STANDARDS-RELATED DOCUMENT

SRD-1 to AJMedP-4

HEAT STRESS CONTROL AND HEAT CASUALTY MANAGEMENT

EDITION A VERSION 1

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NATO LETTER OF PROMULGATION

23 May 2025

1. The enclosed Standards-Related Document, SRD-1 to AJMedP-4, Edition A, Version 1, HEAT STRESS CONTROL AND HEAT CASUALTY MANAGEMENT, which has been approved in conjunction with AJMedP-4 by the nations in the Military Committee Medical Standardization Board, is promulgated herewith.

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TECHNICAL BULLETIN, MEDICAL

HEAT STRESS CONTROL AND HEAT CASUALTY MANAGEMENT

HEADQUARTERS, DEPARTMENT OF THE ARMY

12 APRIL 2022

This bulletin supersedes TB MED 507/AFPAM 48–152(I), dated 07 March 2003.

SUMMARY of CHANGE

TB MED 507
Heat Stress Control and Heat Casualty Management

This major revision, dated 12 April 2022 —

- o Modifies the roles for unit commanders, medical officers, safety officers, medics, and Service members in the mitigation of exertional heat illness (paras 1–4*a* through 1–4*f*).
- o Incorporates Army Directive 2018 – 07 – 11, Prioritizing Efforts—Readiness and Lethality (Update 11) (para 1–4*b*).
- o Updates environmental guidance about recent operation locations for heat stress in military operations (paras 2–1*a* through 2–1*c*).
- o Adds new figure to show the overall frequency and weekly distribution of heat exhaustion over a 5-year period (fig. 2–1).
- o Renumbers Figure 2–1 (Energy (heat) transfer of a Service member performing physical work in a hot environment) as Figure 2–2.
- o Updates guidance on metabolic heat production and energy expenditure related to body heat storage (para 2–2*b*(1)).
- o Adds new paragraph to address evaporative heat loss in hot environments (para 2–2*b*(5)).
- o Updates wet-bulb globe temperature index (paras 2–2*c* through 2–2*e*).
- o Amends paragraph to add tolerable body core temperatures (para 2–3*b*).
- o Adds new figure to illustrate the effect of measurement location on wet-bulb globe temperature index (fig. 2–3).
- o Amends paragraph to add the typical range for skin temperature (para 2–3*c*).
- o Adds new paragraph to address combined effects of heat stress on endurance exercise (para 2–3*g*).
- o Adds new paragraph for nomogram use for temperature and load carriage during self-selected paces (para 2–3*h*).
- o Adds new figure to show independent and combined effects of environmental heat stress on a self-paced endurance task equivalent to a 2-mile run or 3-mile march (fig. 2–4).
- o Adds new figure to provide a trade-off analysis performance nomogram (fig. 2–5).
- o Updates guidance on cognitive performance in the heat (paras 2–4*a* and 2–4*b*).
- o Updates guidance on heat acclimatization (paras 2–5*c* and 2–5*d*).

- Adds new paragraph for the impact of heat acclimatization on heat tolerance, work capacity, and risk for exertional heat illness (para 2–5*f*).

- Adds new table to outline generalized heat acclimatization strategies (table 2–1).

- Provides additional guidance for field measurements of body core temperature as a means of assessing heat strain (paras 3–2*c* through 3–2*g*).

- Adds new table to report the mean absolute difference between rectal and other device temperatures measured in healthy people during vigorous and prolonged outdoor exercise (table 3–1).

- Adds new workload category (very heavy work) criteria (paras 3–3*b*, 3–3*c*, and 3–6*j*).

- Adds new figure to show the comparison between military and sports medicine wet-bulb globe temperature index categories (fig. 3–3).

- Adds new figure to present historical weather data from Fort Benning, Georgia (fig. 3–4).

- Adds new figure to show the comparison of body heat storage rates during a 12-mile march with training modifications (fig. 3–5).

- Provides additional guidance for body cooling strategies (paras 3–4*a* through 3–4*g*).

- Adds new figure to illustrate body cooling methods for the prevention and treatment of exertional heat illness (fig. 3–6).

- Adds new section to address aviator heat stress (paras 3–5*a* through 3–5*d*).

- Adds new table to outline the fighter index of thermal stress for lightweight flight suit (table 3–4).

- Provides additional details for fluid replacement during heat stress (paras 3–6*a* through 3–6*g*).

- Provides guidance on using the Soldier Water Estimation Tool (SWET) for logistical water planning (paras 3–6*b* and 3–6*g*).

- Adds new figure to report the 2017 analysis results of accumulated differences between water intake and measured sweat losses after 4 hours of activity (fig. 3–7).

- Adds new figure to show screenshots of the five required inputs and the mission planning tool calculator (SWET) (fig. 3–8).

- Adds new table to outline hydration optimization strategies (table 3–6).

- Provides guidance on hyponatremia/water intoxication (paras 3–7*h* through 3–7*j*).

- Amends paragraph to indicate there is no direct progression between moderate and severe exertional heat illnesses (para 4–1*b*).

- Updates statistics for the incidence and severity of exertional heat illness (paras 4–2*a* and 4–2*b*).

- Adds new table to identify individual and environmental risk factors for exertional heat illness (table 4–1).

- Renumbers Table 4–1 and adds medications to the table that could increase the risk for heat illnesses (table 4–2).
- Renames paragraph title from heat stroke to exertional heat stroke (para 4–6).
- Relocates guidance for fluid and electrolyte imbalances from para 4–7 into chap 3 (paras 3–6 and 3–7).
- Adds new table that lists commonly measured exertional heat stroke analytes and their recovery time course (table 4–4).
- Inserts new paragraphs for exertional rhabdomyolysis (para 4–7).
- Adds new table to identify potential factors contributing to exertional rhabdomyolysis (table 4–5).
- Adds new “Chain of Survival” guidance for the management of heat casualties (chap 5).
- Adds new “Chain of Survival” guidance for the Emergency Response System (chap 5).
- Adds new “Chain of Survival” guidance for advanced medical treatment facility support (chap 5).
- Provides additional guidance on body cooling (para 5–1*b*).
- Adds new figure to show treatment mock-up of cooling deck (fig. 5–2).
- Adds new figure to illustrate rectal temperature cooling rate (fig. 5–3).
- Adds new table to outline recommended use of ice sheets in the treatment of suspected exertional heat illness (table 5–2).
- Adds new section for considerations for other heat-related conditions (paras 5–4*a* through 5–4*d*).
- Adds new table to provide a framework to identify different types of collapse of a Service member (table 5–3).
- Adds new section for return to duty (paras 5–5).
- Adds new section for surveillance, recordkeeping, and reporting (paras 5–6*a* through 5–6c).
- Adds new table that lists ICD-10 codes for exertional heat illness conditions (table 5–4).
- Removes Appendix C (Hot Weather Deployment Tips).
- Renumbers and renames Appendix D to read Appendix C (Commander’s, Senior NCO’s, and Instructor’s Guide to Risk Management for Prevention of Heat Casualties.
- Provides additional details for the heat injury prevention risk assessment process (app C).
- Removes Appendix E (Preparation of 0.1 Percent Salt Water Drinking Solution).

Army Technical Bulletin, Medical

TB MED 507
HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, DC, 12 April 2022

HEAT STRESS CONTROL AND HEAT CASUALTY MANAGEMENT

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*This bulletin supersedes TB MED 507/AFPAM 48–152(I), dated 7 March 2003.

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CHAPTER 1

INTRODUCTION

1–1. Purpose
This bulletin provides guidance to U.S. and allied military and civilian leaders, safety and occupational health professionals, unit safety officers, and healthcare providers to—

a. Develop an evidence-based preventive program to protect military personnel from heat stress and associated adverse health effects.

b. Understand the diagnosis and treatment of exertional heat illnesses including heat exhaustion (HE), exertional heat injury (EHI), and exertional heat stroke (EHS).

c. Understand the physiological responses and adaptations to heat stress (chapter 2).

d. Implement procedures for managing heat stress (chapter 3).

e. Understand the epidemiology and pathophysiology of exertional heat illnesses (chapter 4).

f. Implement treatments for exertional heat illness (chapter 5).

g. Understand the effect of fluid and electrolyte imbalances (chapter 3).

h. Understand the proper use and interpretation of the wet bulb globe temperature (WBGT) index as it relates to work-rest cycles (chapters 2 and 3).

i. Mitigate exertional heat illness during training and deployment (appendix C).

j. Provide background information for reporting and data collection of epidemiological information to note trends and to identify individual, work, and environmental factors that are not adequately controlled by preventive measures and policies (chapter 5).

1–2. References
See appendix A.

1–3. Explanation of abbreviations and terms
See glossary.

1–4. Roles

a. There should be coordination among unit commanders, medical officers, safety officers, public health personnel, and medics, to implement exertional heat illness educational and training programs at all levels in the command based on the principles of this document. They should review all training and operations annually to make sure adequate planning is made for emergency medical support and exertional heat illness assessment and management where tactically feasible.

b. Unit commanders—

(1) Integrate the medical officer into all unit staff functions where guidance is needed to assess and mitigate the risk of exertional heat illness (see Field Manual (FM) 6–0).

(2) When required during deployment activities, ensure the establishment, manning, training, and equipping of unit field sanitation teams at the company level, or obtain field sanitation team support from another unit, to train individuals and their leaders in personnel protective measures against heat illness, recognition of signs and symptoms, and treatment of heat illness (see Army Regulation (AR) 40–5, Department of the Army Pamphlet (DA Pam) 40–11, and Training Circular (TC) 4–02.3).

(3) Assess training/mission hazards for heat stress (see AR 40–5, AR 385–10, Army Techniques Publication (ATP) 5–19, and TC 4–02.3).

(4) Develop and implement controls for heat stress exposure (appendix C).

(5) Ensure Service members are heat acclimatized.

(6) Ensure Service members are provided adequate clothing, shade, and sunscreen to prevent sunburn.

(7) Apply appropriate fluid replacement guidance and implementation of work-rest cycles when possible.

(8) Ensure that training and operational plans incorporate mitigations to the performance-degrading effects of heat stress on their schedules by adding rest (in shade), hydration stops, and other heat dissipation measures, as feasible.

(9) Provide safe alternative training for individuals or units identified at particular risk of exertional heat illness.

(10) Obtain the estimate of mean (average) and extreme climatic conditions at the deployment site in the advance planning stages, to include the 24-hour pattern of temperature and humidity for the deployment site, as well as the times of sunrise and sunset.

(11) Ensure that communication links are established to obtain regular real-time weather data and, when possible, forecasts to decrease the risk of exertional heat illness and to provide windows of opportunity for critical military operations.

c. Unit medical staff (see FM 4–02)—

(1) Understand the commander's intent and mission goals, advise the commander on the potential adverse effects of heat stress, and propose practical options for control of heat stress under difficult circumstances.

(2) Collaborate with the unit safety officer for heat stress control and heat illness mishap reporting issues.

(3) Assess each component of heat stress (condition of the Service member, environmental heat stress, and mission requirements) to plan for the primary prevention of exertional heat illness.

(4) Assess the workload of the proposed training or operation by answering the following questions:

(a) What work rate and duration is planned?

(b) What uniform/equipment will be worn?

(c) Will the Service member be protected from solar heat load?

(d) Will the Service member be exposed to other sources of radiant heat (such as radiators, boilers, or hot metal objects, or vehicular heat from exhaust, engine heat, etc.)?

(e) Will the Service member have access to heat mitigation procedures (for example, Arm Immersion Cooling System (AICS), fans, and misters)?

(5) Calculate onsite heat stress indices using the WBGT index, and provide guidance for regulating physical training and fluid replacement according to the WBGT index.

(6) Assist the logistician in estimating potable water requirements (drinking and hygiene uses), establishing an adequate water logistics system, and educating Service members on their water requirements.

(7) Provide direct medical oversight during the initial heat acclimatization period (usually a period of 10–14 days).

(8) Plan for and implement public health programs and personnel protective measures to counter exertional heat illnesses, monitor hydration status through tracking, and assess hydration through urine measurements (see paragraph 3–6).

(9) Educate Service members on the steps needed to minimize the risk of developing an exertional heat illness, to include hydration, nutrition, skin hygiene, and avoidance of other risk factors.

(10) Educate Service members in recognizing the signs of impending exertional heat illness and the basics of buddy aid (that is, acute first aid provided by a nonmedical Service member to another person).

(11) Establish a field-expedient surveillance procedure to detect heat strain before significant casualties occur. Establish a surveillance procedure to identify a cluster of casualties (that is, multiple casualties in a brief time period) and recommend criteria to modify or terminate the activity.

(12) Estimate the possible rate of exertional heat illness and arrange required medical support as necessary.

(13) Integrate the estimates of casualty rates, mission-compatible personnel protective measures, and medical support requirements with the alternatives developed by the command staff.

(14) Maintain awareness of what types of exertional heat illnesses are being seen at sick call and what medications are being used.

(15) Develop a casualty evacuation plan to include rapid initiation of cooling and monitoring patients.

(16) Interview Service members diagnosed as having signs and symptoms of an exertional heat illness to describe predisposing conditions and the circumstances surrounding the development of the condition.

(17) Report exertional heat illnesses to the installation Public Health Department for reportable medical event reporting compliance in the Disease Reporting System internet (DRSi).

(18) Communicate to field activities immediately upon recognition of exertional heat illness sentinel events and clusters.

d. Unit safety officers (see AR 385–10)—

(1) Serve as principal advisors to their commanders in all safety and occupational health (SOH)-related matters of mission execution.

(2) Execute the commander's SOH program.

(3) Collaborate with the unit medical officer for heat stress control and exertional heat illness mishap reporting issues.

(4) Report exertional heat illnesses to the U.S. Army Combat Readiness Center (USACRC), as appropriate.

(5) Communicate best practices and share lessons learned.

e. Medics—

(1) Will recognize and treat exertional heat illness and implement measures to reduce the risk of additional casualties. See Soldier Training Publication (STP) 8–68W13–SM–TG.

(2) Report exertional heat illness cases to the supervising Medical Officer.

(3) Report exertional heat illness cases to unit Safety Officer responsible for submission to the USACRC reporting system.

f. Service members (see TC 4–02.3)—

(1) Recognize the early signs and symptoms of exertional heat illness, and report as soon as possible to the unit medic/medical officer if they or their buddy develop symptoms.

(2) Ensure their deployment kits contain an initial supply of sunglasses, sunscreen, lip balm, and skin-care items.

(3) Attend available training and receive appropriate informational materials well in advance of deployment.

(4) Practice the buddy system to monitor performance and health.

g. Local medical commands will track exertional heat illness and report events to the unit/garrison commanders (see AR 40–5).

h. For current training products, job aids, and promotional materials, see the Army Public Health Center (APHC) Web site: https://phc.amedd.army.mil/Pages/default.aspx.

CHAPTER 2

PHYSIOLOGICAL RESPONSES AND ADAPTATIONS TO HEAT

2–1. Heat stress in military operations

a. Environmental heat stress is a significant and even decisive factor in military operations and training. In modern history, campaigns in the Pacific and North Africa (World War II), Vietnam, and Southwest Asia; as well as current conflicts, humanitarian efforts, and security operations in Iraq and Afghanistan, have taken place in severe jungle or desert heat stress conditions of the tropic latitudes (between ~30° N and ~30° S latitude). The summer season in tropic latitudes is particularly challenging. During the course of Operation Iraqi Freedom, security operations conducted near Baghdad in 2006 saw average high temperatures of 108 degrees Fahrenheit (°F) for the entire month of August. However, wars fought in more temperate zones are still subject to debilitating seasonal heat waves like those encountered in the Korean War. For the foreseeable future, environmental heat stress remains an unforgiving, non-adversarial threat that must be properly managed in both training and combat.

b. Heat stress decreases physical and cognitive (mental) performance and increases the risk of exertional heat illness. Fortunately, humans are capable of adaptations that improve tolerance to heat exposure. With adequate adaptation and implementation of appropriate mitigation strategies, military training and operations can be accomplished safely and effectively. Unfortunately, some circumstances can outstrip defenses against climatic heat. The requirement for heavy and extended work, protective clothing, limited water supplies, and operating heavily armored combat vehicles in hot environments can produce crippling heat stress conditions that threaten Service member health, performance, and mission success. Just as operational commanders have always had to consider the potential effects of weather on campaign strategies and weapons systems functions, so too must the environment's effects on the Service member be part of the decision making process.

c. Service members train as they fight. All Marine Corps Recruit Training, more than half of all Army Basic Combat Training, and much of Special Forces training are conducted in the warmer southern U.S. between 30 and 35° N latitude. More EHSs and other exertional heat illnesses occur in southern training posts, particularly during the summer heat season (May to September) (Figure 2–1). Although the heat season represents a risk management issue for commanders, it also provides an opportunity in peacetime to train personnel in using appropriate work-rest cycles, fluid replacement guidelines, and heat mitigation strategies, and to plan for proper exertional heat illness treatment.

d. Effective leadership is key for preparing Service members for training in hot weather environments and for successful hot weather military operations. Service members should have confidence that they can master the environment through the use of preventive measures. Lessons learned from hot weather training and deployments must be maintained with continuity from commander to commander. Leaders must learn their unit's capabilities and manage heat exposure. Supporting medical officers must ensure that the principles of this document are incorporated into their commander's plans and integrated into all phases of training and operations. Local regulations and hot weather standard operating procedures for training should all be informed by this document.

2–2. Environmental heat stress and heat exchange

a. Heat stress refers to environmental and host conditions that tend to increase body temperature (that is, body heat storage). Heat strain refers to physiological and/or psychological consequences of heat stress.

b. Body heat exchange occurs by convection, radiation, conduction, and evaporation. Figure 2–2 schematically shows energy (heat) transfer of a Service member performing physical work in hot weather. Metabolic heat is released from active skeletal muscles and transferred from the body core to skin. Heat exchange from skin to the environment is influenced by air temperature; air water vapor pressures (absolute humidity); wind speed; solar, sky, and ground radiation; and clothing.

(1) Metabolic heat production (energy expenditure) is the single most significant factor related to body heat storage. Therefore, a decrease in heat production is the single most effective way to reduce body heat storage. Body heat is stored in direct proportion to the rate of metabolism, but is modified by heat loss factors (environment and clothing). If body heat loss were not possible, a 176-pound Service member carrying a 40-pound load could march at a rate of 3.5 miles per hour (mph) for only 21 minutes before reaching a potentially lethal body core temperature. In reality, heat storage occurs because heat production is instantaneous and heat loss mechanisms occur more gradually. Eventually, heat loss will match heat production so long as heat loss factors are permissive.

(2) Convection is heat loss occurring by movement of a gas or liquid over the body, whether induced by thermal currents, body motion, or natural movement of air (wind) or water. Heat loss by convection to air occurs when air temperature, in contact with skin, is lower than skin temperature; conversely, heat gain by convection from air occurs when air temperature is higher than skin temperature.

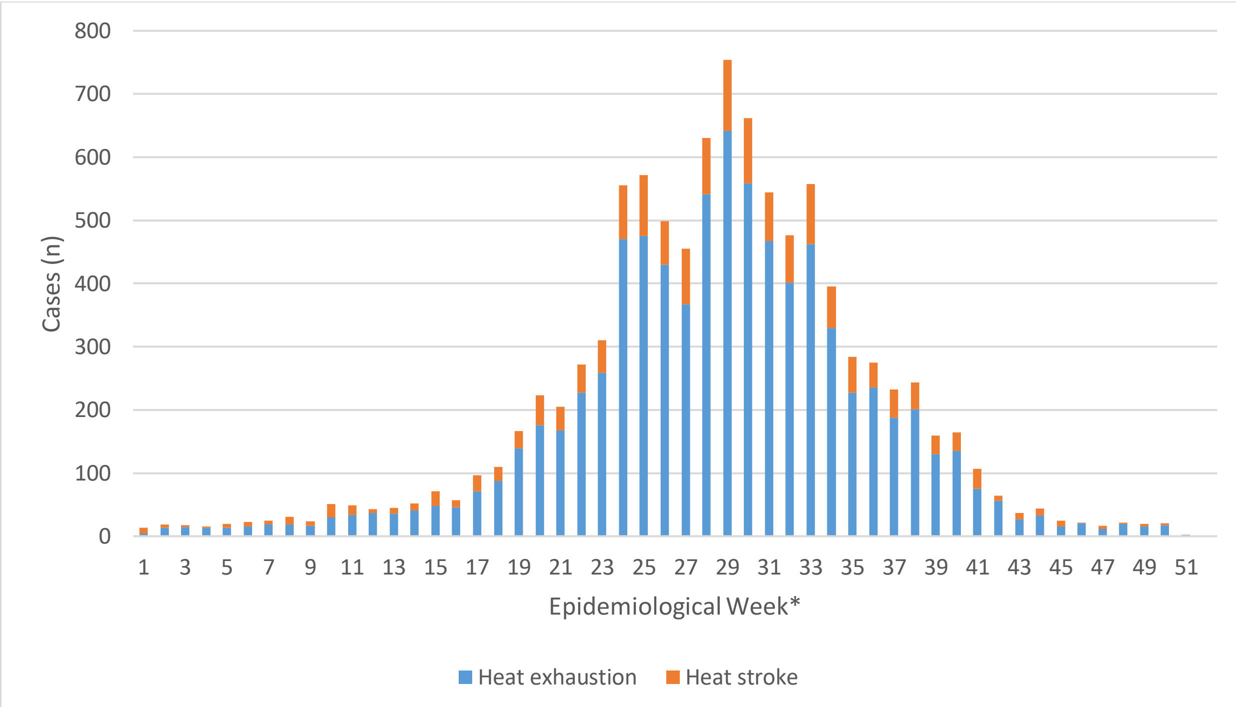


Figure 2-1. Overall frequency and weekly distribution of heat exhaustion and heat stroke over a 5-year period (2015-2019) for U.S. Army personnel.
***The epidemiological week is a standardized method of numbering weeks to allow for the comparison of data from year to year. An epidemiological week starts on a Sunday and ends on a Saturday. The epidemiological week calendar starts on the first Sunday of January.**

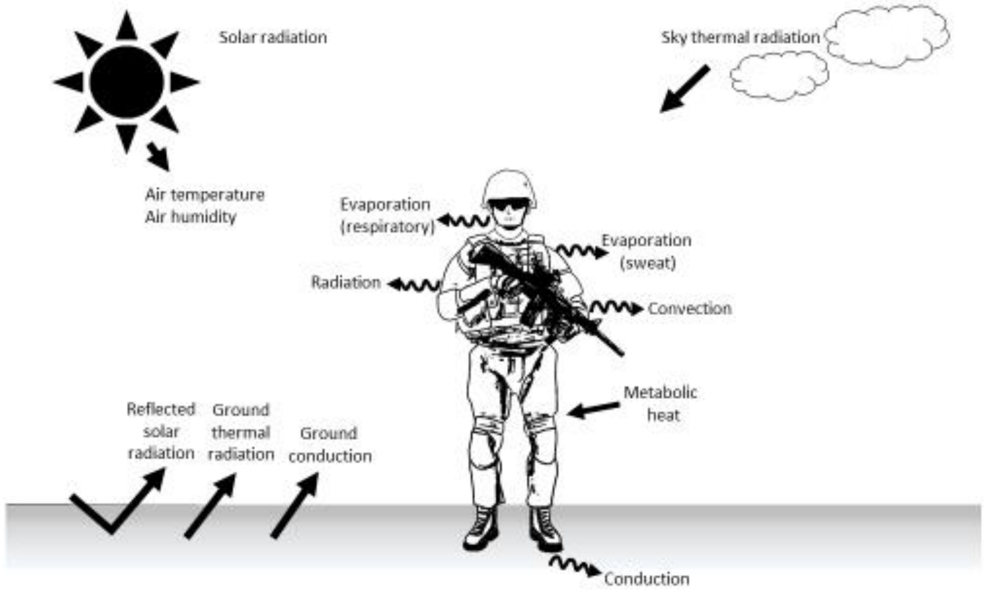


Figure 2–2. Energy (heat) transfer of a Service member performing physical work in a hot environment.
Arrows are standardized to indicate heat gain (solid arrow) or heat loss (squiggly arrow).

(3) Radiation is the transfer of heat in the form of electromagnetic waves (that is, infrared light waves). These waves do not need a substance to carry their heat energy (as in the processes of convection, conduction, and evaporation). Because of this, heat can be transferred from an object of higher temperature to an object of lower temperature even if the objects are surrounded by cold air. Therefore, a Service member can absorb heat from objects in the environment like the sky, ground, and vehicles without coming in contact with them.

(4) Conduction is heat loss that occurs when skin is in contact with a solid object that is cooler in temperature. Heat loss by conduction is usually minimal, but becomes essential when treating exertional heat illness casualties (see paragraphs 3–4 and 5–1). In contrast, contact with surfaces hotter than skin result in heat gain; thus, care must be taken when treating heat casualties who have collapsed to the ground. Similarly, the interior surface of medical transport vehicles can become hot as the outer surfaces can easily exceed those that produce pain or burns (> 114 °F). For example, the surface of an M1A1 battle tank was measured to be 150 °F at mid-day in summer at the Fort Irwin National Training Center.

(5) As air temperature increases, there is greater dependence on evaporative heat loss. When air temperature is higher than skin temperature, evaporative heat loss accounts for all body cooling. Eccrine sweat glands secrete fluid onto the skin surface permitting evaporative cooling when the liquid (that is, sweat) is converted to water vapor. The body can lose water quickly due to heavier sweating, which may for short periods exceed 2 quarts per hour. The rate of sweat evaporation depends upon air movement and the water vapor pressure difference between the skin and the air. Because sweat tends to collect on the skin in still air, it is important to allow air circulation to the skin, especially torso areas, to maximize evaporative cooling. As air temperature and humidity increase together, sweating efficiency declines. If hot air is also very humid, the water vapor pressure of the air (absolute humidity) may become higher than sweat-saturated skin vapor pressures. As a result, sweat evaporation is impeded, sweat drips

from the body, and sweat has no evaporative cooling power. This condition is due to a small water vapor pressure difference between skin and air, which suppresses evaporative sweating from the skin, not an inability of the air to “hold” additional water vapor. Saturated air (100% relative humidity) at any temperature is in a dynamic state of equilibrium between evaporation and condensation. It can be readily demonstrated that sweat can evaporate easily in cool air (< 60 °F) that is completely saturated with water vapor (100% relative humidity). As long as skin temperature remains higher than air temperature (that is, until air temperatures exceed ~ 95 °F), sweat that forms on the skin will have a higher vapor pressure than the surrounding air (even if the air is 100% humidified), and evaporative cooling can continue. The common notion that sweat cannot evaporate when the relative humidity of the air is high depends heavily on the temperature of the air.

c. High air temperature, high humidity, thermal radiation, and low air movement are causes of environmental heat stress. The WBGT index encompasses all of these environmental causes of heat stress into one number that is used to characterize the potential effects of hot environments on the individual. The WBGT and its associated heat stress categories (CAT or flags) were developed in conjunction with Marine training in the 1950s and remains the most relevant index of environmental stress for military, sports, and occupational medicine applications today (though categories differ between military and sport; see paragraph 3–3). A traditional WBGT apparatus measures air temperature from a shaded dry bulb thermometer (T_{db}). The contribution of humidity is determined from a wet bulb temperature (T_{wb}), which is measured by covering a thermometer bulb with a wet wick. A black globe thermometer (T_{bg}), which consists of a 6-inch hollow copper sphere painted matte black on the outside with a thermometer at the center of the sphere, assesses radiant heat (solar load). Air movement is measured from an anemometer. Fortunately, the cumbersome and non-standard instruments for traditional WBGT measurements may now be traded for several modern, automated, and highly portable WBGT monitoring systems that provide comparable results when used and maintained appropriately (see appendix B).

d. The WBGT index is calculated as WBGT, °F = $0.7(T_{wb}) + 0.2(T_{bg}) + 0.1(T_{db})$; it allows safety officers, tactical commanders, and others to assess how heat stress will impact or limit the scope of training or operations. Tables 3–2 and 3–3 have been developed whereby the WBGT is considered and integrated into work-rest cycles and fluid intake recommendations for maximizing performance, improving logistical planning, and minimizing exertional heat illness.

e. The U.S. Armed Forces National Center for Medical Intelligence maintains country dossiers that include historical environmental information for long-range military planning, to include global WBGT. It is neither technically nor scientifically feasible to accurately forecast WBGT. As a result, measured WBGT is best for the tactical commander, especially since WBGT can vary greatly over short durations and distances in unpredictable ways. For example, Figure 2–3 shows common differences in CAT conditions measured at the same time of day at different locations on Fort Benning, Georgia. Out of 42 paired observations, 11 pairs differed by one heat CAT and 5 pairs differed by two heat CAT (38% total disagreement). Neither the Main Post nor the Sand Hill locations were consistently higher or lower (random). Therefore, the WBGT value typically measured at one site and reported by public health (environmental health) for post-wide dissemination should serve only as a general guide. When training or operations require moderate or hard intensity physical demands, the WBGT should be measured at the site of training or location of operations if the mission permits. Trained personnel must record and transmit the WBGT to unit commanders and to supporting medical personnel who are involved in the evaluation and management of any potential heat casualty. No other heat stress index or scale should be used in place of the WBGT.

2–3. Physiology and behavior

a. Body temperature is normally regulated within a narrow range through two parallel processes: behavioral temperature regulation and physiological temperature regulation. Behavioral temperature regulation includes pacing, slowing down or discontinuing work, seeking shade, or removing clothing and equipment. In military situations, behavioral temperature regulation drives are often overridden by motivation to successfully complete the mission. Physiological temperature regulation operates through heat loss responses that include increases in both skin blood flow and sweating, both of which are proportional to body heat storage but modified by air temperature and its effects on skin temperature. Body heat loss by conduction, convection, and radiation is mediated by altering skin blood flow. Body heat loss by evaporation is primarily by secretion of sweat.

b. When body heat is stored, it is reflected by increases in body core and skin temperatures. In response to each, heat loss is initiated through increases in skin blood flow and sweating. When heat loss is permissive, heat balance is eventually restored and body temperature stabilizes to a new, higher level proportional to the heat that was stored before reaching equilibrium heat balance. If the sum of metabolic rate, clothing, and environment is not permissive for heat balance, then skin blood flow and sweating responses will increase. If the responses are insufficient to restore heat balance, body heat storage will continue unabated. The typical range of tolerable body core temperatures covers only ~10 °F (~95 °F to 105 °F) but is buffered by wider fluctuations in skin temperature.

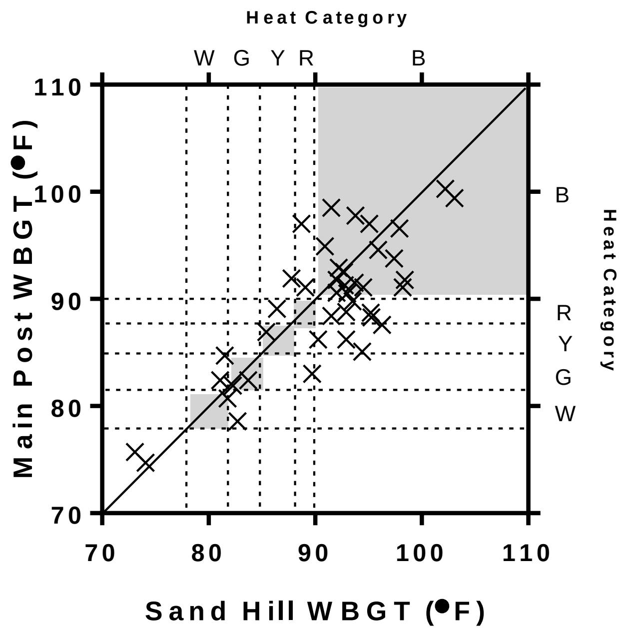


Figure 2–3. Effect of measurement location on WBGT index, Fort Benning, Georgia, July 2005. Distance between the Main Post and Sand Hill was approximately 8 miles. Data points falling outside the gray boxes represent differences in heat category classification between the Main Post and Sand Hill at the same time of day. W, G, Y, R, and B bands represent white (or none), green, yellow, red, and black heat categories, respectively.

c. An increase in skin blood flow delivers warm blood from the body core to the skin surface. As a result, skin temperature increases. When the skin is warmer than the air, heat is lost; when cooler, heat is gained. As a result, heat loss by conduction, convection, and radiation is controlled by varying skin blood flow, and thereby skin temperature. The typical range for skin temperature is almost 30 °F (~68 °F in cold air and 98 °F in hot air), but it is normally ~91 °F and thus conducive for heat loss except on very hot days. When sweating occurs, the tendency of skin blood flow to warm the skin is approximately balanced by the tendency for sweat evaporation to cool the skin. Therefore, after sweating has begun, a high skin blood flow acts to deliver heat to the skin where it is dissipated by both dry (radiation and convection) and wet (sweat evaporation) heat loss mechanisms.

d. Skin temperature is lower than body core temperature but also predictably influenced by air temperature. Thus, in hot environments, skin temperature is increased and the body core-to-skin temperature gradient is narrowed. The requirement for skin blood flow increases as the gradient narrows; thus, a decrease in skin temperature widens the gradient and decreases skin blood flow while achieving the same heat transfer potential. For this reason (and others), skin cooling alone is beneficial for heat balance and reducing heat strain even if it does not decrease body core temperature. When the air temperature is very high and the sum of conditions necessary for heat balance are not permissive, body core temperature will increase; however, this increase within the normal range also acts to widen the body core-to-skin gradient and reduce skin blood flow. A high body temperature is a reflection of heat storage and heat balance, but there is no single “threshold” body temperature that can be linked with pathological or dangerous outcomes.

e. High skin blood flow places a strain on the cardiovascular system by competing for limited volumes of blood needed by vital organs and skeletal muscle. Hot skin and high skin blood flow is associated with pooling of blood in compliant skin and underlying vascular beds. The pooling reduces cardiac filling and stroke volume, thus requiring a higher heart rate to maintain cardiac output. To help compensate for reduced cardiac filling, sympathetic nerve activity is increased to elevate myocardial contractility, maintain blood pressure, and divert blood flow from the viscera to skin for heat loss and muscle beds for metabolism. A reduction in visceral blood flow may play a role in the cascade of events associated with EHS, such as increased gut (stomach and bowel) permeability, endotoxin leakage, and multi-organ system dysfunction.

f. Since high rates of heat production combined with hot environments elicit high sweating rates, Service members will dehydrate if they do not replace their water losses. Dehydration reduces evaporative and convective heat loss, increases body core temperature (~0.36 °F per percent of body weight loss), increases cardiovascular strain (~5 heartbeats per minute per percent of body weight loss), may reduce the body core temperature that can be tolerated, and contributes to exertional heat illness risk. Dehydration also reduces physical work capabilities, especially in the heat. Over consumption of water provides no physiological advantage compared to normal hydration and acts to increase urine water loss. If Service members substantially overconsume fluids (beyond sweat losses) over an extended period of 4 hours or more while not replacing their salt losses, they can develop hyponatremia, a condition in which blood sodium is too low. These topics are further discussed in paragraphs 3–6, 3–7, and 5–4.

g. Figure 2–4 describes the independent and combined effects of environmental heat stress on self-paced endurance exercise. The effects of dehydration, terrestrial altitude, and load carriage on the same task are shown for comparison of the effect magnitude. Note that heat stress (heat category ≥ 4) alone reduces performance by > 10% and by > 20% when combined with dehydration. The combined effect of heat and dehydration is similar to the combination of heat and altitude, while the addition of heat doubles the performance penalty of carrying a load. Extrapolation to a 12-mile march ordinarily completed in 180 minutes would be a slowing to 360 minutes when air temperatures exceed 100 °F. These data emphasize the need for proper hydration and strategic planning around the time of day when conducting the most arduous training and training for record events.

h. The nomogram in Figure 2–5 provides a trade-off analysis whereby march pace (center line) is a function of both air temperature (right line) and load carried (left line) as a percentage of body weight. The nomogram allows a gross estimate of how much of the self-selected pace will be slowed by load, heat, or their combination. For example, the nomogram can be used when time-sensitive movements are desired by allowing strategic planning around temperature (time of day) and load carriage requirements or the optimum distribution of load among troops.

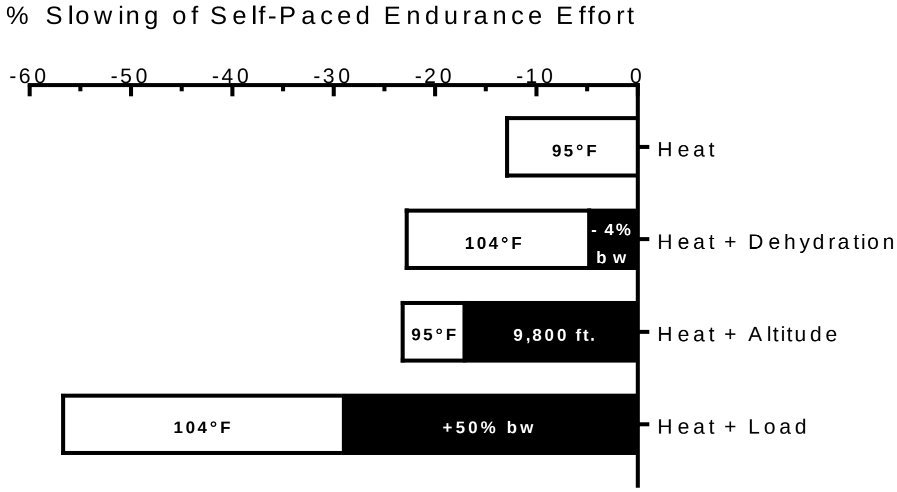


Figure 2–4. Independent and combined effects of environmental heat stress on a self-paced endurance task equivalent to a 2-mile run or 3-mile march.
Stacked open bars show the effects of combining heat stress (95 to 104ºF, < 30% relative humidity (rh)) with dehydration (– 4% body weight (bw)), altitude (9,800 feet), and load carriage (50% bw). Percentage slowing is relative to the same test performed at 68°F when properly hydrated at sea level and without any load, respectively.

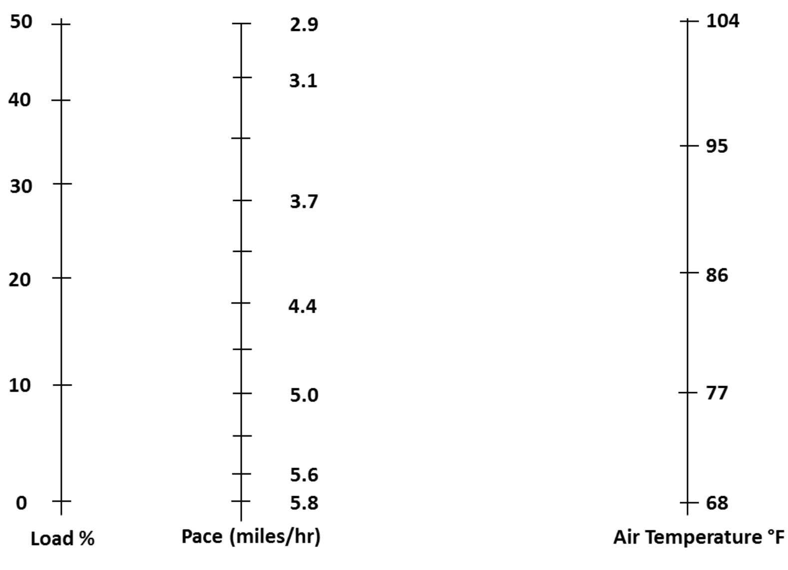


Figure 2–5. Trade-off analysis performance nomogram.
The left and right axes represent the independent factors (load and environmental heat) affecting the middle dependent factor of movement speed. A straight line drawn between any two points on the left and right axes provide the optimized pace for successful task completion.

2–4. Cognitive performance

a. Heat stress can reduce mental performance through increased thermal discomfort stemming from high skin temperatures, high skin wettedness, and cardiovascular strain. However, unlike physical performance, the effects on mental performance are less pronounced and more varied. Mental performance results depend on choice of test, the Service member's familiarity with the test, and whether or not practice is required. The method of and rate of body heating are also important, in addition to the way in which body temperature is measured. However, mental performance appears to be impaired most by heat strain in tedious, monotonous, and repetitive tasks. There is also evidence that heat stress can impair: concentration, short-term memory, reaction time, vigilance, and decision making – the effects of which could have disastrous consequences when performing sentry duty, operating a drone, or discriminating between friend and foe in battle.

b. The effects of dehydration on mental performance are less consistent than for heat. However, dehydration exacerbates heat strain and is likely to produce additive mental distraction owing to secondary biological symptoms such as dry mouth, headache, and psychological symptoms such as degraded mood state. Brain activity measurements using sophisticated imaging techniques show that while mental performance can be preserved when dehydrated, any given mental task requires greater concentration (measured by greater brain oxygen use). Thus, dehydration may place greater demands on cognitive reserve.

2–5. Adaptations to heat stress

a. Biological adaptations to repeated heat stress include heat acclimatization and acquired thermal tolerance. The magnitude of both adaptations depends on the intensity, duration, frequency, and number of heat exposures. These adaptations occur in parallel and are complementary as heat acclimatization reduces physiologic strain, and acquired thermal tolerance improves tissue resistance to injury for any given heat strain.

b. Heat acclimatization is induced when repeated heat exposures are sufficiently stressful to elevate body core and skin temperatures and provoke profuse sweating. During initial heat exposure, physiological strain will be highest, as manifested by elevated body core temperature and heart rate. The magnitude of physiologic strain will decrease each subsequent day of heat acclimatization. Typical body core temperature and heart rate responses to work in the heat are reduced by ~2 °F and 40 beats per minute after acclimatization, respectively. Primary adaptations include an earlier onset of sweating and higher maximum sweating rate, sweat electrolyte conservation, and expanded blood volume. Adaptations serve to improve thermal comfort by keeping skin cooler and dryer, improve fluid and electrolyte balance, and reduce cardiovascular strain. However, heat acclimatization actually "increases" fluid needs.

c. Heat acclimatization is specific to the environment and activity level. Optimal acclimatization requires living and working in the specific environment in which Service members will be deployed. However, acclimatization to hot, dry (that is, desert) or warm, humid (that is, jungle) environments markedly improves a Service member's ability to work in the other environment. Service members who only perform light or brief physical work will achieve the level of acclimatization needed to perform that task. If they attempt more strenuous or prolonged work, they will need to gain additional acclimatization and possibly improved physical fitness to perform that task in the heat. For example, it is unlikely that Service members rapidly deploying from U.S. Army Alaska to take part in Cobra Gold training in Thailand will be prepared for the Asia-Pacific heat and humidity. However, with lead time, heat acclimatization strategies can be used to achieve partial adaptations in as little as 72 hours before deployment. In-theatre (or in-training) exposure itself will also promote further adaptation, with signs of discomfort and distress decreasing each day. Optimal heat acclimatization takes approximately 10 days. Heat acclimatization dramatically improves physical work capabilities in hot and temperate environments. Troops more easily complete military tasks in the heat that earlier were difficult and can complete some tasks that were previously impossible. For this reason, it is important to remember that indigenous forces and allied units who live in, or who have deployed earlier to, a hot environment will be better acclimatized and initially better able to perform physically demanding tasks.

d. At the cellular level, heat acclimatization includes adaptations that make cells more tolerant to heat shock (the exposure of a cell to temperatures higher than normal), which can otherwise lead to cell damage or cell death. This process is known as acquired thermal tolerance and refers to cellular adaptations induced by heat exposure that protect tissue/organs from heat injury. Acquired thermal tolerance allows a Service member to become more resistant to heat injury with subsequently more severe heat exposures. Acquired thermal tolerance can be induced by heat exposure or physical exercise; if both are employed, the benefits will be maximized.

e. Acquired thermal tolerance is associated with heat shock proteins (HSPs), which provide protection and accelerate repair of cells from heat exposure and other stressors. After the initial heat exposure, HSP synthesis begins within hours of heat exposure with the time course and intensity dependent on the cumulative heat strain that is imposed. The time course for induction and decay of HSP responses are similar to those for heat acclimatization. Different types of HSPs exist in different locations and have different functions within a cell. Generally, the tissues more susceptible to heat injury, such as brain and liver, have greater HSP responses than tissues such as skeletal muscle. Other cellular processes probably contribute to improved acquired thermal tolerance. Overall, HSPs appear protective against many of the cascade mechanisms related to poor exertional heat illness outcomes such as heat cytotoxicity, gut permeability, and multi-organ damage.

f. Heat acclimatization and acquired thermal tolerance translate to improved heat tolerance, work capacity, and reduced risk of exertional heat illness. For example, ~90% of Service members cannot patrol for 100 continuous minutes in conditions akin to the summer heat of Baghdad (120 °F) before heat acclimatization, while ~90% can do so easily after 10 days of heat acclimatization and with less strain (lower heart rates and body core temperatures). Importantly, blood cells taken from acclimatized Service members show ~20% greater HSP expression after heat acclimatization; those same cells demonstrate ~20% less stress when incubated in water heated well in excess of EHS body temperatures (110 °F) for 1 hour. Heat acclimatization improves performance and protects health. Table 2–1 provides generalized procedures for becoming heat acclimatized.

Table 2–1. Generalized heat acclimatization strategies

1. Mimic the anticipated deployment environment when possible.
2. Ensure adequate heat stress • Invoke sweating. • Use exercise and rest to modify the heat strain. • Try to achieve between 4 to 14 days of heat exposures. • Try to achieve ≥ 100 minutes of daily heat exposure; use work-rest cycles at start.
3. Methods. • Climate controlled rooms, hot weather, or overdress for indoor exercise. • Start slowly • Acclimatize in heat of day. • Train in coolest part of day. • Integrate heat acclimatization within training. • Use work-rest cycles and build toward continuous work. • Increase heat and training volume as tolerance permits.
4. Other • Be especially observant of salt needs for the first week of acclimatization. • Remember that heat acclimatization increases fluid needs. • High fitness helps facilitate heat acclimatization. • If heat exposure is discontinued, benefits are retained for about 1 week and lost within 1 month

CHAPTER 3

HEAT STRESS MANAGEMENT

3–1. General

a. Heat stress occurs from the combination of mission, individual, and environmental risk factors. Mission risk factors include the metabolic work intensity (heat production), duration of heat exposure, and clothing and/or equipment worn. Special clothing, such as body armor or chemical, biological, radiological, and nuclear (CBRN) protective clothing, can restrict heat loss and increase heat strain. Individual risk factors include a Service member's physical fitness, heat acclimatization status, hydration and nutritional status, and health – to include prior history of heat illness, infection, use of medications, alcohol, or drugs of abuse. Environmental risk factors include air temperature, air water vapor (absolute humidity), wind, solar load (sun), and consecutive days of heat exposure. Fit, healthy, heat-acclimatized, well-hydrated, and well-nourished Service members will experience the least heat strain when training or fighting in hot environments.

b. Service members can effectively operate in any naturally occurring hot environment if they are heat acclimatized, consume adequate water and food (especially salt), and have sufficient shade and rest. Successful management of heat stress results in optimized work potential and heat illness mitigation. Every exertional heat illness prevented is one more Service member still in the fight!

c. Successful management of heat stress depends on proper education of leaders and troops exposed to heat. Leaders must implement procedures to alert troops of dangerous heat stress levels and must apply interventions to reduce exposure and increase resistance of exposed Service members. It is critical to recognize quickly signs of Service member heat distress so that proper management procedures can be implemented accordingly. Heat casualties often occur in groups, or clusters, so when the first heat casualty occurs others may be imminent. Figure 3–1 provides a generalized heat strain decision-making process.

3–2. Heat stress and body core temperature

a. Heat stress can be divided into compensated heat stress (CHS) and uncompensated heat stress (UCHS). CHS and UCHS are primarily determined by interactions among biophysical factors such as work rate (heat production), the environment, and clothing and are secondarily affected by biological factors such as heat acclimatization and hydration status. Compensation refers to a balance between rates of heat gain and heat loss. CHS is reflected by an elevated steady state body core temperature. CHS represents the majority of military situations. UCHS exists when rates of heat gain exceed rates of heat loss. During UCHS, heat storage accumulates and a body core temperature steady state cannot be achieved. If the activity lasts long enough, body temperature (core and skin) will rise until exhaustion occurs at physiological limits. The performance of intense training in hot environments or moderate training when wearing CBRN-style protective clothing in hot environments both represent examples of UCHS.

b. Figure 3–2 provides an illustration of how CHS and UCHS affect steady state body core temperature during easy, moderate, and very hard activity levels that correspond to rates of heat production or watts (W) measured in training. Demanding activities produce greater rates of heat storage, which results in higher steady state body core temperatures during CHS. When the environmental conditions are no longer permissive for matching heat gain to loss (dashed line, UCHS), body heat storage increases and body core temperature rises. The dashed line between CHS and UCHS is slanted such that even mild, green CAT conditions can become UCHS if heat production is high enough and sustained. This is why high-risk (high heat production) activities should be performed during the coolest time of day, but also why EHS may still occur. Heavy clothing shifts the dashed line to the left; lighter clothing shifts the dashed line to the right. A 176-pound Service member who runs 5 miles in 40 minutes while wearing a physical fitness uniform (PFU) would experience UCHS on a red CAT day, but CHS on a

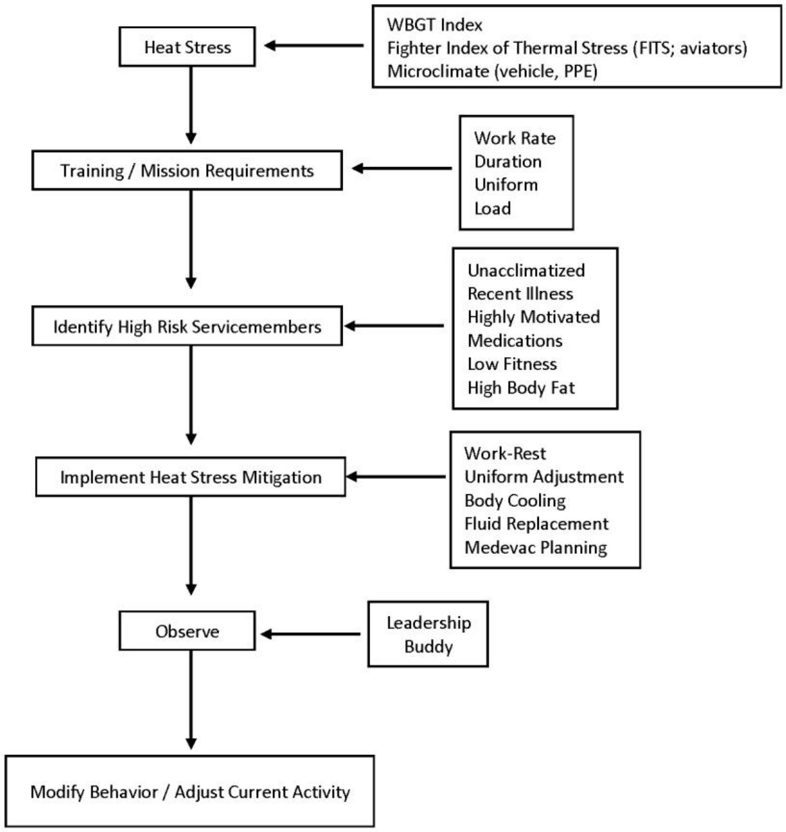


Figure 3–1. Heat stress risk assessment process.
Modification of behavior can include a modification or an adjustment of the current activity. Modification of activity by leadership may be required in order to assess the potential need for additional heat mitigation procedures under the current conditions (including halt of activity, further uniform modifications, Arm Immersion Cooling System (AICS) use, etc.).

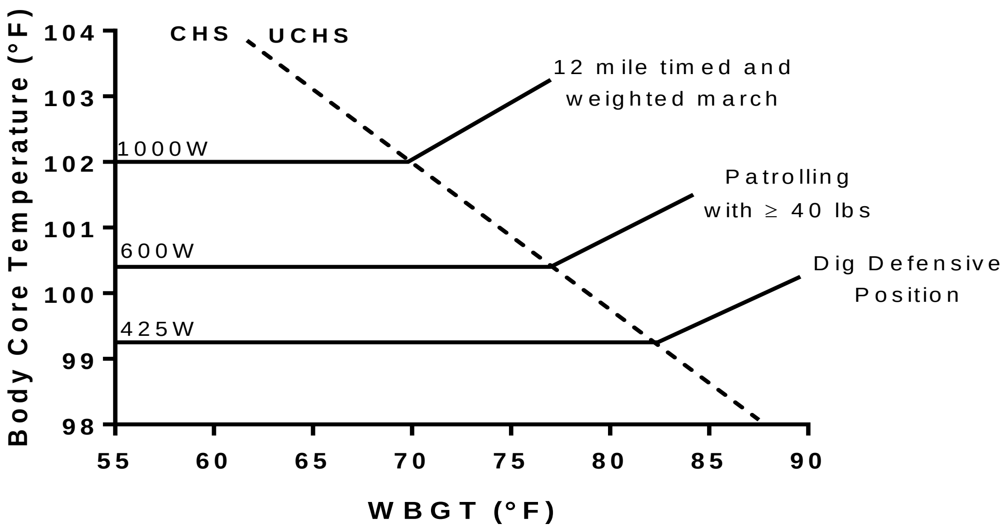


Figure 3–2. Illustration of body core temperature responses during continuous physical work at three metabolic rates during CHS and UCHS

green CAT day. In both cases, the activity may be short enough to allow successful completion; however, the red CAT condition would slow performance (≥ 4 minutes) (Figure 2–4) and potentially increase the risk of exertional heat illness.

c. Body core temperature is a useful measure of human heat strain. It is often measured to determine the severity of exertional heat illness or it is predicted to estimate work tolerance. Heat generated by active muscles is transferred to the body core by the blood (paragraph 2–2). The real purpose of measuring body core temperature is to estimate the temperature of the blood perfusing the brain and other vital organs. However, body heat storage is not equal among all tissues; thus, body core temperature will vary depending upon the measurement site. In general, the farther the temperature sensor is placed from the body core, the less accurate it will be. In a controlled setting, the measurement of esophageal temperature (at the level of the right atrium) closely reflects that of the blood and responds rapidly to changes in body core temperature. However, it is difficult and inconvenient to measure and vulnerable to swallowing and drinking artifacts. Rectal temperature (2–4 inches past anal sphincter) is slightly higher (~0.4 °F) and responds more slowly to rapid changes in body core temperature. Rectal temperature is relatively easy to measure but is often considered impractical. Telemetry pill temperatures are similar to rectal values but only after an extended post ingestion period (≥ 4 hour). Ear canal temperature measurements are often confounded by head and face skin temperatures, so they may be higher or lower than rectal temperatures, but they are usually lower. Temporal (temple), forehead, or axillary (armpit) temperatures similarly reflect body surface temperatures. Oral temperature is very easy to obtain and predictably lower than rectal temperature at rest, but is easily confounded.

d. When body core temperature measurement is desired of suspected heat casualties in the field at training sites or in a medical treatment facility (MTF), rectal temperature is the only method that is sufficiently accurate. The incorrect belief that different body regions are “interchangeable” for measuring body core temperature may stem, in part, from good measurement agreement among different body regions when measured indoors on patients with a fever. Table 3–1 reports the mean absolute difference (MAD) in rectal and other device temperatures measured in healthy people during vigorous and prolonged outdoor exercise. The MAD is not affected by extreme positive or negative differences and is the best indicator of agreement or lack of agreement between devices. The percentage of measurements that were above (+) or below (-) rectal temperature are also given for insight about error directionality. Where two devices were used, their average is reported. Note that non-rectal temperatures generally underestimate rectal temperature. Forehead temperature is underestimated in the shade and overestimated in the sun. The largest individual differences observed in the Table 3–1 data exceeded 8 °F; thus, methods other than rectal temperature cannot be trusted. If rectal temperature is desired but cannot be obtained, delay rectal temperature measurement until arrival at definitive care and continue treating as a heat casualty. Treatment of a suspected heat casualty should never be based on rectal temperature alone (see paragraph 5–1).

Table 3–1. Mean Absolute Difference (MAD) between rectal temperature and other body temperatures measured in 25 volunteers during 3 hours of outdoor exercise in the heat[1]

	---------------------- Body Temperature Measurement Location --------------------------				
	Oral	Temporal[2]	Tympanic	Axillary	Forehead[3]
MAD	2.62 °F	2.55 °F	1.77 °F	4.26 °F	1.37 °F
Directional Error	> 90% below < 10% above	> 90% below < 10% above	> 90% below < 10% above	100% below 0% above	~50% below ~50% above

Notes:
[1]Mean rectal temperatures ranged from 99 to > 102 °F; outdoor air temperature 91 °F
[2]temporal artery scanner
[3]forehead sticker technology

e. A wide variety of accurate (to 110 ºF) and fast responding (~10 seconds) digital thermometers can be obtained through the Medical Services Information Logistics System (MEDSILS, Army), or can be found as part of various medical equipment sets. It is important that medics (or similar designated response personnel) be properly equipped, trained, ready, and willing to use any particular model of thermometer when a measurement of rectal temperature is desired ahead of definitive care, such as in training or remote austere locations.

f. The U.S. Army Research Institute of Environmental Medicine (USARIEM) Heat Strain Decision Aid (HSDA) was developed as training guidance for hot environments. The HSDA was built from a combination of mathematical models and physiological data from laboratory and controlled field study research. The HSDA can be used to estimate safe work times and optimal work-rest cycles based upon activity, clothing, and environmental inputs. The HSDA is used to generalize estimates of thermal strain by predicting the body core temperature response to heat stress for the “average” Service member. The predictions are then compared to the percentage of Service members expected to incur exhaustion from heat strain at those temperatures. Military training guidelines for using work-rest cycles are based, in part, on HSDA outputs. Body core temperature safety endpoints for work-rest (CHS, UCHS) and continuous work tables (CHS) are set to 101.3 ºF and 104 °F, respectively, and assume heat-acclimatized Service members working in a field environment. Body core temperatures below these thresholds are largely sustainable and those above are cautionary for exhaustion from heat strain.

g. In general, high body core temperatures are more tolerable when skin temperatures are cooler and less tolerable when skin temperatures are warmer, which is one reason why body core temperature alone may not always predict exhaustion accurately. CHS circumstances improve (lower skin temperatures) and UCHS degrade (higher skin temperatures) tolerance to high body core temperatures. Like many athletes, healthy, fit, motivated, heat-acclimatized, well-hydrated, and fed Service members are capable of tolerating body core temperatures > 101.3 °F. However, many arduous military training schools create necessary stress scenarios that can increase susceptibility to non-specific strain that make more conservative modeling thresholds prudent. Work-rest cycles, cooling strategies, heat acclimatization, and proper hydration can all be used to help manage and minimize heat stress in both CHS and UCHS circumstances.

h. The wearing of face masks to protect against environmental antigens (for example, viruses) may be required while operating in a hot environment. Respiratory evaporative and convective heat loss is less than 10% of total heat production in a thermoneutral environment. As environmental heat and/or humidity increase, respiratory heat losses actually decrease. A face covering is not 100% impermeable; most heat will still be dissipated in the exhaled air. The perception of increased heat stress while wearing a face covering is due to warm, humid expired air trapped against the skin around the mouth and nose, negatively impacting thermal sensation. However, a typical face mask covers a negligible portion of the total body surface area (<1% BSA for a 4"x6" mask), and skin on the face has not been shown to have a high sweat rate. The impact on evaporative cooling should be minimal.

3–3. Work-rest cycles

a. The recommended air temperature threshold for initiating hot weather WBGT index guidelines is ~75 °F, though exertional heat illness can occur in cooler environments. As the WBGT index increases, physical work intensity should be reduced or more frequent and longer rest periods should be taken. Under extreme conditions when the WBGT index is > 90 °F, training may require extreme modifications or temporary suspension. Work schedules should be customized for the environment, task, and military situation when possible.

b. Table 3–2 provides work-rest and fluid replacement guidelines for heat-acclimatized Service members in a training environment. It considers the average Service member wearing their Service Combat Uniform (SCU). The guidelines support at least 4 hours of work. Four time-weighted work intensities are provided representing easy (~250 W), moderate (~425 W), hard (~600 W), and very hard (~800 W) military tasks; examples are provided. The users should determine the WBGT index at the site of training and then read the recommended work time (see paragraph 2–2). The work-rest cycle is the ratio of minutes of work to minutes of rest within each hour. Table 3–3 provides work limits for continuous activities using similar considerations for WBGT index, work intensity, and clothing. Protective clothing worsens heat strain.

c. The information in Tables 3–2 and 3–3 is robust for use in many different scenarios. Rest means minimal physical activity and, when possible, should be accomplished in shade, with adequate air circulation and without additional clothing or protective equipment. When possible, provide external cooling during rest periods in “cool zones” using methods described in paragraphs 3–4 and 5–1. Leaders should use Tables 3–2 and 3–3 as a complement to experience when matching tabled information to their units’ training mission requirements and available resources. Tables 3–2 and 3–3 should be viewed as a valid and conservative starting point from which leaders may make adjustments; they are not a substitute for common sense and close monitoring. For training scenarios that fall well outside the guidance in Tables 3–2 and 3–3, other approaches may be necessary to mitigate exertional heat illness risk.

d. Several military training and graduation standards require “high-risk” activities with metabolic heat production rates well above 800 W. Two common examples include a 5-mile run in < 40 minutes and a 12-mile march with 55 pounds completed in < 180 minutes. Events like these are held multiple times throughout the year. Summer months make performance standards more difficult to attain and result in more exertional heat illness cases. Heat risk mitigation strategies beyond work-rest cycles must be considered when maintaining training standards while minimizing attrition. Service members’ motivation to successfully complete critical training events, such as those required for graduation from courses, combined with impaired decision-making (see paragraph 2–4), may push themselves into the spectrum of exertional heat illnesses.

Table 3–2. Fluid replacement and work-rest guidelines for training in warm and hot environments[1]

		Easy Work (250 W)		Moderate Work (425 W)		Heavy Work (600 W)		Very Heavy Work (800 W)	
Heat Category	WBGT Index (°F)	Work-Rest	Water Intake (qt/hr)	Work-Rest	Water Intake (qt/hr)	Work-Rest	Water Intake (qt/hr)	Work-Rest	Water Intake (qt/hr)
1 (white)	78-81.9	NL	½	NL	¾	40/20	¾	20/40	1
2 (green)	82-84.9	NL	½	NL	¾	30/30	1	15/45	1
3 (yellow)	85-87.9	NL	¾	NL	¾	30/30	1	10/50	1
4 (red)	88-89.9	NL	¾	50/10	¾	20/40	1	10/50	1
5 (black)	> 90	NL	1	20/40	1	15/45	1	10/50	1

Easy Work	Moderate Work	Heavy Work	Very Heavy Work
• Weapon maintenance • Marksmanship training • Drill and ceremony	• Patrolling with 30-pound load • Low and high crawl • Dig defensive position	• Patrolling with 45-pound load • Four-person litter carry (180 pounds) • Jogging 4 mph	• Two-person litter carry (150 pounds) • Move under direct fire • Obstacle course

Legend:
NL = no limit to work per hour (up to 4 continuous hours).

Notes:

1. Applies for average-sized and heat-acclimatized Service member wearing the Operational Camouflage Patten (OCP) uniform.
2. The work-rest times and fluid replacement volumes will sustain performance and hydration for at least 4 hours of work in the specified heat category.
3. Fluid needs can vary based on individual differences (± ¼ qt/hr) and exposure to full sun or full shade (± ¼ qt/hr).
4. Rest means minimal physical activity (sitting or standing) accomplished in shade if possible.
5. CAUTION: Hourly fluid intake should not exceed 1½ qt.
6. CAUTION: Daily fluid intake should not exceed 12 qt.
7. If wearing heavy protective clothing (CBRN, JSLIST), add 10 ºF to WBGT index for easy work and 20 ºF to WBGT index for moderate and heavy work.

Table 3–3. Recommendations for continuous work duration and fluid replacement in warm and hot environments[1]

		Easy Work (250 W)		Moderate Work (425 W)		Heavy Work (600 W)		Very Heavy Work (800 W)	
Heat Category	WBGT Index (°F)	Work (min)	Water Intake (qt/hr)	Work (min)	Water Intake (qt/hr)	Work (min)	Water Intake (qt/hr)	Work (min)	Water Intake (qt/hr)
1 (white)	78-81.9	NL	½	NL	¾	110	¾	45	¾
2 (green)	82-84.9	NL	½	NL	1	70	1	40	1
3 (yellow)	85-87.9	NL	¾	NL	1	60	1	25	1
4 (red)	88-89.9	NL	¾	180	1¼	50	1¼	20	1¼
5 (black)	> 90	NL	1	70	1½	45	1½	20	1½

Legend:
NL = no limit to work time per hour (up to 4 continuous hours).
Notes:
1. Applies for average-sized and heat-acclimatized Service member wearing the Operational Camouflage Pattern uniform (applies also to SCU equivalent).
2. Fluid needs can vary based on individual differences (± ¼ qt/hr) and exposure to full sun or shade (± ¼ qt/hr).
3. CAUTION: Hourly fluid intake should not exceed 1½ qt.
4. CAUTION: Daily fluid intake should not exceed 12 qt.

e. One simple way to mitigate risk is to adjust the WBGT index assessment strategy toward adoption of sports medicine heat stress CAT during “high-risk” activities. Both military and sports CAT use the same color schemes, but cover different ranges of WBGT. Figure 3–3 illustrates how sports CAT end where military CAT begin. The sports medicine heat stress CAT were developed specifically to alert runners to the degree of environmental heat danger during road races and to allow event planners and medical directors a way to gauge risk. They were designed for people of above average training and fitness who don minimal clothing, and produce and sustain very large amounts of metabolic heat (> 800 W) – usually during the coolest times of day. The risk of performing a 12-mile march with 55 pounds in < 180 minutes (> 800 W) on a military white CAT morning is more accurately assessed as a sports red CAT morning. For non-high-risk activities in which heat production is more modest and work-rest cycles are permitted, the white CAT level of risk is correct. This simple approach provides a valid WBGT index adjustment for risk assessment when high-risk training activities are required.

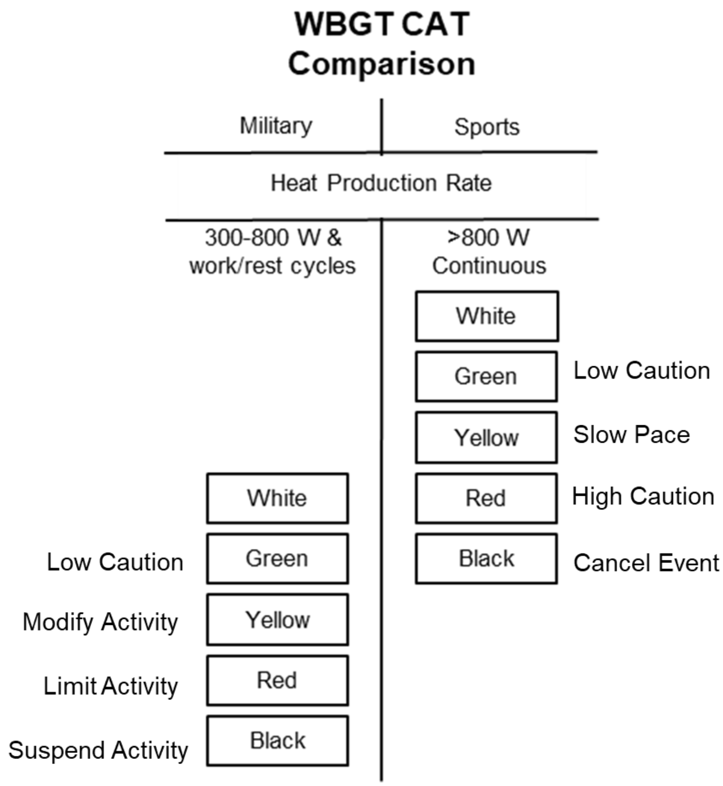


Figure 3–3. Comparison between military and sports medicine WBGT index categories. Military CAT 1 (white: 78-81.9 °F), CAT 2 (green: 82-84.9 °F), CAT 3 (yellow: 85-87.9 °F), CAT 4 (red: 88-89.9 °F), CAT 5 (black: > 90 °F); Sports CAT 1 (white: < 50 °F), CAT 2 (green: 50-64.4 °F), CAT 3 (yellow: 64.5-73.4 °F), CAT 4 (red: 73.5-82.4 °F), CAT 5 (black: > 82.4 °F).

f. In order to conduct high-risk training events safely when environmental conditions are also high risk, training should be targeted for the coolest time of day. Strategies to reduce heat production (slower pace, lighter load), increase heat loss (less clothing), or both can allow training to continue safely. For example, Figure 3–4 plots the dry bulb temperature (T_{db}), relative humidity (rh), wet bulb temperature (T_{wb}), solar heat load (solar), and both military and sports medicine CAT for comparison on July 31, 2017 at Fort Benning, Georgia. A 12-mile march with 55 pounds in 180 minutes while wearing full uniform at any time of day results in a rate of body heat storage that is incompatible with completion without serious risk of exertional heat illness, because the rate of potential heat gain exceeds the rate of potential heat loss (that is, UCHS). However, the lowest rate of heat storage is at 0600 hours when air temperature is lowest and there is no direct sun. Although the humidity is highest, the T_{wb} is stable all day, sweat evaporation remains possible all day, and greater amounts of cooling are possible through radiation and convection at 0600 hours (see paragraph 2–2). As a result, the heat storage rate for the same task at 0600 is almost 20% less than at 1200 hours. Figure 3–5 shows how independently reducing the pace by 10%, the load by 50%, or a uniform change to a PFU all decrease the rate of heat storage for the high-risk march activity performed at 0600 hours. In fact, in this example, if a uniform compromise is made then the same training stimulus (pace and load) can be achieved, because greater heat losses while wearing PFUs reverse UCHS to CHS. A change in uniform combined with reduced pace or load would reduce the heat storage rate (and risk) even more.

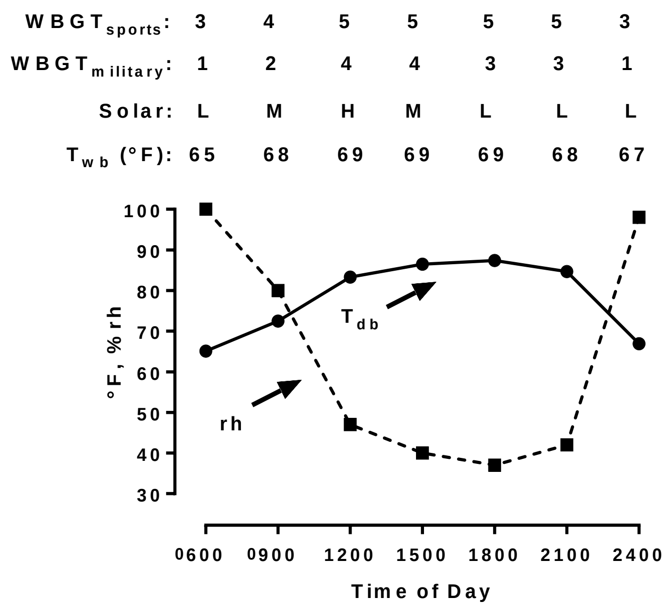


Figure 3–4. Historical weather data from Fort Benning, Georgia, July 31, 2017. L, M, and H represent low, medium, and high solar heat loads.

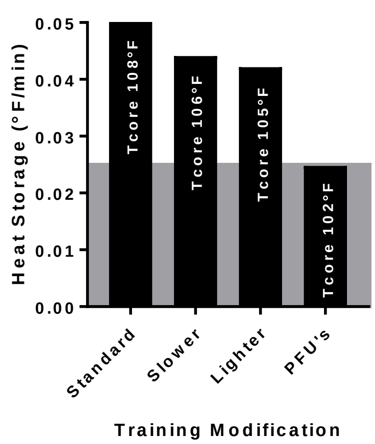


Figure 3–5. Comparison of body heat storage rates during a 12-mile march with 55 pounds completed in 180 minutes (standard), 10% slower, 50% lighter, or with clothing change to the PFU. The gray area is the acceptable heat storage rate limit for completing the task with low exertional heat illness risk. Tcore is projected rectal temperature at 180 minutes.

3–4. Body cooling approaches

a. The single greatest contributing factor to body heat storage and exertional heat illness risk is activity, or work (see paragraph 2–2). The single best way to decrease the rate of heat storage and reduce exertional heat illness risk is to stop activity, or rest. For prevention, rest in a cool environment (for example, air conditioning) may be all that is necessary to promote heat loss and recovery from heat stress, but in the absence of a cool environment, other strategies are needed. To improve heat loss at rest in a hot environment, reduce clothing, seek shade, and take advantage of all body cooling options available. If in MOPP or other enclosed PPE/gear, reduced clothing should occur immediately/at the same time that the activity is stopped.

b. The amount of body heat that can be removed using any particular cooling method depends on several factors. Biophysical factors include the amount and location of body surface area being cooled, the coolant medium (air, water, ice) and temperature, and the efficiency of the cooling method. All of these will interact to determine the potential cooling power. For example, about 6½ pounds of crushed ice has the potential to absorb ~260 W of body heat as it melts to a temperature of 99 °F. However, when applied to major arteries in an attempt to reduce body temperature, the actual heat removal is ~120 W (~46% efficient) due to small body surface area contact, vasoconstriction, and ambient heat gain. The removal of 120 W of body heat would theoretically reduce body core temperature by ~1.2 °F over 20 minutes. Practical factors include size, cost, maintenance, portability, and any power requirements of the cooling method. No single body cooling method is appropriate for all circumstances.

c. Figure 3–6 illustrates different cooling methods categorized by use, potential body cooling power, and practicality. In general, methods to the right possess the greatest potential body cooling power but are limited to small numbers of users, require significant manpower and resources, or both. These cooling methods are for treating exertional heat illness, which is further discussed in paragraph 5–1. Methods to the left are for preventing exertional heat illness. They provide less cooling power but allow multiple users at once and are generally easy to implement at low cost. It is very important to recognize that any “body cooling” is beneficial for recovery from heat stress and prevention of exertional heat illness even when the rate of body core temperature drop is slow. For example, the potential rate of body core temperature cooling using a fan in the shade is ~30% of ice water immersion to the neck, but the method can be very effective in cooling the skin, which reduces cardiovascular strain and significantly improves thermal comfort and morale (see paragraph 2–3). An AICS, shown in Figure 3–6, can be any reservoir of cold water used to immerse the hands and forearms during rest periods and provides ~40% of the body core temperature cooling rate achieved using ice water immersion to the neck. At the end of calendar year 2017, more than 1,000 AICS units were estimated to be in use at a total of eight Army and Marine installations across the Unites States. A preliminary analysis of exertional heat illness before and after AICS use in Ranger Training suggests significant prevention benefits in the form of reduced exertional heat illness severity and projected exertional heat illness treatment costs.

d. What distinguishes high from low practicality is portability, power requirements, and issues such as potential chaffing from wet clothes (for example, field showers). When possible, use of combined preventive cooling methods in “cool zones” is preferred to single methods. The practice of designating and equipping sites for deliberate cooling and rest (that is, cool zones) optimizes recovery from heat strain by accelerating body heat loss. Cool zones should be setup in natural (for example, trees) or artificial (tentage) shade and provide cool water (trailers/tanks/coolers), misters, AICS, and fans (if power is available). It is important to recognize that any method or amount of cooling provides some benefit to a hot Service member and is always recommended over no cooling at all.

e. In use by the military since the 1980s, Microclimate Cooling Systems (MCS) provide body cooling to the wearer by conditioning the “microclimate” between the user's innermost clothing layer and his/her skin. MCS facilitate heat loss by maintaining a temperature gradient between the body core and the skin (see paragraph 2–3). They can be very effective at reducing heat stress and extending work capabilities, particularly in Service members who don protective clothing, are encapsulated in hot vehicles or aircraft, or are otherwise exposed to UCHS conditions.

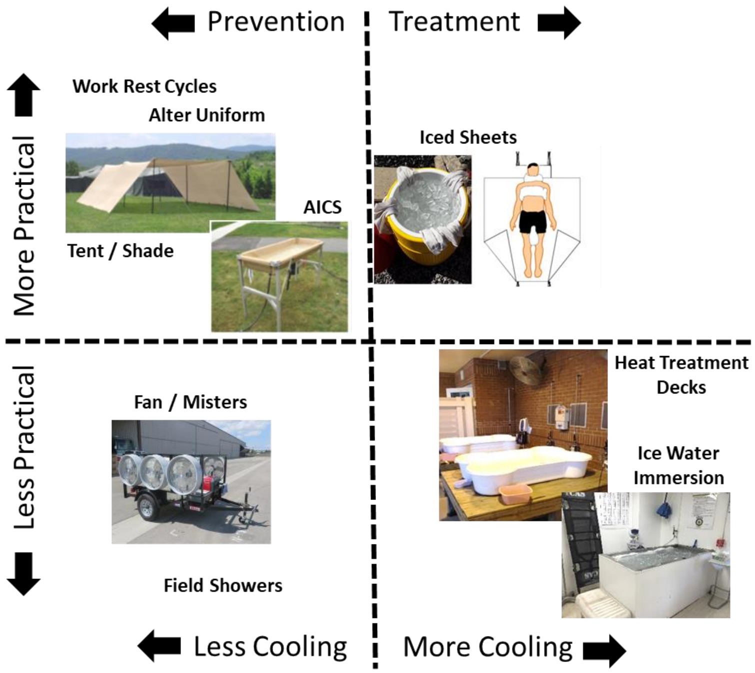


Figure 3–6. Body cooling methods for the prevention and treatment of exertional heat illness

f. Several types of MCS are used to manage heat stress. Most platform-mounted and body-worn MCS circulate a chilled liquid through small diameter tubing embedded in an undergarment worn next to the skin. Other systems ventilate a uniform by blowing ambient or conditioned air under the clothing. Still others use a phase-change material (PCM) (for example, ice, paraffin) to absorb body heat. While there are other types of microclimate cooling systems available commercially, liquid, air, and PCM devices are the most common and have been successfully used by Service members in some armored and wheeled vehicles and rotary wing aircraft retrofitted to accommodate MCS. The MCS technology has recently matured sufficiently for autonomous dismounted Service member operations during moderate and high-risk activities.

g. Military adoption of MCS is extremely limited despite their proven benefits. MCS in combat vehicles requires similar (or less) vehicle power but provides far greater individual cooling than any air conditioner can provide in desert heat conditions. The interior air temperature of a Bradley Fighting Vehicle located in Taji, Iraq was measured at 140 °F at mid-day in June 2004. It is common for interior combat vehicle temperatures to reach 125 °F. A typical vehicle air conditioner might lower the cabin temperature by 20 °F (105 °F). MCS do not cool the cabin air but directly cool the body. It is difficult to compare air conditioning to MCS, but several sources of evidence suggest that using a MCS in the same 125 °F conditions could provide the comfort associated with a cabin temperature of 85 ºF. The delivery of cooling directly beneath a Service member's clothing and equipment is far more effective and efficient than cooling the vehicle's cabin, but cost and vehicle design must be considered early. Another consideration is the primary user community. For example, rotary wing pilots are well suited as MCS users while ground troops exiting wheeled vehicles will experience a thermal burden once leaving the power and protection of an MCS-enabled vehicle. MCS for the dismounted Service member is also a modern capability, but requires carriage of a small load (< 10 pounds), battery recharge, and noise signature considerations. For example, the three military occupational specialties most subject to exertional heat illness include infantry, service/supply, and health care. Although infantry would likely find MCS a hindrance, supporting personnel might derive great exertional heat illness risk mitigation benefits.

3–5. Aviator heat stress

a. Mounted and dismounted MCS are well suited for aviators, flight crew members, and supporting ground crews, respectively. Flight crews encounter heat stress during preflight, engine start, taxiing out, and standing by for takeoff. Total ground time can be considerable even in fighter aircraft. Additionally, the heat load experienced in the cockpit is more severe than on the ramp because of the reduced air velocity, aircraft canopy green house effect, personal equipment worn and increased radiant heat load. The WBGT index in the cockpit may be as much as 20 °F higher than on the ground.

b. Flight crews of all operational aircraft require effective protection from heat and dehydration in order to maintain both physiological resistance to inflight stress and ability to operate a complex weapons system under dynamic conditions. Specifically, aerial combat entails sequences of aerobatic maneuvers with levels of acceleration (gravitational force stress, or G-stress), which challenge human tolerance limits; both heat stress and dehydration will lower the threshold at which the crew may lose consciousness. Although fighter crews experience only limited physical workloads in the cockpit, flight clothing can impose a significant thermal burden for hot weather operations. Multilayered, protective clothing may include cotton underwear; fire-retardant flight uniforms; antigravity suits; a parachute harness; body armor/flak vest; nuclear, biological, and chemical (NBC) equipment; boots; gloves; and a helmet. A chemical defense layer may be added as underwear, or incorporated into the flight uniform or outer garment. The process of dressing in this ensemble, walking to the aircraft, and conducting preflight inspection on a hot ramp significantly raises body core temperature. Thus, an already warm crew enters the cockpit of a heat-soaked aircraft and goes through the sequences required for engine start.

c. Most rotary wing aircraft do not have cockpit cooling exacerbating the risk of heat injury. Modern fighter aircraft often have cockpit cooling during ground operations (standby and taxi); however, the thick clothing and impermeable layers of the antigravity suit mean that the occupants receive only limited benefit. Typically, heat removal occurs so slowly that the aircraft is in combat or returning to base before cooling is complete. In wartime, crews are expected to fly multiple missions in quick succession with little chance to achieve full recovery in terms of body temperature and hydration.

d. The Fighter Index of Thermal Stress (FITS) was derived from the WBGT index. However, since meteorological weather reports do not include T_{bg}, an assumption is made about T_{bg} when skies are clear. The following simplified FITS equation can be used to gauge heat stress expected by aircrew in jet aircraft with canopies:

$$^{o}F = 0.83\ T_{wb} + 0.35\ T_{db} + 5.08$$

Several different FITS tables have been developed based on user preferences or convenience. Table 3-4 uses relative humidity and air temperature since both are commonly reported by meteorological stations. Caution and danger zones are based on achieving likely body core temperatures of < 100 °F and > 100 °F, respectively. Assumptions also include summer pilot clothing with helmet and parachute harness and heat production rates of 175 to 250 W (light activity in Table 3–2). Like ground exertional heat illness risk, aviators are also at greatest risk during the heat season and during daylight hours. The following FITS procedures are designed to minimize heat stress impact as described in Table 3–4:

(1) FITS caution zone (air temperature from 100 °F to 110 °F).

(a) Encourage crews to drink water before cockpit entry, during standby, and in flight (see paragraph 3–6).

(b) Be alert to symptoms of heat stress.

(c) Avoid exercise 4 hours before take-off.

(d) Precool cockpits by means of air-conditioning ground carts.

(e) Assign alternate crewmembers to perform preflight aircraft inspection.

(f) Keep the sun out of transparencies by using rolling roofs or fabric covers.

(g) Transport crewmembers directly to the aircraft.

(h) Limit the permitted duration of in-cockpit standby.

Table 3–4. Fighter Index of Thermal Stress (FITS) for lightweight flight suit (clear sky to light overcast)

		Relative Humidity (%)							
Air Temperature (°F)	Zone	≤ 10	20	30	40	50	60	70	≥ 80
70		67	70	72	74	76	78	81	83
75		71	74	77	79	82	84	86	88
80		75	79	81	84	87	89	92	94
85	Normal	79	83	86	89	92	95	97	99
90		83	87	91	94	97	100	103	105
95		87	92	96	99	102	105	108	111
100		91	96	100	104	108	111	114	117
105	Caution[1]	95	100	105	109	113	116	120	122
110		99	105	110	114	118	122	125	128
115	Danger[2]	103	109	115	119	124	127	130	134
120		107	114	119	124	129	133	136	140

Source: USAF School of Aerospace, 1978.
Notes:
[1] Be aware of heat stress; limit ground period to 90 minutes; ensure minimum 2 hours recovery between flights
[2] Cancel low-level flights; limit ground period to 45 minutes; ensure minimum 2 hours recovery between flights

(2) FITS danger zone (dry bulb temperature 115 °F to 120 °F), plus caution zone recommendations.

(a) Keep the sun out of transparencies by using rolling roofs or fabric covers.

(b) Allow only one change of aircraft before requiring return to ready room in cases of mechanical delay.

(c) Optimize conditions for cooling and rehydration between flights.

(d) Support self-assessment and empower crews to stand down when they judge that further flights would be unsafe.

3–6. Fluid replacement

a. Heat stress increases the requirement for evaporative cooling (see paragraph 2–2). As a consequence, sweat losses and body water needs increase. The military's most valuable weapon – the Service member – requires water for optimal performance. For moderate activities that can be sustained for prolonged periods in very hot environments, sweat losses of 1 quart per hour are common. Dehydration occurs when body water losses are not replaced at these rates or are not replaced at all. For a 176-pound Service member, a body water deficit of 1½ quarts (-2% of body weight) will begin to impair work performance. A deficit of 3¼ quarts (-4% of body weight) would have more dramatic effects – especially in hot environments (Figure 2–4). A -2 to -4% deficit commonly occurs in training and operational scenarios. It should be avoided as it is very likely to reduce work productivity and contribute to non-serious exertional heat illness, but it can also be easily remedied with food (normal source of electrolytes), beverages (see table 3-6 for hydration optimization strategies), and recovery time.

b. A body water deficit of 6½ quarts (-8% of body weight) would make standing in the heat difficult, while a 13-quart deficit (-16% of body weight) would produce incapacitation and possibly death depending on the rate of water loss and proximity to treatment. Deficits this large must be treated with intravenous (IV) fluids and, if conscious, oral fluids. Losses of this magnitude are unlikely except in situations where fluids are severely limited or unavailable. This fact underscores the importance of accurate logistical water planning (see Soldier Water Estimation Tool (SWET) below) and availability of water purification technologies.

c. Diarrhea occurs commonly during military deployments and may produce gastrointestinal (stomach and bowel) body water losses of 1 to 2 quarts per day. Although most "traveler's diarrhea" resolves within 3 to 5 days, it can exacerbate dehydration due to sweat losses – particularly in hot environments. Oral rehydration is the keystone treatment. More severe diarrhea (for example, dysentery, or severe diarrhea containing blood or mucus) can be incapacitating and some forms even life threatening in the absence of medical intervention and IV rehydration.

d. Body water cannot be effectively stored, so there is no benefit to overconsuming fluids to protect against dehydration or improve performance. Large volume fluid intakes generally produce large volumes of urine output. However, stressors like heat and heavy exertion increase fluid retention hormones and decrease urine production. As a result, very aggressive overdrinking in these circumstances can produce water intoxication or low blood sodium (hyponatremia; see paragraph 5–4). For a 176-pound Service member with 42 quarts of body water and a "normal" blood sodium of 140 millimoles per liter (mmol/L), a body water gain of 2 quarts (+2.5% of body weight) would lower blood sodium to < 135 mmol/L; 3 quarts (+3.7% of body weight) would lower blood levels to < 130 mmol/L and would likely manifest gross symptoms of hyponatremia (see paragraph 5–4). Chronic overdrinking combined with heavy sweating and insufficient electrolyte intakes can predispose Service members to hyponatremia the same as acute overdrinking of smaller quantities.

e. When a significant body water deficit occurs (≥ -2% of body weight), thirst and kidney water retention are triggered. In garrison circumstances, hydration is maintained using thirst cues combined with social consumption of beverages. In fact, most fluid is replaced at mealtime and food (electrolytes) helps retain the water consumed (see paragraph 3–7). However, the same stressors that complicate overdrinking also create a discordance between dehydration and thirst sensation – a condition known as involuntary dehydration. A Service member training or fighting in the heat who uses a drink-to-thirst strategy is at serious risk for dehydration and all of its potential consequences. Thirst does not adequately motivate personnel to consume sufficient fluids promptly to replace sweat losses in hot environments. This fact was demonstrated by research commissioned by the U.S. military in response to conditions in North Africa during World War II. Since then, it has also been confirmed in environmental laboratory research studies and in published observations of combat scenarios that simulated conditions in Southern Iraq during Operation Iraqi Freedom. If thirst alone is used to guide fluid replacement, adequate hydration will lag behind fluid needs for several hours because thirst is also quenched before complete rehydration is achieved. Although some in sports medicine promote a "drink-to-thirst" strategy to prevent overdrinking during prolonged exercise, the circumstances in sports are vastly different from those in military operations. "Drink to Thirst" is an appropriate strategy only during training events that are directly analogous to sporting events; specifically timed, competitive events, such as forced road marches performed as graduation requirements for various military schools. For these reasons, military fluid replacement strategies published in this guidance document were created and validated from the most sophisticated combinations of human research and prediction modeling available.

f. The Service member's sweating rate is related to activity level, clothing and equipment worn, and environmental conditions. Tables 3-2 and 3-3 provide water replacement recommendations based on workload and heat category during training and continuous work situations, respectively. Most, but not all, of the variability in the sweating rate is accounted for by these factors with an error of ± ¼ quart per hour. Likewise, exposure to full shade or full sun can decrease or increase fluid replacement needs by ¼ quart per hour. The tables are sufficiently robust to be modified for specific scenarios and still maintain appropriate hydration. Tables 3–2 and 3–3 additionally specify an upper limit for hourly (1½ quarts) and daily (12 quarts) water intake to provide a safeguard against overdrinking and development of water intoxication (hyponatremia) during training. Fluid replacement guidance was established in this TB MED in 1999 and validated in 2003. Figure 3–7 illustrates a 2017 analysis showing that when sweating rates of 324 Service members were measured against adherence to the prescribed drinking rates in tables 3–2 and 3–3, > 90% neither lost nor gained more than 2% of their body weight over 4 hours of activity. Guidance is considered effective if within ± 2% body weight. Urine losses were minimal, as expected. The 2017 analysis in Figure 3-7 further validates the guidance as it was performed using a wider range of indoor and outdoor activity levels (metabolic rates) and modern clothing and equipment configurations of Service members enlisted in the U.S. or Singapore Armies.

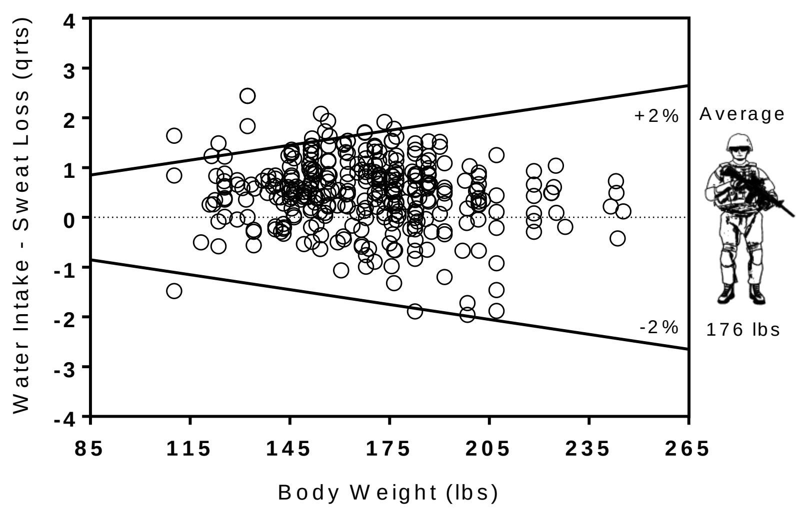


Figure 3–7. Accumulated differences between water intake (in accordance with table 3-2) and measured sweat losses after 4 hours of work expressed as a percentage of body weight. Guidance is considered effective if within ± 2% body weight.

g. Knowledge of daily water requirements is important for logistical planning purposes, particularly in hot environments. During summer training, Service members engaged in Special Forces-like training may require 8 to 10 quarts of water per day, in basic training 5 to 6 quarts per day, and in ordinary garrison support activities 3 to 4 quarts per day. Generally, the volumes listed provide 2 quarts per day to balance the typical dietary and metabolic kidney solute load, while the remainder replaces sweat losses ~1:1. Sweat losses must be replaced with equal amounts of drinking water, representing as much as 70% of the total potable water planned. Figure 3–8 shows screenshots of the five required inputs and the mission planning tool calculator. SWET calculates drinking water needs using the same complicated algorithms required to produce tables 3–2 and 3–3, but with just five simple user inputs. In addition to allowing easy water planning for garrison training, SWET also facilitates knowledge of the potable water portion of “big” water planning; thus, tactical commanders can use SWET to optimize the logistics of water transport. SWET is incorporated into Nett Warrior (an integrated dismounted leader situational awareness system) and is also available for download from the U.S. Training and Doctrine Command App Gateway (TRADOC TAG) for mission planning. Accurate water planning reduces the burden of transporting more water than is necessary and the risks associated with running out.

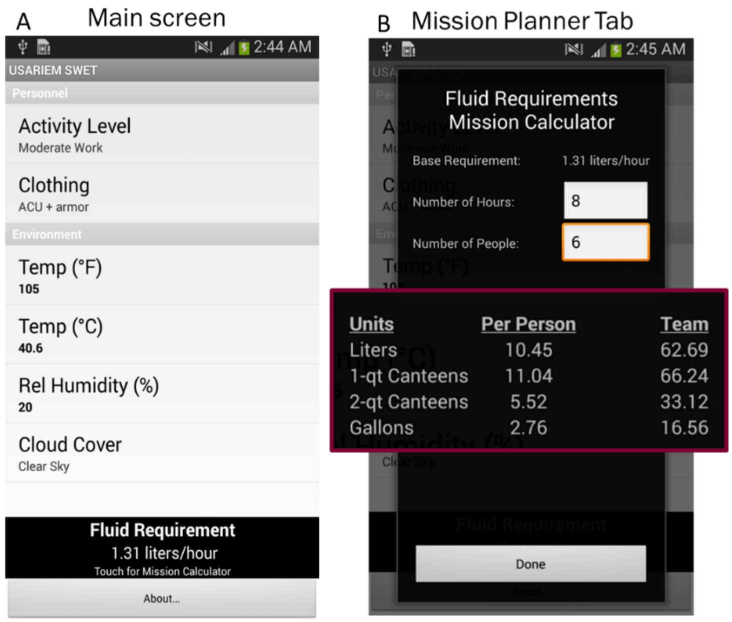


Figure 3–8. Screenshots of Soldier Water Estimation Tool (SWET) main (A) and mission planner (B) screens

h. More than 9,000 training Service members are treated for fluid and electrolyte disorders each year. The incidence of hyponatremia in Army Basic Combat Training continues to be significant, highlighting the importance of education and/or implementation of guidance on both the upper and lower limits of fluid intake (Table 3–2). Two possible hydration-monitoring solutions include fluid intake tracking and hydration status assessment.

i. Fluid intake tracking is frequently accomplished by the buddy system whereby a buddy tracks fluid consumption by recording in a notebook or on a card. A “550” parachute cord or bootlace can be used to self-track canteen consumption. The cord is secured to the uniform and a knot tied for each quart consumed. Beads can be used in place of knots. These procedures should be determined locally. If used properly, either method allows adherence to guidelines (Tables 3–2 and 3–3) and can even be useful for distinguishing exertional heat illness from hyponatremia (see paragraph 5–4).

j. The first and second Gulf Wars saw increasing use of hydration systems (large collapsible bladder drinking systems) in place of, or in addition to, canteen usage. Soon after, 3-liter (~3 quart) systems became standard issue as a component of the modular lightweight load-carrying equipment system of load-bearing equipment and backpacks. Although hydration systems allow hands-free drinking and less frequent filling, the volume and consumption of water from hydration systems are more difficult to track than canteen consumption and may be a contributing factor to both under- and overdrinking problems. Table 3–5 is an adaptation of Table 3–3, whereby a 3-quart hydration system refill policy could be used in place of canteen guidance.

Table 3–5. Alternative fluid replacement guidelines for training in warm and hot environments using a standard refill policy[1]

		Easy Work (250 W)		Moderate Work (425 W)		Heavy Work (600 W)		Very Heavy Work (800 W)	
Heat Category	WBGT Index (°F)	Work-Rest	Refill Freq.	Work-Rest	Refill Freq.	Work-Rest	Refill Freq.	Work-Rest	Refill Freq.
1 (white)	78-81.9	NL	6 hr	NL	4 hr	50/10	4 hr	25/35	3 hr
2 (green)	82-84.9	NL	6 hr	NL	4 hr	40/20	3 hr	20/40	3 hr
3 (yellow)	85-87.9	NL	4 hr	NL	4 hr	35/25	3 hr	20/40	3 hr
4 (red)	88-89.9	NL	4 hr	50/10	4 hr	25/35	3 hr	15/45	3 hr
5 (black)	> 90	NL	3 hr	35/25	3 hr	20/40	3 hr	10/50	3 hr

Legend:
NL = no limit to work time per hour (up to 4 continuous hours).
Notes:
1. Applies for average-sized and heat-acclimatized Service member wearing the Operational Camouflage Pattern (OCP) uniform (applies also to SCU equivalent).
2. Assumes that 3-quart hydration system is filled to start.
3. Refill frequency results in the same drink volumes shown in Table 3–2.
4. The work-rest times and fluid replacement volumes will sustain performance and hydration for at least 4 hours of work in the specified heat category.
5. Fluid needs can vary based on individual differences (± ¼ qt/hr) and exposure to full sun or full shade (± ¼ qt/hr).
6. Rest means minimal physical activity (sitting or standing) accomplished in shade if possible.
7. CAUTION: Hourly fluid intake should not exceed 1½ qt.
8. CAUTION: Daily fluid intake should not exceed 12 qt.
9. If wearing heavy protective clothing (CBRN, JSLIST), add 10ºF to WBGT index for easy work and 20 ºF to WBGT index for moderate and hard work.

k. Real-time hydration assessment is challenging and impractical. However, “daily” hydration assessment can be accomplished in several simple ways to assess the adequacy of fluid intake behaviors in the previous 24 hours. Other hydration assessment methods are also possible, but are not discussed here because their interpretations are easily confounded or they are simply too impractical for daily military use. Table 3–6 reviews simple strategies for optimizing hydration.

(1) Urine color. Service members can monitor hydration status by noting the “first-morning” (upon wakening) color of their urine. Urine assessment at any other time of day is too easily confounded to be useful. In general, a dark colored first morning urine indicates that fluid consumption should be increased. However, color of the urine stream can be difficult to assess due to urinal or toilet bowl dilution that causes lightening of color, and excessive vitamin intake and certain foods like beets and carrots that cause darkening of color. Urine capture into a clear or white cup helps resolve this difficulty and allows for a more accurate assessment.

(2) Urine frequency. Dark and concentrated urine is usually associated with low urine volumes and low urine frequency. Ordinary 24-hour urine volumes are approximately 2 quarts divided among 3 to 7 voids (emptying the bladder). The urge to urinate occurs when the human bladder is holding approximately ½ quart of urine, which is also the minimum volume of urine produced daily to rid the body

Table 3–6. Hydration optimization strategies

1. Assure adequate hydration practices in the previous 24 hours • First morning urine color, specific gravity, or 24-hour frequency
2. Provide sufficient water to replace anticipated losses from sweating • Estimate needs using tabled doctrine (tables 3–2, 3–3, 3–5) or the Soldier Water Estimation Tool (SWET) • Do not exceed 1½ quarts per hour or 12 quarts per day[1]
3. Schedule water breaks and optimize consumption • Plan drinking opportunities during rest and body cooling breaks • Make water more palatable, if possible, by cooling to 50 to 60°F • Flavored water improves consumption but never add flavoring to water trailer or collapsible hydration systems; if adding to canteen, be sure to sanitize after use • Include opportunities for snacks and meals to promote fluid intake and retention • Assure real-time fluid intake adequacy using hydration tracking methods such as recording in a notebook or on a card, or using a cord attached to the uniform
4. Other than water— • Garrison dining provides a variety of beverages that promote rehydration recovery similarly to or better than water (milk, juices, sports drinks) • Moderate caffeine consumption will not promote dehydration, particularly when consumed as a beverage (coffee, tea, soda) • Salt is necessary for water retention; thus, food (electrolyte) intake is necessary for optimum hydration • In high-risk situations, an electrolyte-rich beverage may be used as a supplement to water and food (see paragraph 3–7)
Note: [1] The stomach empties less than 1½ quarts per hour; thus, drinking more than this may result in bloating and increases hyponatremia risk. Circumstances requiring more than 12 quarts per day are possible but rare. Do not exceed 12 quarts per day unless 24-hour urine assessment measures still suggest inadequacy.

of waste. This minimum could therefore be produced in just 1 or 2 small volume voids. Consequently, anything less than 3 voids per day is generally associated with low 24-hour urine volumes and is another indicator of inadequate drinking. Urine frequency assessment should be made on a 24-hour basis. Similarly, frequent urination (> 7 voids per day) in conjunction with very light or clear urine may be interpreted as overdrinking relative to needs.

(3) Urine concentration. Where available, urine-specific gravity can be easily measured with a refractometer or reagent strip, and a value > 1.025 (ratio of urine density to water density of 1.0) can be used as a reasonable cut-point for inadequate fluid replacement.

l. Where water is in limited or short supply, survival will depend on the rate of water loss and time. Limit sweat losses (for example, work at night, reduce physical activity during the day, seek shade) and ration water supplies for drinking. Survival from extreme dehydration is more likely if body water losses occur gradually (days) rather than abruptly (hours).

m. Aviators concerned with the need to urinate during long flights are advised against fluid restriction or purposeful dehydration. G-stress tolerance is lowered by dehydration and important mental functions and reaction time may become compromised (see paragraphs 2–4 and 3–5). The presence of heat stress will exacerbate both and make progressive dehydration more likely. Aviators should be well hydrated but drink the last of their fluids ~1 hour before anticipated cockpit entry. The ~1 hour duration will allow ample time for bladder emptying before any mission. Caffeine-containing beverages will generally not stimulate urine formation more than similar volumes of water as long as the dose is modest

(< 200 mg) and the user is habituated to the effects of caffeine. Typical urine formation occurs at a rate of approximately 65 milliliters per hour, and bladder volumes of 300 to 600 milliliters can be tolerated before the need to void is urgent. Therefore, missions of 5 to 10 hours without urination may be possible once a bladder has been emptied. Physical stress may reduce urine formation while mental stress (worry or fear) may increase it. When fluids are consumed in closer proximity to flight (for example, standby), beverages with higher electrolyte concentrations (see paragraph 3–7) may be retained longer before the need to urinate arises.

3–7. Electrolyte (salt) replacement

a. Water is not the only substance lost in sweat; sodium, chloride and other electrolytes (potassium, calcium, and magnesium) are lost in sweat also. Sweat sodium concentrations can range from 0.75 to 1.50 grams (g) per quart, depending on diet, sweating rate, and heat acclimatization status. Heat acclimatization can reduce sweat sodium concentrations by half, but higher sweating rates make net sodium losses about 30 to 40% less. If we assume that 1 g of sodium is contained in each quart of sweat (~2.5 g salt), then the typical ranges of sweat losses discussed above would result in sodium losses ranging from 3 to 10 g per day. Potassium losses range from 0.5 to 2.0 g per day. Other mineral losses are of little consequence.

b. The Military Dietary Reference Intakes (MDRI) for sodium (3.6 to 5.0 g per day) cover the needs of most Service members living and training in warm or hot environments. The MDRI for potassium (2.5 to 3.2 g per day) also covers sweat potassium losses.

c. Daily electrolyte consumption for garrison dining ranges widely because of food preferences (see Combat Rations Database), but can easily meet the needs described above. Each meal, ready to eat (MRE) contains an average of 3.6 g of sodium (2.0 g in food and 1.6 g in salt packet). If three MREs are consumed, Service members would consume a maximum of 10.8 g of sodium (6.0 g if the salt packets are not eaten). Therefore, Service members should try to consume as much of their MRE ration as possible, to include salt packets, during periods of strenuous physical work in the heat.

d. Increases or decreases in body sodium stores are usually corrected through hormonal and appetite adjustments. Physical activity increases hunger, and the associated increased food consumption usually covers the additional sodium required. If Service members perceive that they need additional sodium, such as the first several days of hot weather exposure, this can be achieved by salting food to taste. Salt tablets are not recommended as their misuse has resulted in gastrointestinal discomfort and incapacitating nausea.

e. One quart of a sports drink usually provides a flavorful 0.4 g of sodium and 250 carbohydrate calories, which makes it a desirable beverage before and during prolonged, strenuous exercise, particularly if food will not be available. A variety of commercial sports drinks are available to purchase with subsistence funds. (Note: Commanders are authorized to purchase commercial sports drinks only from the Defense Logistics Agency catalog.) Regardless of the brand, sports drinks generally meet the following criteria per quart: sodium 0.3 to 0.7 g, potassium 0.08 to 0.20 g, and carbohydrate 50 to 100 g. The type of carbohydrate (for example, glucose, sucrose, or polymers) will meet the energy requirement, although high fructose corn syrup should be avoided as it may cause gastrointestinal side effects.

f. Canteens and hydration systems containing carbohydrate (sugar) solutions increase the growth of harmful bacteria, which increases the incidence of gastrointestinal upset. Additional canteen sanitation is needed when sugar-containing beverages are added. Canteens and hydration systems containing carbohydrate solutions should be rinsed with water daily and treated with a hypochlorite solution every 2 or 3 days. The frequency of these sanitation actions depends on the quality of water, liquid temperature, and composition of the beverage. Flavoring reduces the effectiveness of chlorine to fight microbial growth, so these beverages should be added to already purified water and consumed within several hours. Ideally, carbohydrate solutions should not be added to hydration systems due to added sanitation difficulties.

g. In most training environments, adherence to water intake doctrine and majority consumption of rations (garrison dining or MREs) will provide adequate water and electrolyte replacement. However, for any Service member who is not fully heat acclimatized or who does not consume sufficient rations for any reason, electrolyte depletion and hyponatremia can be a concern when training in hot weather.

h. Most cases of hyponatremia (that is, serum sodium < 135 mmol/L) in the military are due to overhydration/water intoxication rather than electrolyte depletion. To prevent this aspect of the problem, water doctrine recommendations are to not exceed intakes of 1½ quarts per hour or 12 quarts per 24 hours (or 4 full hydration systems). Accurate tracking and battle buddy awareness will also minimize occurrences. However, even these guidelines cannot fully protect against hyponatremia. When electrolyte losses are high (> 10 g per day) and intakes are low (< 4 g per day), matching water intake to sweat loss to prevent excessive dehydration could lower plasma sodium from 140 to < 135 mmol/L in 24 hours. By substituting 2 quarts of water each day with 2 quarts of an electrolyte-rich beverage during high-risk situations, electrolyte intakes would increase to ~6 g per day and generally keep plasma sodium > 135 mmol/L.

i. High-risk situations for hyponatremia include the early heat season before heat acclimatization has been achieved, training scenarios that restrict food availability or produce high levels of stress that reduce appetite, multi-day events with multiple days of red or black CAT conditions, and a command emphasis on drinking during high-risk periods. See paragraph 5–4 for details on symptoms and treatment of hyponatremia.

j. Several commercially-available products may be utilized in circumstances known to increase the risk for developing hyponatremia. The product market changes rapidly and any product can change formulation or leave the market as new products arrive. Products on the list are similar in composition to oral rehydration salts (ORS) like those found in some Medical Equipment Sets for the treatment of diarrhea. They contain enough electrolytes to help mitigate or prevent hyponatremia when sweat losses are high and food intakes are restricted for any reason. They generally contain two or three times more sodium than sports drink. Those sold as medical foods must be purchased with medical funds just like ORS packets; others sold for sport or general consumption may be purchased with subsistence funds. (Note: The first two numbers of the national stock number of a product identifies its commodity area. The Federal Supply Group (FSG) for medical items, including medical foods, is 65; the FSG for subsistence (food) items is 89. This is a way to determine the correct type of funding required for purchase.)

k. Regardless of the specific product, beverages should ideally contain an electrolyte composition closer to sweat but still palatable (that is, 0.75 to 1.5 g sodium per quart). Tablets designed to dissolve in water should be diluted properly to provide the correct concentrations. ORS packets (or MRE salt packets) can also be dissolved in sports drinks to improve flavor since the higher carbohydrate concentration of sports drinks is not a concern in the treatment of non-diarrheal dehydration.

l. Dehydration stemming from infectious diarrhea results in electrolyte losses 2 to 3 times greater than from sweating. Therefore, ORS is the preferred beverage for treating diarrheal dehydration. In the absence of pre-packaged ORS, a simple ORS recipe can be made using 6 level teaspoons of table sugar and ½ level teaspoon of table salt dissolved in 1 quart of potable water.

CHAPTER 4

EXERTIONAL HEAT ILLNESS AND HEAT-RELATED CONDITIONS

4–1. Spectrum of exertional heat illness and related conditions

a. Minor heat-related conditions include exercise-associated muscle cramps (EAMCs; also known as heat cramps), heat syncope, heat edema, miliaria rubra, and sunburn. The spectrum of exertional heat illness includes HE, EHI (heat exhaustion with clinical evidence of injury to vital organs), and EHS. The diagnostic conditions of HE, EHI, and EHS often share overlapping features that blur their interpretation as discrete disorders with their own distinct pathogenesis.

b. Figure 4–1 depicts the spectrum of exertional heat illness in terms of severity and categories of physiological dysfunction (that is, hyperthermia (elevated body temperature), dehydration, damage to the kidney, destruction of cells, and damage to the brain). All illnesses are associated with elevated body core temperature and the consequent metabolic and circulatory perturbations (heat strain) that are brought about by heat stress from exercise and the environment. The disorders share overlapping features and increase in severity along the spectrum.

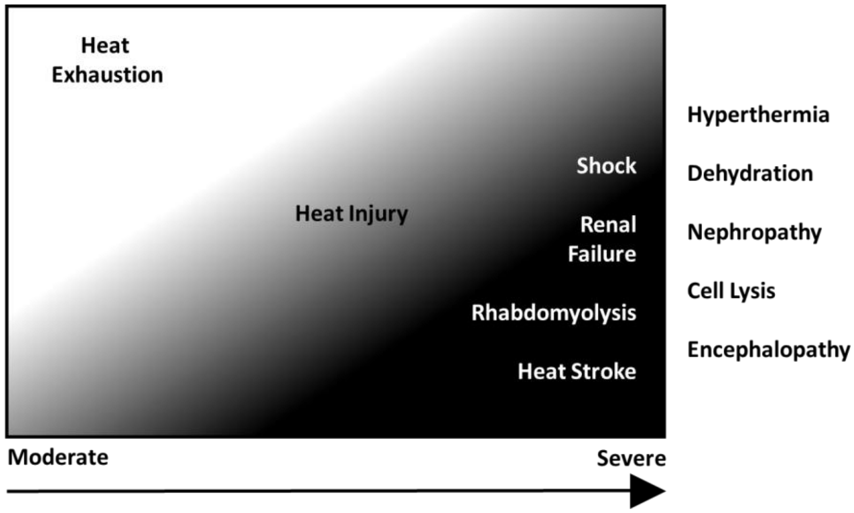


Figure 4–1. Spectrum of exertional heat illness with associated categories of physiological dysfunction

4–2. Epidemiology and risk factors

a. Despite preventive measures, the incidence and severity of documented exertional heat illness has recently increased. In 2019, there were 2,681 active component Service members hospitalized for heat illness with 507 incident cases of the most serious condition of EHS. The annual incidence rate (unadjusted) of cases of heat stroke in 2016 was slightly lower than the rate in 2015. The estimated annual direct medical cost for all exertional heat illness is almost 9 million dollars. The annual direct medical cost of EHS alone is almost 2 million dollars. These costs do not take into consideration the indirect costs associated with lost duty time, indicating that the total cost is, in reality, much higher. Exertional heat illnesses occur more frequently in males and Service members under the age of 19 years. Of the 10 installations with the most exertional heat illness events, the majority are located in the southeastern U.S. (see paragraph 2–2).

b. Less is known about the incidence of exertional heat illness during actual military operations. Documented estimates vary widely across wars fought. Based upon after action reports, the least serious of cases (that is, exertional HE) are treated and return to battle, thus escaping any official reporting system. However, these cases pose a serious threat to resources and mission effectiveness. For example, in 2004, 40 cases of HE were treated at a battalion aid station after the first 72 hours of battle in Najaf, Iraq. It takes between two and four Service members to carry a heat casualty to safety. Exertional heat illness casualties that are never reported to command, safety and public health personnel can drastically reduce the combat power of a squad or even a platoon.

c. EHS often occurs under conditions that the victim has been exposed to many times before without incident, or while others are concurrently being exposed to the same condition without incident. This suggests that these victims are inherently more vulnerable that day and/or some unique circumstances triggered the heat event. Individual and environmental factors that adversely influence thermoregulation can increase the risk of an exertional heat illness (Table 4–1). Risk factors are listed in descending order of risk posed, based on the best available evidence to date. However, while the presence of more than one individual or environmental risk factor logically implies greater risk, the desire to "score" risk factors or assign cumulative risk is not recommended. Presently, there is not enough evidence to justify a quantitative heat illness risk management matrix.

Table 4–1. Individual and environmental risk factors for exertional heat illness

Individual		
Congenital	**Functional**	**Acquired**
Anhidrosis Ectodermal Dysplasia	Very Heavy Exertion Lack of Heat Acclimatization Low Physical Fitness Excess Body Composition Standards Low Work Efficiency for Task	Prior Heat Illness Fever / Infection Medications Burn Graft Miliaria Rubra / Sunburn Dehydration Alcohol Use Sleep Deprivation Supplement Use
Environmental		
High Wet Bulb Globe Temperature (WBGT) Index Clothing and Equipment Lack of Air Movement Lack of Shelter or Shade Previous Day Heat Stress Access to Air Conditioning		

d. Congenital risk factors represent risk factors that an individual is born with that impair thermoregulation. Anhidrosis (inability to sweat) and ectodermal dysplasia (lightly pigmented skin; inability to sweat) impair sweating and limit evaporative heat loss.

e. Functional risk factors include mostly modifiable elements of risk. They include sustained, very heavy exertion (> 800 W) – which is often a fact of military life – that can result in exertional heat illness even in cool weather, because high rates of body heat storage can often overwhelm lower rates of body heat loss (see paragraphs 2–2 and 3–3). The unequivocal benefits of heat acclimatization are reviewed in paragraph 2–5. Service members with low physical fitness (1.5-mile run time of ≥12 minutes) have an increased risk of exertional heat illness. Although having a higher body weight has also been associated with increased risk, it can be difficult to determine muscular weight from excess body fat and the corresponding level of fitness. Body fat does not itself impair thermoregulation, but it does increase heat production as additional weight to be carried. Highly fit and motivated Service members with a high body weight but more muscle may also be at higher risk, despite higher fitness, simply because they must carry more weight. Inefficient task performance also potentially increases exertional heat illness risk because it can result in proportionally more heat (and less work) performed on any given task.

f. Risk factors may be "acquired" through behavior (for example, poor sleep habits or alcohol) or by exposure (for example, illness or sunburn). The mechanisms by which certain medications increase exertional heat illness risk are presented in Table 4–2. There is growing evidence that EHS victims may be sick the day prior to clinical presentation, which can worsen the illness. Fever and inflammation from infection or muscle injury can contribute to exertional heat illness. In addition, while most Service members recover from an appropriately managed exertional heat illness without consequence, prior exertional heat illness is believed to increase risk for a subsequent exertional heat illness event. In fact, Service members

Table 4–2. Drugs implicated in susceptibility to exertional heat illness

Medication or Medication Class	Basic Effect
Anticholinergics (for example, to treat dizziness and nausea)	Impaired sweating
Antihistamines	Impaired sweating
Antipsychotics	Impaired sweating
Tricyclic Antidepressants	Impaired sweating; increased heat production; most have anticholinergic (drying) effects
Mood Stimulants (amphetamines such as ADHD medications; cocaine, ecstasy)	Increased psychomotor activity (fidgeting, repetitive movements); activated vascular endothelium (inflammation of blood vessel linings)
Performance stimulants (supplements, for example, ephedrine/ephedra)	Increased heat production; masked fatigue
Lithium (mood stabilizer)	Nephrogenic diabetes insipidus (inability of the kidney to preserve water)
Diuretic antihypertensives	Salt depletion and dehydration
Beta-blocker antihypertensives (for example, propranolol, atenolol)	Reduced skin blood flow; reduced blood pressure; impaired cardiovascular homeostatic reflexes (ability to maintain blood pressure)
Ethanol (drinking alcohol)	Diuresis (increased excretion of urine); possible effects on intestinal permeability (ability to absorb water)
Angiotensin-converting enzyme (ACE) inhibitor and angiotensin receptor blockers(ARB)	Promote kidney excretion of sodium and water by blocking angiotensin II and aldosterone secretion (that normally maintain blood pressure)
Stimulant decongestants (for example, pseudoephedrine)	Increased heat production
Drugs that can increase sensitivity to sunlight (check prescription warning label)	Structural change in the onboard drug from exposure to ultraviolet (UV) light, possibly causing allergic rash

who suffer an EHS are often observed within 1 year preceding the EHS to have one or more acquired risk factors. Of the ~2,500 documented EHS cases among Service members between 2008 and 2014—

- 20% suffered a prior exertional heat illness;
- 30% were diagnosed with at least one infection 2 months before or within 7 days after the EHS; and
- 33% were taking at least one medication in the 2 weeks leading up to the EHS.

g. The role that dehydration (≥ -2% body weight) plays in thermoregulation, performance, and the exacerbating effects of environmental heat were reviewed in paragraph 2–3. Dehydration increases the risk of fainting when standing in formation and is commonly reported in association with exertional heat illnesses of all types. Gastrointestinal problems can induce dehydration with proportionally larger electrolyte losses (compared to sweat) and increase the risk of exertional heat illness. Skin conditions (for example, burn grafts, miliaria rubra, and sunburn) impair sweating and may increase the risk for exertional heat illness. For example, miliaria rubra (heat rash or prickly heat) measurably impairs sweating by blocking sweat ducts, which leads to measurably greater body heat storage. The degree to which skin conditions impair thermoregulation relates to the surface area affected; most notable effects occur when more than 20% of the body surface area is affected. There is no evidence that conventional sunscreens or standard issue insect repellants impair sweat secretion or evaporation; thus, their use is recommended to protect against sunburn and insect bites.

h. Limited data and the use of "best practices" were required to derive some acquired risk factors. For example, the dietary supplement industry is poorly regulated and may sell products with ingredients that increase the risk of exertional heat illness, similar to some medications (see Table 4–2). Although moderate consumption of weak alcohol-containing beverages (< 4% ethanol) will not cause dehydration, more concentrated sources can; however, all alcohol-containing beverages (regardless of the alcohol concentration) should therefore be avoided when training in hot environments. Similarly, sleep deprivation may or may not impair thermoregulation, but it may weaken resistance to heat and other stressors.

i. The environmental risk of exertional heat illness directly associated with the WBGT index was reviewed in paragraphs 2–2 and 3–3. The WBGT is highest when air temperature and humidity are both elevated and skies are clear (full sun). The need for heavy clothing and equipment, windless conditions, and lack of shelter from the sun are all compounding factors summarized by work-rest and fluid intake recommendations in Tables 3–2 and 3–3. There is also evidence that the prior days' heat stress can be cumulative and a risk factor for exertional heat illness. In addition to body cooling during rest periods (see paragraph 3–4), cumulative days of heat stress may benefit from air-conditioned sleeping arrangements (when possible).

j. Exertional heat illness often occurs during the initiation of exercise in the heat and not necessarily during the hottest part of the day. Some of this can be explained by the performance of high-risk training activities (see paragraph 3–3). However, exertional heat illnesses can occur during any of a number of activities. These facts suggest that the day they became ill, the victims may have begun the exercise-heat stress compromised in some way. In some cases, however, there is no apparent explanation for an event on that particular day, even after carefully scrutinizing known risk factors.

4–3. Definitions of minor heat-related conditions

Minor heat-related conditions include hyperthermia of exercise, exercise-associated muscle cramps (EAMCs; also known as heat cramps), heat/parade syncope, heat edema, miliaria rubra, and sunburn.

a. Hyperthermia is often a natural consequence of exercise (see paragraph 2–2). Under some conditions, body core temperature may rise several degrees above normal without complications. Temperatures for some individuals can exceed 105 °F without pathology. Exercise-heat stress is differentiated from exertional heat illness in that the resultant hyperthermia will decrease naturally upon exercise cessation without requiring cooling intervention and no end-organ dysfunction of vital organs will occur.

b. EAMCs are brief, recurrent, and often agonizing skeletal muscle cramps of the limbs and trunk. The cramp in an individual muscle is often preceded by palpable or visible fasciculations generally lasting ~2 to 3 minutes but can be prolonged in duration. Diffuse (multi-focal) cramping can occur with severe EAMCs. Individuals with EAMCs may have concomitant exercise-associated hyponatremia (EAH) (see paragraph 5-4). Cramps may be precipitated by vigorous use of affected skeletal muscles and may recur in the same individual. The cramp can produce a hard lump in the skeletal muscle; smooth, cardiac, and diaphragm muscles are not involved. An EAMC often occurs in salt-depleted persons during a period of recovery (up to many hours) after prolonged, intense sweating.

(1) The cause of heat cramps is not known; possible mechanisms include fatigue-induced alterations in neuromuscular control and electrolyte abnormalities. It is hypothesized that intracellular calcium is increased via a reduction in the sodium concentration gradient across the cell membrane. The increased intracellular calcium accumulation then stimulates actin-myosin interactions (that is, filaments propelling muscle filaments) causing the muscle contractions.

(2) Other than muscle soreness and minor muscle strain, no significant complications have been reported from EAMCs. An episode of an EAMC does not imply any predisposition to exertional heat illness. No profile is needed except to assure an adequate period of recovery. An attempt should be made to determine the reason for the episode so that appropriate advice can be given to the Service member

and chain of command to avoid future episodes. Dietary salt supplementation (see paragraph 3–7) can reduce the incidence of EAMCs in populations at risk. Service members with recurrent cramping that interferes with functional performance should be considered for further evaluation by an appropriate specialist to rule out an underlying medical condition.

c. Heat/parade syncope is a temporary circulatory insufficiency due to pooling of blood in the peripheral veins, especially those of the lower extremity, with consequent decreased diastolic filling of the heart resulting in inadequate cerebral perfusion. Symptoms range from lightheadedness to loss of consciousness. Fainting in the heat after prolonged standing (heat/parade syncope) often occurs during formations in hot weather environments and is more likely during the initial period of heat acclimatization. In addition, it may occur if standing still after completing a vigorous activity. Dehydration or heat exhaustion may be contributing factors for the occurrence of heat/parade syncope. When syncope occurs during or after work, it may indicate a mild, moderate, or severe form of exertional heat illness. Skin temperature is typically elevated in heat/parade syncope but body core temperature is not unless the attack follows exercise. Victims of heat/parade syncope will recover rapidly once they sit or lay supine, though complete recovery of stable blood pressure and heart rate (resolution of orthostasis or ability to stand without fainting) in some individuals may take 1 to 2 hours. Obtain a complete history to rule out other causes of syncope, including an exertional heat illness or other medical diagnosis (for example, cardiac disorder).

d. Heat edema presents as swelling and uncomfortable tightness of the hands and/or feet. Victims of heat edema may complain that their shoes feel tight or are ill fitting. The physiological mechanism is unknown but probably includes venodilation and extravascular fluid shifts. The symptoms usually resolve within a few days, as the person becomes heat acclimatized. Treatment for this self-limiting condition is reassurance.

e. Miliaria rubra (prickly heat or heat rash) occurs when sweat gland pores become blocked by macerated stratum corneum. Eccrine secretions accumulate in the occluded ducts and infiltrate into the surrounding dermis. These obstructed ducts may rupture with subsequent development of vesicles. This condition may be complicated by a secondary staphylococcal infection. Miliaria skin cannot fully participate in thermoregulatory sweating; therefore, the risk of exertional heat illness is increased in proportion to the amount of skin surface involved. Miliaria rubra is treated through the cooling and drying of affected skin, avoiding conditions that induce sweating, controlling infection, and relieving pruritis. Treatment is handled with chlorhexidine lotion or cream with or without salicylic acid or with low-dose topical corticosteroids (possibly with 0.25% menthol added). For diffuse pustular rash (that is, infection), systemic antibiotics may be prescribed. Prevention includes proper skin hygiene, wearing clean, loose-fitting clothes, and avoiding talc and creams.

f. Sunburn impairs sweating over the affected skin and predisposes Service members to exertional heat illness from systemic inflammation that influences thermoregulation. Sunburn can be prevented by making sun-blocking lotions available to Service members, insisting that they use them, and ensuring Service members are protected from sun overexposure with protective clothing and adequate shelter or shade. Sunburn is generally a self-limiting condition with symptomatic management. Cool compresses or aloe-based gels may be used for symptomatic relief. For significant pain and inflammation, non-steroidal anti-inflammatory drugs (NSAIDs) may be utilized. When sunburn occurs over 5% of the body's surface area, affected individuals should be kept from significant exercise-heat stress until the burn has healed. Service members with extensive and severe sunburn may require hospitalization for fluid management and pain control.

4–4. Heat exhaustion

a. HE is the most common form of exertional heat illness without significant organ injury. It occurs when the body cannot sustain the level of cardiac output necessary to meet the combined demands of increased skin blood flow for heat dissipation as well as blood flow for the metabolic requirements of exercising skeletal muscle and vital organs. Contributing factors include dehydration-mediated drop in circulating volume, blood pooling in dilated blood vessels in the skin, and failure of vessels in the abdominal organs to maintain pressure, which together limit venous return.

b. The signs and symptoms of HE are nonspecific and typically include undue fatigue, transient ataxia (slurred speech, stumbling, falling, incoordination), dizziness, headache, nausea, vomiting, malaise, tachycardia (rapid heart rate), hyperventilation, and transient mildly impaired cognition. Sweating persists and may even be profuse. Blood pressure may be normal to mildly decreased, and there may be an element of orthostasis. The diagnosis of HE versus severe exertional heat illness (see below) is important due to the difference in treatment and prognosis. Treatment should entail cessation of exertion, removal from heat stress, and expeditious cooling to prevent progression to severe heat illness. The distinction between HE, EHI, and EHS at the time of injury can be challenging even for the best clinicians, and often times is best made retrospectively.

4–5. Exertional heat injury

a. As shown in Figure 4–1, EHI represents a condition that is intermediate in severity between HE and EHS. As opposed to HE, individuals with EHI will exhibit more sustained mild confusion and disorientation and demonstrate clinical evidence of injury to a vital organ. EHI improves very slowly with cessation of exertion and removal from heat stress; thermoregulatory control is maintained. Active cooling should be implemented to hasten improvement. Patients demonstrating combativeness, delirium (disturbance in attention and cognition), obtundation (reduced level of consciousness), or coma with severe hyperthermia most likely have EHS rather than EHI.

b. During the first hours of illness, it may be difficult to distinguish EHI from HE by symptoms and clinical appearance alone. Therefore, all suspected EHI patients should undergo laboratory evaluation for damage to muscle tissue or to vital organs (for example, exertional rhabdomyolysis, acute kidney injury) before release, with re-evaluation necessary on the following day.

4–6. Exertional heat stroke

a. General description and guidelines.

(1) EHS is a serious, life-threatening condition characterized by profound central nervous system (CNS) dysfunction (for example, delirium, agitation, inappropriate aggressiveness, convulsions or coma) that occurs in the presence of severe hyperthermia. EHS is often defined as body core temperature (that is, rectal) > 104 °F (see paragraph 3–2), although reliance on a specific rectal temperature value is not advised. In fact, many cases of EHS with severe damage to the brain but modest hyperthermia have been reported. Immediate cooling (recommended) coupled with delay in rectal temperature measurement may logically produce such an outcome. However, the range of rectal temperature varies widely among EHS patients even when proximity to care and treatment regimen are very similar (see Figure 5–3); thus, a specific value cannot be relied upon for diagnosis.

(2) EHS may occur in a hot or temperate environment (see paragraph 2–1) and is a condition experienced by Service members and athletes participating in strenuous physical activity that results in substantial metabolic heat production. Classic heat stroke, in contrast to exertional heat stroke, is more common in vulnerable populations, such as young children, elderly persons, and those without potable water, that are exposed passively to heat and often dehydrated. Classic heat stroke often presents as an epidemic during urban heat waves. Table 4–3 compares the characteristics of patients with classic heat stroke and EHS.

(3) Profound mental status changes present early and universally in victims with advanced EHS. Ataxia, confusion delirium, combativeness, euphoria, hallucinations, rapid eye movement, seizures, and coma may be seen.

(4) Unconscious EHS victims typically present in a limp state. Muscle rigidity with sustained contractions, tremors, and muscle cramps that may alternate with seizures are less frequently observed. Hyperventilation can affect the body’s acid-base balance and may be severe enough to produce muscle contractions. Sustained muscle rigidity may represent rapid hyperthermia.

Table 4–3. Comparison of classic and exertional heat stroke

Patient Characteristics	Classic	Exertional
Age	Young children or elderly	15–45 years
Health	Chronic illness common	Usually healthy
Recent febrile illness or immunization	Uncommon	Common
Prevailing weather	Recent, prolonged heat waves	Variable
Activity	Sedentary	Strenuous exercise
Drug use	Diuretics, antidepressants, anticholinergics, phenothiazines	Usually none, sometimes ergogenic stimulants or cocaine
Sweating	Usually absent	Typically present
Lactic acidosis	Uncommon	Common
Acute kidney injury	Fairly rare (< 5%)	Common (~30%)
Rhabdomyolysis	Unusual	Common, may be severe
Hyperuricemia	Mild	Variable
Potassium	Usually normal	Hypo- or hyperkalemia may be present
Calcium	Usually normal	Hypocalcemia not uncommon
Disseminated intravascular coagulation (DIC)	Mild	May be marked
Glucose	Hypoglycemia common	Variable; hyper- or hypoglycemia may be present

(5) The victim may experience vomiting and diarrhea. These clinical manifestations are a consequence of redistribution of blood flow away from the gut to the skin to facilitate cooling. Compensatory constriction of blood vessels to the gut may produce localized ulcerations in the gut, possibly resulting in blood in the vomit and stool. Vomiting of blood may be a complication of blood clotting abnormalities.

b. Clinical description and guidelines.

(1) EHS is characterized by multi-organ damage that manifests across a varied time course. The principal manifestations of EHS damage occur in the brain, heart, gut, liver, kidneys, and skeletal muscle. The seriousness of multi-organ damage is mostly, but not entirely, predicted by the magnitude of rectal temperature elevation and duration. Pathogenic factors in addition to hyperthermia that may contribute to the evolution of EHS include tissue ischemia, hypo- or hyperkalemia, exercise-induced lactic acidosis, and the systemic inflammatory response perhaps triggered by products of skeletal muscle injury and or endotoxin leaking from the gut. Complicating factors may include, but are not limited to, medications, supplements, concurrent illness, and dehydration (see Tables 4–1 and 4–2). Table 4–4 lists laboratory values for several common EHS analytes and their recovery time course. Although the average numbers of patients measured at 7, 14, and 30 days became increasingly smaller, the value of characterizing the more prolonged time course of blood analyte recovery, in contrast to recovery from exertion and heat exposure without sequelae (paragraph 5–4), cannot be overstated. Table 4–4 suggests that alanine aminotransferase (ALT), aspartate aminotransferase (AST), creatine kinase (CK), and myoglobin may be the best clinical biomarkers of recovery after 14 days.

(2) EHS victims may exhibit either a low or a high cardiac index (CI), depending on their cardiac reserve, volume status, systemic vascular resistance (SVR), and the degree of myocardial injury. Most commonly, the victim evidences low SVR and sinus tachycardia with high CI. However, victims may also present with low CI, hypotension, and elevated central venous pressure. Pulmonary edema may be present and is often severe. Electrocardiogram (ECG) findings are not specific and may include ST segment depression, T-wave abnormalities, and conduction disturbances.

Table 4–4. Commonly measured analytes of exertional heat stroke and their time course for recovery[1]

Analyte	Admission	7 days	14 days	30 days	Reference (IU)
ALT[2]	50.6 ± 1.8	267.9 ± 39.7	104.2 ± 14.7	38.7 ± 2.9	6 – 43
AST[2]	79.3 ± 4.4	114.8 ± 16.1	48.9 ± 6.6	30.4 ± 4.9	10 – 40
BUN	17.6 ± 0.2	16.9 ± 0.7	17.2 ± 1.2	14.8 ± 1.4	7 – 18
Creatinine	1.45 ± 0.02	1.30 ± 0.12	1.20 ± 0.15	1.19 ± 0.13	0.66 – 1.25
CK[2]	1861 ± 140	2392 ± 594	457 ± 133	279 ± 95	22 – 269
Glucose	103 ± 1	92 ± 1	92 ± 1	85 ± 7	74 – 106
Myoglobin[2]	838 ± 63	105 ± 27	170 ± 44	26 ± 9	28 – 72
LDH	588 ± 43	416 ± 84	390 ± 92	578 ± 0[1]	313 – 618

Legend:
IU = international unit
Notes:
[1] The total number of patients evaluated with EHS was 2,529. The number of patients with lab values for serial analysis ranged between n = 816 (lactate dehydrogenase) to n = 2,231 (creatinine) at admission. The average number of patients with clinical measurements at each interval declined from n = 210 at 7 days, n = 48 at 14 days, and 30 days (n = 5).
[2] Elevated above reference range for at least 14 days; all electrolyte and complete blood count values were within the reference range at all times (not reported); data represent the mean ± SD ([1]n = 2); reference ranges reported from lab equipment norms; data obtained from the Defense Health Agency Epidemiology Clinical Records Review of the Military Health Service Data Repository for Service members who experienced EHS.

(3) Acute kidney injury (AKI) is commonly seen with multi-factorial etiology that includes direct heat injury, decreased kidney blood flow, myoglobinuria, and disseminated intravascular coagulation (DIC). Pyuria, proteinuria, microscopic hematuria, and granular casts may be seen on microscopic examination of the urine.

(4) Serum transaminase levels are commonly elevated in EHS, but do not always represent liver injury and may be indicative of skeletal muscle injury. Serum transaminase values up to ~50-60 times the upper limit of normal may be observed. Liver damage is also indicated by reduced albumin, elevated bilirubin, and impairment of coagulation. With severe liver injury, jaundice may be noted within 24 to 36 hours of onset. Most cases of liver injury are reversible, but frank acute liver failure resulting in a need for transplantation can occur.

(5) Abnormalities of hemostasis are manifested clinically by purpura, conjunctival hemorrhages, hemoptysis, hematuria, and neurological findings due to CNS hemorrhage. These abnormalities may be additionally manifested by heparin sensitivity, abnormalities of prothrombin consumption, thromboplastin generation, clotting time, and clot retraction. DIC may be present due to damage to vascular endothelium, hepatocyte damage, rhabdomyolysis, and perhaps thermal platelet activation causing intravascular microthrombi. Fibrinolysis is secondarily activated. Liver dysfunction and thermal injury to megakaryocytes slows the repletion of clotting factors. Platelet count is usually low and so are levels of factors V and VIII. In addition, systemic exposure to lipopolysaccharides (from gut ischemia) and some cytokines (for example, interleukin-6) can also represent triggering events.

(6) Concomitant exertional rhabdomyolysis (ER) with high muscle enzyme levels (for example, CK and myoglobinuria) is common in EHS. The mechanism(s) of ER is described in paragraph 4–7. Large volumes of acute skeletal muscle necrosis results in release of significant quantities of potassium, myoglobin, uric acid, and creatine (which is slowly converted to creatinine) plus phosphate, which sequesters calcium (leading to hypocalcemia). The clinician should be alert for acute compartment syndrome where initial serologic indicators of skeletal muscle damage may be deceptively low.

(7) Electrolyte and hematologic disturbances are not uncommon with EHS (see Table 4–3). Initial potassium levels may transiently be low or low normal as a transient acute consequence of lactic acidosis. However, if there is severe ongoing ER, metabolic acidosis, and/or AKI, hyperkalemia may soon manifest. Massive skeletal muscle necrosis additionally results in release of phosphate, which binds calcium resulting in hypocalcemia. White blood cell count can be as high as 30,000 to 40,000 per microliter. Hypoglycemia is uncommon in EHS except in cases of severe caloric depletion. Significant transient hyperglycemia may be observed and represents an acute stress response that rapidly resolves.

4–7. Exertional rhabdomyolysis

a. General description. ER is a condition involving breakdown of skeletal muscle with release of muscle cell contents into the circulation, which may arise from a variety of stressors that cause injury to skeletal muscle tissue. ER is not always the result of heat strain. Perhaps the most common cause of ER is inadequate conditioning/aerobic fitness for the physical task, particularly associated with an eccentric (muscle stretching against gravity) component, although ER can be the consequence of a variety of internal and external causes (see Table 4–5).

Table 4–5. Potential factors contributing to exertional rhabdomyolysis

Intrinsic	Extrinsic
Baseline Physical Fitness	Training Load
Hydration Status	Unaccustomed Exercise
Hypohydration	Eccentric Predominance
Hyperhydration	Environmental Stress
Metabolic Myopathies	Extremes of Heat and Cold
Glycogen Storage Disease	Drugs and Toxins
Fatty Acid Oxidation Defects	Antipsychotics and Antidepressants
Mitochondrial Disorders	Sedative Hypnotics
Male Gender	Antihistamines
Male > Female	Antilipimic Agents
Sickle Cell Trait	Alcohol
Endocrine Disorders	Infection
Hypothyroidism	Cosackievirus
Hyperthyroidism	Herpes Virus
Autoimmune Diseases	HIV
Polymyositis	Dietary Supplements
Dermatomyositis	Amphetamine-like pre-workout products
Electrolyte Disturbances	Recent Muscle Trauma
Hypernatremia	Excessive Muscle Overload
Hyponatremia	Cumulative or Isolated
Hypokalemia	Exertional heat illness

b. Clinical description. ER is characterized by laboratory findings of myonecrosis with clinical presentation dependent upon the amount of skeletal muscle injury and associated comorbid factors. The skeletal muscle damage with ER is a result of the release of cellular contents into the blood circulation, including myoglobin, potassium, phosphate, CK (also known as creatine phosphokinase, CPK) and uric acid. Although the fraction may be mostly CK from the skeletal muscle (CK-MM), very strenuous exertion can also elevate CK from the heart (CK-MB) in both ER and exercise-induced hyperthermia.

(1) ER should not be defined by a specific CK level. CK levels sometimes as high as 10,000 international units per liter may be a consequence of strenuous exertion alone. Rather, CK, AST, ALT, and lactate dehydrogenase (LDH) levels may also be significantly elevated and should be interpreted in the context of the patient's recent activity. AST, ALT, and LDH levels are typically predominantly of

skeletal muscle origin. These elevations should not be interpreted as evidence of liver dysfunction without evidence of other liver study abnormalities.

(2) The release of large amounts of creatine and nucleic acids into the blood from myonecrosis are converted to creatinine and uric acid, respectively. Elevated serum levels of creatinine and uric acid may give a misleading impression of kidney impairment if they are interpreted apart from blood urea nitrogen (BUN) levels obtained at the same time.

CHAPTER 5

MANAGEMENT OF HEAT CASUALTIES

Successful management of the Service member with exertional heat illness requires an effective chain of survival comparable to that described in the emergency cardiac care literature. Cornerstones in this chain of survival include: recognition of exertional heat illness with field management to include initiation of onsite cooling; basic and advanced emergency medical services (EMS) with transport; advanced medical treatment facility (MTF) support; and post exertional heat stroke care. These cornerstones are executed in three distinct phases: field management (preparation, recognition, onsite cooling), emergent transport (EMS), and advanced care in a MTF. These three phases constitute the emergency response system. This chapter details current evidence-based management of exertional heat illness to optimize Service member survivability, care, and effective return-to-duty.

5–1. Field management

a. *Preparation and recognition*.

(1) Service members should be familiar with the signs and symptoms of exertional heat illness (HE, EHI, EHS) so that they can seek medical support. See Chapter 4 for definitions of minor and significant exertional heat illness.

(2) In controlled settings with potential heat illness, emergency medical care for heat casualties should be arranged in advance. To avoid substantial delay in treatment in settings where heat casualties are common, strenuous physical training should not be conducted without onsite medical capabilities. For example, a recruit-training center should have at least one medic (with equipment, ice, a transport vehicle, and communication system) onsite and have the WBGT monitored while strenuous training is conducted in hot weather. In addition, the first responder(s) will assist the chain of command in implementing the guidelines for preparation and management of heat casualties. First responders for heat casualties can be medics or civilian emergency medical technicians (EMTs).

(3) Management of exertional heat illness should always be urgent to avoid potential complications related to EHI, EHS or concurrent severe ER. Casualties' immediate access to medical support in the field must include, at a minimum, brief assessment of vital signs and mental status; immediate, rapid, and effective cooling; and measurement of rectal temperature if possible. First responders should also be prepared to provide basic life support and first aid for injuries. If transportation to a medical department will require more than 10 minutes, provisions should be made to administer advanced cardiac life support (to include automated defibrillation) and IV fluids prior to arrival at the emergency department (ED).

(4) Upon first recognition of a significant heat casualty (confusion, combativeness, loss or decreased level of consciousness, inappropriate behavior, and/or recurrent vomiting; see Table 5–1), EMS should be activated.

(5) The field medical team needs to provide an accurate clinical description of the symptoms, initial presentation, vital signs, and mental status of the patient, activity precipitating the event, environmental conditions, clothing, and treatment given prior to arrival at the medical facility.

Table 5–1. Warning signs, symptoms, and immediate actions for suspected heat casualties

Common Signs and Symptoms	**Immediate Actions**
• Dizziness • Headache • Nausea • Unsteady walk • Weakness • Muscle cramps • Fatigue • Chills	• Remove from training • Rest casualty in shade, fan and spray with water • Loosen or remove unnecessary clothing • Drink water • Medically evaluate casualty: monitor rectal temperature and mental status • If no medic available, call for ambulance and medical evacuation
Significant Signs and Symptoms	**Immediately call medical evacuation or ambulance for emergency transport while doing the following:**
• Persistent mental status changes • Delirium • Inappropriate behavior or aggressiveness • Convulsions and/or seizures • Coma • High rectal temperature (> 104 ºF) • Recurrent vomiting • Loss of bowel control/fecal incontinence • Flaccid muscles or persistent rigidity • Weak or rapid pulse	• Lay casualty down in shade, elevate feet until medical evacuation or ambulance arrives • Remove as much clothing as possible • Cool rapidly using best method possible: - Pour water over body while fanning - Repeatedly wrap in iced sheets - Apply contour conforming ice bags/frozen gel packs covering torso, neck, and scalp - Douse or immerse in iced/cold water • If conscious, provide sips of water • If persistent hyperthermia not improving, and emergency evacuation delayed, start IV hydration • Monitor airway and breathing

b. Field treatment.

(1) Figure 5–1 presents a schematic for the field treatment of heat casualties.

(2) The severity of the exertional heat illness is often not apparent on initial presentation in the field. Service members involved in strenuous hot weather activity who present with associated symptoms (for example, unsteady gait, sweaty, flushed skin, dizzy, headache, tachycardia, paresthesia, weakness, nausea, cramps) should be immediately evaluated for vital signs, mental status changes, and rectal temperature. Poor or worsening mental status represents a true medical emergency, and these Service members need rapid initiation of effective cooling measures, activation of EMS, and evacuation to an MTF.

(3) All Service members suspected of having exertional heat illness must have early initiation of cooling in the field. Delay in cooling is the single most important factor leading to death or residual serious disability in those who survive. Do not delay cooling for want of rectal temperature. The casualty should lie down in the shade with as much clothing removed as is practical. Body cooling should be initiated as quickly as possible. Thirsty and alert patients can be given oral fluids (initially 1 quart per 30 minutes). HE patients generally demonstrate rapid improvement (within the first hour) with simple cooling measures and rehydration; however, those failing to respond to treatment or manifesting decline in status during treatment should be evacuated to an MTF.

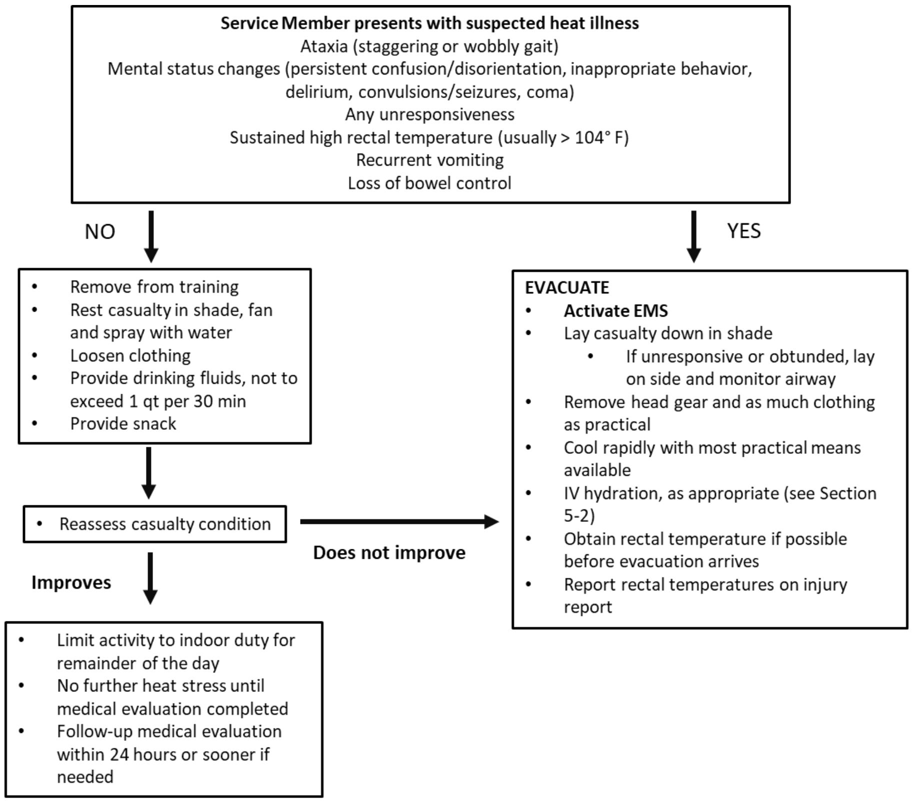


Figure 5–1. Field treatment of heat casualties

(4) Rectal temperature is the only appropriate method to assess body core temperature of a heat casualty (see paragraph 3–2). Do not rely on ear, forehead, armpit, or oral temperature measurements as these are inaccurate (see Table 3–1). Care must be taken during insertion of any rectal thermometer (rigid or flexible) to avoid perforation of the rectum. Some flexible thermometers offer the advantage of being left in place during treatment and transport. Trained individuals, such as medics or EMTs, should measure rectal temperatures.

(5) IV access should only be attempted by appropriately trained individuals and should not delay application of cooling measures or emergency transport (see paragraph 5–2).

(6) Aggressive whole-body cooling must be initiated as soon as possible, using the most practical and effective means available. First, the patient needs to lie down in the coolest location immediately available. An obtunded or comatose patient should be placed on one side with the airway closely monitored to avoid aspiration of vomitus. The tenets of rapid cooling are to mitigate the heat stress and reduce skin and rectal temperature as quickly as possible. Mitigate heat stress by moving the victim to a nearby cooler, shaded environment and concurrently remove all outer garments and head gear.

(7) The most effective, but least practical, means of whole-body cooling is to use cold (ice) water immersion (~36 °F) (see paragraph 3–4). Conscious patients will occasionally fight ice water immersion, thus complicating management. However, cool water (< 68 °F) is less demanding logistically and can still be extremely effective. The rate of rectal temperature drop using immersion primarily depends on how much of the body is immersed, how cold the water is kept, and whether or not the water is stirred or agitated to maximize convective heat loss (see paragraph 2–2). Rates of 0.25 °F to 0.50 °F

per minute are possible. In the absence of a “tub,” EHS victims can lie supine in a waterproof tarp, which can then be filled with ice water and agitated by persons supporting the ends of a tarp. Makeshift “tarp-assisted cooling” can decrease body core temperatures within the range reported for solid, less portable tubs.

(8) In settings in which supplies and ice are limited, field expedient immersion baths that keep water cool can be constructed by digging plastic-lined shaded pits. The water is cooled by contact with the cool ground subsurface and surface evaporation. A shallow canvas tub with elevated frames can also be rigged in ventilated shade, whereby water is cooled by evaporation from the wet canvas surface. In canvas tubs, the water can cool to nearly the atmospheric dew point temperature, often as low as 50 °F in desert-like environments. EHS patients may experience loss of bowel control and vomiting; because of this, water immersion baths of all types should be disinfected between cases if they become contaminated with body fluids or discarded if easily disposable. Nearby streams or ponds can also be used effectively for the same purpose.

(9) Cold or cool water dousing is also an effective method to rapidly lower skin and rectal temperature. Dousing involves placing casualties on a litter over a tub of cold or cool water, which is then continuously used to splash, pour, and massage over the victim (Figure 5–2). Figure 5–3 shows the average (bold line) and individual cooling curves for 113 documented EHS patients with starting rectal temperatures of at least 104 °F. The cooling methodology was the same or very similar to that shown in Figure 5–2. While the average cooling rate is ~0.10 °F per minute, the range of cooling responses is quite wide despite nearly identical treatment protocols. Importantly, all patients cared for in this way receive the benefits of rapid skin cooling.

Figure 5–2. Treatment mock-up of a Navy heat illness cooling deck outside the John H. Bradley Health Clinic, Quantico, Virginia

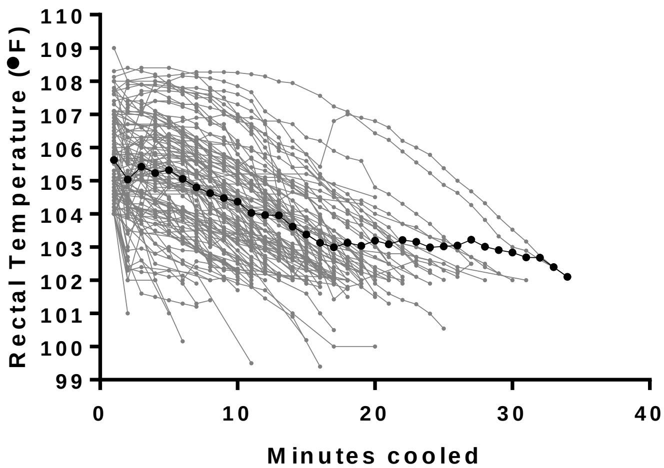


Figure 5–3. Rectal temperature cooling rate in EHS casualties using the method illustrated in figure 5–2

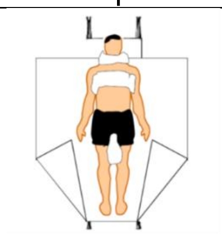
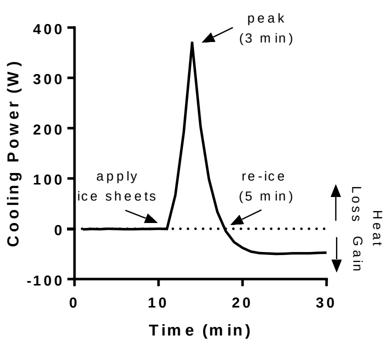
(10) In the absence of immersion or dousing equipment or supplies, other strategies may be implemented in the field to facilitate rapid cooling. These may include—

- Repeatedly applying cooled sheets (iced sheets) to specific body regions;
- Dousing the body with the coldest water available (for example, from AICS unit);
- Using contour conforming ice bags/packs or frozen gel packs (prepared from available sources or procured commercially), or
- Using cool mist spray bottles combined with vigorous fanning.

Cold-water applications may be alternated with massage to encourage local blood flow and heat dissipation. Table 5–2 outlines the best practices for using iced sheets, which can provide an average cooling power of ~120 W for short periods (≤ 6 min) with the potential to reduce rectal temperature at a rate of ~0.06 °F per minute. While this may seem small, a drop of 1.2 °F over 20 minutes could be life-saving. Actual ice bags or frozen gel packs provide a similar rate of cooling but negate the need to “re-ice” at regular intervals and may be kept in place. Additional cooling can be achieved by covering the casualty’s torso and/or legs with an iced sheet and re-icing every 5 minutes. However, failure to re-ice after 6 minutes can result in ~50 to 75 W of heat gain while sheets remain in place.

(11) When possible, it is of value to take advantage of evaporative cooling by use of a fan. Water can be applied by spraying or splashing. Evaporative cooling remains beneficial even in very humid environments as long as skin temperatures are warmer than the air; evaporative cooling potential ceases only when the air is both very humid (> 90%) and hotter than the skin (> 95 °F). As with preventive cooling measures discussed in paragraph 3–4, combinations of cooling methods provide more cooling and are recommended whenever possible (for example, iced sheets combined with fanning).

Table 5–2. Recommended use of iced sheets in the treatment of suspected exertional heat illness[1]

 Step 1	Preparation • Fill ice-chest 1/3 cool water and 2/3 ice • Place ordinary bed sheets in iced water (5 per anticipated heat casualty) • Pre-soak sheets or immerse when Service member's clothing is being removed • Maintain at training site, on evacuation vehicle, or at MTF depending on risk assessment
 Step 2	Application • Lay first sheet down on litter or stretcher • Place casualty on top of first sheet • Place wadded or rolled iced sheets in the casualty's groin, and armpits, and around neck • Place an additional iced sheet over the top of the torso and/or legs
 Step 3	Re-application • Re-wet or replace iced sheets every 3 minutes to achieve maximum rates of body cooling • Controlled studies with heated manikins show significant body heat extraction potential using iced sheets with peak cooling power occurring at 3 minutes • Iced sheets provide continuous cooling power for approximately 5 minutes and should therefore not be left in place for more than 5 minutes before re-icing • Failure to re-ice or remove applied iced sheets after 5 minutes results in heat trapping and heat gain
Note: [1] When possible, cool in shade/under cover and use fanning to complement iced sheet body cooling; overcooling with iced sheets is very unlikely - do not disrupt cooling with iced sheets until reaching definitive care.	

5–2. Emergency Response System

a. Activation of the Emergency Response System.

(1) Upon recognition of a significant exertional heat illness casualty, the emergency response system should be appropriately activated. This activation should begin with the onsite medical team, and progress to the EMS and ED medical staff as necessary. Optimizing this chain of survival with appropriate communication and coordination provides the greatest opportunity for limiting Service member morbidity and mortality. Identifying appropriate EMS vehicles to facilitate enroute cooling and hydration, and preparing the ED for the arrival of a heat casualty, optimizes resources and facilitates appropriate and expedient cooling. Evidence has clearly established that appropriate and timely medical triage is one of the most important variables in Service member health outcomes.

(2) Critical coordination among onsite medical care, the EMS, and ED should be preplanned. Algorithms should clearly address cooling strategies to be utilized, indications for hydration, and importantly, criteria for patient hand-off from one level of care to the next higher level of care. Current evidence has clearly established the effectiveness of onsite cooling prior to transport to a higher level of care, if resources exist to support onsite cooling.

b. Emergency medical services treatment.

(1) Assessment. Altered mental status and/or combativeness may adversely affect the ability of ED personnel to obtain a detailed history of precipitating events. Lack of such information may also delay diagnosis. Emergency medical transport personnel should attempt to obtain this history before evacuating the victim and should communicate the information to medical staff. Of particular importance is the duration and, when available, the maximum degree of hyperthermia.

(2) Adjunctive assessment. The blood glucose should be measured, and adults with blood sugar level less than 60 milligrams per deciliter should be treated with 1 ampule of 50% IV dextrose solution. Service members with signs and symptoms of EAH should have serum sodium measurements made using a point-of-care blood analyzer prior to any initiation of fluids (see paragraph 5–4).

(3) Airway. Administration of supplemental oxygen may help to meet the victim's increased metabolic demands, and it may also be used to treat hypoxia that is commonly associated with aspiration, pulmonary hemorrhage, pulmonary infarction, pneumonitis, or pulmonary edema. In a comatose victim, airway control should be established by placing a definitive airway, dependent upon the training of the provider. Positive-pressure ventilation is indicated if hypoxia persists despite supplemental oxygen administration.

(4) Cooling. During evacuation, cold-water immersion is often not a viable method for treatment. Iced sheets (continuously replaced and rewetted; see Table 5–2), bags of ice, or refrigerated ice packs for covering the body can be used during transport.

(5) Hydration. Vascular access should be established immediately by inserting the largest bore short IV catheter feasible (14 or 16 gauge, ≤ 1 inch preferred); in Service members suspected of EAH, a saline lock IV should be placed. EMS staff should perform testing for hyponatremia and hypoglycemia using a point-of-care blood analyzer, if available. It is critical to obtain serum sodium prior to administration of large volumes of saline in a Service member. Recommendations vary regarding administration rate of fluids. Some clinicians advise a rate of 1 to 2 liters over 4 hours, whereas others encourage a 2-liter bolus over the first hour and an additional liter of fluid per hour for the next 1 to 3 hours. In the absence of a serum sodium determination, there should be no greater than 1 liter of any IV fluids given at any time during the point of injury to arrival at an advanced MTF.

(6) Chilled IV fluids. Many EMS vehicles now carry refrigerated IV fluid to initiate induction of therapeutic hypothermia in cardiovascular emergencies. There is some evidence that chilled IV may reduce the length of hospitalization when used in conjunction with iced sheets. Chilled IV use is not mandatory, but if used should be cooled to a temperature of 39 °F if possible.

5–3. Advanced medical treatment facility support

a. Advanced MTF support is provided by MTFs that have emergency departments.

b. Evaluation and initial stabilization of patients with suspected EHS should include placing the patient in a large treatment room to accommodate the needed number of staff. Patients are often combative and disoriented before reestablishing their baseline mental status. Immediate attention should be directed to airway, breathing, and circulation (ABC), and cooling. Aggressive cooling measures should continue until mental status returns to normal and body core temperature is 102 °F.

(1) The patient's vital signs need to be monitored continuously. A rectal thermistor should be placed for continuous body core temperature recording. After discontinuation of cooling, rectal temperature should be monitored every 5 minutes to ensure that it does not increase.

(2) A large-bore IV catheter should be inserted. Normal saline can be used to replace fluids. It is prudent to be very cautious while rehydrating these patients, as they often have or readily develop pulmonary edema and kidney failure.

(3) Supportive care, as in any emergency medical situation, requires healthcare providers follow the ABC algorithm for stabilization while treating a patient who has an exertional heat illness. In a comatose patient, a cuffed endotracheal tube should be placed to protect the airway. Patients may have severe hypoxemia secondary to aspiration, pneumonitis, pulmonary infarction, pulmonary hemorrhage, or pulmonary edema and therefore may require supplemental oxygen. If hypoxemia persists, positive pressure ventilation may be indicated.

(4) Hemodynamic monitoring with pulmonary artery catheter may be indicated in patients who have compromised cardiac function, hemodynamic instability, or uncertain hemodynamic status. Most patients show a hyperdynamic circulation with high CI, low systemic vascular resistance, and elevated central venous pressure secondary to right-sided heart failure. These patients need mild to moderate fluid replacement, since cooling alone causes vasoconstriction and thus increases blood pressure. Some patients have hypodynamic response with low CI, elevated central venous pressure, and hypotension. Alpha-adrenergic drugs (norepinephrine) are contraindicated until cooling is achieved, because they produce vasoconstriction resulting in decreased heat loss. Moreover, hypotensive patients who do not respond to fluid replacement should receive inotropic support. Dopamine and dobutamine are reasonable choices and have the potential added advantage of improving renal perfusion. Pulmonary artery wedge pressure monitoring should be used in patients with persistent hemodynamic instability. Kidney damage from myoglobinuria and hyperuricemia can be prevented by promoting kidney blood flow with administration of IV mannitol (0.25 milligrams per kilogram (mg/kg)) or furosemide (1 mg/kg). If CK levels exceed 100,000 IU, consider alkalinization of the urine; there is no advantage to alkalinization when levels are lower. Hemodialysis should be considered if anuria, oliguria (< 0.5 milliliters per kilogram of urine per hr for > 6 hr), uremia, or hyperkalemia develops.

(5) Oral and gastric secretions are evacuated via a nasogastric tube that is connected to continuous low suction. Although antacids, proton pump inhibitors, and histamine-2 blockers have been used to prevent gastrointestinal bleeding, no studies to-date demonstrate their efficacy for EHS casualties.

(a) Cooling. Ice packs or iced sheets (changed repeatedly), especially when covering large body surface areas, can provide cooling while the patient lies on a bed board (see Table 5–2). In this situation, cardiopulmonary resuscitation and advanced cardiac life support can safely be implemented. The room should be air conditioned to maintain a low humidity and air temperature. Rapid cooling of hyperthermic patients should continue until the rectal temperature remains below 102 °F, after which cooling can proceed without cold water (such as a tepid shower) until the rectal temperature remains below 100 °F, if needed.

i. The following invasive cooling techniques are not recommended: ice water lavage or enemas and peritoneal lavage with cool fluids. These techniques do not provide faster cooling and have the additional disadvantages of potential complications and substantial inappropriate fluid loads.

ii. Cooling techniques may be ineffective when the victim suffers sustained seizures that generate body heat; therefore, treatment for convulsions should be considered. Intravenous benzodiazepines are preferred for their efficacy and kidney clearance. Initial dosing is either 4 to 8 mg of IV lorazepam or 10 mg of IV diazepam. If seizures persist for more than 10 minutes after the first dose, an additional 4 mg of lorazepam or 10 mg of diazepam should be administered. It should be emphasized that the primary therapy for seizures seen in an EHS event while hyperthermic is rapid and effective cooling.

iii. As a result of drastic cooling, skin temperature may decrease enough to cause shivering. If it is believed the shivering is impeding cooling measures, administration of 12.5 mg of meperidine via slow IV push or 5 mg of diazepam is effective to suppress shivering and to prevent an additional rise in rectal temperature from metabolic heat production. If cold-water immersion is used, the increase in metabolic rate as a result of shivering will be more than offset by the high rate of heat transfer. Therefore, the presence of shivering should not be a cause for concern when this method of cooling is used and rectal temperature has not yet reached 102 °F.

(b) Hydration. Oral fluids work well for most dehydrated patients who are not obtunded and can take fluids without risk of aspiration or vomiting. For moderately dehydrated Service members, oral rehydration is equally as effective as IV infusion (replacing similar volume and salt load) in restoring exercise performance capabilities in the heat. Water is usually given for rehydration; however, for markedly dehydrated Service members, sports drinks or ORS can be of additional value (see paragraph 3–7).

i. IV fluids replenish the extracellular fluid quickly, and sodium chloride can be given parenterally in concentrations substantially higher than can be tolerated orally. Patients with evidence of clinically significant plasma volume depletion (hypotension, tachycardia at rest, or orthostatic signs) should initially receive normal saline in 200 to 250 mL boluses, an amount sufficient to restore normal circulatory function. No more than 1-L of parenteral fluid should be administered without laboratory results, and the composition of subsequently administered parenteral fluid should be guided by measurements of serum electrolytes (for example, serum sodium).

ii. Potassium depletion is best treated orally, but patients with severe EHS may not be able to take oral medications because of obtundation or nausea and vomiting. IV potassium replacement should be administered in half-normal or normal saline; dextrose (which tends to move potassium into cells) should be avoided. Rates of infusion are usually limited to 20 mmol/hr unless paralysis or malignant ventricular arrhythmias are present, in which case higher rates are recommended. Close ECG and neurological monitoring is required.

iii. The earliest ECG sign of hyperkalemia is peaked T waves. Hyperkalemia should always be suspected when young exercising individuals collapse with arrhythmias. When hyperkalemia is found by chemical analysis, the clinician should exclude pseudohyperkalemia, primarily due to needle hemolysis, fist clenching during blood drawing, marked leukocytosis or megakaryocytosis, or erroneous assay. An ECG should be performed while awaiting results of the repeat assay. The acute treatment of severe hyperkalemia is a medical emergency, the management of which has been well described. Treatment of either hypokalemia or hyperkalemia requires careful monitoring of responses because of shifts between intracellular and extracellular compartments and changes in the rate of renal loss.

iv. Rapid lowering of plasma sodium, even from an initially elevated level, can cause cerebral edema. Therefore, significant hypernatremia should be corrected slowly at a reduction of no more than 2 mmol/L per hour sodium to avoid cerebral edema.

(c) Adjunctive therapy.

i. Antipyretics. The use of antipyretics is not effective and may potentially be harmful to EHS victims. Aspirin, an NSAID, and acetaminophen, an analgesic and antipyretic, both lower body core temperature by normalizing the elevated hypothalamic set point that regulates the fever response caused by pyrogens; with exertional heat illness, the set point is normal, with body core temperature elevation reflecting a failure of normal cooling mechanisms. Furthermore, acetaminophen may induce additional liver damage, and administration of aspirin may aggravate bleeding tendencies. Aspirin has also been shown to attenuate protective, reflexive skin blood flow responses that are required for adequate heat dissipation, which will pre-dispose to EHS collapse. Since NSAIDs and acetaminophen do not attenuate body core temperature during environmental heat exposure and the toxicity of these drugs on the gut and liver is exacerbated with heat, the use of these drugs prophylactically or for the treatment of EHS patients is not warranted.

ii. Antibiotics. As previously discussed in the clinical manifestations of exertional heat illness (paragraph 4-6), EHS shares many common findings with the systemic inflammatory response syndrome (SIRS). This relationship has created an interest in the recognition and treatment of occult or co-morbid infection. Numerous systematic reviews and case reports have identified infection as a risk factor for EHS. Recent bacterial pneumonia, for example, may increase the odds of EHS threefold. In addition, others postulate that bacterial translocation from the gut microbiome may take part in the pathophysiology of EHS. Therefore, Service members with EHS need to be carefully examined for overt and occult infection, so that appropriate therapies can be initiated. Use of antibiotics should be limited to specific indications.

iii. Pharmacological agents. No drug has been found to have a significant effect for reducing body core temperature.

iv. Agitation. Patients often develop marked agitation. In the past, the use of chlorpromazine was advocated in such situations. Arguments against the use of chlorpromazine include the associated increased risk of toxicity in patients who have liver failure and the decreased threshold for seizures. Benzodiazepines are sedatives of choice in this situation.

v. DIC. In the presence of coagulopathy, initial therapy with fresh frozen plasma and platelets may be indicated. Monitoring of platelet count, prothrombin time (PT), partial thromboplastin time (PTT), fibrin split products, and fibrinogen is indicated.

vi. Steroids. Use of steroids in EHS has not been shown to be beneficial.

5–4. Considerations for other heat-related conditions

a. EAMC is sometimes observed in the exertional heat illness patient. An EAMC is defined as an involuntary, painful contraction of skeletal muscle during or after exercise. EAMC is typically seen in settings where there is prolonged sweating, often times in those Service members with high sweat salt concentration. The etiology of EAMC is also unknown, but hypothesized to be due to altered neuromuscular control (fatigue) or electrolyte depletion (see paragraph 4–3).

(1) Diagnostic considerations. EAMC is a clinical diagnosis not requiring testing. In patients with EAMC who are unresponsive to conservative therapy or have systemic cramping, an assessment of serum electrolytes should be considered (for example, serum sodium and glucose).

(2) Management considerations. The cornerstone of treatment of the patient with concomitant exertional heat illness and EAMC is rapid and effective cooling. Passive stretching is the most reliable immediate treatment to alleviate the cramped muscle group; however, this may be complicated by cramping of antagonistic muscle groups. In addition, patients with EAMC may have substantial sodium deficits. Fluids and sodium replacement may be considered, but their use is controversial and their effect is equivocal. Salty foods or beverages such as ORS are the preferred means of electrolyte replacement. While some clinicians advocate the use of diazepam or magnesium sulfate to treat EAMC, there is no evidence to support these interventions and may cause untoward side effects.

b. EAH may manifest with similar symptoms as exertional heat illness and often occurs during activities performed in hot weather. EAH is a consequence of hyper-hydration with mild or severe life-threatening manifestations. EAH occurs primarily in Service members who are drinking water well above 1½ quarts per hour, especially during periods of high stress in which antidiuretic hormone levels may be naturally high. Lack of urination is not a reliable indicator of hydration status in these patients. Prolonged periods of sweating combined with poor electrolyte intakes can also result in EAH, though more rarely. High-risk situations for EAH and recommendations for mitigating risk are discussed in paragraph 3–7. EAH symptoms may include acute mental status changes, seizures, coma, headache, confusion, visual disturbances/changes, nausea, and recurrent vomiting. Edema may be seen in the extremities, as well. The recording of fluid consumption is an important step to prevent EAH in Service members (see paragraph 3–6). If EAH is suspected, restrict fluids, rapidly assess serum sodium using a point-of-care blood analyzer, and attempt to document recent fluid intake.

(1) Diagnostic considerations.

(a) Mild EAH. Service members will typically present with headache, nausea, dizziness, and ataxia. Mental status is typically intact. Symptoms typically do not manifest if serum sodium is > 130 mmol/L.

(b) Severe EAH. Service members will present manifestations of elevated intracranial pressure with symptoms that include severe headache or head pressure, visual disturbances, and nausea with recurrent vomiting. Alteration in mental status and/or seizures indicates a worsening cerebral edema and requires immediate intervention.

(2) Management considerations. EAH can be comorbid with exertional heat illness and clinicians are directed to have a high index of suspicion. When clinically suspected, restrict or stop fluid consumption. Obtain access to serum sodium determination with emergent consideration for hypertonic saline, as appropriate. Mild EAH cases may be managed with observation, fluid restriction, and oral salt ingestion. Consider IV hypertonic saline for EAH with mental status changes and serum sodium < 130 mmol/L.

c. ER typically occurs concomitantly with exertional heat illness to varying degrees, but may also appear independently. ER is a condition involving breakdown of skeletal muscle with release of myocyte contents into the circulation. It may arise from a variety of stressors that cause injury to skeletal muscle tissue. Principal concerns of ER include acute kidney injury and immediate metabolic perturbations, in particular hyperkalemia.

(1) Diagnostic considerations.

(a) Significant asymptomatic elevations of skeletal muscle enzymes (CK, transaminases, LDH) are very commonly observed in vigorously exercising populations engaged in the same activities that may precipitate exertional heat illness. Hence, a significant portion of skeletal muscle enzyme elevation seen in exertional heat illness is likely a consequence of the exertional activity versus hyperthermia stress. Importantly, several common biomarkers of EHI, such as AST, ALT, CK, and myoglobin, appear to remain elevated longer (> 14 days) than following ordinary strenuous exercise (< 7 days) (see Table 4–4). Transaminase elevations from skeletal muscle breakdown are often misinterpreted as reflecting liver dysfunction or damage. Hence, determination of liver injury requires assessment of other tests that reflect liver function (for example, albumin, bilirubin, prothrombin time (PT), activated partial thromboplastin time (aPTT)). Myoglobin release from skeletal muscle breakdown occurs to a variable extent with ER. Persistent high serum concentrations of myoglobin may induce kidney damage (for example, kidney tubular necrosis). This may be reflected by the presence of brown (cola-colored) urine and casts in urine microscopy. When present, this indicates the need for IV fluid intervention to mitigate significant kidney damage independent of absolute CK levels.

(b) Those with clinically significant ER typically manifest symptoms of skeletal muscle injury; this may include myalgias, weakness, localized muscle swelling, erythema, and significantly restricted motion in involved muscle(s). Pain out of proportion to what one would normally expect from the activity and severe skeletal muscle dysfunction with palpable tightness may be indicators of compartment syndrome. In these cases, where muscle ischemia from compartment syndrome is suspected, compartment pressure testing must be performed expeditiously as tightness and intracompartmental pressures will decline with progression of myonecrosis. Be aware multiple and atypical muscle compartments may be involved. Confirmed cases require fasciotomy to relieve ischemia, which usually mitigates metabolic perturbations of ER as well as the magnitude of myonecrosis. Note that initial muscle enzymes obtained soon after injury may be deceptively low, not manifesting significant elevation for hours after onset. Persistent lactic acidosis may be the initial harbinger of compartment syndrome with muscle ischemia. The patient with a large volume of ongoing muscle ischemia may manifest severe or fulminant ER with many major metabolic perturbations in the hours following symptom onset. Such cases require intensive care unit management and identification of all ischemic muscle compartments requiring fasciotomy.

(2) Management considerations. In those with exertional heat illness, rapid and effective cooling is the first priority (see paragraph 5–3). Where co-morbid ER is clinically suspected, IV fluid bolus therapy (for example, 2 to 4 L) should be administered soon after onset to mitigate acute kidney injury and effects of myoglobin. Early and aggressive fluid therapy should be guided by serum electrolyte determination to avoid complications, including exacerbating complications of EAH. Those manifesting brown (cola-colored) urine will require continuous high volume IV fluid therapy (targeting urine output of 200–300 mL/hr) until clearing of myoglobinuria. Cases of fulminant ER usually progress to development of SIRS with kidney failure, liver dysfunction, and DIC. In cases where ER is continually worsening or difficult to manage, assess for ongoing ischemia from compartment syndrome and be vigilant in identifying all compartments involved. Even if muscle necrosis has already occurred, fasciotomy with debridement of necrotic muscle may dramatically attenuate metabolic complications of severe/fulminant ER and improve outcome.

d. Exercise Collapse Associated with Sickle Cell Trait (ECAST) is thought to be common and can be benign, but has also been associated with hematuria, kidney papillary necrosis, and splenic infarction. In addition, sickle cell trait (SCT) is clearly associated with an increased relative risk of exercise-related sudden death in Service members. It has been demonstrated in military personnel that the risk of exercise-related death in Service members with SCT is about 40 times higher than those without SCT; however, the absolute risk of death is still very small (approximately 1:3,000 African American Service members who are SCT positive). While the mechanism of ECAST is unknown, it is speculated that intravascular sickling is induced by localized hypoxemia, acidosis, and hyperthermia in strenuously exercising muscles. Many of these cases manifest sustained exertional compartment syndrome, often times involving multiple compartments. Most literature identifies potential risk factors as excessive heat stress, poor hydration status, and lack of exercise acclimatization. ECAST may manifest independently or co-morbidly present with exertional heat illness.

(1) Diagnostic considerations. Most cases of ECAST have occurred during accelerated conditioning or physical fitness testing. The initial presentation of ECAST is often confused with heat cramping, HE, or EHS. However, unlike EHS, sickle collapse often occurs early in a workout before a Service member's body core temperature has had time to rise. Furthermore, ECAST can be characterized as a "conscious collapse," which may help differentiate this collapse from an acute cardiac event or EHS. The most telling symptom of an ECAST event is increasing pain and weakness in the working muscles, especially the legs, buttocks, and lower back. Table 5–3 provides a framework to identify different types of collapse in the Service member.

Table 5–3. Different types of presentations following collapse of a Service member

ECAST	EHS	Acute Cardiac Event	Asthma/Respiratory Collapse
Conscious, can talk	Altered mental status	Unconscious	Breathless, anxious
Slumps to ground	Bizarre behavior	Sudden collapse	Prior episodes
Temp often < 104 ˚F	Temp often > 104 ˚F	Often normothermic	Auscultate – poor air movement
May have cramping muscles	May have cramping muscles	Muscles normal	Excessive use of respiratory muscles
No seizure activity	May have seizure activity	May have seizure activity	May have seizure activity
Occurs early in training	Occurs late in training	No warning	Usually after high intensity

(2) Management considerations. Early recognition of ECAST is critical for Service member survival. In addition to early rapid and effective cooling, the clinician should activate the EMS, administer IV fluids, provide supplemental oxygen, if available, and communicate with the receiving MTF. The receiving emergency department physicians should be alerted to the possibility of explosive rhabdomyolysis and possible grave metabolic consequences. Treatment will include immediate hospital transfer for aggressive fluid and electrolyte management, as well as cardiac monitoring.

5-5. Return to duty. A consistent definition to the type and diagnosis of exertional heat illness is critical to the safe disposition, profiling, prevention of further injury, and the prognosis of the Service member. All medical personnel must familiarize with and be able to differentiate the types of exertional heat illness in accordance with AR 40–501. Service members admitted to the hospital with EHI or EHS will have an eProfile up to the maximal time required for recovery documented prior to discharge. See AR 40–501, table 3–2 for details on profiling for HE, EHI, and EHS with or without sequelae.

5–6. Surveillance, recordkeeping, and reporting

a. Surveillance. Surveillance is the cornerstone to the public health approach to exertional heat illness prevention because an understanding of the presence and magnitude of a problem is necessary before any of the other steps can be implemented. Surveillance includes heightened provider and leadership awareness of cases meeting the exertional heat illness criteria (described in Chapter 4) and vigilance in recordkeeping and disease reporting through the installation public health department or, in an operational or training setting, preventive medicine units, through appropriate channels to the Armed Forces Health Surveillance Branch. The USACRC should be notified per applicable Army policies (for example, AR 385–10) of any class A through D occupational illness/injury, including exertional heat illness. Only through data-based-policy and decision-making can exertional heat illness and its serious complications be minimized.

b. Recordkeeping. Recordkeeping provides data for DOD and the Army. Safety and medical documentation of a heat illness event should include the circumstances under which the exertional heat illness occurred and the time course of clinical symptoms and signs as well as —

(1) Training activities at the time of the exertional heat illness event;
(2) Personal risk factors in the training population;
(3) Weather conditions;
(4) Amount and timing of exercise;
(5) Adherence to work-rest cycles and fluid consumption;
(6) Clothing and gear involved;
(7) Medications (prescriptions and over-the-counter) taken in the days preceding the event; and
(8) Nutritional supplement use taken in the days preceding the event.

When combined with active monitoring of outcomes and all exercise-related deaths, a more thorough understanding of trends and potential areas for programmatic interventions to reduce morbidity and mortality can be gained at tactical, operational, and strategic levels.

c. Reporting instructions.

(1) EHIs occurring in deployed settings will be reported in accordance with applicable combatant command/unit level policy to include safety channels (Mishap Reporting) and DRSi.

(2) Non-deployed units should coordinate with the installation public health department, examining provider, military medical treatment facility, and command safety to ensure that heat illnesses diagnosed at any level/location are reported. National Guard and Reserve units with or without preventive medicine personnel should report heat illnesses through command channels and command safety through the USACRC.

(3) All heat illnesses meeting the case definition outlined by the Armed Forces Reportable Medical Events Guidelines and Case Definitions should be entered into the Disease Reporting System internet.

(4) International Classification Disease (ICD)-10 coding guidance for exertional heat illness is as follows:

(a) HE: T67.3 Heat exhaustion, anhidrotic; T67.4 heat exhaustion due to salt depletion; or T67.5 heat exhaustion, unspecified, should be used, as appropriate.

(b) EHI: There is not an ICD-10 code for EHI. Providers should code cases of EHI as heat exhaustion, unspecified (T67–5) as the primary diagnosis, with appropriate additional diagnostic codes based on the clinical presentation. Examples include but are not limited to N17.9 acute kidney injury (non-traumatic), K72.00 acute and subacute hepatic failure without coma or M62.82 rhabdomyolysis.

(c) EHS: T67.0 Heat stroke and sunstroke is the appropriate code.

(d) Minor heat illness: Heat syncope T67.1; heat cramps T67.2; heat edema T67.7; T67.8 Other effects of heat and light and T67.9 effect of heat and light, unspecified, should be used sparingly and only when no other ICD–10 code is appropriate for the clinical presentation (see Table 5–4).

Table 5–4. ICD–10 codes for exertional heat illness conditions

Condition	**ICD–10 Code**		
	Initial	Subsequent Encounter	Sequelae
Heat syncope	T67.1XXA	T67.1XXD	T67.1XXS
Heat edema	T67.7XXA	T67.7XXD	T67.7XXS
Heat cramp (EAMC)	T672.1XXA	T672.1XXD	T672.1XXS
Heat exhaustion (HE), unspecified Unspecified Anhidrotic Salt Depletion	 T67.5XXA T67.3XXA T67.4XXA	 T67.5XXD T67.3XXD T67.4XXD	 T67.5XXS T67.3XXS T67.41XXS
Exertional heat injury (EHI)	No code exists[1]	No code exists	No code exists
Exertional heat stroke (EHS)	T67.02XA	T67.02XD	T67.02XS
Heat stroke and sunstroke (Classic)	T67.01XA	T67.01XD	T67.01XS
Miliaria rubra	L74.0	No code exists	No code exists
Sunburn	L55.9[2]	No code exists	No code exits
Heat fatigue	T67.6XXA	T67.6XXD	T67.6XXS
Exertional rhabdomyolysis (ER)	M62.82[3]	No code exists	No code exists
Exercise Collapse Associated with Sickle Cell Trait (ECAST)[4]	D57.3	No code exists	No code exists
Hyponatremia	E87.1	No code exists	No code exists
Effects of heat and light Unspecified Other	 T67.9XXA T67.8XXA	 T67.9XXD T67.8XXD	 T67.9XXS T67.8XXS

Notes:
[1] See paragraph 5–6*c* above for exertional heat injury coding guidance.
[2] L55.0 Sunburn of first degree; L55.1 Sunburn of second degree; L55.2 Sunburn of third degree.
[3] No code exists for exertional rhabdomyolysis. ICD–10 code M62.82 refers to rhabdomyolysis. As there are other possible causes of rhabdomyolysis, those associated with exertion should also include: “volume depletion (dehydration)” (ICD–10: E86.0, E86.1, E86.9); “effects of heat” (ICD–10: T67.0–T67.9); “effects of thirst (deprivation of water)” (ICD–10: T73.1); “exhaustion due to exposure” (ICD–10: T73.2); or “exhaustion due to excessive exertion (overexertion)” (ICD–10: T73.3), depending on the clinical presentation.
[4] No code exists for ECAST. D57.3 refers to sickle-cell trait. Additional codes for heat exhaustion, unspecified T67.5, or heat syncope T67.1 should be included as well.

APPENDIX A

REFERENCES

Section I
Required Publications

There are no entries for this section.

Section II
Related Publications

Armed Forces Reportable Medical Events Guidelines and Case Definitions (January 2020)

AR 40–5
Army Public Health Program

AR 40–25/OPNAVINST 10110.1/MCO 10110.49/AFI 44–141
Nutrition and Menu Standards for Human Performance Optimization

AR 40–400
Patient Administration

AR 40–501
Standards of Medical Fitness

AR 385–10
The Army Safety Program

ATP 4–02.55
Army Health System Support Planning

ATP 4–25.12
Unit Field Sanitation Teams

ATP 4–44/MCRP 3–17.7Q (FM 10–52)
Water Support Operations

ATP 5–19
Risk Management

ATP 7-22.01
H2F Testing

ATP 7-22.02
H2F Drills and Exercises

DA Pam 40–11
Army Public Health Program

DA Pam 385–40
Army Accident Investigations and Reporting

FM 4–02
Army Health System

FM 6–0
Commander and Staff Organization and Operations

FM 7–22
Health and Holistic Fitness (H2F)

Office of the Surgeon General
Textbooks of Military Medicine, Medical Aspects of Harsh Environments, Vol 1

STP 8–68W13–SM–TG
Soldier’s Manual and Trainer’s Guide MOS 68W, Health Care Specialist Skill Levels 1, 2, and 3

TC 4–02.3
Field Hygiene and Sanitation

Training and Doctrine Command Regulation 350–6
Enlisted Initial Entry Training Policies and Administration

Training and Doctrine Command Regulation 350–29
Prevention of Heat and Cold Casualties

U.S. Department of Health and Human Services Publication No. 86–113
Occupational Exposure to Hot Environments

Water Planning Guide
Potable Water Consumption Planning Factors by Environmental Region and Command Level
USACASCOM, 25 November 2008

Section III
Prescribed Forms

There are no entries for this section.

Section IV
Referenced Forms

Except where otherwise indicated, the following DA Form is available on the APD Web site (http://armypubs.army.mil).

DA Form 2028
Recommended Changes to Publication and Blank Forms

Section V
Selected Bibliography

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APPENDIX B

WET BULB GLOBE TEMPERATURE INDEX

B–1. Method

a. The WBGT is an empirical index of environmental heat stress.
(1) Outdoor WBGT equals 0.7 natural wet bulb plus 0.2 black globe plus 0.1 dry bulb.
(2) Indoor WBGT equals 0.7 natural wet bulb plus 0.3 black globe.

b. The WBGT index is computed from readings of a—
(1) Stationary wet bulb thermometer exposed to the sun and prevailing wind.
(2) Black globe thermometer similarly exposed.
(3) Dry bulb thermometer shielded from direct rays of the sun.

c. All readings for the WBGT index are taken at the location representative of the conditions to which Service members are exposed (see paragraph 2–2). Traditional wet bulb and globe thermometers are suspended in the sun at a height of 4 feet above the ground. A period of 20 minutes should elapse before readings are taken. Modern “all-in-one” WBGT instruments should be placed on a tripod 4 feet above the ground and a similar warmup period allowed before making a first measurement.

B–2. Equipment

The traditional equipment required to measure the WBGT index is mentioned in field hygiene and sanitation manuals and is described in detail in this TB MED. However, a number of automated devices, known as heat stress monitors, that are more compact and portable than the larger original apparatus are readily available. Any WBGT device, whether mechanical or digital, should be calibrated by test, measurement, and diagnostic equipment support personnel on schedule in accordance with guidelines for the equipment.

B–3. Use of WBGT to control physical activity

a. The WBGT should be measured when the air temperature is 75 °F or higher.

b. When the WBGT index reaches 78 °F (26 °C), heavy physical work may precipitate heat illness or injury; therefore, hard physical work should be limited.

c. When the WBGT index reaches 82 °F (28 °C), moderate and heavy physical work should be modified.

d. When the WBGT index value reaches 85 °F (29 °C), increase rest periods for moderate and heavy work. Outdoor classes in the sun should be avoided.

e. When the WBGT index value reaches 90 °F (32 °C), easy, moderate and heavy work should be limited and physical training and very heavy work should be suspended for all personnel (excluding very heavy work during essential operational commitments not for training purposes, where the risk of heat illness/injury may be warranted).

f. Wearing of ballistic protection adds minimally to heat strain independent of the added weight carried, but protective clothing can shorten work times by as much as half.

g. Specific guidance for work periods, work-rest ratios, and fluid replacement during training is provided in Table 3–2, specific guidance for continuous work duration and fluid replacement is provided in Table 3–3, and specific guidance for alternate fluid replacement is provided in Table 3–5.

h. Most public health assets at the installation level use the WBGT to provide updates to the Commander and those working or living at these locations on the current heat category and, if needed, provide guidance on the work-rest cycle and other control measures.

i. WBGT can vary by location on very large facilities (see paragraph 2–2). Therefore, units are encouraged to make WBGT measurements in close proximity to training – particularly during conduct of high-risk activities.

APPENDIX C

COMMANDER'S, SENIOR NCO'S, AND INSTRUCTOR'S GUIDE TO RISK MANAGEMENT FOR PREVENTION OF HEAT CASUALTIES

A comprehensive hot weather injury prevention and management program should follow the principles of risk management by identifying hazards, assessing the hazards in terms of severity and probability, developing controls and making risk decisions, implementing appropriate controls to abate the hazards, and continuing to supervise and evaluate the controls to prevent heat casualties. Commanders conduct deliberate and real-time risk assessments for all operations and must ensure subordinate leaders and Service members receive and understand the information from the risk assessment to include the controls used to mitigate risk. Spot-checking and supervision by first-line leaders should be employed to ensure control measures are being implemented. Units train using risk management principles; therefore, it is imperative that commanders and leaders are educated on the prevention of hot weather injuries using this terminology. Heat casualty prevention is a Command responsibility (AR 40–5). This appendix outlines the five steps of the risk assessment process as it applies to heat injury prevention.

C–1. Step 1: <u>Identify the hazards</u>

Hot weather presents a natural hazard that can be made hazardous by various risk factors. These factors are listed in Table 4–1 and discussed in paragraph 4–2. A summary of the major factors for consideration is provided below.

a. Major Functional Risk Factors.

(1) High-Risk Activities (very heavy exertion) such as a 5 mile run in < 40 minutes and 12-mile march with 55 pounds in < 180 minutes can present a risk for exertional heat illness even in low heat category conditions; sequential days of high-risk activities with little recovery also increases risk.

(2) Lack of heat acclimatization (early heat season; fewer than 5 days exposure to hot weather).

(3) Low physical fitness (unable to run 2 miles in < 16 minutes).

(4) Exceeds body composition standards.

b. Major Acquired Risk Factors.

(1) Prior heat illness.

(2) Recent illness, fever, or infection.

(3) Use of some medications.

c. Major Environmental Risk Factors.

(1) High WBGT heat category and sequential days of high heat category weather.

(2) Clothing and equipment that add thermal insulation and decrease potential heat loss/exchange.

(3) Lack of shelter or shade.

C–2. Step 2: <u>Assess the hazards</u>

The potential for heat casualties can be assessed by—

a. Using the WBGT to determine the heat category when ambient temperature is over 75 °F. The WBGT should be assessed at the training site throughout the training day; do not rely on the heat category determined elsewhere on the installation.

b. Knowing your Service members individual risk factors. Early identification of who will be at increased risk (prior heat illness, concurrent illness, use of certain medications, etc.) will aid in the assessment of who may be at increased risk.

c. Checking the hydration status at the start of each training day. Using a parachute cord with beads is one way to track how many times a canteen or hydration system is refilled during the day. If hydration is inadequate, encourage extra fluid at night or in the morning. Note: the use of urine color to assess hydration status is only recommended for the first morning void. See paragraphs 3–6 and 3–7.

C–3. Step 3: <u>Develop controls and make risk decisions</u>

The risk of heat casualties can be mitigated through—

a. Education, to include

(1) Establishing standing operating procedures.

(2) Posting heat casualty prevention information where it is easily accessible.

(3) Ensuring all Service members are trained in recognition and treatment of heat illnesses (see paragraph 5–1).

b. Appropriate training event planning, to include—

(1) Minimizing consecutive days of heavy physical training when heat stressors exist.

(2) Reviewing work-rest cycles and establishing mandatory work-rest schedules (Table 3–2) when possible. Include active cooling (for example, AICS) during rest periods or rest in the shade when possible.

(3) Planning to perform heavy work (including physical training) in early morning or evening hours whenever possible. Avoid the heat of the day.

(4) Considering training alterations that improve heat loss (uniform) and/or reduce the training intensity (pace, load) if particularly high-risk activities must be performed (> 800 W). If training or events are "for record" and alterations are not feasible, understand that the higher risk alters the strategy from prevention to intervention; mitigate the most serious of heat illness outcomes with proper medical coverage and proper body cooling availability.

(5) Providing shade to reduce solar load. When necessary, shelters to provide shade can be improvised with canvas, ponchos, or parachutes. Ensure that shaded areas have good air circulation.

(6) Providing for shaded, shallow trenches to rest in when possible. Resting on hot ground increases heat stress; the more body surface in contact with the ground, the greater the heat strain. The ground heated by the sun can be substantially hotter than the air. Cooler ground is just inches down.

(7) Providing medical and evacuation support.

(8) Providing adequate hydration.

(9) Choosing the appropriate time of day (morning is cooler), location, clothing apparel, and location in training cycle for the training event.

(10) Providing means of cooling, such as the AICS and/or "Cool Zones" (or similar), to facilitate heat loss in hot weather (see paragraph 3–4).

(11) Planning operations to include water resupply points every 3 hours (see Table 3–5). Carry as much water as possible when separated from approved sources of drinking water. Ensure that Service members always have at least 1 quart in reserve; know when and where water resupply will be available. Service members can live longer without food than without water.

c. Identifying the following:

(1) Previous heat exhaustion, heat injury, or heat stroke among Service members. The uniforms should be marked with tape or cord in order to identify those who may need to be watched more closely.

(2) Overweight Service members and those who are unfit.

(3) Service members on medications that may increase risk of becoming a heat casualty (see Table 4–2). Mark the uniforms with tape or cord.

(4) Service members who are ill. Consider having these Service members report to sick call.

(5) Heat category hourly. The WBGT must be positioned at the training site.

d. A hydration monitoring system such as parachute cord with beads or similar.

e. Knowledge of standardized guidelines for warm weather training conditions such as the fluid replacement and work-rest guides.

f. Maximizing physical fitness and heat acclimatization prior to deployment. Maintain physical fitness during deployment with maintenance programs tailored to the environment. Physically fit Service members acclimatize to heat faster than less fit Service members. Significant heat acclimatization requires 3 to 5 days. Full heat acclimatization takes 7 to 14 days. Work intensity and duration should be adjusted accordingly. Gradually increase the exercise intensity and duration, working up to an appropriate physical training schedule adapted to the environment. During the first 2 days of heat exposure, light recreational activities (for example, softball, volleyball) are appropriate. By the third day of heat exposure, 2-mile unit runs at the pace of the slowest participants are feasible. The least fit Service members will suffer the greatest heat strain. Additional heat acclimatization strategies are provided in Table 2–1. Heat acclimatization increases sweating, which enhances evaporative cooling. Therefore, heat acclimatization does not reduce, but typically increases, fluid requirements.

g. Ensuring water control points throughout designated training areas.

C–4. Step 4: <u>Implement controls</u>

Heat casualty controls can be implemented through the following:

a. Make risk decision at the appropriate Command level based on local standing operating procedure (SOP).

b. Plan the timing and frequency of training events in consideration of the heat stress.

c. Implement work-rest and fluid replacement guidelines based on the heat category. During recovery periods, emphasize rest, shade, rehydration, and eating.

d. Encourage appropriate fluid consumption. Forced hydration orders are discouraged and can be dangerous.

e. Ensure adequate hydration of all Service members before any exercise or physical work.

f. Provide sufficient time for complete consumption of meals. Complete consumption of rations including salt packets will provide an adequate salt intake. Service members may have a few days of increased salt requirements upon initial hot weather deployment, because sweat contains more sodium before heat acclimatization. Additional salt supplementation is not necessary except in high-risk situations (see paragraph 3–7).

g. Conduct random checks by unit leaders and buddy checks by fellow Service members to monitor hydration status and the overall well-being of Service members. Monitor hydration status by noting the color of a Service member's first morning urine. The urine color at other times of day is an unreliable indicator of hydration status. Teach Service members that dark yellow first morning urine and infrequent urination throughout the day (< 3 voids) indicate that fluid consumption should be increased. If Service members are urinating more frequently large volumes of clear urine, they may be drinking too much.

h. Remove barriers to drinking. Make flavored, cool water accessible and provide enough time to drink and eat. Service members drink most of their water with meals; improving water availability increases food consumption. Carbohydrate and electrolyte beverages (sports drinks) are not required and, if used, they should not be the only source of liquid for extended periods. For healthy Service members, these beverages generally provide no advantage over water; however, they can enhance fluid consumption because of their flavor. If meals have not been consumed for several hours before, sports drinks can provide an advantage (over water) when performing strenuous work in the heat. If hyponatremia is an identified risk, concentrated salt beverages like ORS or MRE salt packets added to MRE sports drink powder are recommended. Cool water by shading and insulating water buffaloes or by using small mobile chillers. Drink water instead of splashing it on skin when supplies are limited.

i. Modify the clothing worn and equipment carried as necessary to reduce heat strain.

j. Establish drinking schedules by using Tables 3–2, 3–3, and 3–5. Water required to replace sweating may exceed the body's ability to absorb fluid, which is about 1.5 qt/hr. Service members should not be expected to drink more than this amount per hour; the rest must be consumed later.

k. Wear appropriate uniforms to protect against sun, wind, and other hazards. Use hats, head cloths, goggles, and sunscreen as necessary.

l. Wearing the OCP (or equivalent SCU) will reduce heat strain by protecting Service members from solar load. When not in direct sun (or brush), loosen and take off clothing to improve ventilation and evaporative cooling.

m. Keep clothing clean, since clean clothes protect better and help prevent skin rashes. Whenever possible, wash clothing and air-dry or sun dry.

n. Change socks at least twice a day. Prolonged wear of wet socks can lead to foot injury (for example, blisters) or foot fungus (for example, athlete’s foot). Sweat accumulation in the boot can be reduced by wearing a sock that is absorptive and thick enough to "wick" moisture away from the foot. Wearing a thin polypropylene sock next to the skin under your sock can also help prevent blisters.

o. Wearing the Joint Service Lightweight Integrated Suit Technology (JSLIST) decreases evaporative cooling and increases heat strain. Wearing underwear and the complete OCP, with the sleeves rolled down, under the JSLIST, provides additional protection against chemical agents. However, this clothing combination will also substantially increase the risk of heat casualties. Wearing only underwear under the JSLIST should be considered, depending on mission requirements and threat level.

C–5. Step 5: <u>Supervise and evaluate</u>

The final step to the risk management process is the supervision and evaluation of the controls taken to prevent heat casualties. Examples are as follows:

a. Enforce SOPs.

b. Ensure subordinate leaders and Service members at all levels receive the deliberate and real-time risk assessment information and understand the required controls prior to delegating responsibilities to ensure control measures have been implemented.

c. Monitor progress of implementation of control measures.

d. Conduct spot checks of cadre and recruits regarding heat category, work-rest guidelines, fluid replacement, etc.

e. Conduct spot checks of recruits by asking questions while observing their mental status and physical capabilities. Look for common signs and symptoms of both minor and major heat illnesses.

f. Adjust work-rest schedules, work rates, and water consumption according to conditions.

g. If and when the first heat illness occurs, halt training and reassess hazards and controls before resuming training.

GLOSSARY

Section I
Acronyms

ABC
airway, breathing, and circulation

AICS
Arm Immersion Cooling System

AKI
acute kidney injury

ALT
alanine aminotransferase

APHC
U.S. Army Public Health Center

AST
aspartate aminotransferase

ATP
Army Techniques Publication

BUN
blood urea nitrogen

BWL
body weight loss

CAT
category

CBRN
chemical, biological, radiological, and nuclear

CHS
compensated heat stress

CI
cardiac index

CK
creatine kinase

CNS
central nervous system

DA Pam
Department of the Army pamphlet

DIC
disseminated intravascular coagulation

DRSi
Disease Reporting System internet

EAH
exercise associated hyponatremia

EAMC
exercise associated muscle cramp

ECAST
Exercise Collapse Associated with Sickle Cell Trait

ECG
electrocardiogram

ED
emergency department

EHI
exertional heat injury

EHS
exertional heat stroke

EMS
emergency medical services

EMT
emergency medical technician

ER
exertional rhabdomyolysis

°F
degrees Fahrenheit

FITS
Fighter Index of Thermal Stress

FSG
Federal Supply Group

g
gram

HE
heat exhaustion

HSDA
Heat Strain Decision Aid

HSP
heat shock proteins

ICD
International Classification Disease

IU
international unit

IV
intravenous

lb
pound(s)

JSLIST
Joint Service Lightweight Integrated Suit Technology

LDH
lactate dehydrogenase

MAD
mean absolute difference

MCS
microclimate cooling system

MDRI
Military Dietary Reference Intakes

MEDEVAC
medical evacuation

mg/kg
milligrams per kilogram

mL
milliliters

mmol/L
millimoles per liter

MOPP
mission-oriented protective posture

mph
miles per hour

MRE
meals, ready to eat

MTF
medical treatment facility

NBC
nuclear, biological, and chemical

NL
no limit

NSAIDs
non-steroidal anti-inflammatory drugs

OCP
Operational Camouflage Pattern uniform

ORS
oral rehydration salts

PCM
phase-change material

PFU
physical fitness uniform

qt/hr
quarts per hour

SCT
sickle cell trait

SCU
Service Combat Uniform

SIRS
systemic inflammatory response syndrome

SOP
standard operating procedure

SVR
systemic vascular resistance

SWET
Soldier Water Estimation Tool

STP
Soldier Training Publication

TAG
TRADOC App Gateway

TRADOC
U.S. Training and Doctrine Command

UCHS
uncompensated heat stress

USARIEM
U.S. Army Research Institute of Environmental Medicine

W
watt

WBGT
wet bulb globe temperature

Section II
Terms

Acquired thermal tolerance
Cellular adaptations that allow tissues, organs, or organisms to become more resistant to heat injury.

Buddy aid
Acute medical care (first aid) provided by a nonmedical Service member to another person (JP 4-02).

Cognitive
Mental capacity.

Dehydration
Reduction of total body water, with some resultant reduction in plasma volume.

Delirium
Disturbance in attention and cognition.

Diuresis
Increased excretion of urine.

Diuretic
Drug prescribed to increase excretion of urine, often prescribed to expel water and salt, to treat hypertension.

Dysentery
Severe diarrhea containing blood or mucus.

Endotoxin
Component of the exterior cell wall of Gram-negative bacteria, like E. coli, that causes fever.

Etiology
Cause.

Exertional heat cramps
Brief, recurrent, and often agonizing skeletal muscle cramps of the limbs and trunk.

Exertional heat exhaustion
Condition in which the body cannot sustain the level of cardiac output necessary to meet the combined demands of increased skin blood flow for heat dissipation as well as blood flow for the metabolic requirements of exercising skeletal muscle and vital organs. Symptoms are non-specific and typically include undue fatigue, transient ataxia, dizziness, headache, nausea, vomiting, malaise, tachycardia, hyperventilation and transient mildly impaired cognition.

Exertional heat illness
A spectrum of illnesses associated with elevated body core temperature and the consequent metabolic and circulatory perturbations (heat strain) that are brought about by heat stress from exercise and the environment.

Exertional heat injury
Condition that is intermediate in severity between HE and EHS; characterized by more sustained mild confusion and disorientation, with clinical evidence of injury to a vital organ.

Exertional rhabdomyolysis
Condition involving breakdown of skeletal muscle with release of myocyte contents into the circulation, which may arise from a variety of stressors that cause injury to skeletal muscle tissue.

Exertional heat stroke
Life-threatening condition characterized by CNS dysfunction (for example, delirium, agitation, inappropriate aggressiveness, convulsions or coma) that occurs in the presence of severe hyperthermia.

Gastrointestinal
Pertaining to the stomach and bowel.

Gut
Stomach and bowel.

Heat acclimatization
Body's improved response to heat stress after a few days of heat exposure and regular strenuous exercise.

Heat edema
Swelling and discomfort of the hands and feet.

Heat rash
A pruritic red popular rash, located in areas of restrictive clothing and heavy sweating.

Hyperpnea
Abnormally deep or rapid breathing.

Hyperthermia
Elevated body temperature.

Hyponatremia
Low blood sodium. Often the consequence of prolonged excessive hydration combined with inadequate sodium replacement, for sweat losses. Serious cases have resulted from misdiagnosis as dehydration and overly aggressive rehydration.

Lysis
Destruction.

Medical evacuation
The process of moving any person who is wounded, injured, or ill to and/or between medical treatment facilities while providing en route medical care (FM 4–02)

Microclimate cooling
Systems that cool or dissipate heat from the body's surface without cooling the entire working environment.

Miliaria rubra
Prickly heat or heat rash.

Millimole
One thousandth of a mole. A mole is the atomic weight of a molecule of a chemical in grams, a measurement used in chemistry to equate chemicals by number of molecules instead of by scale weight.

Mishap
Any unplanned event or series of events that results in death, injury, or illness to personnel, or damage to or loss of equipment or property. (Mishap is synonymous with accident.)

Nephropathy
Damage to the kidney.

Nett Warrior
An integrated dismounted leader situational awareness system used during combat operations. See https://asc.army.mil/web/portfolio-item/soldier-nw/.

Nomogram
A diagram representing the relations between three or more variable quantities by means of a number of scales.

Obtunded/obtundation
Reduced level of consciousness.

Parade syncope
Fainting during prolonged standing due to inadequate venous blood return to the heart and brain.

Potable
Safe for drinking and hygiene uses; drinkable.

Strenuous exercise
Physical activity that exceeds 70 percent of a person's physical fitness level.

TRADOC App Gateway
A source for the SWET app. See https://rdl.train.army.mil.

Urine-specific gravity
Ratio of urine density to water density of 1.0.

Void
To urinate, or empty the bladder.

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