
 - Severe hypothermia: < 82°F (28°C).
- **Frostbite.** Medical condition in which localized damage is caused to skin and other tissues due to freezing.
- **Trench foot.** A nonfreezing medical condition caused by prolonged exposure of the feet to damp, unsanitary, and cold conditions.

TABLE 22-1

THERMAL INJURIES IN ACTIVE COMPONENT SERVICE MEMBERS, 2010–2014

Type of Injury	2010		2011		2012		2013		2014	
	N	Rate*	N	Rate*	N	Rate*	N	Rate*	N	Rate*
Heat stroke	322	2.2	361	2.6	365	2.5	324	2.3	344	2.5
Other heat injuries	2,562	17.8	2,618	18.1	2,293	16.1	1,847	13.1	1,683	12.2
Cold injuries	534	3.8	526	3.7	432	3.1	415	3.0	617	4.5

*per 10,000 person-years

Data sources: (1) Update: heat injuries, active component, US armed forces, 2014. *MSMR*. 2015;22(3):17–20. (2) Nagarajan S. Update: cold weather injuries, active and reserve components, US armed forces, July 2010–June 2015. *MSMR*. 2015;22(2):7–12.

age. In contrast, cold injuries were higher in females than in males across the 5-year period, for reasons that are not completely understood. Since then, increased

efforts in training, equipment, and education among the troops have still not resulted in reduced injury rates due to cold exposure.⁵

MILITARY APPLIED PHYSIOLOGY

Human performance is compromised by extremes of temperature, as well as depth and increased altitudes above sea level. Work efficiency can be reduced at all extremes, and efficiency must be considered in any temperature, altitude, flight, or undersea mission. Understanding the basic principles of applied physiology that contribute to these performance decrements are critical for the MMO, who is frequently called on for the proper interpretation of resources and guidelines that discuss environmental stress. Knowledge of physiology enables the MMO to identify and modify those factors that can be mitigated or leveraged for success in the operational environment, while promoting prevention by educating the individual warfighter as well as the unit leadership.

Heat

Although the human body has remarkable resilience against cold, it can tolerate only minor temperature elevations (up to 9°F) without developing systemic dysfunction, which ultimately leads to multiorgan failure and death, if body temperature cannot be lowered.⁶ Accordingly, the human body has multiple mechanisms to dissipate heat, including convection, conduction, radiation, and most importantly, evaporation (Figure 22-1).

During exercise, the human body acts to dissipate the excess heat generated by 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 core temperature, convection, conduction, and radiation are no longer effective. Environmental conditions also effect 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, service members become susceptible to exertional heat illness.

Limitations on 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 the metabolic demands of active skeletal muscle and transporting heat to the skin surface for cooling. Further complicating mat-

ters is the dehydration that most individuals develop during intense exercise in the heat, which decreases plasma volume. Studies suggest that during intense exercise in the heat, for every 1% of body weight lost from dehydration, there is a concomitant increase in core body temperature of 0.22°C (0.4°F).⁶ In other words, other factors being equal, a service member who loses only 1% of body weight from dehydration during intense exercise in the heat would be 1°C cooler compared to a buddy who loses 6% of body weight. This would equate to a temperature difference of approximately 39°C (102°F) versus 40°C (104°F) at the end of a training session. A number of additional factors influence the rate at which a person's core body temperature rises during vigorous activity, including fitness level, degree of acclimatization to heat, clothing/equipment, use of certain types of nutritional supplements, and physiologic response (eg, degree of tachycardia).

During exercise the body's temperature becomes elevated in response to the increase in metabolic heat production; a modest rise in temperature is thought to represent a favorable adjustment that optimizes physiologic functions and facilitates heat loss mechanisms (as described in Figure 22-1). With compensated heat stress, the body achieves a new steady-state core temperature proportional to the increased metabolic rate and available means

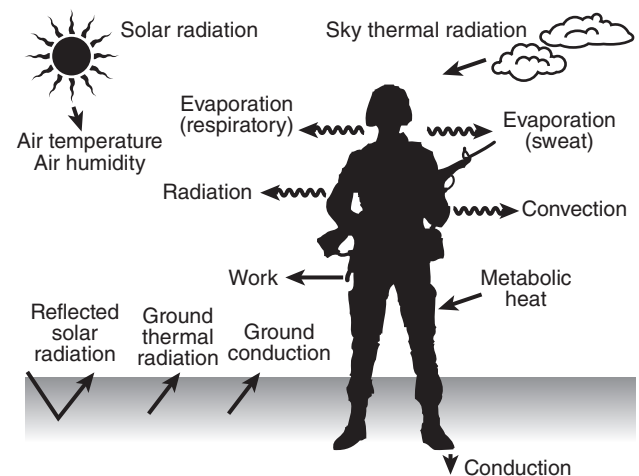


Figure 22-1. Physiological and environmental mechanisms of heat generation and dissipation.

for dissipating heat. Studies in runners describe this mechanism as exercise-induced hyperthermia; runners have demonstrated that they can complete events successfully with significantly elevated core temperatures (103°–104°F) and remain entirely asymptomatic.⁷ Uncompensated heat stress results when cooling capacity is exceeded and the service member or athlete cannot maintain a steady temperature. Continued exertion in the setting of uncompensated heat stress increases heat retention, causing a progressive rise in core body temperature and increasing the risk for severe heat illness.

Service members, unfortunately, do not always have time to properly acclimatize, and may encounter scenarios in which a failure to compensate may result in an exertional heat illness. Body temperature can increase through a number of mechanisms: exposure to environmental heat (impeded heat dissipation); physical exercise (increased heat production); fever from systemic illness (elevated set point with subsequent activation of shivering); and medications that may cause neuroleptic malignant syndrome and malignant hyperthermia.

Importantly, febrile persons have accentuated elevations in core temperature when exposed to high ambient temperature, physical exercise, or both. Environmental temperature and humidity, medication, and exercise heat stress in turn challenge the cardiovascular system to provide high blood flow to the skin, where blood pools in warm, compliant vessels such as those found in the extremities. When blood flow is diverted to the skin, reduced perfu-

sion of the intestines and other viscera can result in ischemia, endotoxemia, and oxidative stress.⁸ In addition, excessively high tissue temperatures can produce direct tissue injury (heat shock: >41°C [105.8°F]).

The magnitude and duration of heat shock influences whether cells respond by adaptation (acquired thermal tolerance), injury, or death (apoptotic or necrotic). Heat shock, ischemia, and systemic inflammatory responses can result in cellular dysfunction, disseminated intravascular coagulation, and multiorgan dysfunction syndrome. In addition, reduced cerebral blood flow, combined with abnormal local metabolism and coagulopathy, can lead to dysfunction of the central nervous system. This situation is an example of uncompensated heat stress, which can severely denigrate a service member's performance, put the individual at risk for significant morbidity and mortality, and compromise the unit's mission.

Cold

As previously stated, the human body is much more resilient against cold and lowered changes in temperature than heat. Despite this hardiness, cold exposure can significantly impact warfighter performance, and ultimately the completion of the mission. The principles of heat exchange discussed above remain the same; however, the MMO must be aware of several additional factors related to cold.

Convection becomes critically important when service members lose significant amounts of heat in windy environments in the absence of protective clothing; the wind chill temperature calculation factors convective heat loss into risk. Convective loss can become even more important when soldiers are exposed to cold water because the convective heat transfer coefficient of water is about 25 times greater than that of air.⁹ Radiant heat loss can become an issue as the sun goes down and service members are exposed to a clear night sky. Conductive heat loss can be a concern with soldiers sleeping on cold ground or snow; heat loss can become even more magnified if clothing is wet. Non-evaporative sweat in cold weather can also lead to wet clothing, decreasing its insulation capacity.

Heat conservation is supplemented by mechanisms to increase heat production. Cold exposure leads to an increase in metabolic heat production, which can help offset heat loss. Body temperature is normally regulated through two parallel processes: behavioral temperature regulation and physiologic temperature

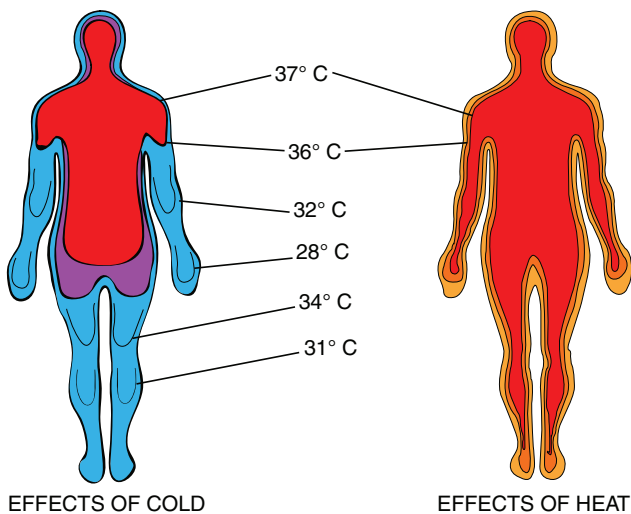


Figure 22-2. Effects of cold exposure on heat conservation (left) and heat dissipation (right).

TABLE 22-2
HUMAN PERFORMANCE STRATEGIES TO MITIGATE HEAT AND COLD INJURY

Environment	Performance Risk Factor or Challenge	Strategy
Heat	Lack of heat acclimatization	Acclimatization strategy (TB MED 507/Air Force Pamphlet 48-152, <i>Heat Stress Control and Heat Casualty Management</i>)
Heat	Lack of aerobic fitness	Improve aerobic fitness (FM 7-22, <i>Army Physical Readiness Training</i>)
Heat	Mismatch of hydration and work/rest	Institution of appropriate work, rest, and hydration guidance (Army Institute of Environmental Medicine/Army Public Health Center work/rest and water consumption table, Table 22-4)
Cold	Lack of cold weather acclimatization	Acclimatization/habituation strategy (Army TB MED 508, <i>Prevention and Management of Cold Weather Injuries</i>)
Cold	Inappropriate environmental clothing	Appropriate clothing (Army TB MED 508, <i>Prevention and Management of Cold Weather Injuries</i>)

regulation. Behavioral thermoregulation includes reducing direct cold exposure using clothing or protective shelter, and increasing physical activity. Unfortunately, mission requirements may prevent these actions, causing service members to rely on the physiologic mechanisms of peripheral vasoconstriction and shivering to preserve body heat. Shivering can be sustained longer than exercise, but exercise results in twice the rate of heat production. Shivering does come with a metabolic cost with an increase in oxygen uptake.

Heat conservation through peripheral vasoconstriction is the principal physiologic mechanism utilized to mitigate cold stress (Figure 22-2). The resulting decrease in peripheral blood flow reduces convective heat transfer from the body's core to the shell (skin, subcutaneous fat, and muscle). This vasoconstrictor response results in a lower skin temperature while preserving the body's core temperature. The vascular shunting of blood from the skin and limbs to the

vital organs, while defending the core temperature, can paradoxically contribute to the etiology of cold-induced injuries.

Multiple individual factors can contribute to modifying the physiologic response to cold.⁹ Individuals with a high body surface area to mass ratio (ectomorphs) lose more body heat than those with lower body surface area to mass ratios (endomorphs). Gender and ethnicity have been demonstrated to be risk factors as well. Females and African Americans have twice the rate of cold injury, which may be secondary to long, slender fingers and a greater body surface area to mass ratio. Fitness and training, which are significant risk factors for heat injury, do not have an effect on cold temperature regulation. However, fatigue is an important militarily relevant risk factor for cold injury and can impair both peripheral vasoconstriction and shivering. Finally, inadequate nutrition can be a key contributor to a risk for cold injury because hypoglycemia can impair the shivering response.

HUMAN PERFORMANCE OPTIMIZATION STRATEGIES FOR EXTREME ENVIRONMENTS

Primary prevention is the cornerstone to optimizing human performance in extreme environments. This section discusses military relevant human performance optimization strategies to assist in preventing injury and optimizing performance among service members. Table 22-2 lists evidence-based strategies, including the targeted risk factor, to optimize warfighter performance in environmental extremes.

Heat Strategies

Tolerance of extreme heat and humidity depends upon a number of functional, acquired, and congenital factors, the most important of which is acclimatization (Table 22-3).¹⁰ Acclimatization is the body's ability to improve its response to and tolerance of heat stress over time. Thus, allowing sufficient time and using

TABLE 22-3
FACTORS UNDERLYING HEAT INTOLERANCE IN THE YOUNG ACTIVE POPULATION

Congenital	Functional	Acquired
Ectodermal dysplasia	Low physical fitness	Sweat gland dysfunction
Chronic idiopathic anhidrosis	Lack of acclimatization	Dehydration
	Low work efficiency	Infectious disease
	Reduced skin area to body mass ratio	X-ray irradiation
		Drugs, supplements
		Large scarred burn areas
		Previous heat stroke

optimal training strategies that enable service members to acclimatize is critical for improving performance and mitigating the risk for exertional heat illness (EHI). Observational studies have found that the first week of training in high heat and humidity, for both service members and athletes, is the period of greatest risk for EHI.^{6,11} Acclimatization requires at least 1 to 2 weeks. However, any improved tolerance of heat stress generally dissipates within 2 to 3 weeks of returning to a more temperate environment. Acclimatization in warfighters is accomplished with a combination of environmental exposure with exercise; the Army/Air Force publication *Heat Stress Control and Heat Casualty Management* (TB MED 507/Air Force Pamphlet 48-152) details optimal acclimatization strategies.⁶

The major physiologic adjustments that occur during heat and humidity acclimatization include expanded plasma volume, improved cutaneous blood flow, lowered threshold for initiation of sweating, increased sweat output, lowered salt concentration in sweat, and lowered skin and core temperatures during a standard exercise.¹² These adaptations allow for better dissipation of heat during exercise and limit increases in body temperature compared to service members who have not acclimatized. Exhibit 22-3 describes the known physiologic benefits of acclimatization. Table 22-4 details current guidance for ground units published by the US Army Institute of Environmental Medicine.⁶ The table’s recommendations are based upon an assessment of the wet bulb globe temperature to determine the heat category.

Improving performance in the heat also leverages many proactive strategies to keep service members cool and mitigate the risk of heat illness. A strategy utilized in the military is “heat dumping,” in which heat is transferred to the environment using techniques such as cool mist showers. One novel intervention used in the military is the arm immersion cooling system (AICS) (Figure 22-3). The AICS is a simple, efficient method for facilitating body (core and skin)

temperature cooling and reducing the risk of serious heat illness. The AICS takes advantage of the rapid rate of heat transfer from the skin directly into cool water (compared to transfer into evaporative sweat or air), and the large surface area to mass ratio of the forearms. Several studies have reported that hand and forearm immersion in cool (50°–68°F) water reduces core and skin temperature faster than a noncooling control, extends tolerance time, and increases total work time.¹³

EXHIBIT 22-3

ACTIONS OF HEAT ACCLIMATIZATION

- Thermal comfort: improved
- Exercise performance: improved
- Core temperature: reduced
- Cardiovascular stability: improved
- Heart rate: lowered
- Stroke volume: increased
- Blood pressure: better defended
- Myocardial compliance: improved
- Sweating: improved
 - Earlier onset
 - Higher rate
 - Redistribution
 - Hydromeiosis resistance
- Fluid balance: improved
- Electrolyte loss: reduced
- Skin blood flow: improved
 - Earlier onset
 - Higher rate
- Total body water: increased
- Metabolic rate: lowered
- Plasma volume: increased and better defended

TABLE 22-4
WORK/REST AND WATER CONSUMPTION TABLE

Work/Rest and Water Consumption Table

Applies to average sized, heat-acclimated Soldier wearing ACU, hot weather. (See TB MED 507 for further guidance.)

Easy Work	Moderate Work	Hard Work
<ul style="list-style-type: none"> • Weapon Maintenance • Walking Hard Surface at 2.5 mph, < 30 lb Load • Marksmanship Training • Drill and Ceremony • Manual of Arms 	<ul style="list-style-type: none"> • Walking Loose Sand at 2.5 mph, No Load • Walking Hard Surface at 3.5 mph, < 40 lb Load • Calisthenics • Patrolling • Individual Movement Techniques, i.e., Low Crawl or High Crawl • Defensive Position Construction 	<ul style="list-style-type: none"> • Walking Hard Surface at 3.5 mph, ≥ 40 lb Load • Walking Loose Sand at 2.5 mph with Load • Field Assaults

- The work/rest times and fluid replacement volumes will sustain performance and hydration for at least 4 hrs of work in the specified heat category. Fluid needs can vary based on individual differences (± ¼ qt/hr) and exposure to full sun or full shade (± ¼ qt/hr).
- **NL** = no limit to work time per hr.
- **Rest** = minimal physical activity (sitting or standing) accomplished in shade if possible.

Heat Category	WBGT Index, F°	Easy Work		Moderate Work		Hard Work	
		Work/Rest (min)	Water Intake (qt/hr)	Work/Rest (min)	Water Intake (qt/hr)	Work/Rest (min)	Water Intake (qt/hr)
1	78° - 81.9°	NL	½	NL	¾	40/20 min	¾
2 (green)	82° - 84.9°	NL	½	50/10 min	¾	30/30 min	1
3 (yellow)	85° - 87.9°	NL	¾	40/20 min	¾	30/30 min	1
4 (red)	88° - 89.9°	NL	¾	30/30 min	¾	20/40 min	1
5 (black)	> 90°	50/10 min	1	20/40 min	1	10/50 min	1

- **CAUTION: Hourly fluid intake should not exceed 1½ qts.**
- **Daily fluid intake should not exceed 12 qts.**
- If wearing body armor, add 5°F to WBGT index in humid climates.
- If doing Easy Work and wearing NBC (MOPP 4) clothing, add 10°F to WBGT index.
- If doing Moderate or Hard Work and wearing NBC (MOPP 4) clothing, add 20°F to WBGT index.

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Table courtesy of the US Army Institute of Environmental Medicine and US Army Public Health Center.

Cold Strategies

Although service members can successfully leverage acclimatization as a strategy to prevent heat illness, strategies for acclimatization are not as well developed as a protective mechanism to combat cold stress. Cold acclimatization manifests in three different patterns of thermoregulatory adjustments: habituation, metabolic acclimatization, and insulative acclimatization. Habituation involves the blunting of both shivering and cold-induced vasoconstriction with prolonged exposure. Studies have demonstrated that short, intense cold exposures (<1 hour) several times a week for 2 to 3 weeks can stimulate a habituation response.⁹ Metabolic acclimatization involves an exaggerated shivering response, while insulative acclimatization involves enhanced heat conservation methods. With insulative acclimatization, cold exposure elicits a more rapid and more pronounced decline in skin temperature and lower thermal conductance at the skin than in the unacclimatized state.

Because acclimatization is not an optimal strategy to mitigate cold stress, other strategies to combat cold stress injuries and optimize performance must be considered. Selected strategies involve avoidance, appropriate work/rest cycles, and **suitable** clothing. Cold-weather clothing is specifically designed to protect against hypothermia by reducing heat loss to the environment (Figure 22-4). Protective insulation is determined by how much air is effectively trapped by clothing. Service members require clothing that can accommodate a range of ambient temperatures and physical activity levels, and that can protect against wind, rain, and snow. This is accomplished by following two important concepts when dressing for activities in the cold: layering and staying dry. Multiple layers of clothing allow air to be trapped to serve as insulation, and allow the individual to adjust layers according to environmental conditions and activity level. Layers can be removed as the ambient temperature or physical activity levels increase,



Figure 22-3. Arm immersion cooling system.

thereby reducing sweating and moisture buildup within clothing. The Army publication *Prevention and Management of Cold Weather Injuries* (TB MED 508)⁹ is



Figure 22-4. Generation III Extended Cold Weather Clothing System. Provides soldiers a multi-layered, versatile insulating system adaptable to varying operational and environmental conditions. March 2, 2010. Army Program Executive Office (PEO) Soldier photo. Reproduced from: <https://www.flickr.com/photos/peosoldier/4777344669/>.

an excellent resource that details the practical prevention of cold weather injuries through the appropriate selection of clothing.

HEAT AND COLD STRESS AND THE MILITARY MEDICAL OFFICER

Role of the Military Medical Officer

MMOs are expected to have scientific background in the physiology of extreme environments, as well as the medical knowledge to provide recommendations for prevention of environmental injuries, to assist in the treatment of such injuries, and to make return-to-duty determinations when restriction from activity or deployment may be essential. Above all, the best treatment strategy for all potential environmental injuries or illness is primary prevention. In addition to leveraging acclimatization, the MMO must be proactive in assessing environmental stress and implementing appropriate work/rest and hydration strategies.

The services systematically approach risk management for environmental stress comparably to approaches for other stresses, utilizing a series of steps.¹⁴ The five steps of risk management—identify the hazards, assess the hazards, develop controls and make risk decisions, implement controls, and supervise and evaluate—are used across the services to help them operate as a joint force and optimize readiness (Figure 22-5).

When leadership identifies an environmental risk of EHI, the risk management process is carefully planned to assess the risk and implement

mitigation strategies. Activities implemented to reduce risk include those previously discussed: education, acclimatization, appropriate adjustment of activities to include work/rest and hydration strategies, and being prepared for early EHI management. Depending upon the degree of assessed risk, leaders of increasing rank are required to review and approve training plans. Arguably the

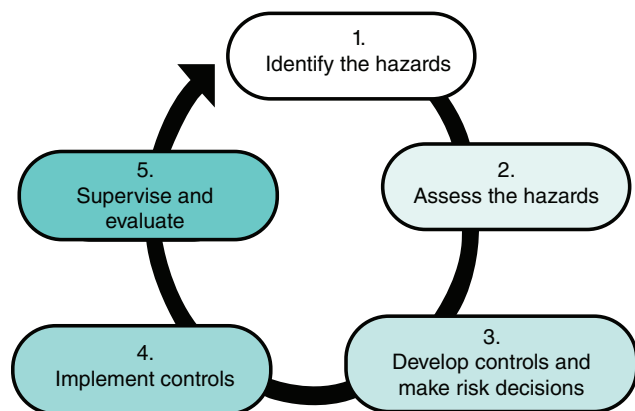


Figure 22-5. The Army risk management process.

military's most important tool in preventing EHI is leadership; all leaders are expected to proactively implement preventive measures to mitigate the threat of heat casualties.

To mitigate the consequences of cold exposure, the MMO should know that physiologic acclimatization to cold stress can occur, but it is generally considered modest at best, and requires more time to develop and is less practical than heat acclimatization. MMOs must review all possible techniques and strategies to minimize cold injuries.

Guidance to the Commanding Officer

Ultimately, MMOs serve in support of the commanding officer, and they must remain aware of issues related to environmental conditions. Developing credibility and trust are key; without them, an MMO will be less effective in mitigating environmental risks. Being aware of individual service member needs, having access to resources for finding new strategies, and identifying realistic countermeasures are important for success.

MILITARY RESOURCES

General

- The Medical Surveillance Monthly Report (<https://www.afhsc.mil/Search/SearchMSMR>) provides evidence-based estimates of the incidence, distribution, impact, and trends of illnesses in service members and associated populations. Annual reports are published on topics such as environmental illnesses, which allow for comparisons of prior year data and assessment of preventive strategies.

Heat

- The US Army Public Health Command Heat Injury Prevention website (<http://phc.amedd.army.mil/topics/discond/hipss/Pages/HeatInjury-Prevention.aspx>) provides heat casualty prevention information such as the Composite Risk Management for Heat Injury Prevention, Identification, and Response, FY 2010.
- The US Army Research Institute of Environmental Medicine (<http://www.usariem.army.mil/>) has additional resources such as the Ranger & Airborne School Students Heat Acclimatization Guide.
- Commanders and healthcare providers in the Army and Air Force should use TB MED 507/ Air Force Pamphlet 48-152, *Heat Stress Control and Heat Casualty Management*,⁶ to develop a comprehensive heat illness prevention program. This program should be complemented

with Army risk management doctrine, as detailed in FM 5-19, *Composite Risk Management*. These documents provide the framework for early recognition of climatic injuries and implementation of preventive measures.

- The US Army Training and Doctrine Command has published regulations providing guidance to commanders for prevention of heat casualties in TRADOC Regulation 350-29, *Prevention of Heat and Cold Casualties* (<http://www.tradoc.army.mil/tpubs/regs/tr350-29.pdf>).
- Navy medical personnel can find guidance on the management of exertional heat illness published by the Bureau of Medicine and Surgery. Current policy is identified in Technical Manual NEHC-TM-OEM 6260.6A, *Prevention and Treatment of heat and Cold Stress Injuries* (<http://www.med.navy.mil/sites/nmcphc/Documents/policy-and-instruction/oem-prevention-and-treatment-of-heat-and-cold-stress-injuries.pdf>).

Cold

- Cold Injury Prevention (Army Public Health Center [Provisional] webpage: <https://phc.amedd.army.mil/Pages/default.aspx>).
- Army TB MED 508, *Prevention and Management of Cold Weather Injuries*,⁹ a quintessential military resource detailing guidance on cold injury, was published in 2005 and supersedes TB MED 81/NAVMED P-5052-29/AFP 161-11, 30 September 1976.

SUMMARY

This chapter has introduced the basics of optimizing service member performance in hot or cold operational settings. Specifically, the historical relevance of the environment to success in military operations, the basic applied physiology relevant to

understanding the warfighter in the environment, and evidence-based strategies demonstrated to preserve performance in environmental extremes are discussed. The MMO operates in a unique setting with limited resources, where urgency and proper

planning can mark the difference between success and failure on the battlefield. It is important to remember that MMOs serve not just to treat wounded, but also

to provide guidance to the commanding officer to optimize the unit's performance and ultimately support mission success.

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