Chapter 13

PREVENTION OF COLD INJURIES

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INTRODUCTION

Cold injuries have been recorded as a major problem for military operations in cold environments since Xenophon's march of the Ten Thousand in 401/400 BCE,[1] which involved severe frostbite problems in mercenaries crossing Armenia in winter, and Hannibal lost almost half his army of 47,000 while crossing the Alps in 218 BCE.[2] The problem of the identification and treatment of cold injuries continues to this day to plague modern military operations. The ability of warfighters to perform and survive in a cold environment requires knowledge and understanding of both the nature of the environmental threat and methods of coping with it.

The major cold injuries are frostbite; trench foot and immersion foot, which are now grouped in the new category, nonfreezing cold injury (NFCI); and hypothermia. Frostbite involves crystallization of tissue fluids in the skin or subcutaneous tissue after exposure to freezing temperatures, with the degree of injury depending on the speed of cooling. NFCI is the result of long-term exposure of the feet to cold, wet conditions. Trench foot can occur at temperatures above freezing and its development is time-dependent, with the injury severity increasing with the duration of exposure. Immersion foot is usually associated with chronic immobilization of the extremities or a static, upright position involving cold water exposure, or both. Hypothermia occurs when the core body temperature reaches 35°C (95°F).

Military operations in cold, snowy environments increase the chances for minor cold injuries that can limit unit effectiveness due to lost man-hours. Cold weather increases the difficulty of performing tasks related to eating, drinking, and normal hygiene. An increased solar load due to reflected light from snow or high-altitude operations increases the risk of exposure to ultraviolet (UV) radiation. Snow can also conceal hazards in the terrain and increase the risk of falls, resulting in injury.

Snow blindness (solar keratitis) is a temporary visual disturbance due to injury of the conjunctiva and superficial cells of the cornea caused by UV light. Increased UV radiation can also affect the skin, causing sunburn and chapped lips. Excessive sunburn can affect the wearing of cold-protective clothing, thus increasing the risk of cold injury. Sunburn is also an indicator of the role of UV radiation in producing oxidative stress, which can depress the body's immune function and increase the risk of systemic infection.[3,4]

Exposure to cold, dry air depresses mucociliary function, which compromises lower airway defense mechanisms. Edema and vasoconstriction of upper airway mucosa cause rhinitis.[5] Accumulation of mucus secretions may block drainage of the sinus resulting in sinusitis. Interior environmental conditions (eg, overheated dry air) inside heated living spaces (eg, tents) can compromise normal respiratory functions.

Personal hygiene is more difficult in cold environments, and lapses in hygiene can lead to gastrointestinal disturbances. Cold weather and dehydration exacerbate such problems as constipation (due to changes in diet, dehydration, or unwillingness to defecate), which may eventually lead to development of hemorrhoids. Diarrhea can exacerbate the problem of dehydration.

Dental hygiene can be another problem in cold-weather military operations, owing to lack of time and facilities for adequate preventive care. Field diets (operational rations) consist of refined carbohydrates ingested at frequent intervals, which increases the need for dental cleaning. Lack of preventive care can cause acute necrotizing ulcerative gingivitis. Toothache in normal teeth or teeth with extensive restoration is common with prolonged exposure to cold. Cold-induced contraction and expansion of dental fillings in teeth may allow for bacterial invasion and subsequent tooth decay.[6]

Complexity and Multiplicity of Environmental Threats

The environment is characterized by both meteorological and geographical considerations that affect the injury potential associated with operational activities. Conditions are termed cold-wet when the temperature is around freezing and the ground alternately freezes and thaws. On the other hand, cold-dry conditions occur when temperatures are below freezing and the ground is frozen. The ambient temperature is affected by both wind and humidity. Geographical considerations are the natural features of the terrain. Operations in mountainous terrain increase the severity of the effects of cold temperature and increased solar load, while operations in flatlands suffer from little cover and increased exposure to wind. Desert environments can create a potential for cold injuries due to the extreme day-to-night variation in temperature. The presence of waterways, either open or frozen, increases the risk of cold injury resulting from water immersion.

Fig. 13-1. These US Army soldiers from the 6th Infantry Division (Light), shown setting up camp in Alaska, illustrate the problems of working in a cold, dark environment.

The combination of increased hours of darkness, icy surfaces, and wearing heavy, bulky clothing makes movement and work more difficult (Figure 13-1). In these conditions, the possibility of slips and falls causing severe muscle and connective tissue damage or broken bones is increased. Any injury in a cold environment enhances the risk of circulatory shock. Protection of a field casualty who is receiving first aid is more difficult, owing to the increased risk of cold injury when cold-weather clothing is removed.

Military personnel serving on ships operating in cold environments and personnel serving on land will experience similar problems with safety and cold injuries. Shipboard personnel will experience greater risks associated with hypothermia because of the threat of falling overboard. The time that an unprotected person can exert any effort to survive (swimming, pulling oneself out of the water) is 2 to 5 minutes in –1.6°C (29°F) seawater.[7] And whether on land or at sea, the accumulation of snow and ice on exposed metal surfaces (eg, tanks, ships) enhances the possibility of falls.

Issues Relevant to Military Operations in Cold Environments

Civilians seldom put themselves in high-threat situations and consequently do not suffer large numbers of cold injuries. Military personnel, on the other hand, have to function in whatever environment they are placed. Mission requirements may require prolonged cold exposure, limited preparation time for unit movements, limited resupply, and inadequate equipment. Many different military occupations will increase the risk of cold injury during cold-weather military operations. Personnel who handle petroleum products, antifreeze, or alcohol are exposed to extreme risk of frostbite because these substances remain liquid at temperatures well below –17.7°C (0°F). At these temperatures, contact of these substances with skin or mucous membranes can cause an immediate freezing injury. Saturation of uniforms with these liquid substances will negate insulation properties and expose the wearer to increased risk of injury.

The effect of cold weather on nuclear, biological, and chemical warfare operations can be significant.[8] A nuclear explosion on a frozen area will have greater blast effects, due to reflection of the blast waves, which increases the danger zone. A frozen danger zone will also compromise the ability of military personnel to quickly entrench. Radioactive fallout can be concentrated because of wind and snow conditions. Effective chemical warfare relies on the vaporization of the chemical to cause damage. In a cold climate, agents with high freezing points (eg, hydrogen cyanide, cyanogen chloride, Lewisite, mustard agent, and ammonia) will not be effective, but many nerve and choking agents (eg, tabun, sarin, soman, VX, VR-55, SA, phosgene, DP, and nitrogen mustards) will be effective. Agents that lack volatility at cold temperatures may become persistent agents and be deposited on the snow. Contact with these agents can result in their penetrating the military uniform, causing direct skin contact; or the agents can be carried on the military uniform into a warm area, such as a tent, where the agent may then vaporize and cause damage.

There are problems in the use and care of chemical protective gear (ie, mission-oriented protective posture gear, MOPP) at freezing environmental temperatures (0°C, 32°F). There is no standard procedure for wearing MOPP gear in cold environments, but usually it will be worn over the cold-weather clothing. This will require that parts of the cold weather clothing be removed to prevent overheating, increasing the risk of cold injury. Oral fluid replacement will be difficult while military personnel are in MOPP 4 gear because the external drinking tube will freeze. The rubber used for the mask will become stiff and brittle and more likely to tear. The filters used with the mask will freeze. The mask has metal rivets that must be covered to protect the face from contact cold injury. If the mask is carried outside the uniform, it will be dangerous to don until it is warmed. Wearing MOPP gear can increase risk of physiological injury or fatigue if worn correctly because sealing it requires tight straps, which restrict blood flow. Chemical detectors will be less effective and autoinjectors containing nerve agent antidotes will freeze unless protected. Decontamination procedures are based on using water solutions, which will freeze. The use of nonfreezing solutions for decontamination will increase the risk, because these solutions will instantly cause a cold injury at freezing ambient temperatures. (Medically relevant features of nuclear, biological, and chemical protective equipment are also addressed in *Medical Consequences of Nuclear Warfare*[9] and *Medical Aspects of Chemical and Biological Warfare*,[10] other volumes in the Textbook of Military Medicine series.)

On ships serving in cold environments, major problems for personnel will stem from the accumulation of ice on exposed surfaces. Icing will occur first on small items and will affect lifelines and railings. The primary effects of topside icing are the changes in displacement and center of gravity, both of which increase the ship's instability. The severity of ice accumulation will depend on the type of ship, the ship's stability status, and its ballasting capability. These problems compound the safety considerations for shipboard personnel on the weather decks.[7] The increased instability of the ship will increase the danger that personnel will fall overboard, and it will also increase the amount of cold water on deck, which, in turn, further increases the danger of cold injuries.

COLD INJURY POTENTIAL

Environmental conditions in combination with physical activity, the duration of exposure, amount of protection, level of fitness, and individual cold susceptibility all contribute to an individual's risk for cold injury. Temperature, precipitation, and wind combine to increase the rate of body heat loss (ie, the intensity of exposure) and increase the risk of cold injury, which can be expressed as

$$\text{Risk} = (\text{time} \bullet \text{intensity of exposure}) \div (\text{adaptability to cold exposure} \bullet \text{technology})$$

where *time • intensity of exposure* is a measure of the cold stress (ie, the probability of developing cold injury), and *adaptability to cold exposure • technology* is a measure of an individual's resistance to the cold stress. The term "adaptability to cold exposure" can also be defined as thermocompetence, and "technology" refers to such items as clothing.

Intensity of Cold Stress

Freezing temperatures and low humidity favor the development of frostbite. Near-freezing temperatures in conjunction with moisture favors the development of trench foot. The presence of wind accelerates body heat loss and increases the risk for hypothermia. Cold water immersion produces the largest gradient for body heat loss and poses a significant threat of hypothermia. There are gradations of severity within each injury that are determined by the intensity and duration of exposure. Predictions for survival under different conditions can be obtained from a curve that plots estimated survival times against immersion in water at different temperatures (Figure 13-2).

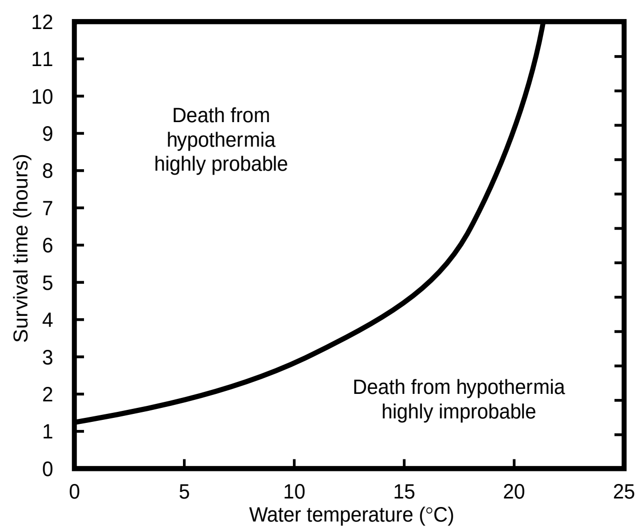

Fig. 13-2. This graph provides estimated survival times for humans immersed in different water temperatures. Survival times are based on an individual wearing a flotation device, so drowning is not possible. The survival time is based on minimal movement (swimming or treading water) and is based on the drop in core body temperature (ie, hypothermia). For example, a normal, uninjured, 70-kg man immersed (to the neck) in water at 0°C could be expected to survive (albeit in a hypothermic state) for 45 to 90 minutes. The *effective* survival time (not seen on this chart), on the other hand, is the time when a person can swim (without a flotation device) and could help himself out of the water. The speed of cooling is based on effective insulation, which can be due to an increased level of body fat or to protective clothing (antiexposure suit), or both.

Table 13-1 shows the relationship between core temperature and symptoms of hypothermia. The combination of wind and low temperatures creates a marked cooling effect on the body called the wind chill effect. Wind accelerates body heat loss under both cold-wet and cold-dry conditions. Wind increases convective heat loss from the surface of clothing because of its ability to penetrate loose-fitting clothing or openings, and wind removes the still, warm, layers of air trapped in the garments. If the clothing is wet, evaporative cooling is increased, which can account for up to 80% of body heat dissipation.

The addition of moisture to surfaces exposed to the environment greatly increases the rate of heat loss and increases the occurrence of cold injury. This moisture is usually from precipitation but can occur from perspiration soaking the insulation layers. In a cold environment with low humidity, perspiration contributes to body heat loss. Under cold-wet conditions, the combination of freezing and thawing causes wetting of the boots, which leads to cold injuries. The wetting of the skin of the feet will, over time, produce excessive hydration of cells and is a primary cause of trench foot.

The wind chill index, which establishes a risk of cold injury for different combinations of wind and temperature, has been developed and used as a tool for judging environmental risk (see Figure 12-4 in Chapter 12, Human Psychological Performance in Cold Environments). There are limitations for use of the wind chill index, in that it overestimates cooling power based on the effects of wind on the skin surface and underestimates cooling for clothed surfaces.

Adaptability to Cold Exposure

The ability of an individual to resist cooling involves many factors, including body composition, fitness level, fatigue, age, military rank, race, nutritional status, hydration status, tobacco use, legal and illegal drug use, and morale.

An increase in subcutaneous fat results in an increase in the insulation layer, which increases the resistance to cooling, during both exposure to cold air and immersion in cold water. However, military personnel tend to be more physically fit and consequently have lower levels of subcutaneous fat.

TABLE 13-1

CORE TEMPERATURE IN RELATION TO HYPOTHERMIA

°C	°F	Hypothermic Signs and Other Conditions
37	98.6	"Normal" oral temperature
36	96.8	Increased metabolic rate, in an attempt to balance heat loss
35	95.0	Maximal shivering
34	93.2	Individual usually responsive; normal blood pressure
33	91.4	—
32	89.6	Consciousness clouded; most shivering ceases
31	87.8	Pupils dilated; blood pressure difficult to obtain
30	86.0	Progressive loss of consciousness; increased muscular rigidity; slow pulse and respiration
29	85.2	Cardiac arrhythmia develops
28	82.4	Ventricular fibrillation may develop
27	80.6	Individual appears dead
26	78.8	—
25	77.0	Ventricular fibrillation may appear spontaneously
24	75.2	Pulmonary edema develops
23	73.4	—
22	71.6	Maximum risk of ventricular fibrillation
21	69.8	—
20	68.0	Heart standstill
19	66.2	—
18	64.4	Lowest accidental hypothermia patient with recovery

Adapted from Harnett RM, Sias FR, Pruitt JR. *Resuscitation From Hypothermia: A Literature Review for United States Coast Guard, US Coast Guard Headquarters*. Clemson, SC: Clemson University; 1979: 3. Contract DOT-CG-72074-A, Task 5.

Physical fitness has not been shown to correlate with decreased cold injury risk, but fitness levels are an important deterrent to fatigue, which is predisposing to cold injuries. Age has a significant effect on the incidence of cold injury, but military populations tend to be in the age range with the greatest resistance to cold injury. A low military rank correlates with an increased risk of cold injury because individuals of low rank have the greatest cold exposure for the longest duration.[11]

In a laboratory study,[12] black people were reported to have greater susceptibility to freezing injury than white people, which may be related to a stronger sympathetic nervous system response to cooling or a diminished cold-induced vasodilation response. Caution should be exercised in extrapolating this observation, however, because racial susceptibility to cold injuries has not been studied in battlefield situations.

Increased calorie intake is necessary to sustain the increased heat production and the increased work required to function in a cold environment.[13] Tobacco use is contraindicated in a cold environment because its vasoconstrictor action may increase the risk for peripheral cold injury.

Morale is a very important aspect of survival in a cold environment. Feelings of isolation, frustration, and depression can lead to fear for one's safety, which can negatively affect the will to live.

Technology

Humans have adapted to living in a cold environment by using protective clothing to survive. Clothing acts as insulation, which prevents body heat from escaping. Therefore, certain guidelines have evolved that should help in the selection of clothing. Dressing in layers, if possible, allows the soldiers to increase or decrease their insulation. Tight-fitting clothing that constricts blood flow to the extremities should be avoided. In a cold environment, a universal rule is to dress cool, because it is important to prevent the accumulation of perspiration. The accumulation of body oils and perspiration in fabrics reduces the insulation value of the fabric by reducing the air trapped in the fabric pores. The presence of perspiration in the clothing accentuates convective cooling and loss of body heat.

Tentage used in cold environments is designed on the same layering principle as cold weather clothing. The usual tent for army field operations is the Arctic 10-Man Tent. This tent has a strong, tightly woven outer shell, which is impervious to rain and snow. The inside liner is a lighter-weight fabric and is hung to provide an air space along the outer shell. This tent does not have a floor and suffers from the problem of moisture accumulation. After the first use, it becomes heavy and stiff and difficult to move. In contrast, the US Marine Corps uses a 4-man tent that consists of a floored tent and a rainfly that creates an anteroom for equipment storage. However, this tent does not have an insulative liner to create a dead-air space, which would make it more comfortable at colder temperatures. General purpose tents of various sizes may also be used for medical and command functions.

The larger tents are heated with the M1950 Yukon Stove, which is an effective heater but it may be the source of many injuries. The Yukon stove burns all fuels but is usually used with gasoline supplied from a 5-gal can mounted on a tripod outside the tent. When the Yukon stove is clean and set up properly, very little carbon monoxide (CO) accumulates inside the tent. There is a real danger of CO poisoning any time a stove (squad stove or individual stove) is used inside a tent without a vent pipe. CO is clear, odorless, and tasteless, which make it a very dangerous product of incomplete combustion and contaminant in unventilated quarters.

COLD INJURY PREVENTION

Function and performance in a cold environment are determined by maintenance of adequate whole body and local heat balances. Mathematical models have been developed for describing heat balance and simulation of the thermoregulatory processes involved, and have been used to develop guidelines for cold exposure (eg, work/rest cycles). The earlier models were descriptive; they were based on an analysis of heat exchange and physiological adjustments to thermal stress conditions.[14] Later models included a control component that responded to the effects of heat exchange and simulated human thermoregulatory adjustments.[15] These models may predict skin and core temperatures and allow an assessment of the risk of harsh environments on health and performance. One of the earliest predictors of response to cold was the wind chill index, which related to the cooling effect of wind on bare skin at different wind speeds. When cold weather clothing is worn correctly and all bare skin is covered, and all other logistical material (eg, food water, tents) are accounted for, there is no limit for humans functioning in the cold. The most conservative method of estimating cold stress, the wind chill chart is divided into zones of little danger, moderate danger, and great danger. A safe method is to curtail all unnecessary training operations when environmental conditions fall in the red "great danger" area. This chart is still in widespread use for determining the danger associated with military operations. Later models have added values for ventilation, condensation, and water retention for clothing, and these models may be useful in prediction of survival in cold environments.[16]

However, there are many limitations to the use of the current models. The heat transfer in clothing under transient and dynamic conditions has been poorly described. The physiological components of the response are also poorly described, and the criteria for prediction of certain effects are unclear.[17] Perhaps the biggest problem is the inability of the models to incorporate individual variation. Because morale is such an important part of survival in the cold, behavioral components of the responses must be included if the models are to be useful. Models have been used to predict survival times in cold water and give general guidelines for safety. Models have also been used to develop work/rest cycles in cold environments.

Training

Individual training before deployment should stress the role of the individual in the prevention of cold injury. Fatigue, hydration, nutrition, lack of cold weather skills, tobacco use, and a nonawareness of weather factors are known to be very important precursors to cold injury. Physical conditioning should be maximized before deployment to a cold environment because more-fit individuals are better at resisting extremity cooling. Physical conditioning should continue in the cold environment. There is no limitation to exercise in cold weather if an individual is wearing proper layered clothing and using prudent techniques. Training in cold weather will reinforce the fact that military units cannot be beaten by the weather if they are adequately trained and prepared. Troops should have training exercises in which they wear the cold weather clothing before deployment and should perform the military maneuvers that will be expected in the cold environment.

Fatigue can occur even with superior physical conditioning. The combination of wearing heavy, bulky clothing and struggling against wind, ice, and cold will lower the threshold for fatigue. The wearing of the 18-lb Extended Cold Weather Clothing System (ECWCS) increases the amount of work being performed. The wearing of the vapor barrier boots (Type I or Type II) also increases the work demand, because weight (4-5 lb) carried on the feet has a much greater multiplier effect for increasing effort than weight carried on the body. Fatigue causes loss of attentiveness and diminishes physical coordination. Symptoms of fatigue are loss of coordination, dizziness, shortness of breath, and chills. One of the best preventives against fatigue is to always work within your capabilities. Working with a buddy is strongly recommended,[18] as neither the development of facial cold injuries nor the cold-induced personality changes associated with decreased core body temperature can be detected by the individual involved. The buddy system enables military personnel to look out for each other and recognize the added time and effort needed under the particular weather conditions.

Nutrition

Long-term deployment of a combat unit requires the use of operational rations (Meal, Ready-to-Eat [MRE]; Ration, Cold Weather [RCW]; Food Packet, Long Range Patrol Ration [LRPR]) until kitchen facilities can be established. The caloric requirement for cold environments is 4,500 kcal/d. Within 10 days, one hot meal will be provided. This meal will be made from canned ingredients (B rations) and will be served in addition to the hot fluids provided for consumption (a hot-wet meal). The second 10 days calls for one hot-wet meal per person per day, in addition to operational rations. The plan for the third 10 days is to furnish two hot-wet meals daily, in combination with one operational ration. Food supply is not a consideration on board ship, but personnel should be aware that exposure to cold will usually require greater effort, which demands an increased caloric intake (Figure 13-3).

Most operational rations require water for rehydrating and to improve palatability, but all rations require potable water to increase consumption. A method for heating the ration (MRE ration heater) or heating water (individual stove) is required. Studies[19] on the use of operational rations have shown that troops do not consume sufficient calories to maintain body weight, and it is suggested that food consumption should increase when time is set aside for hydration and food consumption on a regular basis. In addition, consumption is increased when meals are eaten in a group setting (so-

Fig. 13-3. Hot meals during cold weather operations are important, both to increase morale and to prevent cold injuries.

cial effect). Once hot-wet meals are available, it is important to serve them hot and to encourage immediate consumption.

Hydration

Supplying, purifying, and delivering potable water are difficult tasks in cold environments. Water intake is essential to maintain the body's chemical balance and has been shown to enhance food intake.[20] *Water intake is the most important survival requirement in a cold environment*. Each individual requires at least 4 qt (canteens) of water each day. Caffeinated beverages such as coffee and hot chocolate cause increased water loss, and increased water consumption is therefore required. An increased level of activity will also increase the requirement for water intake. Hydration problems are minimized when water is consumed on a schedule and consumption is verified. The symptoms of dehydration include an increased pulse rate, constipation, and dark urine in small quantities as opposed to the normal straw-colored urine.

During most field operations, water will be delivered to units in 5-gal containers or will be obtained by individuals using stoves to melt snow. All water sources should be considered unusable until purified by boiling (at least 12 min is required at sea level) or by iodine tablet disinfection. Effective disinfection is achieved in 4 hours, and flavor additives should not be added until after that amount of time has transpired. A completely frozen 5-gal can will require 8 hours in a heated environment to thaw. Direct heating of water cans (plastic or ceramic-lined) is contraindicated. If stoves are to be used, then a gallon of fuel will be sufficient to produce 13 gal of water (the amounts are altitude-dependent) from snow or ice, which then must be purified before being consumed. In cold environments, thirst is an insufficient stimulus to maintain hydration, so it may be necessary to engage in forced drinking to maintain hydration. On board ship, the danger of dehydration is no less of a problem and individuals should augment fluid intake. Additional water will be required for personal hygiene.

Clothing

The ECWCS is a layered insulating system designed to maintain adequate environmental protection between 4.4°C (40°F) and –51°C (–60°F) (Figure 13-4). The ECWCS has 23 components—a mixture of clothing items, handwear, headwear, and footwear—and uses moisture-management principles to move perspiration away from the skin. The ECWCS is issued by the unit, whose job determines the need for the field gear. Each individual service member in the designated unit should receive the complete clothing ensemble and be instructed on how to wear and care for the ensemble. There is a sequence for wearing the items and this sequence should be employed. *The fit of each item is critical*. Every item must be tried on in its correct sequence. If clothing is too tight, it will restrict blood flow and increase risk for a cold injury.

The current method for cold weather dressing is to layer the protection to trap air and also to allow some layers to be removed as needed. The concept of the clothing is to move perspiration away from the skin (using man-made fibers that do not absorb moisture) and to prevent outside moisture from penetrating the clothing (by means of a directional-flow nylon and polytetrafluorethylene laminate material). Even with this system, it is still neces-

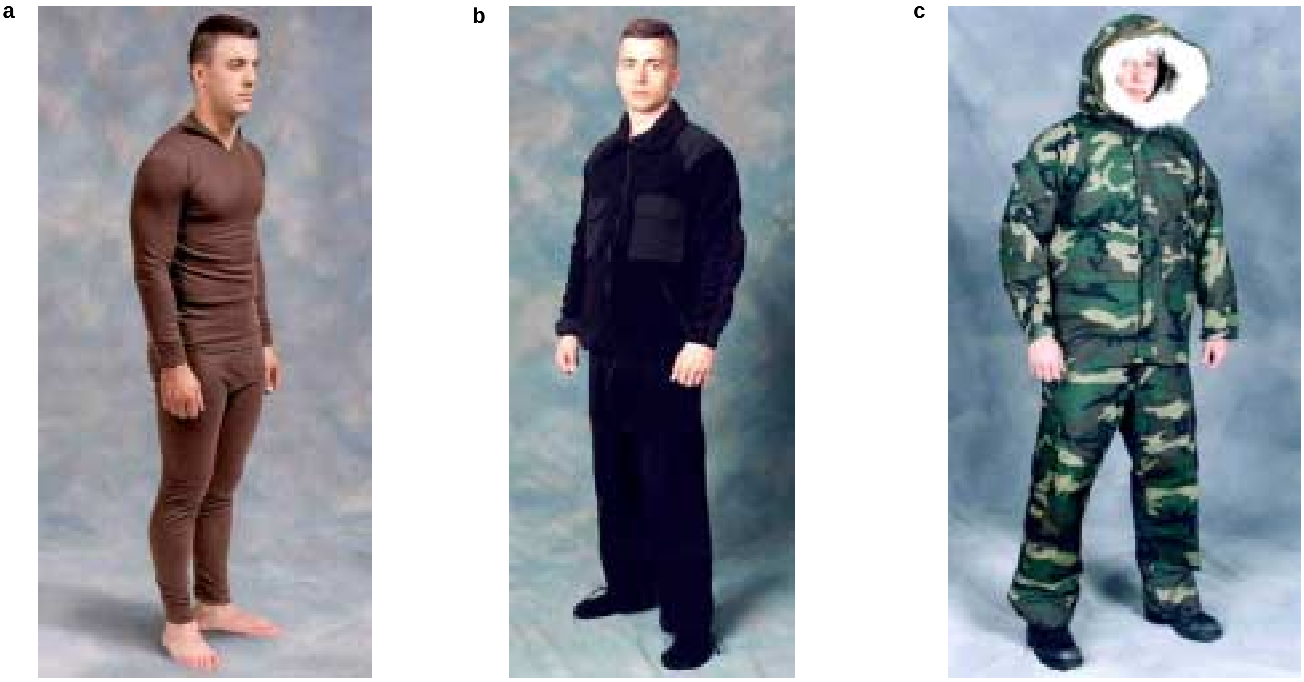

Fig. 13-4. These three views illustrate the layering principle on which the Extended Cold Weather Clothing System (ECWCS) is designed: (**a**) the polypropylene underwear, (**b**) the polyester pile insulation layer, and (**c**) the outer garment. Source: US Army Soldier and Biological Chemical Command, Soldier Systems Center, Natick, Mass.

sary to minimize the amount of perspiration produced by venting the clothing or removing clothing items when not needed to maintain warmth. Because the fabrics in the undergarments perform a wicking action and the outside garments rely on microscopic pores to repel moisture, it is very important to keep the clothing as clean as possible. These general guidelines have led to widespread use of the acronym COLD, which stands for Clean clothing, don't *O*verheat, dress in *L*ayers, and keep the clothing *D*ry.

New fabrics have been developed to allow one-way movement of moisture and have been incorporated into ensembles that stress the removal of moisture from the skin to negate some problems associated with the accumulation of perspiration. Under this concept, clothing made from natural fibers (cotton or wool) should not be worn with the uniform. Cotton retains moisture and becomes clammy, which encourages body cooling, whereas wool retains moisture and creates a barrier to the movement of moisture. The only time an exception is made is when wool garments (which retain insulation when wet) are worn as part of the cold weather uniform on US Navy ships.

The fabrics in the ECWCS ensemble require special attention. The polypropylene and polyester fiberpile undergarments must be gently washed in cold water. Liners, coats, and trousers can be washed in warm water. All items should be drip-dried or dried on very low heat settings. Overwhites (ie, camouflage garments for wearing in the snow) should be spot cleaned and washed in warm water using only a powdered detergent. Pressing any item in the ensemble will damage the fabric and should not be done. External rips and tears can be patched with fabric tape or stitched.

The most critical clothing component in a cold environment is the wearing of a proper boot. No single ideal boot exists for all cold weather military applications, so all boots offer a compromise solution. Cold feet will inhibit cold weather operations faster than any other environmental factor. The best approach to prevent cold injury is to practice these techniques for foot care:

- *Make sure the boots fit properly*. The sock combination involves wearing a thin polypropylene sock next to the skin and then a heavy wool sock to absorb moisture. If the boots are too tight in the toe area, get a larger size. If the operation will require the use of loaded backpacks, then the boots should be fitted while the soldier is carrying the weight, because feet expand when a load is added.

- Remove the boots and socks two to three times daily. Wash, dry, massage, and exercise the feet to restore circulation. Put on clean dry socks. If possible, dry out the inside of the boots with a towel.
- *Do not sleep with footwear on*. Before sleeping, remove the footwear and dry it and the feet. When in a static position, avoid (as much as possible) standing in mud and water.
- Exercise the feet (wiggle the toes) and legs to stimulate blood circulation. Elevate feet to minimize swelling. Be alert for numbness. Seek medical help at the first sign of injury. Continued exposure will make the injury worse.

Several different boots can be worn with the ECWCS, and the decision of which to wear should be based on environmental conditions. The boot selection includes the cold weather boot (Type I), extreme cold weather boot (Type II) (Figure 13-5), standard combat boot, GORE-TEX (manufactured by WC Gore and Associates, Newark, Del) combat boot, and ski-march boot. When either the Type I or Type II boot is used, foot care becomes extremely important because these boots are waterproof and the skin of the feet will become macerated over time, due to the fluid buildup around the foot. The fluid is not able to evaporate, increasing the risk of incapacitating foot injury.

US Navy cold weather clothing is divided into two temperature ranges:

- A-2 intermediate clothing, for temperatures down to –6.7°C (20°F), and
- A-1 extreme cold weather clothing, for temperatures down to –17.6°C (0°F).

One-piece antiexposure suits consisting of a durable external shell, a closed-cell foam insulating layer, and an inside liner are adapted for deck use on all ships as extreme cold weather clothing, with the added benefit of increased cold water survivability. These exposure suits are designed to be used only in certain environments, because they do not allow layering or venting to prevent moisture accumulation. Water-resistant insulated jackets and trousers can be worn over normal work uniforms but will require a life jacket. Headgear (wool watch caps, fleece-lined caps, balaclavas, and hoods), footwear (Type I vapor barrier boots or extreme cold weather mukluks), handwear (gloves or mittens), and underwear (thermal underwear and heavy wool socks) are included in the cold weather clothing ensemble. Because the environment on ships will be wet, the use of wool is more acceptable aboard ship than in dry, cold environments.

The availability of laundry facilities on US Navy ships makes it easier to maintain the cold weather clothing. To maintain its insulative effectiveness, it is essential that the clothing be washed and dried according to the manufacturer's specifications. In preparation for cold weather operations, backup clothing must be available. The greatest problem with the ECWCS system is the footwear because the boots are waterproof. Personnel must be encouraged to change socks often. Shipboard personnel should strive to stay dry (water spray or perspiration) and should change clothing as often as needed to maintain dryness.

a

b

Fig. 13-5. (**a**) For cold weather, the vapor-barrier Type I boot is for use in temperatures down to –28°C (–20°F). (**b**) The vapor barrier Type II boot should be used in extreme cold weather, all temperatures below –28°C (–20°F). Reprinted from US Army Soldier and Biological Chemical Command, Soldier Systems Center, Natick, Mass.

Shelter

One individual must always be awake when a stove is used in a tent. The cold weather ensembles are not fireproof and can cause severe injury because the undergarments made from man-made fabrics will melt onto the skin. The four-man tent does not provide a vent pipe, and ventilation is accomplished by opening the outside door.

When regular tents are not available and shelter is required, either natural shelters or improvised shelters can be used for short durations. An effective shelter must meet the requirements for protection from the elements, heat retention, ventilation, and some type of facility for drying wet clothing. It is possible to use natural shelters such as caves, rock overhangs, or hollow logs, but their use is risky when a fire is used. Controlled fire is necessary in cold environments, because uncontrolled fire is a threat to survival. Many types of shelters can be built if enough time and resources are available. A simple snow wall or snow trench can be used as a shelter from wind. A snow cave requires deeper snow and considerable effort to make, but it can offer excellent environmental protection for more than one or two people. If ponchos are available, then a one- or two-man shelter can quickly be assembled. With sufficient time and using trees and evergreen boughs, more elaborate tentlike structures (eg, a lean-to, A-frame, or tepee) can be constructed.

Individual Awareness During Cold Exposure

Cold injuries are preventable when each person of a ship's crew or a land-based military unit is prepared and trained for operations in cold weather. Awareness begins with the individual and should begin before deployment to a cold environment. Prevention of cold injuries begins with an assessment of preexisting risk for cold injury by the medical officer's examination of individual medical records for medications or existing medical conditions. Any medications that might affect blood flow, thermoregulation, or cognitive function would be contraindicated for cold exposure. (Existing conditions, such as Raynaud's syndrome, diabetes mellitus, chronic pulmonary disease, obstructive vasculopathies, peripheral neuropathies, or a prior cold injury will increase the risk of a cold injury; personnel with such conditions would not be deployed.) Immunizations for influenza and tetanus are important prophylaxes before deployment. The importance of maintaining a nutritional intake commensurate with physical effort, along with adequate hydration to prevent hypohydration, should be stressed. With command checking, the use of a communal spot for urination, coupled with proper discarding of uneaten rations, can be used as indicators of hydration as well as caloric intake. Individuals should be aware of the initial signs of cold injuries and encouraged to report these as soon as possible. The unit medics should document all reported incidences to the medical staff to avoid long-term problems.

All personnel should be advised to develop a buddy system to aid in the early detection of possible cold injury. Because early detection is important in limiting the extent of injury, it is important for buddies to observe and communicate effectively with each other. The medics should work individually with service members to make sure they know the early signs of cold injury, and emphasize that just because a body part has stopped hurting does not mean that the danger of cold injury has ended.

Leadership

The importance of leadership by example in a cold environment cannot be overstated. Several problems areas are unique to the cold environment. When an individual dons several layers of clothing and puts up the parka hood, the hearing and field of vision are restricted, and individuals can become oblivious to their surroundings. Team efforts are critical; a manifestation of cold stress is a tendency to withdraw within oneself and assume a cocoon-like existence. Mental processes become sluggish. Cold-stressed personnel may want to stay in warm tents and sleeping bags to escape the cold, and in the process will neglect their duties, even to the extent of compromising security. The remedy for these behaviors is physical activity. It is very important to keep individuals and entire units informed and involved in the activities. Special attention should be given to troops who grew up in warm environments and are not familiar with cold weather activities.

Military operations in mountain or cold climates require careful assessment of time and distance factors. These factors must always be considered when movements are planned, and safety must not be compromised so that certain timetables can be met. It is important to set a reasonable pace and maintain that pace to conserve as much energy as possible; energy conservation helps prevent cold injuries.

Field Signs and Prevention of Cold Injuries

To minimize cold injuries, an effective rule for the field is that individuals should always be able to feel their toes and fingers and, if the digits are numb, then the medic or buddy should check them. If the digits are insensitive, the tendency is to warm them as fast as possible. However, this approach has an inherent peril: a soldier may not perceive the heat that is being applied, and the cold injury will be exacerbated by a thermal burn. Cold injuries are classified as localized freezing (frostbite), localized nonfreezing (trench foot, immersion foot), and generalized (hypothermia).

Frostbite. Frostbite, a freezing injury, is characterized by an uncomfortable sense of cold, followed by numbness. Individuals may complain of tingling, burning, aching cold, sharp pain, decreased sensation, or no sensation. Visually, the skin will turn from red to waxy white. The areas most likely to be affected are the nose, toes and fingers, ears, cheeks, forehead, and exposed wrists.

Prevention of frostbite involves dressing properly, keeping clothing clean and dry, avoiding fatigue, not touching bare metal, being aware of signs of frostbite, and using a buddy system to watch for signs of injury.

Trench Foot. Trench foot, a nonfreezing cold injury, results from long-term exposure of the feet to above-freezing cold and moisture, coupled with the failure of personnel to take proper care of their feet during cold-wet operations. It is one of the most common problems facing personnel in cold weather operations. With trench foot, the feet appear pale and feel cold, numb, and stiff, and walking is difficult. The feet swell and become very painful. They will appear blotchy purple with waxy skin and poor circulation.

Prevention of trench foot depends on keeping the feet clean and dry. To prevent trench foot, personnel should change socks often, use a sweat suppressant on feet (ie, DrySol, manufactured by Person & Covey, Inc, Glendale, Calif), and use exercise and massage to increase circulation when feet are warm and dry.

Hypothermia. Hypothermia occurs when the body is unable to maintain adequate warmth and the core body temperature drops. Signs of hypothermia include uncontrollable shivering with an impaired ability to accomplish complex tasks. Together, shivering and vasoconstriction of the fingers and toes indicate that the individual is in danger of developing—or has already developed—mild hypothermia. Shivering *by itself* is not a solid indicator of hypothermia. The victim may feel very tired, experience muscle weakness, exhibit loss of coordination, and display atypical behavior and poor decision making. PHYSIOLOGICAL WARNING: These signs *must* be taken seriously by the person in charge.

Prevention of hypothermia depends on dressing properly for the environment and maintaining body heat. On board a ship, wearing a one-piece antiexposure suit can reduce the risk of hypothermia associated with falling overboard.

Field Treatment

Freezing and Nonfreezing Cold Injuries. The first step in cold injury management is to detect the injury. Pain is evident when tissue starts to freeze but will subside as the injury worsens (see Chapter 14, Clinical Aspects of Freezing Cold Injury). In addition, the injured (ie, frozen) extremity may be difficult to examine directly due to its being covered by clothing. When an injury is suspected, the injured area must be protected from further injury by cold or trauma. The decision to rewarm the injury should be based on the safety of the individual and whether he or she can safely be evacuated from the cold environment. Once the tissue is thawed, it is more susceptible to a second freezing injury, which will worsen the consequences of the injury. The injury should be assessed, and evacuation should occur as soon as it can be done safely. The injured extremity should never be exposed to temperatures above 39.4°C (103°F), which could aggravate the injury. The injury should be protected against trauma during the evacuation. Careful records should be maintained concerning all aspects of the injury and treatment. If the injury is a nonfreezing cold injury (see Chapter 15, Nonfreezing Cold Injury), the same problems of detection, protection, and evacuation are encountered. Both freezing and nonfreezing cold injuries are slow to evolve and even slower to resolve, and evacuation—as speedily as is safely possible—is recommended.

Hypothermia. The challenge of rewarming the hypothermic individual in the field is to know his or her core body temperature, which indicates the degree of hypothermia. Assessing core temperature in the field, however, is not possible without low-reading thermometers to measure rectal or esophageal temperatures (for further information, see Chapter 11, Human Physiological Responses to Cold Stress and Hypothermia), and these are not available for field use. As a consequence, the rule of thumb is to stabilize the victim of hypothermia in the field and remove him or her from the cold environment.

There are many techniques for rewarming a victim of hypothermia, but they must be used *with caution*. First, in the field, a victim of mild hypothermia (the victim can talk but seems disoriented and is shivering) can be placed in an insulated, warmed sleeping bag so that he or she can shiver until warm. If the victim is wet, it is imperative to remove the wet clothing before putting him or her inside the sleeping bag. Putting the hypothermic individual between two volunteers, for sharing of body heat, can be effective, but only for mild cases of hypothermia. This method requires no heating units but is also the least effective. Other, more effective techniques for rewarming a victim of hypothermia in the field are not recommended because the equipment necessary to monitor cardiovascular changes is rarely available. In general, the only method for rewarming available to field troops is the use of shared body heat. While this method will not be effective in rewarming a severely hypothermic individual, it (along with putting the person into a warm, insulated sleeping bag, out of the weather) will help stabilize the victim and prevent more heat loss. When treating a hypothermic casualty in the field, the main concerns are (1) to prevent further heat loss and (2) to remove the casualty from the cold environment, while (3) not decreasing the casualty's chances for survival by attempting to implement aggressive rewarming techniques.

The second method involves rewarming with warm water in a portable bathtub or life raft. The water temperature should be no greater than 42.2°C (108°F), and the warm water will have to be replenished. The casualty's core body temperature should always be monitored, along with the heart rate and blood pressure.

The third method involves the use of a warmed, humidified mixture of warm air and oxygen to limit heat loss and start rewarming. The temperature of the air mixture is critical, as it should not exceed 46°C (115°F). This method will inhibit shivering, which may give medical personnel a false indicator that the patient is improving.

The fourth method, which should be used in a medical treatment facility, involves infusing warmed intravenous solutions.

Beyond Cold Stress: Related Problems in Cold Climates

Cigarettes and alcohol consumption increase the risk of cold-related injury. Smokers maintain blood levels of CO that are 4- to 5-fold higher than those of nonsmokers, making smokers more susceptible to CO poisoning as well as decreased peripheral blood flow. Alcohol intake and CO poisoning can be related. Alcohol impairs judgment and coordination, which increases the risk of falls, and reduces alertness, which may result in a greater risk of fire and CO poisoning.

CO poisoning can result from sleeping in unvented, heated tents or from sleeping in a vehicle that is left running. Military personnel should always be aware of their surroundings and the direction of the wind. A vehicle parked downwind with its motor running can create a dangerous situation, in which exhaust from the vehicle will penetrate the cab.

Exposure of unprotected skin and eyes to sunlight may cause sunburn and snow blindness. Military personnel should use an alcohol-free sunscreen that contains *p*-aminobenzoic acid to block UV radiation (must have blocking factor ≥ 15). The use of sunglasses that block UV radiation will minimize the chance of snow blindness.

Lapses in personal hygiene can increase the chances of illness and disease. The armpits, groin area, face, ears, and hands should be cleaned daily by using sponge baths, air baths, or by rubbing with a dry cloth while in a tent or shelter. Hair, fingernails, feet, and mouth and teeth should be cleaned regularly. Facial hair allows ice to form near the skin, possibly predisposing it to frostbite.

Special Situations

Cold Water Immersion

Military personnel who are operating around open water must be protected against drowning and immersion syndrome. Immersion syndrome occurs when the water is cold enough to cause apnea and cardiac arrest in certain individuals (for additional information, see Chapter 17, Cold Water Immersion). Individuals who withstand or survive these immediate challenges may have a decrease in core temperature, causing excessive fatigue and confusion, leading to poor judgment that results in drowning. Because water conducts heat 32 times faster than air, any efforts to tread water or swim will increase the body's heat loss and hasten the onset of hypothermia; therefore, it is *essential* that shipboard personnel wear a personal flotation device.

Several techniques, all recommended by the military, will increase survival time in cold water. The most obvious is to avoid direct exposure to the water; in the case of a sinking ship, personnel should enter the water in a raft or lifeboat. They should wear or don a personal floatation device as soon as possible, and wear several layers of clothing. Personnel who are in the water should avoid movement and use the heat-escape-lessening posture (HELP; Figure 13-6). HELP minimizes the exposure to cold water of the swimmer's groin and the lateral surface of the chest because the arms are folded across the chest and pressed to the sides. The knees are drawn up and the legs crossed at the ankles. If more than one person is involved, the huddle position should be used to reduce heat loss. In this position, the chest, abdomen, and groin area should be pressed together. These survival techniques require that personnel practice and wear personal flotation devices. Treading water in the HELP position in heavy seas is a major challenge.

Fig. 13-6. (**a**) With the individual wearing a personal flotation device, the heat-escape-lessening posture (HELP) can increase survival time in cold water. The swimmer assumes a fetuslike position, which minimizes cold water exposure of the groin and lateral chest. (**b**) The huddle position should be used when more than one person is in cold water, and all are wearing personal flotation devices. In addition to conserving each individual's body heat, the huddle position helps prevent the swimmers from becoming separated before they are rescued. Reprinted with permission from Pozos RS, Born DO. *Hypothermia: Causes, Effects, Prevention.* Piscataway, NJ: New Century Publishers; 1982: 94, 96.

The huddle position requires that all participants be able to tread water.

The following is the basic order of cold water rescue:

- Make sure that you are in a safe position before you attempt a rescue operation. Do not make yourself another victim.
- Try to reach the individual and pull him out of the water.
- If you cannot reach the individual, throw him a floatation device and attempt to tow him to shore.
- As a last resort, because this places the rescuer at risk of hypothermia, swim to the individual. If the casualty is unconscious, then swimming to him will be the only option.
- Make sure that if you swim to the casualty, you are tethered to a buddy on shore or in a boat. Do not attempt this procedure by yourself.

Field management of a submersion incident involves the ordinary ABCs of resuscitation: ensure a patent *a*irway, ensure that the casualty is *b*reathing, and ensure that the casualty is not in *c*irculatory shock. The basic cardiopulmonary resuscitation procedures should be followed. Evacuate the casualty to an appropriate medical treatment facility as soon as possible.

Mountain Operations

Although the particular medical problems associated with military operations in mountain environments are discussed in Volume 2 of *Medical Aspects of Harsh Environments*, a brief overview of the prevention of cold-related injuries at altitude is included here in the interest of completeness. For soldiers fighting at high altitude, such as mountain terrain, the main physiological effects are hypobaric hypoxia, or a reduced atmospheric oxygen concentration leading to less oxygen in the blood, and cold stress. Humans can tolerate exposure to extreme altitude for only short periods without supplemental oxygen. With an acute ascent to high altitude, plasma volume immediately decreases owing to diuresis and the shifting of fluid into the cells. This shifting of fluid accounts for the increased hematocrit observed at altitude.

Three major clinical problems can occur with acute exposure to high altitude. The first is acute mountain sickness (AMS). The signs of AMS are rapid or irregular breathing, rapid pulse, and vomiting. Symptoms include headache, nausea, depressed appetite, generalized weakness, and dizziness. The second condition is high-altitude pulmonary edema (HAPE), in which fluid accumulates in the lungs. The symptoms of HAPE include a persistent cough; discharge of a pink, frothy sputum; disorientation; and fainting. Signs include cool, clammy skin; rapid breathing; a rapid, weak pulse; and blue lips. The third condition is high-altitude cerebral edema (HACE), which causes swelling of the brain. Signs of HACE include bizarre behavior, hallucinations, confusion, excessive fatigue, and coma.

The best treatment for these conditions is to avoid them by careful staging of the rate of ascent to the high altitude. These medical conditions are rare below 8,000 feet but can occur with rapid ascent to 8,000 feet and beyond. Scheduling a 48-hour rest at 8,000 feet, followed by a 24-hour rest after reaching 10,000 feet, and proceeding no more than 1,000 feet per day up to 14,000 feet will minimize the occurrence of all three conditions: AMS, HAPE, and HACE. AMS is not fatal but may progress if not treated by descending to a lower altitude; however, both HAPE and HACE can be fatal and require immediate medical attention.

When military units operate in mountain terrain, increased demands are made on personnel, owing to the terrain and weather. Weather becomes a factor because it can superimpose the rigors of the cold climate on the altitude stress. A cold injury at altitude is not different from a similar one at sea level, but the variable weather at altitude can rapidly increase the risk of weather-induced injuries. In addition to the possibility of AMS, there is a greater exposure to UV radiation at altitude because of the thinner air, causing less filtering and increased reflection of the UV radiation off the snow cover. This leads to a greater risk for snow blindness.

Leaders of military units must be especially vigilant to methods of preventing injuries. Standard leadership practices include careful evaluation of the terrain to plan routes and time requirements, and to assess difficulty. Leaders should keep in mind the ability of the unit, keep the unit together as a group to minimize straggling, and maintain a steady pace, incorporating rest breaks to allow adequate maintenance of hydration and nutritional status. In a difficult environment, the unit is only as strong as its weakest link. The usual procedures of individual protection apply and include the proper dressing and establishment of protection from the environment.

SUMMARY

Cold injuries can occur at any temperature below freezing, and nonfreezing cold injuries can occur at temperatures above freezing. Hypothermia occurs when the core body temperature falls to 35°C (95°C). As the environmental temperature decreases and the wind velocity increases (eg, during mountain operations), the danger of cold injuries increases. Military operations in extreme cold pose great risk for individuals in terms of injury potential, and training and constant attention to detail are required to avoid these injuries. Winter weather does not forgive and it cannot be defeated. For the unit to survive and function, command leadership must understand the limitations and problems associated with operations in hostile environments, and train and prepare the personnel.

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