

# Exertional Heat Stroke in Navy and Marine Personnel: A Hot Topic

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Although exertional heat stroke is considered a preventable condition, this life-threatening emergency affects hundreds of military personnel annually. Because heat stroke is preventable, it is important that Navy critical care nurses rapidly recognize and treat heat stroke casualties. Combined intrinsic and extrinsic risk factors can quickly lead to heat stroke if not recognized by deployed critical care nurses and other first responders. In addition to initial critical care nursing interventions, such as establishing intravenous access, determining body core temperature, and assessing hemodynamic status, aggressive cooling measures should be initiated immediately. The most important determinant in heat stroke outcome is the amount of time that patients sustain hyperthermia. Heat stroke survival approaches 100% when evidence-based cooling guidelines are followed, but mortality from heat stroke is a significant risk when care is delayed. Navy critical care and other military nurses should be aware of targeted assessments and cooling interventions when heat stroke is suspected during military operations. (*Critical Care Nurse*. 2015;35[1]:52-59)

**H**eat stroke is a persistent problem among firefighters,<sup>1</sup> athletes,<sup>2</sup> and military personnel,<sup>3</sup> all of whom have occupations that require physical exertion in humid or hot environments. Military occupations in particular involve physically demanding tasks, such as carrying heavy loads for extended periods, often with unpredictable rest periods.<sup>4</sup> When protective equipment such as body armor is worn, heat dissipation is further blocked.<sup>5</sup> These extreme conditions place US military personnel and the military nurses who care for them at risk for heat injuries.<sup>6</sup>

Heat stress is determined by environmental (ie, radiant and ambient temperature, air movement, and humidity) and behavioral (eg, ergogenic agents, work intensity, and protective clothing) factors.<sup>7,8</sup> Just a few of these risk factors combined can quickly lead to an exertional heat injury. The less severe conditions can be treated on site with the person resuming normal activities the same day. Conversely, exertional heat stroke (EHS) is a life-threatening emergency, and rapid cooling must be administered immediately to ensure survival.<sup>9</sup> The high incidence of heat illnesses<sup>3</sup> in the US military might indicate that rapid recognition of heat injury and use of sound clinical nursing practices are not being applied consistently from ship to ship or unit to unit. Because EHS morbidity and mortality are preventable, it is important that critical care nurses in the Navy and other branches of the military rapidly recognize

**Table 1** Heat-related illness criteria

Clinical condition	Definition <sup>a</sup>	Core temperature	Related symptoms	Related signs
Heat syncope	Dizziness or fainting in a hot environment due to postural blood pooling in lower extremities	Normal	Generalized weakness, syncope	Postural syncope with rapid recovery once supine
Heat cramps	Painful muscle spasms during exercise in the heat	Normal or elevated but <40°C (104°F)	Painful muscle contractions (commonly in calf, quadriceps, or abdominal muscles)	Affected muscles are stiff and tender to palpation
Heat exhaustion	Diminished physical activity in the heat due to cardiovascular compromise	37°C-40°C (98.6°F-104°F)	Fatigue, nausea, vomiting, headache	Flushed, profuse sweating with or without clammy skin, normal mental status
Classic heat stroke	Severe hyperthermia primarily due to heat exposure	>40°C (104°F)	Heat exhaustion symptoms present before mental status changes	Hot skin with or without sweating, mental status changes (disorientation, ataxia, loss of consciousness); can develop slowly over several days
Exertional heat stroke	Severe hyperthermia primarily due to strenuous exercise	>40°C (104°F)	Heat exhaustion symptoms present before mental status changes	Hot skin with or without sweating, mental status changes (disorientation, ataxia, loss of consciousness); rapid onset

<sup>a</sup> Definitions from Pryor et al<sup>9</sup> and Epstein and Roberts.<sup>13</sup>

and treat patients with potential EHS during military operations. Previous military reviews have focused on organizational practices and the onus of responsibility for EHS up the chain of command.<sup>10</sup> For critical care military nurses, however, it is crucial to rapidly recognize and treat heat stroke in the field. Therefore, the aim of this column is to discuss the definition, risk factors, treatment, and nursing implications of EHS.

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### Definition of Heat Stroke

Heat stroke is a life-threatening emergency characterized by a rapid increase in the body's core temperature ( $T_{core}$ ) to greater than 40°C (104°F), multiple organ dysfunction,<sup>9</sup> and central nervous system abnormalities (eg, delirium, confusion, agitation),<sup>11</sup> with a mortality rate as high as 18% in military populations.<sup>12</sup> Exertional heat stroke, especially when combined with strenuous activity, can occur during exposure to hot or mild climates. Conversely, classic heat stroke occurs only in hot climates. The heat injury spectrum is listed in Table 1.

### Incidence of Exertional Heat Stroke

EHS mortality is significant in athletes and certain occupations, such as agricultural workers.<sup>14</sup> Among athletes, EHS is the third leading cause of mortality.<sup>15</sup> Moreover, among athletes and military personnel, the frequency of EHS continues to increase despite safety measures.<sup>12,15-18</sup> Despite knowledge of EHS risk factors, the incidence of heat stroke or heat exhaustion in the US military has not decreased in the past 5 years, estimated in 2013 at 0.25 and 1.57 per 1000 person years, respectively.<sup>3</sup> Highly motivated individuals might be tempted to ignore heat safety rules, especially during

**Table 2** Risk factors for heat illness<sup>a</sup>

Intrinsic (internal) factors	Extrinsic (environmental) factors
History of heat-related event	Level of exertion
Age (< 15 or > 65 years)	Excess clothing or protective equipment
Alcohol consumption	Lack of water
Existing medical conditions (ie, respiratory, hematologic, or cardiovascular)	Temperature (ambient)
Dehydration	Humidity
Sleep deprivation	Wet bulb globe temperature
Medications or supplements	
Obesity	
Overmotivation	
Inadequate acclimatization, poor aerobic conditioning, or both	
Recent illness	
Sickle cell trait	

<sup>a</sup> Based on information from Armstrong et al,<sup>2</sup> Epstein et al,<sup>10</sup> Casa et al,<sup>17</sup> Glahn et al,<sup>20</sup> and Wallace et al.<sup>21</sup>

dangerous operations, placing them at even greater risk of EHS.<sup>10</sup> Military units' awareness of heat injury is also important. One military unit or ship might place greater emphasis on work/rest cycles, environmental monitoring, and so on than another unit.

### Risk Factors

Recognizing inherent risk factors can help Navy critical care nurses make informed clinical decisions during training and deployments. Additionally, US Navy medical

missions, such as disaster response, usually include the care of diverse, vulnerable popula-

tions, such as the young and the elderly.<sup>19</sup> EHS risk factors (Table 2) are commonly classified into 1 of 2 areas: intrinsic (related to the individual) and extrinsic (environmental, task-related, or contextual).

### Intrinsic Risk Factors

In addition to a history of heat illness, intrinsic risk factors can range from sickle cell trait to high motivation.<sup>6,16,22,23</sup> Military training includes the indoctrination of military culture, such as "mission first," which can

**Table 3** Medications implicated in exertional heat illness<sup>a</sup>

Effect	Type of medication
Reduces rate of sweating	Antihistamines Anticholinergics
Alters skin blood flow	Calcium channel blockers Female reproductive hormones Capsaicin
Lowers cardiac contractility	β-Blocking medications Calcium channel blockers
Increases heat production (ergogenic), hypothalamic set point, or both	Sympathomimetics Amphetamines Ephedra 1,3-dimethylamylamine (sympathomimetic properties) Salicylates (supratherapeutic doses)

<sup>a</sup> Based on information from Howe and Boden,<sup>11</sup> Seto et al,<sup>25</sup> Kao et al,<sup>26</sup> Lee,<sup>27</sup> Lopez and Casa,<sup>28</sup> Fink et al,<sup>29</sup> Oh et al,<sup>30</sup> and Eliason et al.<sup>31</sup>

lead motivated persons to ignore important physiological warning signs. Other data from the US military show that overweight military personnel have a higher risk for sustaining heat injuries.<sup>22</sup> Low aerobic fitness has been cited as a predisposing factor for EHS.<sup>24</sup> Poorly conditioned athletes must work harder to keep up with fit teammates and thus may ignore warning signs such as dehydration, tachycardia, or sweating cessation. Numerous classes of medications have also been implicated in heat stroke (Table 3).

The mechanism by which common medications contribute to heat stroke depends on the class of drug. Anticholinergics (antihistamines, antidepressants, or antipsychotics) decrease production of sweat.<sup>11</sup> Cardiovascular agents, such as antihypertensives or diuretics, decrease the natural physiological responses to dehydration and hyperthermia.<sup>25</sup> Of special concern to young, healthy populations is the recent increase in use of dietary supplements.

Recent publications indicate that US Marines are among the highest military users of dietary supplements.<sup>26</sup> Ergogenic stimulants, such as amphetamines or ephedra, increase heat production. Ephedra, from the Chinese plant ma-huang,<sup>27</sup> along with 1,3-dimethylamylamine (DMAA), is associated with serious heat injury in athletes<sup>28,29</sup> and with EHS<sup>30</sup> and death<sup>31</sup> in the military. Although the exact mechanism underlying heat injury in many ergogenic aids is not fully characterized, published reports clearly

indicate that US Navy and other critical care nurses should screen EHS patients for recently used medications or ingestion of dietary supplement.

### Extrinsic Risk Factors

Professions in the US Armed Forces are particularly hazardous, with constant exposure to strenuous physical exertion and climate extremes. For instance, summer temperatures in Afghanistan routinely reach 51°C (124°F).<sup>32</sup> During military operations, personnel perform tasks while wearing body armor, which weighs a mean of 12.3 kg (27 lbs),<sup>33</sup> often without sufficient rest. Because of the nature of military operations, these factors are difficult to modify and might place military personnel in scenarios that exceed their physical capacity. Therefore, these individuals are at increased risk when subjected to individual and environmental factors that predispose them to EHS. It is clear from the evidence that EHS develops as a result of many complex factors and can vary from person to person. However, hyperthermia is always the common denominator underlying any risk factor.<sup>6</sup>

### Hyperthermia

Hyperthermia is an increase in  $T_{\text{core}}$  above the body's natural set point.<sup>6</sup> Human homeostasis requires a narrow operating temperature around 37°C.<sup>34</sup> To accomplish this, a thermoregulatory system composed of compensatory and noncompensatory systems communicate together for thermoregulation when  $T_{\text{core}}$  fluctuates.<sup>35</sup> During strenuous physical activity, body temperature increases in healthy persons, but as metabolic processes and/or environmental conditions exceed cardiovascular and central nervous system compensation, hyperthermia ( $T_{\text{core}} > 40^\circ\text{C}$ ) ensues<sup>13</sup> and the risk of EHS increases.<sup>10</sup>

Temperatures as high as 46.5°C (116°F) have been reported in patients who have recovered from heat stroke,<sup>36</sup> but survival at such an extreme  $T_{\text{core}}$  is rare. The severity of tissue injury due to hyperthermia depends on the critical thermal maximum,<sup>37</sup> defined as the maximum intensity and duration of tissue heating before cellular death occurs.<sup>38</sup> At extreme core temperatures, thermoregulatory mechanisms are overwhelmed, cellular proteins begin denaturing, and apoptosis (programmed cellular death) can occur within 5 minutes.<sup>39,40</sup> Failure to promptly recognize and treat hyperthermia can lead to EHS within minutes, a life-threatening medical emergency. The integrated effects of hyperthermia leading to derangement

of the central nervous system and multiorgan dysfunction are typical of EHS (Figure 1). More extensive reviews are available.<sup>13</sup>

### Clinical Management

The extent and severity of EHS might not be readily apparent in the chaos of military operations. Because mild forms of heat illness, if not recognized, might rapidly progress to EHS, immediate evaluation is necessary to assess the severity of symptoms and, if needed, to initiate cooling rapidly. When cooling is provided immediately, survival is near 100%.<sup>18</sup> Reducing  $T_{\text{core}}$  to less than 40.5°C in less than 30 minutes is the current recommendation.<sup>9</sup>

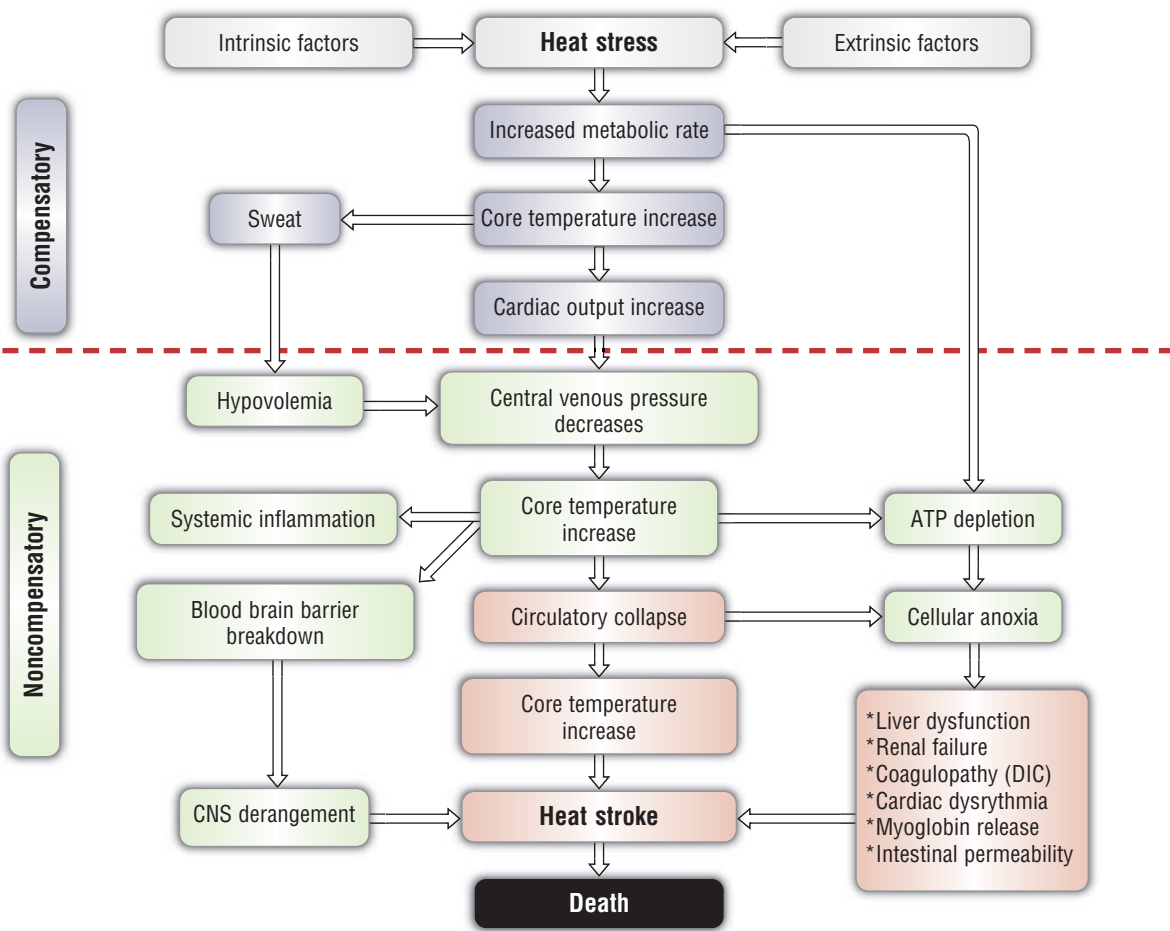
### Supportive Interventions

The initial priorities most relevant to EHS are hemodynamic status,  $T_{\text{core}}$ , and mental status. Upon presentation of EHS, critical care nursing staff must assess and stabilize vital signs, correctly recognize signs and symptoms of EHS, and begin cooling. The hallmark of EHS is altered function of the central nervous system, such as confusion and combativeness. Nursing management for EHS starts with assessing airway, breathing,

and circulation (ABCs). Baseline consciousness should also be

Central nervous system abnormalities such as confusion and agitation often are the first signs of heat stroke.

immediately established, along with an initial score on the Glasgow Coma Scale. Additional assessments include, when possible, medical history, medications, and/or dietary supplements used, body temperature at admission and maximum known temperature, clinical features apparent at admission, and vital signs. Critical care nursing interventions also include advanced hemodynamic monitoring and initiating fluid resuscitation with crystalloid intravenous solutions per the institution's protocol, preferably chilled (4°C) 0.9% sodium chloride solution.<sup>41</sup> Lactated Ringer solution is not used, because liver function can be suppressed by overheated tissues, leading to unmetabolized lactate and worsening lactic acidosis.<sup>20</sup> Numerous studies<sup>42-44</sup> have demonstrated that axillary, aural (tympanic), oral, and skin temperatures often indicate a falsely low  $T_{\text{core}}$ , especially after intense exercise in the heat. Rectal temperature remains the reference standard for assessment



**Figure 1** The event sequence leading to heat stroke and death from the compensatory to the uncompensable phase. Physical activity, especially during hot conditions, initiates a “compensable” thermoregulatory response (above the dashed horizontal line). When individual ability to compensate is surpassed, central venous pressure decreases, core temperature increases leading to thermoregulatory failure if prompt treatment is not initiated. This thermoregulatory failure triggers cellular death, intracellular imbalance (energy depletion), and circulatory failure. The multiple body system failures, if not immediately treated, lead to death.

Abbreviations: ATP, adenosine triphosphate; CNS, central nervous system; DIC, disseminated intravascular coagulation.

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of  $T_{core}$  in a potential EHS patient and the end point is a  $T_{core}$  less than 39°C (102°F).

### Cooling

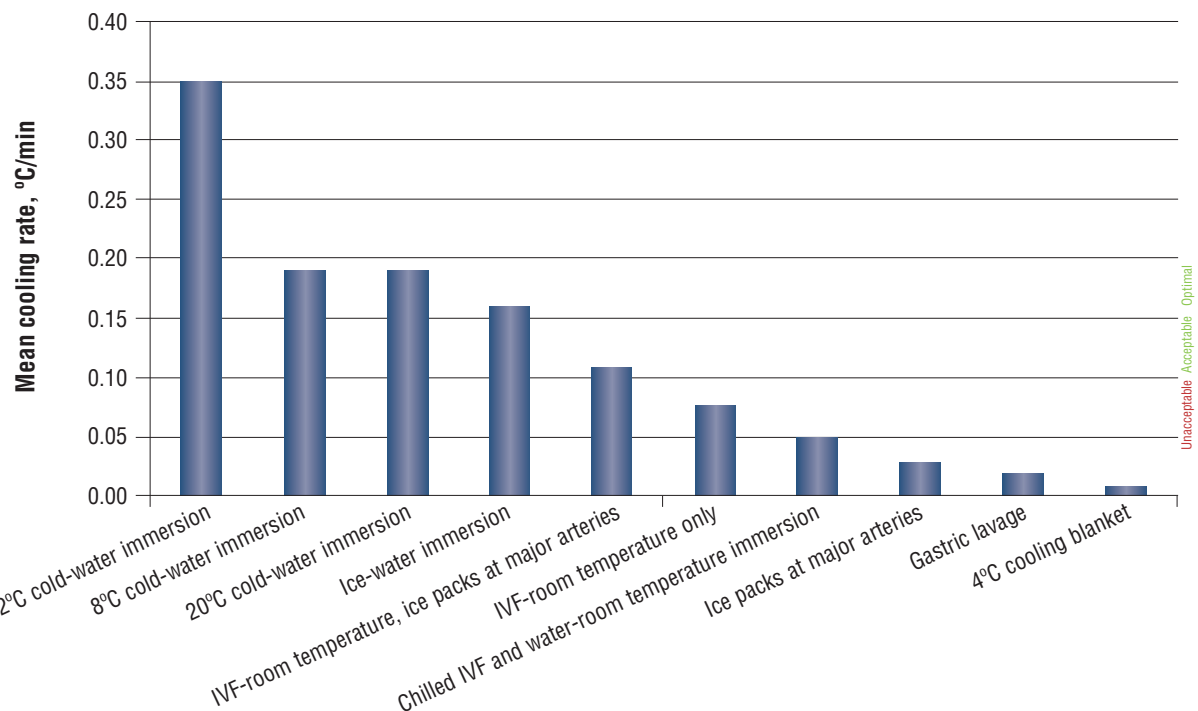
Once hyperthermia is confirmed by rectal temperature, or if a high suspicion of hyperthermia exists while one is waiting for positive confirmation, cooling measures should begin without delay. Effective heat dissipation relies on the rapid transfer of heat from the body’s core to the skin and from the skin to the environment.<sup>9</sup>

The most important determinant in an EHS outcome is the amount of time that patients’ core body

temperature is above the threshold (38.6°C) for cellular damage.<sup>45</sup> Reducing the  $T_{core}$  to less than 40°C within 30 minutes or less is critical.<sup>6</sup> When in doubt, the maxim “cool first, transport second” should be employed to ensure rapid treatment.

The fastest way to decrease  $T_{core}$  is to remove restrictive clothing and equipment and immerse the body (trunk and extremities) in a pool or tub of cold water (approximately 1°C-14°C, or 35°F-57.2°F).<sup>46</sup> Once the patient is immersed in cold water, aggressive stirring or continuous water motion will replace warmed water at the skin with cold water. Additionally, wrapping a cold, wet towel





**Figure 2** Relative cooling rates by heat stroke nursing intervention. Optimal cooling rates (>0.155°C/min), acceptable cooling rate (>0.079°C/min and <0.154°C/min), or unacceptable cooling rates (<0.078°C/min).

Abbreviation: IVF, intravenous fluids.

Adapted with permission from Pryor et al,<sup>9</sup> ©2013 with permission from Elsevier.

around the top of the head will enhance rapid cooling further.<sup>45</sup> It is recognized that cold water is not always available in remote areas. One alternative, when resources are limited, is to douse the victim with immediately available water. This method can reach a cooling rate of 0.1°C to 0.2°C per minute.<sup>47</sup> Cooling rates for the most common cooling methods are presented in Figure 2.<sup>9</sup>

### Civilian Nursing Implications

Heat exposure is one of the most deadly natural hazards in the United States. The Centers for Disease Control and Prevention<sup>48</sup> estimates that between 1992 and 2006, heat stroke claimed the lives of 423 Americans, more than hurricanes, lightning, floods, tornados, and earthquakes combined. These injuries require aggressive clinical treatments consisting of rapid cooling and supportive nursing care, such as fluid resuscitation to preserve organ function. Therefore, although this article is focused on Navy critical care nursing, the concepts of rapid recognition and cooling are universal and apply to any critical care nurse caring for a heat stroke victim.

### Conclusion

EHS requiring critical care nursing intervention represents a substantial risk of morbidity and mortality to Navy and Marine Corps personnel. With military EHS rates at high levels despite scientific advances, never before has it been so clinically important to recognize and rapidly treat potential EHS casualties. EHS rates in the Marine Corps, for instance, were more than 5 times higher than the rates in other military branches in 2011.<sup>49</sup> Data also suggest that military heat stroke survivors have twice the mortality risk from cardiovascular, kidney, and liver failure within 30 years of initial hospitalization compared with military survivors of nonheat injuries.<sup>21</sup> According to the best evidence available, ice-water or cold-water immersion is the most effective cooling treatment and is recommended as the definitive treatment.<sup>46</sup> If this method is unavailable, case reports demonstrate that continual water dousing combined with fanning is a practical alternative until advanced treatment is available. Practical resources for the implementation of EHS prevention and emergency procedures can

**Table 4** Military and civilian resources for exertional heat illness guidelines

Resource	Website	Description
Uniformed Services University, Consortium for Health and Military Performance	<a href="http://champ.usuhs.mil">http://champ.usuhs.mil</a>	Clinical consultation for exertional heat illness and related conditions such as exertional rhabdomyolysis
US Army Research Institute of Environmental Medicine	<a href="http://www.usariem.army.mil">http://www.usariem.army.mil</a>	Army clinical and educational resources regarding heat physiology, acclimation, and related operational issues
US Army Medical Department	<a href="http://www.cs.amedd.army.mil">http://www.cs.amedd.army.mil</a>	Provides a link to <i>Medical Aspects of Harsh Environments</i> , Volume 1
American College of Sports Medicine	<a href="http://www.acsm.org">www.acsm.org</a>	Civilian guidelines and consensus regarding exertional heat illness
US Marine Corps Heat Injury Prevention Program	<a href="http://www.imef.marines.mil/portals/68/Docs/IMEF/Surgeon/MCO_6200.1E_W_CH_1_Heat_Injury_Prevention.pdf">http://www.imef.marines.mil/portals/68/Docs/IMEF/Surgeon/MCO_6200.1E_W_CH_1_Heat_Injury_Prevention.pdf</a>	Marine Corps resource for the prevention of heat injury guidance per MCO 6200.1E, including acclimatization and work-rest cycles

be found in multiple locations (Table 4). The evidence underscores the need for prompt identification of potential EHS victims and aggressive cooling measures in the field as key critical care nursing actions. **CCN**

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To learn more about military critical care nursing, read "Tales From the Sea: Critical Care Nurses Serving Aboard the USNS *Comfort* and USNS *Mercy*" by Faulk and Hanly in *Critical Care Nurse*, August 2013;33:61-67. Available at [www.cconline.org](http://www.cconline.org).

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