TB MED 508

TECHNICAL BULLETIN

PREVENTION AND MANAGEMENT OF COLD-WEATHER INJURIES

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.

HEADQUARTERS, DEPARTMENT OF THE ARMY

April 2005

TECHNICAL BULLETIN
MEDICAL 508*

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 1 April 2005

PREVENTION AND MANAGEMENT OF COLD-WEATHER INJURIES

You can help to improve this bulletin. If you find any mistakes or have a recommendation to improve procedures, please let us know. Mail a memorandum or DA Form 2028 (Recommended Changes to Publications and Blank Forms) directly to Office of The Surgeon General, ATTN: DASG-PPM-NC, 5111 Leesburg Pike, Falls Church, VA 22041-3258.

		Paragraph	Page
Chapter 1	INTRODUCTION		
	Purpose	1-1	1
	References	1-2	1
	Explanation of abbreviations and terms	1-3	1
	Roles	1-4	1
Chapter 2	PHYSIOLOGIC RESPONSES AND ADAPTATIONS TO COLD		
	Cold stress in military operations	2-1	5
	Heat exchange	2-2	6
	Environmental cold stress	2-3	7
	Physiological responses to cold	2-4	8
	Physiological responses to exercise-cold stress	2-5	11
	Individual factors modifying physiological responses to cold	2-6	12

*This bulletin supersedes TB MED 81/NAVMED P-5052-29/AFP 161-11, 30 September 1976.

		Paragraph	Page
	Cold strain and performance	2-7	15
	Adaptations to cold stress	2-8	16
Chapter 3	COLD STRESS MANAGEMENT		
	General	3-1	19
	Hypothermia avoidance guidance	3-2	21
	Frostbite avoidance guidance	3-3	28
	Nonfreezing cold injury avoidance guidance	3-4	33
	Other injuries related to cold weather	3-5	33
	NBC clothing and decontamination	3-6	35
	Food and fluid requirements	3-7	36
Chapter 4	COLD INJURY: IDENTIFICATION AND TREATMENT		
	Types of cold injuries	4-1	41
	Predisposing factors	4-2	42
	Hypothermia	4-3	47
	Frostbite	4-4	53
	Nonfreezing cold injury	4-5	60
	Profiles and medical board	4-6	65
	Surveillance	4-7	65
Appendix A	REFERENCES		67
Appendix B	COLD WEATHER DEPLOYMENT TIPS		71
Appendix C	RISK MANAGEMENT STEPS FOR PREVENTING COLD CASUALTIES FOR USE BY COMMANDERS, SENIOR NCOs, AND INSTRUCTORS		75
Appendix D	EXTENDED COLD WEATHER CLOTHING SYSTEM		79
Glossary			83

List of Tables

Number	Title	Page
3-1	Intensity of exercise for selected military tasks	23
3-2	Insulation value of different pieces of Army clothing	24
3-3	Immersion time limits at different water temperatures and immersion depths	28
3-4	List of recommended preventive measures to decrease frostbite risk	31
3-5	Time in seconds to reach a finger-skin temperature of 32 °F while touching various materials at different temperatures	32
3-6	Daily energy expenditures (measured by doubly labeled water) of military activities	38
4-1	Predisposing factors for hypothermia	45
4-2	Predisposing factors for frostbite and peripheral cold injury	46
4-3	Core temperature and associated physiological changes that occur as core temperature falls	47
4-4	Signs and symptoms of hypothermia	51
4-5	Degrees of frostbite	54
4-6	Stages of freezing cold injury	57
4-7	Rewarming protocol	59
4-8	Recovery stage classification of NFCI based on symptomatology and time from rewarming	62

List of Figures

Number	Title	Page
2-1	Energy (heat) transfer of a soldier performing physical work in cold weather	6
2-2	Effect of cold stress on decreasing skin temperature, increasing peripheral insulation, and reducing the size of the body core	8
2-3	Decrease in finger-skin temperature upon initial exposure to cold (water) and subsequent CIVD responses with continued exposure	9
2-4	Comparison of metabolic rates (METs) during thermoneutral rest, shivering in cold water, and two levels of exercise (1 MET is equal to resting metabolism.)	10
2-5	Patterns of cold acclimatization	16
3-1	Cold strain risk management process	20

List of Figures (Continued)

Number	Title	Page
3-2	Approximate amount of clothing insulation needed at different air temperatures and physical activity levels	22
3-3	Effects of exercise and wind speed on finger (covered with mitten) and forehead skin temperatures in 14 °F air	29
3-4	Windchill temperature index	30
3-5	Time in minutes until the occurrence of cheek frostbite in the most susceptible 5 percent of personnel	30
3-6	Energy expenditure while walking at different velocities in various terrain conditions	37
4-1	Types of cold injuries	41
4-2	Frequency of occurrence of hospitalization for cold-weather injuries among Active Duty soldiers, by winter season, 1980-1999	42
4-3	Number of reported cases of cold-weather injuries from 1998-99 to 2002-03	43
4-4	Cases of cold weather injury hospitalizations by location of Army installation	44
4-5	Rewarming curves for shivering and exercise following cold water immersion	50
4-6	Pictures of frostbite	56
4-7	Nonfreezing cold injury	61
4-8	Schematic of factors and mechanisms that contribute to nonfreezing cold injuries	63
D-1	Lightweight long underwear	79
D-2	Expedition-weight long underwear	79
D-3	Fleece-layered jacket and trousers	80
D-4	Polyester batting jacket and trousers	80
D-5	Gore-Tex™ parka and trousers	80

CHAPTER 1

INTRODUCTION

1-1. Purpose
This bulletin provides guidance to military and civilian health care providers, allied medical personnel, and unit commanders and leaders to—

a. Develop an evidence-based prevention program to protect military personnel from cold stress and associated adverse health effects.
b. Understand the physiologic responses and adaptations to cold (chapter 2).
c. Implement procedures for managing cold stress (chapter 3).
d. Understand the principles and proper use of cold-weather clothing.
e. Understand the diagnosis and treatment of nonfreezing and freezing cold injuries and other medical conditions associated with cold weather.
f. Identify the risk factors for cold injuries and implement treatment (chapter 4).
g. Understand the principles and use of the windchill temperature index.
h. Prevent cold injuries during deployment and training.
i. Provide background information for reporting injuries 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.

1-2. References
Required and related publications are listed in appendix A.

1-3. Explanation of abbreviations and terms
The glossary contains a list of abbreviations and terms used in this publication.

1-4. Roles

a. Unit commanders, medical planners, medical officers, preventive medicine personnel, medics, and combat lifesavers will coordinate to implement educational and training programs at all levels in the command based on the principles of this document. They will review all training and operations to make sure adequate planning is made for emergency medical support and cold injury assessment and management where tactically feasible.

b. Unit commanders, and leaders when appropriate, will—

(1) Integrate the medical officer into all planning decisions for cold-weather operations.

(2) Assess training/mission hazards from cold, wetness, and wind exposure.

(a) During the advance planning stages, incorporate information about the mean and extreme climatic conditions at the deployment site, to include the 24-hour pattern of temperature and humidity and the times of sunrise and sunset.

Use of trademarked names does not imply endorsement by the U.S. Army but is intended only to assist in identification of a specific product.

(b) Obtain regular real-time, local weather data and predictions to identify windows of opportunity for critical military operations.

(3) Develop and implement controls for cold, wetness, and wind exposure.

(a) Ensure soldiers are provided adequate clothing, shelter, heaters, warming areas, food, and warm beverages for cold-weather operations.

(b) Ensure that only Army-approved heaters are used and personnel are trained in the use of the heaters (see paragraph 3-5a(3)).

(c) Consider modifying outdoor activities when windchill categories indicate extreme risk of frostbite.

(d) Initiate a buddy system under cold conditions, and have personnel check each other for cold injuries.

(4) Provide safe alternative training for individuals or units identified as being at particular risk for cold casualties.

c. Medical planners will determine regional high and low temperatures when preparing their Medical Intelligence Preparation of the Battlespace (MIPB) and ensure that the commander is briefed on how to protect unit personnel and what climate injuries the medical commander can expect to treat.

d. Unit medical personnel will—

(1) Understand the commander’s intent and mission goals and advise the commander on the potential adverse effects of cold weather and propose practical options for control of cold, wetness and wind exposure under difficult circumstances.

(2) Assess each component of cold exposure (environmental factors, condition of the soldier, work load and mission requirements) to plan for the primary prevention of cold injuries by answering the following questions:

(a) What are the anticipated temperatures and wind speeds to which soldiers will be exposed, and will the soldier be protected from the effects of cold temperatures, wetness and wind?

(b) What uniform/equipment will be worn, and is clothing clean and without holes or broken fasteners?

(c) What work intensity and duration is planned?

(d) Will the soldier be exposed to other materials that increase the risk of a cold injury (such as bare metal objects, fuels or petroleum, oil or lubricants (POL)?

(e) Will the soldier be able to move around to keep warm, dress down to avoid overheating, or seek shelter to avoid rain/wind/snow?

(f) Will feet be dry and warm, and will soldiers be given opportunities to change socks/footwear?

(g) Will the soldier be with a buddy who can assist/watch over him or her to prevent a cold injury?

(3) Determine onsite windchill temperature using the windchill temperature index table and provide guidance for adjusting physical training and clothing according to the windchill category and work intensity.

(4) Assist the logistician in estimating clothing, shelter, and heater requirements.

(5) Educate the soldiers about the steps needed to minimize the risk of cold injury, to include risk factors such as age, race, fitness, hydration, nutrition, rest, alcohol and drugs, and actions to avoid cold injury such as understanding environmental and personal risks, establishing observational checks, avoiding contact cooling, using clothing properly, and exercising.

(6) Educate soldiers in recognizing the signs of impending cold injury and the basics of buddy aid.

e. Preventive medicine officers will—

(1) Estimate the rate of cold injury and arrange required medical support associated with each course of action.

(2) Develop a casualty evacuation plan to include a means of warming and monitoring patients.

(3) Integrate the estimates of mission injury rates, mission-compatible preventive measures, and medical support requirements to determine if alternative plans need to be developed by the command staff.

(4) Become aware of what types of illnesses are being seen at sick call and what medications are being used.

(5) Interview soldiers diagnosed as having signs and symptoms of cold injury to describe predisposing conditions and the circumstances surrounding the development.

(6) Use the Tri-Service Reportable Medical Events System to report cold casualties.

(7) Communicate to field commanders immediately upon recognition of cold injury sentinel events and clusters.

f. Soldiers will—

(1) Be familiar with the causes and risks of cold injury and the personal protective measures they can take to prevent cold injury.

(2) Attend cold injury threat and risk communication briefings and receive appropriate written cold injury prevention materials well in advance of deployment.

(3) Apply personal protective measures and use protective clothing and equipment properly (loose and in layers) when required.

(a) Ensure that their cold-weather clothing is clean, dry, and in good repair, without holes or broken fasteners.

(b) Consume adequate food and fluid for optimal performance in the cold.

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

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

(5) Report to the unit medic/medical officer if they or a buddy develops cold injury symptoms.

This page intentionally left blank

CHAPTER 2

PHYSIOLOGIC RESPONSES AND ADAPTATIONS TO COLD

2-1. Cold stress in military operations

a. Troops participating in military deployments will often encounter cold stress that requires management for successful mission accomplishment. Excessive cold stress degrades physical performance capabilities, significantly impacts morale, and eventually causes cold casualties. Cold stress environments include not only exposure to extremely low temperatures (for example, Arctic regions), but also cold-wet exposures (for example, rain, immersion) in warmer ambient temperatures.

b. U.S. military operations have been conducted successfully in cold-weather climates where troops were required to endure low temperatures and cold-wet exposure for long hours and push their physiologic limits (for example, World War II European campaigns, Korea, Balkans, and Afghanistan). However, cold-weather conditions impair many aspects of normal military functioning in the field, which can in turn influence soldier health and performance.

(1) Food and water requirements may be high, yet supply can be difficult, resulting in inadequate nutrition and hydration.

(2) Furthermore, cold weather contributes to increased disease and non-battle injury since maintaining proper field sanitation and personal hygiene is difficult, and sick and injured individuals are susceptible to medical complications produced by cold.

(3) Operational problems often arise in cold weather. Mission completion may be delayed because of physical performance decrements, equipment malfunctions, and slow movement of vehicles and personnel. Also, cold-weather clothing can be difficult to integrate with nuclear, biological, and chemical (NBC) protective clothing/equipment.

(4) In addition, mission requirements that demand intense physical activity, little food, and no sleep make successful cold stress management difficult because these requirements disrupt the normal physiological responses to the cold.

c. Military operations can occur in the coldest weather and with minimal logistical support, leaving troops under-equipped for the hostile conditions. Individuals in these situations must rely on their prior training and strong leadership in cold strain management. This training can determine whether the mission will succeed or fail with either few or high casualty rates. Individuals in these situations often are not fully prepared, and, consequently, unit commanders and trainers must actively plan to prevent cold casualties. Military training exercises, whether initial entry training, special badge qualification training, or military operations training, often occur during cold-weather seasons and can provide an opportunity to teach personnel how to follow appropriate guidelines for successful completion of missions in cold environments.

d. Leadership is key for training in cold-weather environments and for successful cold weather military operations. Soldiers need to have confidence that they can master the environment through the use of preventive measures. Lessons learned from previous cold-weather deployments must be emphasized. Leaders must learn their unit's capabilities and manage cold exposure relative to the provided guidance. Guidance is based on the "average" soldier, although there is significant individual variability. Supporting medical officers must ensure that the principles of this document are incorporated into the commander's plans and are applied to all phases of training and operations: pre, during, and post. See appendix B for cold-weather deployment tips.

2-2. Heat exchange

Body heat exchange occurs through four mechanisms: convection, radiation, conduction, and evaporation. Figure 2-1 schematically shows energy (heat) transfer of a soldier performing physical work in cold weather. Metabolic heat (about 70 percent of energy expended) is released from active skeletal muscles and transferred from the body core to skin. Heat exchange from the skin to the environment is influenced by air temperature; humidity; wind speed; solar, sky, and ground radiation; and clothing.

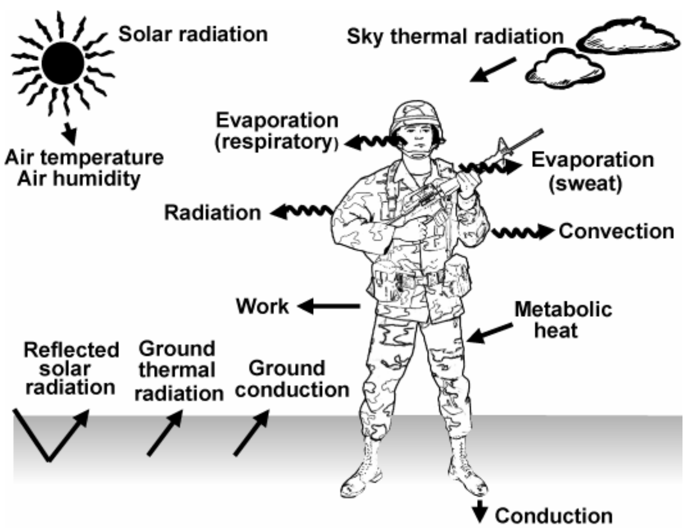


Figure 2-1. Energy (heat) transfer of a soldier performing physical work in cold weather

a. Convection of heat occurs by the movement of a gas or liquid over the body, whether induced by body motion or natural movement of air (wind) or water, when air/water temperature is below body temperature. This movement decreases the boundary layer over the skin that insulates against heat loss. In air environments, convective heat transfer can be significantly increased by wind (if clothing does not create a barrier), and for soldiers wading in water convective heat loss can be very large even when the difference between body surface and surrounding fluid temperature is small. This is because the heat capacity of water is much greater than that of air, and the convective heat transfer coefficient of water is about 25 times greater than that of air.

b. Radiative heat loss away from the body occurs when surrounding objects have lower surface temperatures than the body and is independent of air motion. However, radiation from the sun, ground, and surrounding objects can have a high radiative capacity and cause the body to gain heat even though the air temperature is below that of the body. For example, on a very sunny day a soldier on a snowy surface may gain a significant amount of heat, despite low air temperatures. However, even when ambient air temperatures are relatively high, heat loss from exposed skin is greater under a clear, night sky than during daylight hours.

c. Conduction of heat occurs between two objects that are in direct contact and have different surface temperatures. Sleeping on cold ground/snow and touching metal objects and fuels are common ways this occurs during cold weather military operations. Heat conduction is greater during exposure when skin and clothing are wet than when the skin is dry. Wetness decreases the insulation of clothing and increases the contact area between skin and a surface.

d. Evaporative heat loss occurs when liquid turns to water vapor. Evaporative heat loss is associated with sweating and respiration. The rate of sweat evaporation depends upon air movement and the water vapor pressure gradient between the skin and the environment, so in still or moist air the sweat tends to collect on the skin. When soldiers perform strenuous exercise in heavy clothing, significant heat strain and sweating can occur. After exercise, the nonevaporated sweat will reduce clothing insulation and possibly form ice crystals. Breathing cold air can slightly exacerbate respiratory water loss during exercise, since cold air has lower water content than warmer air. Therefore, the most significant avenue of evaporative heat loss during exercise in cold conditions is the same as in warm conditions, that is, sweating.

2-3. Environmental cold stress

a. Cold stress refers to environmental and/or personal conditions that tend to remove body heat and decrease body temperature. Cold strain refers to physiological and/or psychological consequences of cold stress.

b. Low air temperature, high humidity/rain/immersion, little thermal radiation, and high air movement are all causes of environmental cold stress. Air temperature is measured from a shaded dry bulb thermometer. The contribution of humidity is determined from a wet bulb temperature (measured by covering a thermometer bulb with a wet wick). Radiant heat (solar load) is assessed by a "black globe" thermometer consisting of a 6-inch hollow copper sphere painted matte (flat) black on the outside and a thermometer at the center of the sphere. Air movement is measured from an anemometer.

c. The U.S. Army employs the windchill temperature (WCT) index as one measure to mark levels of environmental cold stress. The WCT integrates wind speed and air temperature to provide an estimate of the cooling power of the environment and the associated risk of peripheral cold injury. The windchill temperature is the equivalent still-air (that is, no wind) temperature at which heat loss through bare skin would be the same as under windy conditions. Note that individuals riding in open vehicles or exposed to propeller/rotor-generated wind can be subject to dangerous windchill, even when natural winds are low. Ambient dry bulb (<32 °Fahrenheit (F)) and contact surface temperatures (exposed skin) are used to determine the risk of frostbite. There is no risk of frostbite when the ambient air temperature is above 32 °F even though the WCT may be below freezing due to strong winds. Wet skin will not freeze if the air temperature is above 32 °F, but wet skin below 32 °F will freeze faster than dry skin.

d. When assessing weather conditions for troops operating in mountainous regions or for aircraft flight personnel, altitude must be considered, if weather measurements are obtained from stations at low elevations. Temperatures, windchill, and the risk of cold injury at high altitudes can differ considerably from those at low elevations. In general, it can be assumed that air temperature is 3.6 °F (2 °Celsius (C)) lower with every 1,000 feet above the site at which temperature was measured. Winds are usually greater at high altitude, and there is less cover above the tree line.

2-4. Physiological responses to cold

a. *Body temperature*. Body temperature is normally regulated within a narrow range through two parallel processes: behavioral temperature regulation and physiological temperature regulation. Behavioral thermoregulation includes avoiding or reducing cold exposure using clothing and shelter, and increasing physical activity. In military scenarios, behavioral thermoregulatory actions can often be overridden by mission requirements and situations (for example, inability to move) or lack of resupply (inability to change into dry clothing or find shelter). Therefore, soldiers will need to maintain their body temperatures via physiological changes. Physiological temperature regulation consists of the heat conservation response of vasoconstriction and the heat producing response of shivering.

b. *Heat conservation*.

(1) Humans exhibit peripheral vasoconstriction upon cold exposure. The resulting decrease in peripheral blood flow reduces convective heat transfer between the body's core and shell (skin, subcutaneous fat and skeletal muscle), effectively increasing insulation by the body’s shell. Because heat is lost from the exposed body surface faster than it is replaced, skin temperature declines. This is illustrated for the extremities in figure 2-2.

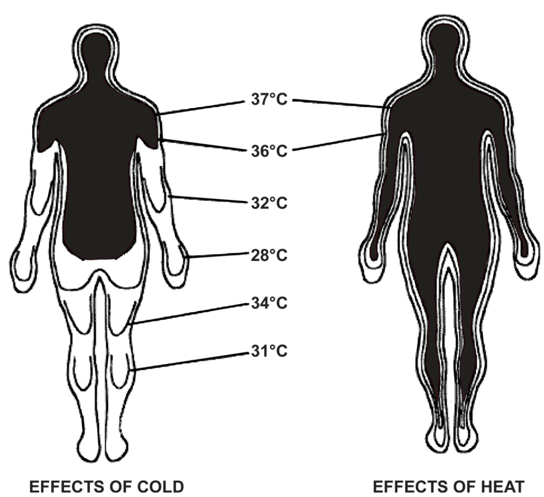


Figure 2-2. Effect of cold stress on decreasing skin temperature, increasing peripheral insulation, and reducing the size of the body core

(2) During whole-body cold exposure, the vasoconstrictor response extends beyond the fingers and occurs throughout the entire body's peripheral shell. Skin vasoconstriction begins when skin temperature falls below about 95 °F (35 °C) and becomes maximal when skin temperature is about 88 °F (31 °C) or less; however, as cold strain becomes greater, other underlying tissues will vasoconstrict and increase the insulating layer while constricting the body core area. Therefore, underlying muscles can become cold and stiff. Thus, the vasoconstrictor response to cold exposure helps retard heat loss and defend core temperature, but at the expense of a decline in peripheral tissue temperatures. Figure 2-2 also demonstrates core temperature contraction with concomitant declines in peripheral temperatures during cold exposure.

(3) The vasoconstriction-induced blood flow reduction and fall in skin temperature contribute to the etiology of peripheral cold injuries, particularly digits and appendages (such as the ears and nose). Cold-induced vasoconstriction has pronounced effects on the hands, fingers, and feet, making them particularly susceptible to cold injury, pain, and a loss of manual dexterity. Another vasomotor response, cold-induced vasodilation (CIVD), modulates the effects of vasoconstriction in the fingers, toes, nose, and ears. Figure 2-3 illustrates this CIVD response in the finger.

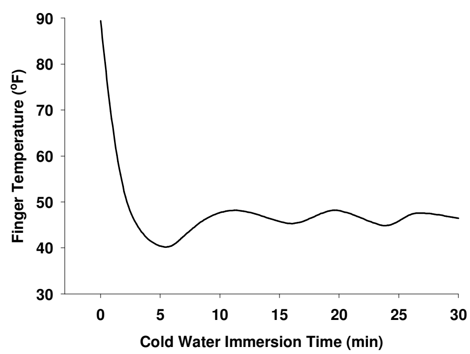


Figure 2-3. Decrease in finger-skin temperature upon initial exposure to cold (water) and subsequent CIVD responses with continued exposure

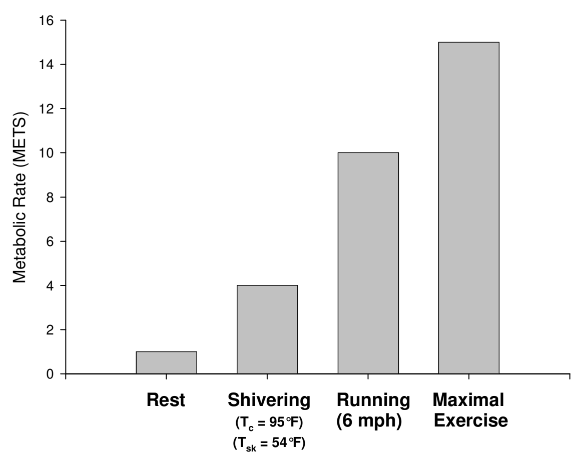
(a) Following the initial decline in skin temperature during cold exposure, a transient increase in blood flow occurs in the cooled finger, toe, cheek, nose, and ear. The CIVD is also transient, resulting in periodic oscillations of skin temperature. A similar CIVD occurring in the forearm appears to reflect vasodilation of muscle as well as cutaneous vasculature. The increased blood flow increases tissue temperatures to protect tissues and also to sustain dexterity in fingers. Originally thought to be only a local effect of cooling, evidence suggests that a central nervous system mechanism also mediates CIVD. For example, when core temperatures are low, the CIVD response is blunted. Therefore, hypothermic soldiers are at increased risk for peripheral cold injury.

(b) CIVD is enhanced if a person's hands are repeatedly exposed to the cold while the core and skin temperatures are maintained. This response was first noted in fishermen who routinely cleaned fish with their hands in cold water while wearing proper clothing to keep their bodies warm. The fisherman maintained warmer finger temperatures than the general population. Most people demonstrate a CIVD response, although the response can be blunted in those with preexisting vascular impairments such as Raynaud's syndrome and diabetes or those who have used vibrating machinery or tools for a long time.

c. *Heat production*.

(1) Cold exposure elicits an increased metabolic heat production in humans, which can help offset heat loss. In humans, cold-induced heat production is attributable to skeletal muscle contractile activity, during which about 80 percent of the total metabolic energy expended is liberated as heat. Humans initiate this thermogenesis by either voluntarily modifying behavior (increasing physical activity) or through shivering. While certain animals exhibit an increased metabolic heat production by noncontracting tissue in response to cold exposure (that is, nonshivering thermogenesis), adult humans lack this mechanism.

(2) Shivering, which consists of involuntary, repeated, rhythmic muscle contractions, may start immediately or after several minutes of cold exposure (lowered skin temperature and increased heat loss). It usually begins in the torso muscles, then spreads to the limbs. The intensity and extent of shivering varies according to the severity of cold stress. As shivering intensity increases and more muscles are recruited to shiver, whole-body oxygen uptake increases, typically reaching about two to three times the resting metabolism during sedentary exposure to cold air, but often greater than four times the resting metabolism during sedentary immersion in cold water. Figure 2-4 compares the responses of shivering-induced metabolic heat production to a typical physical training running pace (6 miles per hour (mph)) and maximal exercise. Note that running will produce more than twice the rate of heat production than heavy shivering. However, shivering can be sustained longer than heavy or maximal exercise.



Note: T_c is core temperature; T_{sk} is skin temperature.

Figure 2-4. Comparison of metabolic rates (METs) during thermoneutral rest, shivering in cold water, and two levels of exercise (1 MET is equal to resting metabolism.)

d. *Diuresis and fluid balance*.

(1) A widely recognized effect of exposure to cold is an increase in urine flow rate, that is, cold-induced diuresis (CID). This response is likely caused by a redistribution of body fluids from the extremities and skin to the central circulation as peripheral vasoconstriction occurs. CID is self-limiting, meaning the response diminishes as body water content falls in dehydrated individuals. CID is also prevented by moderate intensity exercise during cold exposure. However, if CID has already occurred by the time exercise begins and the soldiers perform at high levels of physical activity and elevate their core temperature, they may need to rehydrate and reestablish their body water/vascular volume to insure optimal performance.

(2) Fluid intake often becomes inadequate during cold exposure accompanied by strenuous activity. Thirst sensation is blunted in cold persons, and cold environments often present practical constraints on voluntary drinking (such as water availability, desire to avoid urinating outdoors in cold climates, and time to hydrate). Even in cold environments, metabolic heat production can exceed heat loss, with the resulting heat storage causing hyperthermia and initiating thermoregulatory sweating. The problem is that clothing insulation needed for warmth and comfort in cold environments is much greater during rest and light activity than during strenuous activity. Therefore, if one begins exercising vigorously while wearing clothing selected for sedentary activities in the cold, sweating and the resultant fluid requirements can increase substantially if soldiers do not adjust their clothing layers. If these increased drinking requirements go unmet, dehydration will ensue, just as occurs during exercise in the heat. Dehydration adversely impacts physical work performance (particularly if cold strain is minimized by clothing) but does not alter heat conservation or CIVD responses.

2-5. Physiological responses to exercise-cold stress

a. *Thermal balance*.

(1) Exercising in cold air usually maintains or increases core temperature because heat production is greater than heat loss. Generally, the higher the exercise intensity, the higher the steady-state core temperature and skin temperature in a well-clothed soldier. The precise effect of exercise intensity on core temperature during exercise-cold air stress will depend on the severity of cold stress, total amount of clothing insulation worn, and anthropometric factors, such as body fat.

(2) Exercising in water or during a rainfall has different effects on thermal balance compared to air. Heat loss is about 25 times higher in water than air. This means heat losses can potentially be greater than heat production generated by either exercise or shivering. For example, while executing a mission through a river or swamp, heat loss can be greatly accelerated and increase a soldier’s susceptibility to hypothermia. Furthermore, if exercise is also performed with the arms and legs while in cold water, greater heat losses will occur than if exercise was performed only with the legs. This is because arms have a greater surface-area-to-mass ratio and thinner subcutaneous fat than legs. Light exercise in water temperatures less than 59 °F has been shown to accelerate body cooling in thin people, compared to resting cold water exposure.