Management of Heat and Cold stress

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RTO TECHNICAL REPORT **TR-HFM-187**

Management of Heat and Cold Stress Guidance to NATO Medical Personnel

(Gestion des contraintes thermiques (chaleur et froid) Conseils aux personnels médicaux de l'OTAN)

Findings of Task Group HFM-187.

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses

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Glossary and List of Acronyms

Glossary

Balaclava	Cloth headgear that covers the whole head, exposing only part of the face.
Bivouacking	Defined as a temporary encampment, often in an unsheltered area.
Non-commissioned officer	A military person who is not an officer, but who has leadership responsibilities.
Soldier	A military person who serves in the Army, Navy, Air Force, Marines, or Coast Guard.
Watts	Unit of measurement for power 1 Joule/s or 0.86 kcal/hr.

List of Acronyms

CBRNE	Chemical, Biological, Radiological, Nuclear and Explosive
CHS	Compensable Heat Stress
CO	Carbon monoxide
MTF	Medical Treatment Facility
NFCI	Non-Freezing Cold Injury
POLs	Petroleum, Oil and Lubricants
UCHS	Uncompensable Heat Stress
UV	Ultraviolet
VB	Vapor Barrier
W	Watt
WBGT	Wet Bulb Globe Temperature
WCTI	Wind Chill Temperature Index

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Management of Heat and Cold Stress – Guidance to NATO Medical Personnel

(RTO-TR-HFM-187)

Executive Summary

NATO ground forces operate in the extreme heat of Iraq, Afghanistan, Africa and Lebanon, and the numbing cold Bosnia and Afghanistan. In addition, NATO humanitarian efforts must deal with indigenous populations exposed to global warming and shortages of potable water. Thermal management problems have been amplified because of: a) modern military trends of high-tempo operations; b) new equipment such as body armor, load carriage and electronic devices that require exposed hands to operate; and c) older, less healthy and fit recruit populations. NATO HFM-ET-088 convened a meeting at the Institute of Naval Medicine in Alverstoke, United Kingdom, and reviewed NATO thermal management problems and capability gaps. The objectives of HFM/RTG 187 were to: a) compare and assess the technical resources that are currently used for an evidence-based 'risk management system' for thermal strain and consider their suitability for such a purpose; b) facilitate development of integrated thermal risk management doctrine and educational programs to ensure health and performance sustainment of NATO forces; c) identify research gaps and opportunities in the above areas; and d) review novel approaches for performance sustainment in thermally challenging environments;

The ET concluded that: a) current thermal management capabilities are not fully utilized by NATO forces in order to educate military leaders on optimizing troop health and performance sustainment; b) significant scientific and capability gaps exist regarding thermal illness and injury susceptibility, early diagnosis and treatment; c) significant scientific and capability gaps exist regarding thermal management for operational effectiveness; and d) emerging molecular-biotechnology advances may provide opportunities for significant advances. With rapidly disappearing NATO scientific capabilities in military and civilian communities, it is increasingly difficult to address these pervasive thermal and related harsh-environment issues. NATO RTO HFM-RTG 187 reviewed thermal management policies for NATO nations and produced both a technical report on thermal management for leaders and medical personnel, and low-tech information brochures on thermal (heat and cold) management. These products represent 'best practices' and can be translated into the languages of NATO Nations and allied forces.

Gestion des Contraintes Thermiques (Chaleur et Froid) – Conseils aux Personnels Médicaux de l'OTAN

(RTO-TR-HFM-187)

Synthèse

Les forces au sol de l'OTAN opèrent sous une chaleur extrême en Irak, Afghanistan, Afrique, Liban et sous un froid engourdissant en Afghanistan et en Bosnie. De surcroît, dans ses tâches humanitaires l'OTAN doit faire face à des populations indigènes exposées au réchauffement climatique et à des pénuries d'eau potable. Les problèmes de gestion thermique se sont vus amplifiés en raison: a) des tendances militaires modernes à conduire des opérations de haute intensité; b) des nouveaux équipements comme les gilets pare-balles, l'emport de charges et les appareils électroniques (mains exposées lors de l'opération); et c) des populations de recrues plus âgées, en moins bonne santé et moins aptes. La HFM-ET-088 (Commission sur les Facteurs humains et la médecine) de l'OTAN avait convenu d'une réunion à l'*Institute of Naval Medicine* à Alverstoke au Royaume-Uni et avait examiné les problèmes de gestion thermique et les écarts de capacité de l'OTAN. L'ET a conclu que: a) les capacités de gestion thermique ne sont pas entièrement exploitées par les forces de l'OTAN pour apprendre aux commandants militaires à optimiser le maintien de la santé et de la performance de leurs troupes; b) d'importants écarts scientifiques / de capacités existent en ce qui concerne la susceptibilité, le diagnostique précoce et le traitement des malaises / blessures liés aux ambiances thermiques; c) d'importants écarts scientifiques / de capacités existent en ce qui concerne la gestion thermique pour l'efficacité opérationnelle; et d) les avancées émergentes en biotechnologie moléculaire peuvent donner lieu à d'importantes percées. En raison de la disparition rapide des capacités scientifiques de l'OTAN au niveau des communautés militaires et scientifiques, il est de plus en plus difficile de traiter ces sujets omniprésents d'ambiances thermiques et les environnements rudes qui s'y rapportent.

La HFM/RTG-187 avait pour but de: a) comparer et évaluer les ressources techniques qui sont actuellement utilisées pour un « système de gestion des risques » basé sur des éléments tangibles pour les contraintes thermiques et réfléchir à leur pertinence à cette fin; b) faciliter le développement d'une doctrine et de programmes d'enseignement intégrés pour la gestion des risques thermiques afin de garantir le maintien de la santé et des performances des forces de l'OTAN; c) identifier les écarts et occasions de recherche dans les domaines ci-dessus; et d) étudier les nouvelles approches visant au maintien des performances en environnement à ambiance thermique problématique.;

La HFM-RTG-187 de la RTO de l'OTAN a déterminé que: a) les capacités de gestion thermique ne sont pas entièrement exploitées par les forces de l'OTAN pour apprendre aux commandants militaires à optimiser le maintien de la santé et de la performance de leurs troupes; b) d'importants écarts scientifiques / de capacités existent en ce qui concerne la susceptibilité, le diagnostique précoce et le traitement des malaises / blessures liés aux ambiances thermiques; et c) d'importants écarts scientifiques / de capacités existent en ce qui concerne la gestion thermique pour l'efficacité opérationnelle. La HFM-RTG-187 de la RTO de l'OTAN a examiné les politiques de gestion thermique pour les pays de l'OTAN et a rédigé un rapport technique sur la gestion thermique destinés aux commandants et au personnel médical, et des brochures d'informations de faible technicité sur la gestion thermique (froid et chaud). Ces documents représentent les «meilleures pratiques» et peuvent être traduits vers les langues des forces alliées et pays de l'OTAN.

Chapter 1 – INTRODUCTION

1.1 PURPOSE AND OBJECTIVES

a) Troops participating in military training and deployments often will encounter heat and cold stress that requires management for successful mission accomplishment. However, hot and cold weather conditions impair many aspects of normal military function in the field, which will influence Soldier health and tactical performance. Excessive heat/cold stress will not only degrade mental and physical performance capabilities, but can eventually cause heat/cold casualties.

b) The objectives of the HFM-187 were to produce a comprehensive Heat and Cold Stress Management Technical Report that included appendices (A and B) which can be extracted to produce low-tech information products (risk management posters and cards). These products represent 'best practices' and can be translated to the languages of NATO Nations and allied countries.

c) This technical report provides evidence-based preventive medicine guidance to NATO medical personnel and leadership to:

1) Implement procedures on managing heat and cold stress.

2) Understand and identify the risk factors for heat and cold casualties.

3) Sustain performance and minimize heat and cold casualties during training and field operations.

d) 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 field operations, i.e., before, during and after deployment.

1.2 LEADERSHIP ROLES

a) Unit commanders, medical staff and non-commissioned officers should coordinate to implement educational and training programs at all levels in the NATO command based on the principles of this document. They should review all training and field operations to make sure adequate planning is made to minimize heat/cold stress to enable performance optimization, heat- or cold-injury assessment and management, emergency medical support and evacuation where tactically feasible.

b) Unit medical personnel will:

1) Understand the commander's intent and mission goals and advise the commander on the potential adverse effects of heat/cold stress and propose practical options for risk management of heat and cold stress under difficult circumstances.

2) Assess each component of heat/cold stress (condition of the Soldier, environmental heat/cold stress, and mission requirements) to plan for the primary prevention of heat/cold casualties.

3) Calculate on-site heat/cold stress indices using the Wet Bulb Globe Temperature (WBGT) and Wind-Chill Temperature Index (WCTI) and provide guidance for regulating physical work, clothing and equipment, nutrition and fluid replacement and casualty prevention.

4) Educate the Soldiers on the steps needed to minimize the risk of heat/cold casualties and optimize performance.

5) Develop heat/cold casualty evacuation plans.

Chapter 2 – HEAT STRESS MANAGEMENT

2.1 HEAT EXCHANGE IN HOT ENVIRONMENTS

a) Body heat exchange occurs by convection, radiation, conduction, and evaporation. Metabolic heat (~70 percent of energy expended) is released from active skeletal muscles and transferred from the body core to skin. Heat exchange from skin to the environment is influenced by air temperature; air humidity; wind speed; solar, sky, and ground radiation; and clothing.

1) Convection is heat transfer by moving a gas or liquid over the body, whether induced by thermal currents, body motion or natural movement of air (wind) or water. Heat loss by convection to air occurs when ambient temperature, in contact with body surface, is below skin temperature. Conversely, heat gain by convection from air occurs when air temperature exceeds that of the body surface.

2) Heat loss by radiation occurs when surrounding objects have lower surface temperatures than the body, and heat gain by radiation (solar, sky, large objects and ground) occurs when surrounding objects have higher surface temperatures than body surface temperature. Radiative heat exchange is independent of air motion.

3) Conduction of heat to or from solid objects is usually minimal, since little contact surface is involved. Contact with hot liquids or surfaces above 46°C (114°F) can produce pain and slightly higher temperatures can produce burns.

4) Evaporative heat loss becomes more important as ambient temperature increases, and accounts for all body cooling when ambient temperatures are equal or above skin temperatures. Eccrine sweat glands secrete fluid onto the skin surface permitting evaporative cooling when liquid is converted to water vapor. When more body heat must be dissipated, these fluid losses increase due to heavier sweating, which may exceed 1.5 liters per hour in extreme conditions. 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. If sweat is not evaporated, the skin surface becomes soaked, which suppresses sweat secretion. For this reason, it is important to allow air circulation to the skin, especially torso areas, to maximize evaporative cooling. Sweat that drips off the body or clothing provides no cooling benefit.

2.2 HEAT STRESS AND STRAIN, AND THEIR IMPACT ON THE MILITARY

a) Heat stress refers to environmental and host conditions that tend to increase body temperature. Heat strain refers to physiological and or psychological consequences of heat stress. Heat stress is imposed by the combination of mission and individual and environmental risk factors. Environmental risk factors include temperature, humidity, wind, and solar load. Mission risk factors include the work intensity (metabolic rate), duration of heat exposure, and, radiological and nuclear equipment worn. Wearing special clothing, such as body armor or Chemical, Biological, Radiation, Nuclear and Explosive (CBRNE) protective clothing, will impede heat dissipation and increase heat strain. Individual risk factors include the Soldiers' physical fitness, heat acclimatization status, hydration and nutrition status, and health (including prior history of heat stroke, use of medications, alcohol or drugs abuse). Fit, healthy, heat acclimatized, fully hydrated, and well-rested soldiers will encounter the least heat strain when performing a given military task in hot weather.

b) Heat stress can impair physical and cognitive performance. Soldiers can effectively operate in any naturally occurring hot environment if they are heat acclimatized, consume adequate water and diet (for example, salt), and have sufficient shade and rest. Successful management of heat exposure results in optimal work capabilities and avoidance of heat casualties.

c) Successful management of heat stress depends on proper education of leaders and troops exposed to heat. Leaders must implement procedures to alert troops of dangerous heat stress levels and must apply interventions to reduce exposure and increase resistance of exposed Soldiers to heat illness. Being alert to signs of Soldier distress in the heat is critical so that management procedures can be adjusted accordingly. Heat casualties often occur in groups, so when the first heat casualty occurs others may be imminent. Figure 2-1 provides the heat stress risk management process.

d) In addition to heat stress risk management, plans should be made for treatment of heat casualties (heat exhaustion and heat stroke). For these casualties, preparation should include arrangements for rapid cooling (cool or cold water immersion, ice sheets, water spray with fanning) and evacuation.

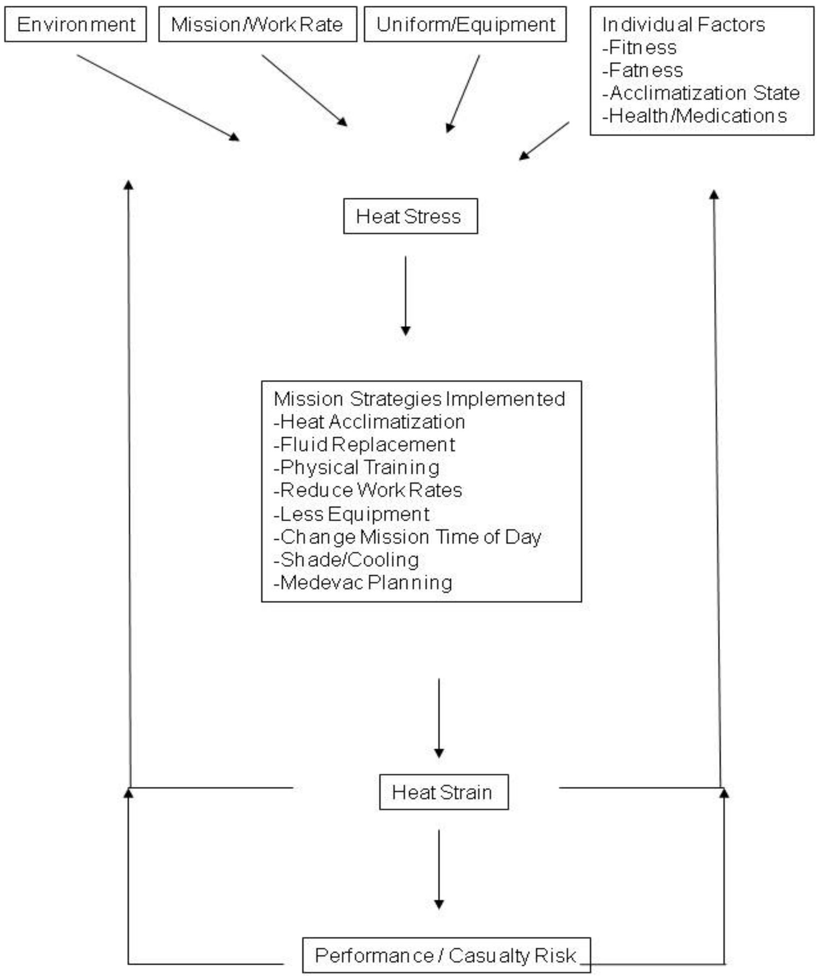

Figure 2-1: Heat Stress Risk Management Process.

2.3 HEAT STRESS AND CORE TEMPERATURE

a) Heat stress can be divided into compensated heat stress (CHS) and uncompensated heat stress (UCHS). CHS and UCHS are primarily determined by biophysical factors (environment, clothing, work rate) and are modestly affected by physiological status (heat acclimatization and hydration status). The CHS exists when heat loss occurs at a rate equal to heat production so that a steady-state core temperature can be achieved at a sustainable level for a requisite activity. The CHS represents the majority of military situations. The UCHS occurs when the individual's evaporative cooling requirements exceed the environment's evaporative cooling capacity. During UCHS, soldiers cannot achieve steady-state core temperature, and core temperature rises until exhaustion occurs at physiological limits. The UCHS examples include performing intense exercise in oppressive heat, wearing protective clothing/equipment in hot weather or hot confined spaces.

b) Metabolic rate during marching is dependent upon speed, terrain (slope and surface), and load carried. The metabolic rate is proportional to the amount of body heat that must be dissipated to the environment. Metabolic rates of 250 watts (W), 425 W, and 600 W represent easy, moderate and hard intensities of military tasks (see Table 2-1), while 1000 W represents an activity like competitive running. Wearing heavy and moisture-impermeable clothing has the same effect as exposure to a hotter climate.

Table 2-1: Fluid Replacement and Work/Rest Guidelines for Warm-weather Training Conditions. This Applies to Average-sized and Heat-acclimatized Soldier Wearing a Combat Uniform.

		Easy Work (250 W)		Moderate Work (425 W)		Hard Work (600 W)	
Heat Category	WBGT[6,7] °C (°F)	Work/Rest[1,3]	Water[4,5] Intake (l/hr)	Work/Rest	Water Intake (l/hr)	Work/Rest	Water Intake (l/hr)
1	25.6 – 27.7 (78-82)	No Limit (NL)[2]	½	NL	¾	40/20 min	¾
2 (green)	27.7 – 29.4 (82-85)	NL	½	50/10 min	¾	30/30 min	1
3 (yellow)	29.4 – 31.1 (85-88)	NL	¾	40/20 min	¾	30/30 min	1
4 (red)	31.1 – 32.2 (88-90)	NL	¾	30/30 min	¾	20/40 min	1
5 (black)	>32.2 (>90)	50/10 min	1	20/40 min	1	10/50 min	1

	Easy Work	Moderate Work	Hard Work
	• Weapon maintenance • Walking: hard surface at 4.0 km/hr (2.5 mph), <15 kg load (30 lb) • Manual of arms • Marksmanship training • Drill and ceremony	• Walking: loose sand at 4.0 km/hr (2.5 mph), no load • Walking: hard surface at 5.6 km/hr (3.5 mph), <18 kg load (40 lb) • Patrolling • Individual movement techniques (low crawl, high crawl) • Defensive position construction	• Walking: hard surface at 5.6 km/hr (3.5 mph), ≥18 kg load (40 lb) • Walking: loose sand at 4.0 km/hr (2.5 mph) with load • Field Assaults

Notes:

1) The work/rest times and fluid replacement volumes will sustain performance and hydration for at least 4 hours of work in the specified heat category. Fluid needs can vary based on individual differences (± ¼ l/hr) and exposure to full sun or full shade (± ¼ l/hr).
2) NL equals no limit to work time per hour (up to 4 continuous hours).
3) Rest means minimal physical activity (sitting or standing), accomplished in shade if possible.
4) CAUTION: Hourly fluid intake should not exceed 1 ½ liters.
5) Daily fluid intake should not exceed 12 liters.
6) If wearing body armor, add 2.8°C (5°F) to WBGT index in humid climates.
7) If wearing CBRNE clothing (completely encapsulated and impermeable) add 5.5°C (10°F) to WBGT for easy work, and 11°C (20°F) to WBGT for moderate and hard work.

c) Measuring rectal temperature is the most accurate way to evaluate core body temperature of heat casualties, early in the field or at training sites and in the clinical setting at a medical treatment facility (MTF).

d) Military training guidelines for using work/rest cycles are based on maintaining core temperatures of 38.5°C (101.3°F) and 38°C (100.4°F), for CHS and UCHS, respectively. Military training guidelines for continuous physical work times (for example, physical training runs) are based on maintaining core temperature of 40.0°C (104°F) in acclimatized individuals with appropriate fluid replacement. Core temperatures below these levels can be sustained with few persons incurring exhaustion from heat strain. During military operational settings, less conservative guidelines (higher core temperatures) can be employed.

e) Considerable inter-individual variability exists between and among physically fit, heat acclimatized and field-seasoned soldiers in their ability to tolerate higher core temperatures. Likewise, any given soldier will tolerate higher and lower core temperatures during CHS and UCHS, respectively. During CHS, soldiers can tolerate high core temperatures for extended durations (because core temperature elevation is mostly due to metabolic rate and skin temperatures are relatively low), and exhaustion is often associated with dehydration or physical fatigue (from working at sufficiently high metabolic intensities to induce high core temperatures). During UCHS, soldiers incur heat exhaustion at relatively low core temperatures (because core temperature is elevated by impeding heat loss to the environment combined with high skin temperatures) causes excessive cardiovascular strain. Most hot-weather military situations probably fall between CHS and UCHS.

f) The CHS is managed by heat acclimatization, hydration and work rate. UCHS is managed by minimizing heat stress exposure, limiting metabolic rate, and using microclimate cooling during work.

2.4 HEAT ACCLIMATIZATION

a) Physical work and training programs for unacclimatized soldiers should be limited in intensity and time when initially exposed to heat stress. Approximately two weeks of progressive heat exposure and physical work should be allowed for near complete heat acclimatization. Heat acclimatization should be induced before deployment, if possible, or integrated during the first few weeks of deployment.

b) By the second day of heat acclimatization, significant reductions in physiologic strain can be observed. By the end of the first week and second week, ~50 percent and ~80 percent of the physiologic adaptations (for the average soldier) are complete, respectively. A day or two of intervening cool weather will not interfere with acclimatization to hot weather. Soldiers who are less fit or unusually susceptible to becoming heat casualties and will require several additional days or weeks to fully acclimatize. Very fit soldiers can achieve marked (~70 percent) heat acclimatization in one week. Once adaptation to heat has been attained, the time that individuals may spend in cooler conditions before returning to a hot environment could be as long as one month, without the need for extensive re-adaptation to heat.

c) Heat acclimatization is necessary even for very fit soldiers, but they will acclimatize to heat faster than less fit soldiers. The full effects of heat acclimatization are relative to the initial physical fitness level and the total heat stress encountered by the soldier. Soldiers who only perform light physical work will achieve the level of heat acclimatization needed to perform that task. If they attempt more strenuous work, they will need to gain additional heat acclimatization and possibly improve their physical fitness to perform that task in the heat. Less fit soldiers have reduced work capabilities in the heat. For example, women and middle-aged soldiers often have lower work capabilities than men or young adult soldiers, respectively. However, if physical fitness is matched and they are heat acclimatized, they should have similar work capabilities in the heat.

d) Heat acclimatization requires a minimum exposure of two hours per day (can be broken into two 1-hour exposures) with a physical exercise task requiring cardiovascular endurance, (for example, marching or jogging) rather than strength training (pushups and resistance training). The exercise intensity should be gradually increased each day, working up to the physical intensity required for the mission. Resting in the heat, with minimal activity, results in only partial acclimatization; physical exercise in the heat must be performed to accomplish optimal acclimatization for that work intensity in a given hot environment.

e) Maximize physical fitness and heat acclimatization prior to deployment to hot environments. Maintain physical fitness during deployment in the hot environment. If the new environment is much hotter than what the troops are accustomed to, light recreational activities (i.e., football, basketball, etc.) may be appropriate for the first two days. By the third day, unit runs (20 to 40 minutes) at the pace of the slowest participants are feasible.

f) Two groups of soldiers at extremes need to be monitored: a) the least fit soldier, who will have the most difficult time (take longer and suffer greater heat strain) acclimatizing to heat, and b) the most motivated soldiers, who may overdo their physical activity and be susceptible to becoming heat casualties.

g) Table 2-2 provides heat acclimatization strategies that can be considered before and after deployment.

Table 2-2: Heat Acclimatization Strategies.

1) Mimic the deployment climate.

2) Ensure adequate heat stress by:
   - Invoking profuse sweating.
   - Using exercise and rest to modify the heat strain.
   - Having 4 to 14 days of heat exposures.
   - Maintaining the daily duration of at least 120 minutes.

3) Start early (1 month before deployment)
   - Performance benefits may take longer than physiological benefits.
   - Be flexible with training.
   - Build confidence.
   - Pursue optimum physical fitness in the current climate.

4) Methods
   - Pre-deployment: Climate controlled room or hot weather.
   - Integrate with training by adding additional acclimatization sessions; inserting acclimatization with training; alternating acclimatization days with training days, and no detraining.
   - Mimic the deployment environment by working out in a warm room wearing sweats if you are in a cool / temperate environment.

5) On arrival
   - Start slowly at reduced training intensity and duration and limit heat exposure.
   - Increase heat and training volume (intensity and duration) as tolerance permits.
   - Acclimatize in heat of day.
   - Physical training should be conducted in coolest part of day.
   - Use work/rest cycles or interval training.
   - Be especially observant of salt needs for the first week of acclimatization.
   - Sleeping in cool or air-conditioned rooms will not affect heat acclimatization status and will aid recovery from heat stress.

h) If recently deployed troops must perform physical work during the period of acclimatization, take advantage of the cooler hours (morning, evening, or night).

i) Adequate water must be provided and consumption must be monitored. Heat acclimatization increases the sweating rate, and therefore increases water requirements. As a result, heat-acclimatized soldiers will dehydrate faster if they do not consume fluids. Dehydration negates many of the thermoregulatory and physical capability advantages conferred by heat acclimatization and high physical fitness.

2.5 WET BULB GLOBE TEMPERATURE

a) NATO employs the WBGT to quantify levels of environmental heat stress. The WBGT is an empirical index used to determine various physical activity levels and fluid replacement strategies to maximize performance and minimize heat casualty risk during training.

b) The WBGT is an empirical index of environmental heat stress:

   1) Outdoor WBGT equals 0.7(natural wet bulb) + 0.2(black globe) + 0.1(dry bulb).

   2) Indoor WBGT equals 0.7(natural wet bulb) + 0.3(black globe).

Degrees F and C can be converted by:

°C = (°F – 32) x 0.555

°F= (ºC x 1.8) + 32

c) The WBGT can vary greatly over short durations and distances in unpredictable ways. For example, on a sunny calm day, an open field may have a higher WBGT than an adjacent forest, but on a windy cloudy day, the forest may have a higher WBGT. Therefore, the WBGT value measured at one location on a post or region should serve only as general guides. When training or operations require moderate or hard intensity physical demands, the WBGT should be measured at the site of training or location of operations if the mission permits.

2.6 WORK/REST CYCLES

a) The recommended threshold WBGT value for initiating hot weather guidelines is 23°C (75°F) depending on the work intensity. As the WBGT value increases, physical work intensity should be reduced (or include more frequent and longer rest periods), or under extremely severe conditions (WBGT index >32°C (90°F)), possibly suspended. Work schedules should be customized to the climate, work intensity and military situation.

b) Table 2-1 provides work/rest and fluid replacement guidelines for heat-acclimatized soldiers in a training environment, with the average soldier wearing combat clothing. The guidelines support at least four hours of work. Three time-weighted work intensities are provided representing easy (~250 W), moderate (~425 W), and hard (~600 W) military tasks; examples are provided. The users should determine the existing weather conditions (WBGT) at the site of training and then read the recommended work time. The work/rest cycle is the ratio of minutes of work to minutes of rest within each hour.

c) The information in Table 2-1 is sufficiently robust to estimate guidance for many different scenarios. Soldiers often perform several hours of moderate or hard work interspersed with several hours of easy work. In these situations, the recommended work times for moderate and hard work periods are overly conservative. Leaders need to gain experience with estimating guidance for different scenarios and matching that information to their unit's work capabilities. Leaders must recognize that working soldiers too hard in the heat may result in increased heat casualties that day or greater susceptibility to becoming a heat casualty on the following day. Conversely, unnecessarily limiting work in the heat will result in sub-optimal performance.

d) Table 2-3 provides guidelines for the duration of continuous work at metabolic intensities representing easy, moderate, or hard military tasks (see Table 2-1 for examples of these tasks and fluid replacement during warm- or hot-weather training). Factors increasing the metabolic intensity of a task include carrying heavier backpack loads, marching at faster paces or uphill and loading heavier objects. Remember that activities such as physical fitness runs usually elicit much higher metabolic rates (~1,000 W) than the 'hard work' military activities (~600 W) represented in this table. It is assumed that soldiers performing these continuous-effort tasks shall not have incurred significant exercise heat stress or dehydration prior to this activity, and will have an extended period of rest in order to cool down, as well as adequate rehydration afterward.

Table 2-3: Recommendations for Continuous Work Duration and Fluid Replacement during Warm-weather Training Conditions. This Applies to an Average-sized and Heat-acclimatized Soldier Wearing Combat Clothing. (NL is no limit.)

		Easy Work		Moderate Work		Hard Work	
Heat Category	WBGT °C (°F)	Work (min)	Water[2] Intake (l/hr)	Work (min)	Water Intake (l/hr)	Work (min)	Water Intake (l/hr)
1	25.6 – 27.7 (78-82)	NL[1]	½	NL	¾	70	1
2 (green)	27.7 – 29.4 (82-85)	NL	½	150	1	65	1 ¼
3 (yellow)	29.4 – 31.1 (85-88)	NL	¾	100	1	55	1 ¼
4 (red)	31.1 – 32.2 (88-90)	NL	¾	80	1 ¼	50	1 ¼
5 (black)	>32.2 (>90)	180	1	70	1 ½	45	1 ½

Notes:

1) NL (no limit) can sustain work for at least 4 hours of work in the specified heat category.

2) Fluid needs can vary based on individual differences (± ¼ l/hr) and exposure to full sun or full shade (± ¼ l/hr).

e) Rest indicates minimal physical activity and should be accomplished in the shade with adequate air circulation and without additional clothing or protective equipment. Soldiers should avoid resting on hot ground (such as in the desert) by digging a shallow trench to locate cooler ground.

f) If soldiers are performing physical training as a unit, they should open ranks (double arm interval) to ensure adequate air motion for cooling. Soldiers in the middle of the formation will experience significantly greater heat strain.

g) Protective clothing (CBRNE) and body armor can increase heat strain, and several 'rule of thumb' adjustments can be made. The WBGT index value should be increased by ~6°C (10°F) for easy work and by ~12°C (20°F) for moderate and hard work when wearing CBRNE protective clothing. Body armor has more modest effects on work/rest guidelines and water requirements; if the environment is humid (observe dripping sweat), then a WBGT index increase by ~3°C (5°F) should be employed.

h) Figure 2-2 plots the relationship between work-time tolerance and metabolic rate for soldiers during UCHS, wearing CBRNE protective clothing in hot weather (30°C; (86°F)) 50 percent relative humidity). This tolerance curve should be used for any suspected UCHS condition. Note that as the time-weighted metabolic rate is reduced the soldier's work-time tolerance is increased. Either lowering the work intensity or providing rest periods can reduce the metabolic rate. Table 2-1 gave examples of military tasks that have time-weighted metabolic rates of approximately 250 W, 425 W and 600 W.

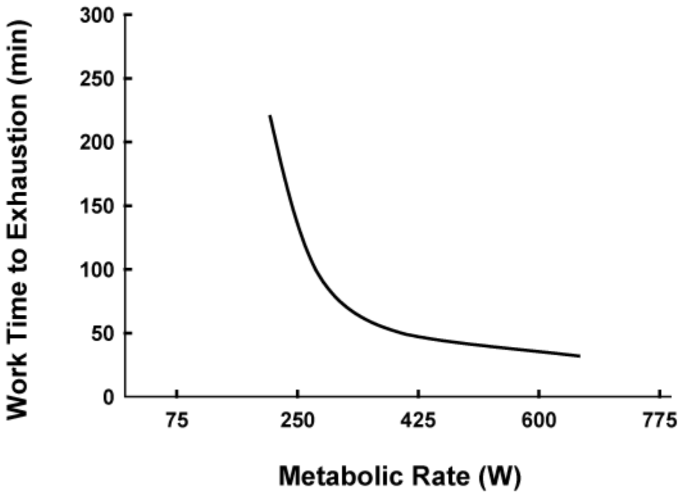

Figure 2-2: Influence of Time-weighted Metabolic Rate (W) on Work Time when Wearing CBRNE Protective Clothing (closed) in Hot Weather in Soldiers with UCHS.

2.7 MICROCLIMATE AND OTHER COOLING TECHNOLOGIES

a) Microclimate cooling systems are effective in alleviating heat stress and extending physical work capabilities in soldiers wearing protective clothing or exposed to UCHS conditions. Microclimate cooling has been successfully used in armored vehicles; however, the technology has not matured sufficiently to support dismounted soldiers working at high metabolic rates.

b) Microclimate cooling systems use circulating cooled air or liquid in tubes over the skin or ice packet vests to remove body heat. In addition, microclimate cooling facilitates heat loss by maintaining the temperature gradient between the body core and the cooled skin. The amount of heat transferred from the body to any microclimate system is dependent on several factors, including: a) the amount and location of body area covered (and in contact with skin) by the device; b) coolant temperature; c) flow rate; d) skin temperature, and e) insulation from the ambient heat.

c) Air-cooled garments are lighter to wear and rely on sweat evaporation to cool the person. While air is not as efficient as water due to the difference in specific heat, air-cooled systems are effective in reducing heat strain and in some environments are felt to be as effective as water-cooled devices. In addition, air-cooled vests provide drier skin conditions thereby improving thermal comfort as opposed to that provided by liquid-cooled systems. In environments uncontaminated by biological and or chemical agents, ambient air can be employed to circulate under the protective clothing. However, less sweat will be evaporated to provide cooling if ambient humidity is high, and local skin irritation results if the ambient humidity is low and the air temperature too hot.

d) Microclimate cooling systems that use ice as the cooling medium are not as effective as either liquid- or air-cooled systems, and the logistical problems rendered by ice-cooled systems make them impractical for use as cooling devices in many situations. Once the ice has completely melted, cooling is minimized. The cooling efficiency of an ice packet vest can be improved by increasing the number of ice packets attached to the vest (up to the limit of total torso surface area coverage).

e) Arm Immersion Cooling is an easy and effective way to decrease body temperatures. Placing the hands and forearms into cold/cool water (10-20°C (50-68°F)) can decrease core temperatures at a rate of up to 0.5-1.0°C per 10-minute time period.

Figure 2-3: Arm Immersion Cooling System. To use, Soldiers Place their Forearms in the Cool Water, Covering the Area from the Fingers to the Elbow.

f) Showers to wet down soldiers in combat clothing have been utilized with limited effectiveness and can lead to skin irritation. The combination of opening clothing and fanning the sweat-soaked underlayers can provide some cooling.

g) Cooling methods for treating heat casualties might include cool- or cold-water immersion (e.g., plastic tubor pool) or ice sheets (e.g., bedsheets stored in ice beverage cooler with ice water mixture).

h) Ineffective Technologies. Other recent technologies have been found not to mitigate heat stress. These include the RTX device (negative pressure device on hand with palm cooling), Reflectech (to deflect heat from radiation) and aluminized or mylar blankets.

2.8 FLUID AND ELECTROLYTE (SALT) REPLACEMENT

a) Heat stress increases the sweating rate and therefore body water needs. If fluid is not fully replaced, then dehydration will occur. The myth that soldiers can be taught to adjust to decreased water intake has been proven wrong many times.

b) Thirst does not adequately motivate personnel to promptly consume sufficient fluids to replace sweat losses in hot environments when sweat losses are high. If thirst alone is used to guide fluid replacement, adequate hydration lags behind fluid needs for several hours or until extended periods of recovery with meals.

c) Soldiers can monitor hydration status by noting the color and volume of their urine and their body weight. Dark, low volume and infrequent urination indicates that fluid consumption should be increased. Likewise, frequent and large volumes of clear urine indicate that fluid replacement should be reduced. The relationship between urine color and or specific gravity (an easily obtained measurement) with the magnitude of dehydration is not precise. Soldiers can monitor their body weight before and after exercise (or upon awakening), as most weight loss will be from water. One liter (approximately one quart or 32 ounces) of fluid equals about 1 kilogram (or approximately 2 lbs.) of weight. Note that unclothed weight should be used to avoid the confounding effects of soaked clothing.

d) Assure full hydration of all soldiers before any work period. Provide sufficient water to replace the volume of sweat loss during work. Establish drinking schedules and encourage and monitor drinking. Make water more palatable, if possible, by cooling it (10°-15°C (~50°-60°F)) and/or by lightly flavoring it. Plan for operations that allow for water supply points to be available every three hours or less.

e) Provide adequate time for meals and make fluids readily available. Soldiers usually drink most of their water with meals, and eating food improves water consumption. During mealtimes, soldiers can drink a variety of fluids (milk, juice, tea and coffee, sports drink), as each will be equally effective in replacing body water. In addition, meals provide the salt intake necessary to retain body water. Other beverages or fluids served in dining facilities (except those containing alcohol), such as milk, are acceptable for fluid replacement; however, for sanitary reasons, they should not be placed in canteens for use in the field.

f) Drinking is limited by how fast fluid is emptied from the stomach (the average is approximately 1.2 l/hr) and absorbed by the small intestine (this exceeds the gastric emptying rate). If the stomach is too full, soldiers will feel bloated. Drinking enough to fill the stomach facilitates rapid gastric emptying.

g) The sweating rate is related to activity level, clothing/equipment worn and environmental heat stress conditions. In hot weather, soldiers often have sweating rates of ~0.3 to ~1.0 l/hr while performing most military activities, ~0.5 to 1.2 l/hr while performing vigorous training activities, and >1.2 l/hr while wearing CBRNE protective clothing while working. These higher sweating rates represent considerable heat strain, and activities eliciting these usually cannot be sustained for extended periods.

h) Tables 2-1 and 2-3 provide water replacement recommendations for work/rest schedules and continuous work situations during training, respectively. The tables specify an upper limit for hourly (1.5 liters) and daily (12 liters) water intake to provide a safeguard against overdrinking and development of water intoxication (hyponatremia) during training. Considerable individual variability exists for water requirements as the tables give values for the average soldier. Small soldiers, such as petite women, will have lower sweating rates, while very large persons will have higher sweating rates; therefore, actual fluid replacement may need to be decreased or increased by ~1/4 l/hr for those soldiers. Likewise, exposure to full shade or full sun can decrease or increase fluid replacement needs by ~1/4 l/hr.

i) The tables are sufficiently robust to be modified for specific scenarios and still maintain appropriate hydration. For example, if soldiers deviate from the recommended work times and extrapolate the appropriate hourly fluid intakes, the legend cautions the user not to drink in excess of 1.5 l/hr and no more than 12 l/day. If soldiers increase their work time per hour but do not modify fluid intake, the original recommendation still prevents excessive dehydration during several hours of training.

j) Knowledge of daily water requirements for hot environments is important for planning purposes. Soldiers will consume from ~3 to 12 l/day during military training in hot climates. In training conditions, physical activity levels are decreased at higher WBGT levels, and water needs are therefore reduced. However, soldiers may not have the option of reducing physical activity during operational conditions.

k) During operational conditions, mission needs may demand sustained high-intensity work greater than that encountered during training conditions. In extremely active soldiers, who are also very fit and highly heat acclimatized, water requirements can be >12 l/day. World War II desert operations showed that a few very active soldiers could have daily water requirements of >15 l/day.

l) For unit water planning, knowledge of daily water and sodium requirements can be useful. Daily water and sodium requirements depend upon the environmental heat stress, activity level and duration of exposure. Table 2-4 presents the daily water and sodium requirements for two levels of daily soldier activity.

m) Daily energy expenditures should be considered to estimate water requirements for most active field units, and these vary between military activities. Metabolic rates for military units that are performing field activities (i.e., tactical maneuvers) usually falls between
~3,500 and ~5,000 kcal/day.

Table 2-4: Daily Water (liters/quarts) and Sodium (grams) Requirements at Various WBGTs Based on Daily Energy Expenditures for Moderate (3,500 kcal) Daily Activity and High (5,500 kcal) Daily Activity Levels.

WBGT	3,500 kcal	5,500 kcal
10°C	3 liters/qts 2 grams	6 liters/qts 4 grams
20°C	5 liters/qts 3 grams	10 liters/qts 6 grams
30°C	6 liters/qts 4 grams	14 liters/qts 8 grams

n) If the average daytime WBGT were ~20°C (68°F), the daily water requirements could range from ~5 (3,500 kcal) to ~10 (5,500 kcal) l/day for most units. The daily water requirement could achieve >12 l/day for the highest energy expenditure (5,500 kcal/day) at a high WBGT, thus representing the upper limit for water requirement for very fit and very active units.

o) In addition to water, sodium, chloride and other electrolytes (potassium, calcium, and magnesium) are lost in sweat. Sweat sodium concentration can range from 0.25-1.6 grams per liter depending on diet, sweating rate, and heat acclimatization status. Heat acclimatization conserves sodium by decreasing sweat salt (NaCl) content by ~50 percent. For example, sweat sodium decreases to 0.6 grams per liter for the average soldier.

p) Table 2-4 provides the appropriate daily sodium requirements for heat-acclimated soldiers (assuming sweat sodium concentration of 0.6 grams per liter) over a range of daily energy expenditures (activity levels) and daily mean WBGT index levels.

Chapter 3 – COLD STRESS MANAGEMENT

3.1 HEAT EXCHANGE IN COLD ENVIRONMENTS

a) Body heat exchange occurs through four mechanisms: convection, radiation, conduction and evaporation. In cold environments, heat exchange from the skin to the environment is influenced by air temperature; wind speed; humidity; solar, sky, and ground radiation; and clothing. 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 still boundary air layer over the skin that insulates against heat loss. In cold air environments, convective heat transfer can be significantly increased by wind (if clothing does not create a barrier), and for soldiers wading in cool or cold 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 ~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 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 or 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 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 non-evaporated 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, i.e., sweating.

3.2 COLD STRESS RISK MANAGEMENT

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. Excessive cold stress degrades physical performance capabilities, cognitive performance capabilities, significantly impacts morale, and eventually causes cold casualties.

b) Cold stress is imposed by the combination of environmental, mission, and individual risk factors. Environmental risk factors include temperature, wind, precipitation, immersion, and altitude. Mission risk factors include the work intensity; duration of cold exposure; and the availability of adequate shelter, clothing and food. Individual risk factors include physical fitness, body composition, fatigue, race, gender, and health (including prior history of cold injury, use of medications, nicotine, alcohol and drugs abuse, and inadequate calories).

c) Hypothermia (core temperature <35°C (<95°F) may occur during prolonged exposures to extreme cold or cold-wet conditions. In addition, particularly vulnerable populations include soldiers who are very thin, wounded and/or sick.

d) Figure 3-1 outlines the cold stress risk management process for preventing cold injuries. An important aspect of this is recognizing changes in weather conditions so that troops can be alerted to potential modifications that may be necessary to reduce exposure and susceptibility to cold injuries. Therefore, the risk management process must continually be re-evaluated as conditions change. Finally, being alert to signs of soldier distress in the cold is critical so that risk management procedures and interventions can be adjusted accordingly.

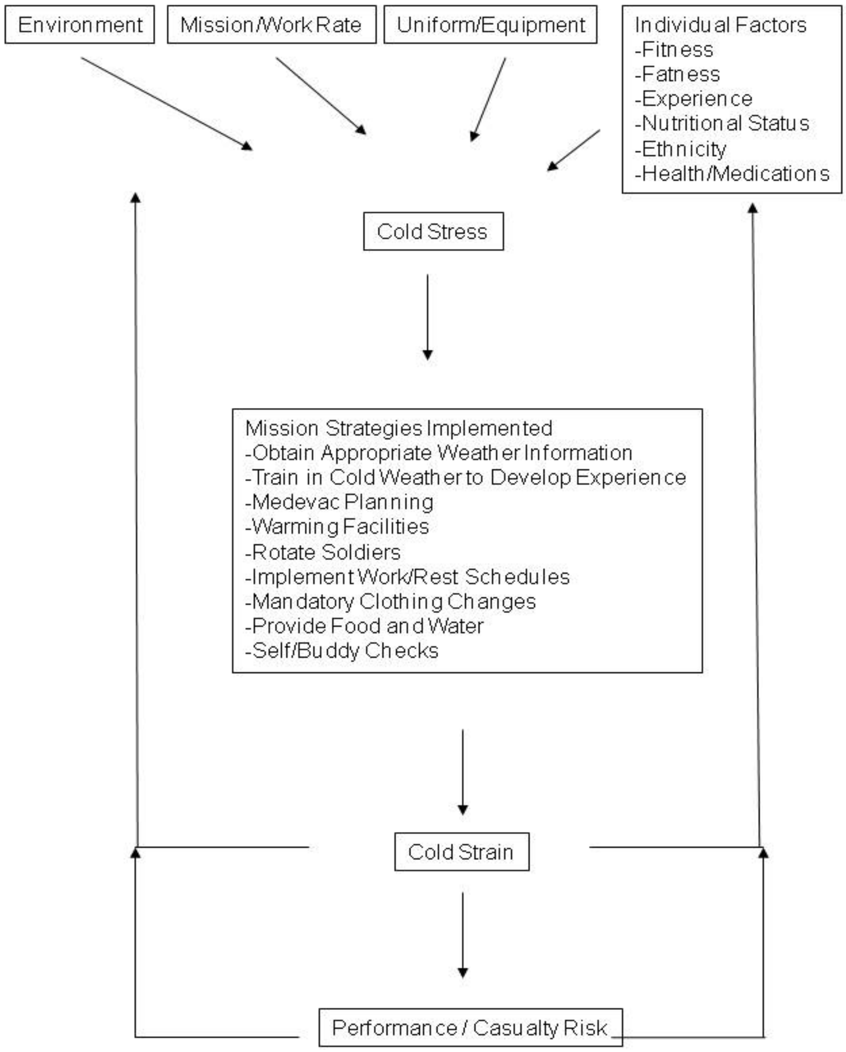

Figure 3-1: Cold Stress Risk Management Process.

3.3 WIND-CHILL TEMPERATURE INDEX

a) NATO employs the Wind Chill Temperature Index (WCTI) to determine environmental cold stress. The WCTI 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 wind-chill temperature is the equivalent still-air (i.e., 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- or rotor-generated wind can be subject to dangerous wind chill, even when natural winds are low. Ambient dry bulb (<0°C (32°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 0°C (32°F), even though the WCTI may be below freezing due to strong winds. Wet skin will not freeze if the air temperature is above 0°C (32°F), but wet skin below 0°C (32°F) will freeze faster than dry skin. Temperatures, wind chill and risk of cold injury increase at high altitudes as air temperature is ~2°C (3.6°F) lower with every 0.3 kilometers (1000 feet) above the site at which temperature was measured.

3.4 PHYSIOLOGICAL RESPONSES TO EXERCISE-COLD STRESS

a) Thermal balance

1) Performing physical work in cold air usually maintains or increases core temperature because heat production is greater than heat loss. Generally, the higher the work intensity, the higher the steady-state core temperature and skin temperature in a well-clothed soldier. The precise effect of work intensity on core temperature during 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) Physical work in water or during a rainfall has different effects on thermal balance compared to air. Heat loss is ~7-10 times higher in water than air. This means that heat loss can potentially be greater than heat production generated by either physical work 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 physical work is also performed with the arms while in cold water, greater heat losses will occur than if work 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 intensity work in water temperatures less than 15°C (59°F) has been shown to accelerate body cooling in thin people, compared to resting cold water exposure.

3.5 COLD STRAIN AND PERFORMANCE

a) Physical work

1) Physical work generally takes longer in cold environments. Cold stress that does not markedly decrease core body temperature or allow muscle temperatures to go below 36°C (97°F) does not alter most physical work performance tasks. However, for every 0.2°C (~0.1°F) fall in core or muscle temperature that occurs, maximal endurance work capability is lowered by ~5 percent, work endurance time is lowered by 20 percent, and maximal strength and power output is lowered by 5 percent.

b) Manual dexterity

1) Manual dexterity is important for many military tasks, including marksmanship, weapons and equipment maintenance, setting up tents and tying knots, lighting stoves and keyboard operations.

2) The decrease in manual dexterity is mainly dependent on ambient temperature and wind speed (quantified in the WCTI) and exposure duration. For a standard winter clothing ensemble the problem area for manual dexterity can be identified using Fig. 3-2. Commanders may use this chart as an indication for enhanced risks related to manual dexterity degradation.

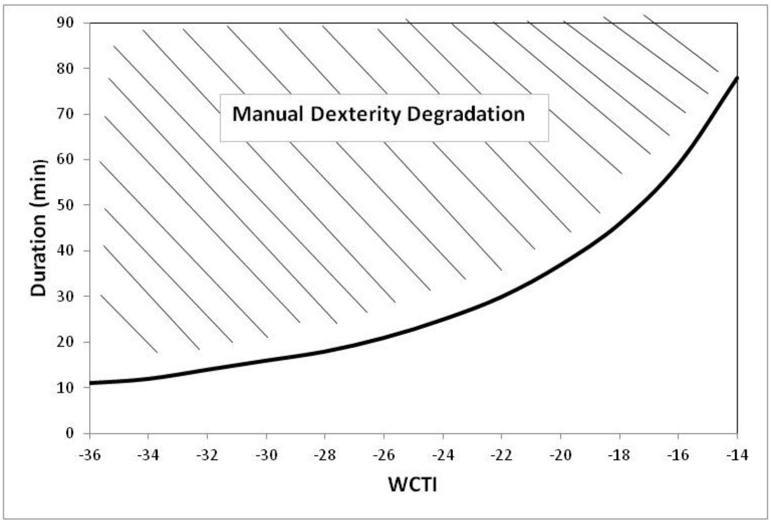

Figure 3-2: The Left Upper Area (Hatched) in the Figure Indicates Combinations of WCTI and Exposure Durations for which the Finger Skin Temperature will Drop Below 15°C(60°F) and Manual Dexterity will be Impaired. For these Experiments, Gloved Hands were Bared Briefly Before and During Performing the Dexterity Tasks in the Cold.

3) Pain sensations increase when skin temperatures decrease to 15°C (59°F), and manual dexterity declines due to cooling of tissues and decreases in joint mobility. Finally, tactile sensitivity is reduced as skin temperatures drop below 6°C (43°F). These changes occur due to decreased tissue temperatures, meaning that a soldier can have a normal body core temperature but still have a significant decline in dexterity performance because the hands and fingers are cold.

4) The relationship between finger temperature and manual dexterity performance changes is not linear; rather, there is a clear breakpoint at skin temperatures below 15°C (60°F) as dexterity performance drops off by 10 to 20 percent, and a second sharp decline occurs at a skin temperature less than 6°C (43°F) when tactile sensitivity is lost. Immersion of the hands and forearms in 10°C (50°F) water for as short as 5 minutes can lower manual dexterity by 20 to 50 percent.

c) Cognition/Thinking

1) Cold strain can degrade mental performance on complex thinking tasks by ~20 percent. Memory registration for newly presented information is impaired when core temperature falls below 36.5°C (97.7°F) and a 70% impairment is observed at core temperatures of 34-35°C (93.2-95.0°F).

3.6 WET ENVIRONMENTS

a) Rain will wet clothing thus reducing clothing insulation and accelerate body heat loss, increasing the risk for hypothermia. Wading in streams or working in the rain substantially increases a soldier's susceptibility to hypothermia because water has a high thermal conductivity and accelerates heat loss by ~25 times. For example, a person could sit in 10°C (50°F) air for 3-4 hours and not experience a fall in core temperature, whereas immersion in 10°C (50°F) water could cause a person to become hypothermic in 1-2 hours.

b) The ability to defend body temperature is challenged by water immersion. Core temperature cooling during immersion is dependent on both the water temperature and the immersion depth. Deeper immersion covers a greater amount of the body surface area and significantly increases body temperature cooling rates and risk for hypothermia. Fast-moving streams increase heat loss and cause body temperatures to cool faster than still bodies of water.

c) Table 3-1 presents guidelines for exposure time during immersion at various water temperatures and immersion depths. These exposure times reflect the time it takes the body core temperature to fall to 35.5°C (95.9°F) to avoid hypothermia. These guidelines are based on wearing standard combat clothing; wearing different clothing will modify the cooling rate and exposure times. These immersion time limits are approximations for the average soldier. Leaders must recognize that some soldiers will cool faster (i.e., those who are leaner) than the time limits predicted by the table.

Table 3-1: Guidelines for Immersion Time at Different Water Temperatures and Immersion Depths in Order to Avoid Hypothermia.

Water Temperature	Ankle-Deep	Knee-Deep	Waist-Deep
10°-13°C **(50-54°F)**	7 hours If raining, 3.5 hrs	5 hours If raining, 2.5 hrs	1.5 hours If raining, 1 hrs
13-16°C **(55-59°F)**	8 hours If raining, 4 hrs	7 hours If raining, 3.5 hrs	2 hours If raining, 1.5 hrs
16-19°C **(60-64°F)**	9 hours If raining, 4.5 hrs	8 hours If raining, 4 hrs	3.5 hours If raining, 2.5 hrs
19-21°C **(65-69°F)**	12 hours If raining, 6 hrs	12 hours If raining, 6 hrs	6 hours If raining, 5 hrs
>21°C (70°F)	>12 hours	>12 hours	>6 hours

d) Extra clothing, a sleeping bag and appropriate equipment should be protected in order to keep them dry upon entering the water environment.

3.7 CLOTHING FOR PROTECTION FROM THE COLD

a) Cold-weather clothing is designed to protect against hypothermia by reducing body heat loss to the environment. When clothing becomes wet, the insulation capability provided is degraded, and conductive heat losses increase substantially.

b) Insulation is determined by how much air is effectively trapped by clothing. However, dressing for cold weather is more complicated than simply wearing thicker clothing. Soldiers require clothing that can accommodate a range of ambient temperatures and physical activity levels, and can protect against wind, rain and snow. This is accomplished by following two important concepts when dressing for activities in the cold: layering and staying dry.

c) Multiple clothing layers are preferred. This method allows air to be trapped and serve as insulation, allowing the individual to adjust clothing layers according to the environmental conditions and activity level. Layers can be removed as the ambient temperature or physical activity levels increase, thereby reducing sweating and moisture build up within clothing.

d) The inner layer is intended to be in direct contact with the skin to wick away moisture. It is made from polyester or polypropylene, materials that do not readily absorb moisture, yet transport moisture along the fibers to the outer layers. The middle layer is made from polyester fleece and is the primary insulation layer. This layer is also designed to wick moisture to the surface so that the moisture can evaporate. The outer layer is a semi-permeable material and is designed to allow moisture transfer to the air while repelling wind and rain. Vents under the arms allow soldiers to individually adjust the ventilation under the outer layer to avoid moisture build up. Clothing layers should be added or removed so that soldiers feel ‘cool’ to ‘comfortable’.

e) The amount of clothing needed is a function of the air temperature and the physical activity level of the soldier. Less clothing is required as the physical activity levels increase. Likewise, clothing requirements become greater as the air temperature decreases. If the soldier begins to sweat, he needs to remove clothing so that his skin still feels ‘cool’ to ‘comfortable’ and sweating stops. Likewise, if the wind velocity increases, the soldier may need to add another insulating layer or a wind-proofing shell. Cold sensations and shivering are indications that a soldier is becoming cold. If this occurs, action must be taken to warm the soldier through preventive actions, e.g., increasing clothing, increasing activity, providing shelter). Commanders need to allow soldiers to choose their own clothing combinations based on the soldiers’ individual responses.

f) An important planning consideration is not only knowing how much clothing is needed during physical activity in the cold, but also recognizing that as soon as physical activity stops, body heat loss will be significant. Physical activity increases peripheral blood flow, resulting in greater heat transfer to the environment. Sweating that may occur with heavy work, even in cold conditions, and its evaporation will also increase heat loss after activity stops and its soaking of clothing will reduce its insulation. This highlights the problem of needing less clothing during a movement but, conversely, requiring more layers after being forced to remain stationary in a foxhole or a defensive position.

g) Heat loss from a bare head can be very significant in cold air when soldiers are adequately clothed elsewhere. Winter caps and balaclavas can decrease this heat loss substantially. Hats should be put on before the soldier feels cold, and before he has incurred a significant loss of body heat.

h) Similarly, gloves and mittens should be worn before the hands become cold. As physical activity increases and the hands become warm, gloves can be removed to allow cooling through the hands and to limit sweat accumulation in the fabric.

1) Liner gloves that fit directly against the skin wick away moisture. Contact gloves prevent the skin from coming directly into contact with cold objects, thereby reducing the risk of contact cooling or contact frostbite at temperatures below freezing. Soldiers should have an extra pair of contact gloves in case the first pair becomes wet due to sweating or handling wet or snowy objects. At very cold air temperatures, a trigger-finger mitten inside the arctic mittens will provide adequate protection.

2) Using mittens, as opposed to gloves, will provide greater protection from cold injuries by decreasing the surface area by which heat loss can occur. However, this increased protection will likely be countered by markedly reduced manual dexterity with mitten use.

3) There are specific gloves for soldiers handling Petroleum, Oil and Lubricants (POLs). An extreme cold-weather glove for POL handlers is worn over the cold-weather glove inserts.

i) Feet sweat at rest and even more so during physical activity. Layering using two pairs of socks is recommended. The first layer should be a thin nylon or polypropylene sock that wicks moisture away from the skin. The second layer should consist of a wool or wool-blend sock that can absorb the sweat from the foot. This sock should not be so thick that the boot fits too snugly as this can cause constriction of the blood vessels and increase the risk of cold injury. Boots may need to be sized larger so that a liner and an insulated sock can be worn.

1) Even with boots that are breathable, foot sweat will cause socks to become wet, increasing conductive cooling and cold-injury risk. Wet socks therefore must be changed periodically, as having wet feet for prolonged periods (>12 hours) increases the risk for cold injury.

2) Snow can fall inside any boot and melt, creating a cold-wet microenvironment. Gaiters can help prevent this from occurring, and can also increase insulation by trapping air, helping to keep feet warmer and drier.

3) Soldiers should not sleep with footwear on for several reasons. Feet need to be dried out overnight to maintain the skin integrity and prevent non-freezing cold injuries. If boots are worn or placed inside a sleeping bag, they will not dry, but will accumulate additional moisture. Boots should be placed in a warm area to dry within a soldier's shelter. Placing socks and boots next to intense heat (from fires or heaters) may damage them. Avoid placing boots in below freezing temperatures because the moisture in them can freeze; cold injuries can occur when placing feet in cold boots.

j) There are several types of boots for cold-weather operations. Each nation has different boots and each should determine the appropriate boot for their expected mission. Proper fitting of boots is essential, because tight boots will constrict blood flow, yet loose boots can cause blisters and also allow considerable snow to fall into the boot.

k) Clothing becomes ineffective if it becomes excessively dirty. Dirt compresses the insulation and clogs the pores in breathable fabrics. Soldiers must clean their clothing according to the manufacturer's recommendations. Wet clothing can be hung to dry inside a shelter with a stove.

l) Sleeping bag systems also use layers and different bags to increase insulation. These systems typically have an outside bivy cover that provides protection from wind and rain. A patrol sleeping bag provides protection down to ~2°C (35°F), and a cold-weather sleeping bag, by itself, protects down to -20°C (-5°F). Combining this cold-weather sleeping bag with the patrol bag can provide protection to -34°C (-30°F). These sleeping bags need to be wiped down and aired out so that moisture does not accumulate inside.

m) In summary, soldiers should remember the acronym 'COLD' for dressing in the cold and avoiding hypothermia.

1) Keep it -----**C**lean.

2) Avoid ------**O**verheating.

3) Wear it -----**L**oose and in Layers.

4) Keep it -----**D**ry.

3.8 FROSTBITE AVOIDANCE GUIDANCE

a) Frostbite accounts for the largest number of cold injuries, and severe frostbite can disable a soldier for life. Inadequate planning and training and lack of experience contribute to high injury rates. However, frostbite can be avoided by simple, yet effective, countermeasures.

1) Leaders should follow a cold stress risk management process (Figure 3-1) before conducting cold-weather operations to identify potential hazards and plan accordingly.

2) Classroom training on cold injuries and avoidance is not sufficient to prepare troops for operating in cold weather. Therefore, opportunities to learn through experience in a controlled situation are invaluable. Gradually increasing exposure and training time in the cold for troops will give them the confidence and ability to recognize potential areas of risk early enough to employ countermeasures, and will enable them to work successfully in the environmental conditions with little impact on the mission.

b) The relative risk of frostbite can be determined by monitoring the air temperature and wind speed. Air temperature is the most important determinant for the risk of frostbite. The further the air temperature falls below freezing, the greater the risk of frostbite.

1) Physical activity is an effective countermeasure for increasing skin temperature when wind is not present; however, when exposed to wind, physical activity does not alter the temperature of exposed or covered skin. Effective countermeasures for minimizing the impact of wind include covering exposed skin, adding windproof clothing and seeking shelter (bivouacking in tree line).

c) Leaders should evaluate the relative risk of frostbite by using the WCTI value. The WCTI integrates wind speed and air temperature to provide an estimate of the cooling power of the environment. It standardizes the cooling power of the environment to an equivalent air temperature for calm conditions. WCTIs are grouped into frostbite risk zones based upon the period of time in which exposed cheek skin will freeze in more susceptible persons in the population (Table 3-2), assuming they are using precautions (e.g., gloves, proper clothing). Table 3-3 gives the general guidance that should be followed for the different time-to-frostbite risk zones. Skin from the cheek was chosen because this area of the body is typically not protected, and studies have observed that the cheek, along with the nose, are the coldest areas of the face. Wet skin exposed to the wind will cool even faster.

Table 3-2: Wind-Chill Temperature Index in Degrees Celsius and Fahrenheit. The Actual Wind-Chill Temperature, Based on the Combination of Air Temperature and Wind Speed, is Shown on the Table. Coloring Indicates the Time to Frostbite for Exposed Facial Skin.

Air Temperature (°C)

Wind Speed (km/h)	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
5	4	-2	-7	-13	-19	-24	-30	-36	-41	-47	-53	-58
10	3	-3	-9	-15	-21	-27	-33	-39	-45	-51	-57	-63
15	2	-4	-11	-17	-23	-29	-35	-41	-48	-54	-60	-66
20	1	-5	-12	-18	-24	-30	-37	-43	-49	-56	-62	-68
25	1	-6	-12	-19	-25	-32	-38	-44	-51	-57	-64	-70
30	0	-6	-13	-20	-26	-33	-39	-46	-52	-59	-65	-72
35	0	-7	-14	-20	-27	-33	-40	-47	-53	-60	-66	-73
40	-1	-7	-14	-21	-27	-34	-41	-48	-54	-61	-68	-74
45	-1	-8	-15	-21	-28	-35	-42	-48	-55	-62	-69	-75
50	-1	-8	-15	-22	-29	-35	-42	-49	-56	-63	-69	-76
55	-2	-8	-15	-22	-29	-36	-43	-50	-57	-63	-70	-77
60	-2	-9	-16	-23	-30	-36	-43	-50	-57	-64	-71	-78
65	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79
70	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-80
75	-3	-10	-17	-24	-31	-38	-45	-52	-59	-66	-73	-80
80	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81

FROSTBITE GUIDE

Low risk of frostbite for most people
Increasing risk of frostbite for most people in 10 to 30 minutes of exposure
High risk for most people in 5 to 10 minutes of exposure
High risk for most people in 2 to 5 minutes of exposure
High risk for most people in 2 minutes of exposure or less

Air Temperature (°F)

Wind Speed (mph) ↓	**40**	**30**	**20**	**10**	**0**	**-10**	**-20**	**-30**	**-40**
5	36	25	13	1	-11	-22	-34	-46	-57
10	34	21	9	-4	-16	-28	-41	-53	-66
15	32	19	6	-7	-19	-32	-45	-58	-71
20	30	17	4	-9	-22	-35	-48	-61	-74
25	29	16	3	-11	-24	-37	-51	-64	-78
30	28	15	1	-12	-26	-39	-53	-67	-80
35	28	14	0	-14	-27	-41	-55	-69	-82
40	27	13	-1	-15	-29	-43	-57	-71	-84
45	26	12	-2	-16	-30	-44	-58	-72	-86
50	26	12	-3	-17	-31	-45	-60	-74	-88
55	25	11	-3	-18	-32	-46	-61	-75	-89
60	25	10	-4	-19	-33	-48	-62	-76	-91

Frostbite Times

Yellow – Frostbite could occur in 30 minutes.
Blue – Frostbite could occur in 10 minutes.
Red – Frostbite could occur in 5 minutes.

Table 3-3: List of Recommended Preventative Measures to Decrease Risk of Frostbite.

FROSTBITE RISK			
LOW	**INCREASING**	**HIGH (5-10 min)**	**HIGH (2-5 min)**
• Increase surveillance with self and buddy checks	• Mandatory buddy checks every 20-30 minutes	• Mandatory buddy checks every 10 minutes	• Mandatory buddy checks every 5 minutes
• Wear appropriate layers and wind protection including head, hands, feet, face	• Wear appropriate layers and wind protection including head, hands, feet, face	• Wear appropriate layers and wind protection including head, hands, feet, face	• Wear appropriate layers and wind protection including head, hands, feet, face
• Cover exposed flesh if possible	• Cover exposed flesh if possible	• Cover exposed flesh if possible	• Cover exposed flesh if possible
• Wear vapor barrier (VB) boots below -18°C (0°F)	• Wear VB boots below -18°C (0°F)	• Wear VB boots	• Wear VB boots
• Avoid sweating	• Avoid sweating	• Avoid sweating	• Avoid sweating
	• Provide warming facilities	• Provide warming facilities	• Provide warming facilities
		• Work groups of no less than 2 personnel	• Work groups of no less than 2 personnel
		• No exposed skin	• No exposed skin
		• Stay active	• Stay active
			• Be ready to modify activities due to extreme risk
			• Keep task duration as short as possible

d) Fingers may be more susceptible than cheeks for freezing. Exposed fingers will freeze at a WCTI that is ~3°C (~10°F) warmer than the cheek because there is less blood flow in the fingers compared to the face during cold exposure. Therefore, when the WCTI is below -23°C (-9°F), there is an increased risk of finger frostbite, and soldiers should take appropriate precautions (i.e., put on gloves, increase physical activity). The risk for frostbite is less at WCTIs above -23°C (-9°F), but appropriate actions to reduce the risk should still be taken. Figure 3-3 shows the small finger temperature as a function of time when the finger is in contact with snow.

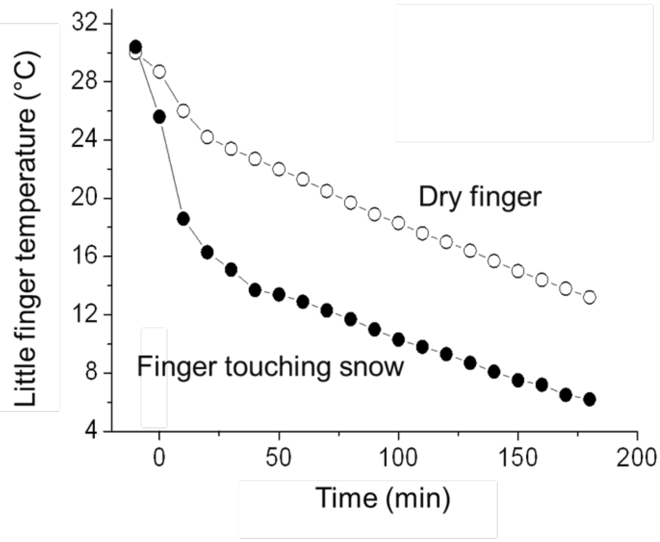

Figure 3-3: Impact of Cold Stress (-10°C, 7 km/hr (14°F, 4.5 mph) air motion) on Little-Finger Temperature Over Time When Finger is Dry and After Finger is Wet by Touching Snow.

e) Leaders must recognize that wind speeds obtained from weather reports do not take into account man-made wind and that the local weather may vary greatly depending on the local topography. Individuals riding in open vehicles or exposed to propeller- or rotor-generated wind can be subject to dangerous wind chill, even when natural winds are low. Running and skiing also produce wind across the body at the same rate the body is moving. In addition, wind speeds are generally faster at high altitudes where there is little tree cover. Moving from a sheltered bivouac to a mountain ridge line will increase the likelihood of being exposed to a lower WCTI. Mountains can create their own weather patterns by altering wind speed and direction and influencing precipitation. All of these factors make pre-planning and route selection for soldier movement important in order to minimize the effects of temperature, wind and weather on cold-injury susceptibility.

f) Fingers and other exposed skin areas can cool very rapidly when touching cold materials, especially metal and liquids. Extreme caution must be taken if it is necessary to touch cold objects with bare hands at temperatures below freezing as contact frostbite can occur. Contact gloves should always be used to create a barrier between the hand and material, and can reduce performance decrements associated with hand cooling even at temperatures above freezing. Tape can be used on weapons to significantly reduce contact cooling and risk of frostbite.

g) Table 3-4 shows that touching the trigger area of a weapon (steel) with a bare finger at a weapon temperature of -10°C (14°F) will cause the finger skin temperature to reach 0°C (32°F) in just 15 seconds. Fuels have a very low freezing point (-40°C), and contact with these super-cooled fuels can cause instantaneous frostbite. Protective clothing must be used when handling fuels and POL products to avoid splashing on exposed skin. Rifle butts and charging handles also cause contact frostbite to the face and nose when soldiers are sighting and firing weapons. Tape on the areas of contact will reduce the risk of contact frostbite.

Table 3-4: Time for Finger Temperature to Reach 0°C (32°F) When Touching Various Materials. Both the material and air temperatures were at -10°C (14°F).

	Time
Nylon	6 min 30 s
Wood	6 min 27 s
Steel	31 s
Aluminum	18 s

h) Straps on gloves and other equipment should not be too tight as that might decrease blood flow and thus increase risk of cold injury (by impeding flow of warm blood to tissues). Backpacks should be taken off every few hours to allow increased circulation.

i) Soldiers should NOT blow warm breath into mittens or gloves because it can cause the hands to become even colder due to the vapor from the breath adding moisture to the glove that may freeze and contribute to further cooling.

j) Face camouflage paint should not be used when the air temperature goes below 0°C (32°F), because the paint conceals any changes in skin color which signal the early development of frostbite. Spreading petroleum jelly or other emollients onto the skin increases the risk of frostbite by trapping moisture, which will freeze.

k) Cold-injury surveillance (i.e., tracking and observation) of troops is one of the most effective means to prevent frostbite. Troops should be taught to check on their colleagues (see Table 3-3) by looking for blanched skin on the fingers, ears, cheeks, nose and toes. Leaders must also ensure that soldiers are comfortable about reporting any potential problem and that there will be no negative consequences from reporting. Many frostbite injuries occur because a soldier is afraid of appearing 'weak' by mentioning to the chain of command that something is wrong (e.g., that his fingers are numb). In such instances, appropriate preventive measures that could resolve the problem are not taken, and a cold injury then develops.

3.9 NON-FREEZING COLD-INJURY AVOIDANCE GUIDANCE

a) Non-freezing Cold Injuries (NFCI) occur when conditions are cold and wet (air temperatures between 0° and 15°C (32° and 55°F)), the hands and feet cannot be kept warm and dry, and soldiers are relatively inactive. The feet are the most common area of injury, which is reflected in the common name of the principal type of NFCI, trench foot. Fighting in defensive positions such as foxholes or small vehicle crew compartments restricts movement, and soldiers often must remain inactive inside these areas for long periods. If these areas are cold and damp, trench foot can become a serious problem, whether the dampness is caused by the environment or from sweat accumulation in the socks.

b) Prevention of trench foot can be achieved by encouraging troops to remain active and increase blood flow to the feet, rotating personnel out of cold-wet environments, and keeping feet dry by frequently changing socks. Boots and liners should be periodically taken off and separated and allowed to dry.

3.10 OTHER INJURIES RELATED TO COLD WEATHER

a) Carbon monoxide (CO) poisoning

1) CO is a poisonous gas that cannot be seen or smelled. CO binds to red blood cells more readily than oxygen, so less oxygen is available to vital organs and tissues. t is contained in the exhaust from stoves and vehicles, and can build up in closed spaces that are poorly ventilated. Early signs of CO poisoning are headache, confusion, dizziness, and drowsiness. Persons found unconscious in a closed tent or vehicle may be victims of CO poisoning, especially if the lips and skin are bright red.

2) CO poisoning can be prevented by maintaining adequate ventilation. Tents should not be airtight. Soldiers should not remain stationary in idling vehicles for long periods. Under no circumstances should anyone sleep in an idling vehicle. Occupants of idling vehicles should ensure that exhaust pipes are not blocked by snow banks, and the windows of the vehicle are slightly opened.

3) Approved space heaters should be used. Only properly trained soldiers should be permitted to set up, light, refuel, and maintain stoves. Stovepipes must be kept clean and must be tall enough to draft properly. Proper ventilation and maintenance of these heaters is crucial. A fire guard must be posted at all times, and the pathway to the tent door must be kept clear to allow easy escape in case of fire.

b) Snow blindness and sunburn

1) Snow blindness and sunburn are caused by exposure of unprotected eyes and skin to ultraviolet (UV) radiation. The threat of snow blindness and sunburn depends on the intensity of sunlight, not the air temperature. Snow, ice and lightly colored objects reflect the sun's rays, increasing the risk for injury.

2) Snow blindness results when solar radiation '"sunburns' unprotected eyes. Eyes may feel painful and gritty, and there may be tearing, blurred vision and headache. The use of protective eyewear or goggles that block >90 percent of UV radiation will help to prevent snow blindness. Sideshields or deeply wrapped lens designs should be used. If sunglasses are not available, opaque eye covering (e.g., tape-covered eyeglasses) with narrow horizontal slits provide adequate field-expedient eye protection.

3) Sunburn to the skin increases heat loss during cold exposure, increasing susceptibility to hypothermia. It also leads to uncomfortable or painful feelings that decrease soldier performance. Sunburn can be prevented by using a appropriate sunscreen. For cold weather, an alcohol-free sunscreen lotion that bocks both UVA and UVB rays should be used. (Alcohol evaporates more easily and will cool the skin.)

c) Respiratory tract

1) Cold weather leads to a host of possible complications for the respiratory system. Problems include bronchospasm, nasal discharge, and upper respiratory tract infections. Soldiers with a history of respiratory diseases are most susceptible to bronchospasm

during heavy exercise in very cold air and must be watched carefully. Breathing through a mask or scarf while in cold weather will provide some relief. Bronchospasm can also be caused by fumes from fuel-fired heaters.

3.11 CBRNE CLOTHING AND DECONTAMINATION

a) Wearing CBRNE individual protective clothing and equipment during cold-weather operations increases the risk for both cold and heat injuries. CBRNE-protective clothing gloves and facemask can fit tightly, so they restrict the blood flow to the fingers and face, increasing the susceptibility of these areas to frostbite. Heavy work will increase sweat accumulation in the gloves, degrading the insulation, and increasing frostbite susceptibility in the fingers. CBRNE clothing also limits the ability to visually inspect for signs of cold injury.

b) Wearing an impermeable CBRNE-protective overgarment over heavy cold-weather clothing creates the unexpected situation where heat exhaustion becomes a possibility for soldiers working hard, even in temperatures as low as -30°C (-22°F). The added insulation and decreased ventilation of CBRNE-protective clothing can result in heavy sweating and wetting of the clothing during hard physical activity. When this activity ceases, large heat losses ensue, and finger and toe temperatures can decrease significantly.

c) When mask carriers are worn outside the clothing at below freezing temperatures, donning the cold mask can cause a contact freezing injury, especially at the points where exposed rivet heads contact the face. In temperatures below -18°C (0°F), mask carriers must be placed under the parka to keep the mask warm and flexible enough to provide an adequate seal.

d) Since the CBRNE is worn outside the cold-weather clothing, it may be necessary to remove insulating clothing layers to prevent overheating. Vapor barrier boots or issue overboots are generally authorized replacements for chemical protective boots.

e) Cold-weather gloves or mittens can be worn over chemical protective gloves. Individuals whose tasks require a high degree of manual dexterity may be unable to wear cold-weather gloves or mittens over the rubber gloves. In this case, polypropylene glove liners worn beneath the chemical protective gloves may provide some cold contact protection for brief periods.

3.12 FOOD AND FLUID REQUIREMENTS

a) Soldiers expend more energy during cold weather due to a combination of heavy clothing and equipment and the increased effort required for working or walking in snow or mud or for preparing positions in frozen ground. For example, walking on 15 cm (6 in) of snow doubles the energy requirement of walking on asphalt.

b) Military units performing field activities in the cold often expend ~4,400 kcal per day (kcal/d), with some groups exceeding 6,000 kcal/d. Therefore, food requirements are approximately 4,400 kcal/d for most active field units.

c) The extra calories often needed for cold-weather operations can be obtained by eating a normal breakfast, lunch, and dinner, and then supplementing with frequent snacks throughout the day. A good tip for soldiers participating in cold-weather operations is to eat a snack before bed at night. This will help keep the soldier warmer during sleep, which prevents shivering and allows sounder, more restful sleep. Soldiers who must hike, ski or snowshoe for very long distances will benefit by eating more foods high in carbohydrates.

d) Fluid requirements during cold-weather training will vary according to physical activity levels, but, for most people, ~3-6 liters per day should be consumed. This includes the water that is in food. Rations only average ~0.2 liters of fluid per meal (< ¼ liter), so soldiers will get less than

1 liter total fluid from three meals. The best time for Soldiers to rehydrate is at mealtime. Soldiers usually drink most of their water with meals, and eating food improves water consumption soldiers can drink a variety of other fluids (juice, sports drinks, tea, coffee), as each will be equally effective in replacing body water. Drinking warm fluids may improve consumption and morale. In addition, meals provide the salt intake necessary to retain body water.

e) Plan operations that include water resupply points. Providing water in the field can be logistically difficult due to the freezing of canteens, and larger containers, and the tubing and mouthpiece of personal hydration systems. It is the responsibility of soldiers to ensure that freezing of these containers does not occur. Canteens and Camelbacks must be carried within clothing, and metal containers must not be left outside in below-freezing temperatures. Accordingly, there must be sufficient time planned for melting and purifying snow or ice. Unmelted snow must not be consumed because it can lower body temperature, may not be potable and can irritate the mouth.

f) Soldiers can monitor hydration status by noting the color and volume of their urine. Dark, low volume and infrequent urination indicate that fluid consumption should be increased. Likewise, frequent and large volumes of clear urine indicate that fluid replacement should be reduced

Appendix A – HEAT STRESS MANAGEMENT MATERIAL FOR INFORMATION PRODUCTS

PREVENTION

Sunburn

- Minimize exposure of skin to the sun, particularly at mid-day and during initial days of deployment
- Apply sunscreen liberally to exposed skin and often if sweating heavily
- Proper wear of clothing, cap and approved sun glasses

Heat Rash (Prickly Heat)

- Proper wear of clothing (not too tight or restrictive).
- Keep skin dry in susceptible areas (e.g, groin, arm pits and neck).
- Shower (nude) and wash with soap after excessive sweating.

Heat Exhaustion and Heat Stroke

- Heat Exhaustion and Heat Stroke both appear as excessive fatigue and collapse with mental disorientation.
- Ensure capabilities for immediate cooling (e.g., cool- or cold-water immersion, water to spray and fans to evaporate, iced towels or sheets to wrap casualties) of heat exhaustion or stroke cases.
- Ensure evacuation capabilities are available for suspected heat stroke cases.
- Allow for heat acclimatization (see **PERFORMANCE** section).
- Monitor WBGT.
- Keep soldiers in shade (natural or solar screen) whenever possible.
- Drink fluids and follow water-replacement guides.
- Follow work/rest cycles.
- Identify and monitor high-risk individuals.
- Maintain buddy system and seek care for those demonstrating heat illness symptoms.
- Re-evaluate training and/or mission if several heat casualties occur.

Heat Cramps

- Eat all meals in order to replace salt lost in sweat.
- Consume salt-supplemented beverages if adequate meals have not been consumed prior to prolonged periods of heavy sweating.
- Ensure adequate heat acclimatization (see **PERFORMANCE** section).

Dehydration

- Don't rely on thirst, as it lags behind water needs.
- Consume full meals and drinks at mealtime.

- Cool beverages to improve fluid consumption.
- Follow fluid-replacement guidelines.
- Monitor urine color (dark), low frequency and volume; if dark and infrequent, drink more.

Over Hydration (Hyponatremia)

- Follow fluid-replacement guidelines and avoid overconsumption.
- Replace lost salt by consuming meals, snacks and sports drinks, as directed.
- Monitor urine color (light), with high frequency and volume; if light and frequent, drink less.

Fluid Replacement and Work/Rest Guide

Table A-1: Fluid Replacement and Work/Rest Guide.

Heat Category	WBGT (°C) (°F)	Easy Work		Moderate Work		Hard Work	
		Work/ Rest	Water Intake (L/h)	Work/ Rest	Water Intake (L/h)	Work/ Rest	Water Intake (L/h)
1	25.6-27.7 (78-82)	NL	~½	NL	~¾	40/20 min	~¾
2 (Green)	27.7-29.4 (82-85)	NL	~½	50/10 min	~¾	30/30 min	~1
3 (Yellow)	29.4-31.1 (85-88)	NL	~¾	40/20 min	~¾	30/30 min	~1
4 (Red)	31.1-32.2 (88-90)	NL	~¾	30/30 min	~¾	20/40 min	~1
5 (Black)	> 32.2 (>90)	50/10 min	~1	20/40 min	~1	10/50 min	~1

Acclimatized (after approximately two weeks training) wearing combat clothing

- The work/rest times and fluid replacement volumes will sustain performance and hydration for at least 4 h of work in the specified heat category. Fluid needs vary based on individual differences (~¼ L/h) and exposure to full sun or full shade (~¼ L/h).
- NL = no limit to work time per hour.
- Rest means minimal physical activity (sitting or standing), accomplished in shade if possible.
- CAUTION: Hourly fluid intake should not exceed ~1 ½ liters.
- Daily fluid intake should not exceed 12 liters (or quarts).
- If wearing body armor or combatant protective equipment, add 2.8 ^{0}C (5°F) to WBGT.
- If wearing CBRNE protective clothing when fully encapsulated, add 5.6°C (10°F) to WBGT index for easy work, and 11.2°C (20°F) to WBGT index for moderate and hard work.
- **Easy Work** = Walking hard surface 4 km/hr (2.5 mph), < 13.6 kg (30 lbs) load, weapon maintenance, marksmanship training.
- **Moderate Work** = Patrolling, Walking on sand at 4 km/hr (2.5 mph) with no load.
- **Hard Work** = Walking on sand at 4 km/hr (2.5 mph) w/load, field assaults.

Continuous Work Duration and Fluid Replacement Guide

Table A2: Continuous Work Duration and Fluid Replacement Guide.

Heat Category	WBGT (°C) (°F)	Easy Work		Moderate Work		Hard Work	
		Work (min)	Water Intake (L/h)	Work (min)	Water Intake (L/h)	Work (min)	Water Intake (L/h)
1	25.6-27.7 (78-82)	NL	~½	NL	~¾	70	~1
2 (Green)	27.7-29.4 (82-85)	NL	~½	150	~1	65	~1 ¼
3 (Yellow)	29.4-31.0 (85-88)	NL	~¾	100	~1	55	~1 ¼
4 (Red)	31.1-32.2 (88-90)	NL	~¾	80	~1 ¼	50	~1 ¼
5 (Black)	> 32.2 (>90)	180	~1	70	~1 ½	45	~1 ½

Acclimatized (after approximately two weeks training) wearing combat clothing (unacclimatized soldiers will have reduced work capabilities).

This guide is accurate only for trainees with no previous heat injury or dehydration prior to this activity, and who will have several hours of rest afterwards.

- Wet Bulb Globe Temperature (WBGT).
- NL can sustain work for at least 4 hours in the specified heat category.
- Fluid needs vary based on individual differences (± ~¼ l/h) and exposure to full sun or shade (± ~¼ l/h).

PERFORMANCE

Fatigue occurs more rapidly and physical performance is impaired by heat stress, but it can be restored by heat acclimatization. Most soldiers' physiological responses to heat stress improve in 5-14 days of exposure to heat and regular strenuous exercise.

Once heat acclimatization has been attained, the time that individuals may spend in cooler conditions before returning to a hot environment could be as long as one month, without the need for extensive re-acclimatization to heat. The benefits of heat acclimatization are retained to the extent that after 12 days of no heat, heat acclimatization can be regained in two days. After 26 days of no heat exposure, re-acclimatization takes approximately four days.

Table A-2: Heat Acclimatization Strategies.

1) **Mimic the deployment climate.**

2) **Ensure adequate heat stress by:**
- Invoking profuse sweating.
- Using exercise and rest to modify the heat strain.
- Having 4 to 14 days of heat exposures.
- Maintaining the daily duration of at least 120 minutes.

3) **Start early (1 month before deployment)**
- Performance benefits may take longer than physiological benefits.
- Be flexible with training.
- Build confidence.
- Pursue optimum physical fitness in the current climate.

4) **Methods**
- Pre-deployment: Climate-controlled room or hot weather.
- Integrate with training by adding additional acclimatization sessions, inserting
- acclimatization with training, alternating acclimatization days with training days, and avoiding detraining.

- Mimic the deployment environment by working out in a warm room wearing sweats if you are in a cool/temperate environment.

5) **On arrival**
- Start slowly at reduced training intensity and duration, and limit heat exposure.
- Increase heat and training volume (intensity and duration) as tolerance permits.
- Acclimatize in heat of day.
- Physical training should be conducted in coolest part of day.
- Use work/rest cycles or interval training.
- Be especially observant of salt needs for the first week of acclimatization.
- Sleeping in cool or air-conditioned rooms will not affect heat acclimatization status and will aid recovery from heat stress.

TREATMENT

Sunburn

- Move to shade.
- Apply moisturizing lotion to affected areas.
- Do not break blisters.
- Administer analgesics for pain.

Heat Rash (Prickly Heat)

- Clean affected areas and keep dry.
- Control itching and infection with prescribed medications.

Heat Exhaustion and Heat Stroke

- Move to shade and loosen or remove clothing.
- Lie flat and elevate feet.
- Immediately initiate aggressive active cooling. Cool- or cold-water immersion is the preferred method, but the victim can also be wrapped in iced towels or sheets. In addition, spray or pour water on victim and fan for a cooling effect.
- Assess soldier's mental status on a frequent and regular basis.
- If possible, measure rectal temperature and cool to ~38.5°C (101.3°F).
- As recovery occurs, provide fluids to drink. Initially provide one full canteen (quart or liter) of cool water every 30 minutes.
- If heat exhaustion symptoms (e.g., faintness, nausea, confusion) persist past 30 minutes, evacuate for further medical care.
- If any SEVERE mental status changes (delirium or convulsions) occur, heat stroke may be present and the soldier must be immediately evacuated. Heat stroke is a **medical emergency** and can lead to death.

Heat Cramps

- Sit quietly in the shade or in a cool area.
- Massage affected muscle.
- Drink oral rehydration package, sports drink or a 0.05 to 0.1% salt solution.
- Get medical evaluation if cramps persist.

Appendix B – COLD STRESS MANAGEMENT MATERIAL FOR INFORMATION PRODUCTS

PREVENTION

Hypothermia

- Hypothermia results from low core temperatures (<35°C (95°F)) and is characterized by severe shivering, lethargy, difficulty working and mental confusion.
- Severe hypothermia is a life-threatening condition that is characterized by unconsciousness, weakening and/or loss of pulse, slow breathing and absence of shivering.
- Prepare sheltered areas for warming.
- Select clothing materials that provide good insulation, have low water-absorbing capacity (no cotton), and are waterproof (when appropriate) and breathable.
- Wear clothing in layers and adjust them to environmental conditions and work rate.
- Keep clothing dry and change or dry wet clothes.
- Provide warm or hot beverages and food.

Frostbite

- Frostbite is characterized by frozen body tissue, with the most susceptible areas being the fingers, toes and ears and the nose.
- Be aware of the risk for frostbite (see Wind-Chill Temperature Index Chart).
- Use contact gloves to handle all equipment. Never use bare hands, as skin touching metal can induce frostbite in seconds.
- Avoid spilling liquids on skin or clothes.
- Do not use face camouflage or petroleum jelly below freezing temperatures
- Keep face and ears covered and dry by wearing a hat and balaclava.
- Keep socks clean and dry, and avoid tight boots.

Non-Freezing Cold Injuries (e.g., Immersion Foot or Trench Foot)

- Non-freezing cold injuries are characterized by numb, swollen body tissue that often has had prolonged wet-cold exposure (above freezing).
- Keep feet and hands clean and dry. Change wet or damp socks and gloves as soon as possible.
- Dry your boots and liners at least once per day.
- Use gaiters to keep snow out of boots. Gaiters made with semi-permeable membranes will allow sweat to evaporate.

Snow Blindness

- Use sunglasses with side protection in a snow-covered environment.

Carbon Monoxide Poisoning

- Carbon monoxide poisoning is caused by breathing gases from incompletely burned fuels (from heaters, engines and poorly vented fires).
- Carbon monoxide poisoning is characterized by headache, confusion, dizziness and drowsiness, followed by unconsciousness.
- Use only approved heaters that are appropriately ventilated in sleeping areas, and ensure that personnel are properly trained to operate the heaters.
- Never sleep in idling vehicles.
- Always post a fire guard when operating a heater in sleeping areas.

Table B-1: Wind-Chill Temperature Index in Degrees Celsius and Fahrenheit. The Actual Wind-Chill Temperature is Shown on the Table Based on the Combination of Air Temperature and Wind Speed. Coloring Indicates the Time to Frostbite for Exposed Facial Skin.

Air Temperature (°C)

Wind Speed (km/h)	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
5	4	-2	-7	-13	-19	-24	-30	-36	-41	-47	-53	-58
10	3	-3	-9	-15	-21	-27	-33	-39	-45	-51	-57	-63
15	2	-4	-11	-17	-23	-29	-35	-41	-48	-54	-60	-66
20	1	-5	-12	-18	-24	-30	-37	-43	-49	-56	-62	-68
25	1	-6	-12	-19	-25	-32	-38	-44	-51	-57	-64	-70
30	0	-6	-13	-20	-26	-33	-39	-46	-52	-59	-65	-72
35	0	-7	-14	-20	-27	-33	-40	-47	-53	-60	-66	-73
40	-1	-7	-14	-21	-27	-34	-41	-48	-54	-61	-68	-74
45	-1	-8	-15	-21	-28	-35	-42	-48	-55	-62	-69	-75
50	-1	-8	-15	-22	-29	-35	-42	-49	-56	-63	-69	-76
55	-2	-8	-15	-22	-29	-36	-43	-50	-57	-63	-70	-77
60	-2	-9	-16	-23	-30	-36	-43	-50	-57	-64	-71	-78
65	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79
70	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-80
75	-3	-10	-17	-24	-31	-38	-45	-52	-59	-66	-73	-80
80	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81

FROSTBITE GUIDE

Low risk of frostbite for most people.
Increasing risk of frostbite for most people in 10 to 30 minutes of exposure.
High risk for most people in 5 to 10 minutes of exposure.
High risk for most people in 2 to 5 minutes of exposure.
High risk for most people in 2 minutes of exposure or less.

Air Temperature (°F)

Wind Speed (mph) ↓	**40**	**30**	**20**	**10**	**0**	**-10**	**-20**	**-30**	**-40**
5	36	25	13	1	-11	-22	-34	-46	-57
10	34	21	9	-4	-16	-28	-41	-53	-66
15	32	19	6	-7	-19	-32	-45	-58	-71
20	30	17	4	-9	-22	-35	-48	-61	-74
25	29	16	3	-11	-24	-37	-51	-64	-78
30	28	15	1	-12	-26	-39	-53	-67	-80
35	28	14	0	-14	-27	-41	-55	-69	-82
40	27	13	-1	-15	-29	-43	-57	-71	-84
45	26	12	-2	-16	-30	-44	-58	-72	-86
50	26	12	-3	-17	-31	-45	-60	-74	-88
55	25	11	-3	-18	-32	-46	-61	-75	-89
60	25	10	-4	-19	-33	-48	-62	-76	-91

Frostbite Times

Yellow – Frostbite could occur in 30 minutes.
Blue – Frostbite could occur in 10 minutes.
Red - Frostbite could occur in 5 minutes.

PERFORMANCE

- Manual dexterity is impaired in cold.
- Hypothermia impairs mental and physical capacities.
- Adjust clothing layers to minimize sweating when working.
- Drink sufficient fluids to replace sweat losses in order to sustain performance.
- Snow blindness decreases your ability to perform in the cold.
- Carbon monoxide exposure reduces physical and mental performance.

TREATMENT

Hypothermia

- Remove victim from cold to warm area.
- Remove wet clothing, wrap victim in dry blankets or a sleeping bag, and move to warming areas.
- Avoid rapid heating and manipulating extremities (do not massage or give alcohol).
- Provide warm beverages to conscious victims.
- Minimize handling or moving of victim so as not to induce cardiac arrest.
- Never assume someone is dead until determined by a medical authority, even if a victim is cold and not breathing.
- Severe hypothermia is a medical emergency and victims should be evacuated as soon as possible.
- In wounded soldiers, hypothermia increases the risk of dying.

Frostbite

- Remove victim from cold to warm area.
- Slowly warm the frozen areas and do not expose them to any intense heat source.
- Do not thaw frozen areas if re-freezing is likely or break blisters.
- Do not use frozen body areas (e.g., walk on frozen feet).
- Do not massage or rub frozen areas. Do not apply snow or ice to frozen areas.
- If severe frostbite is suspected, evacuate the victim as soon as possible.

Non-Freezing Cold Injuries (e.g., Immersion Foot or Trench Foot)

- Remove victim from cold to warm and dry area and remove wet clothing.
- Dry and clean body tissue gently. Re-warm feet by exposing them to warm air, but do not expose to extreme heat.
- Do not allow victim to stand or walk on injury.
- Do not massage, rub, moisten or use lotions.
- Do not break blisters.
- Evacuate victim to a medical facility.

Snow Blindness

- Rest in total darkness and bandage eyes with gauze.
- Evacuate if no improvement within 24 hours.

Carbon Monoxide Poisoning

- Move to fresh air and administer oxygen if available.
- Perform CPR and evacuate, if needed.

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14. Abstract

NATO ground forces have operated in the extreme heat of Iraq, Afghanistan, Africa and Lebanon, and the numbing cold of Bosnia and Afghanistan. NATO forces often lack adequate doctrine, training and/equipment to avoid thermal illness and injury, and to minimize debilitating effects on fighting capabilities. Thermal (heat and cold) illness and injuries are an important cause of non-battle-related illness and injury in deployed troops, which can consume forward medical resources and gravely degrade operational effectiveness. The August 2004 battle of Najaf, Iraq, resulted in 10 percent of engaged forces being incapacitated from heat stress and evacuated. NATO forces report heat illnesses often deplete forward medical support. The U.S. Army has had an ~8-fold increase in heat stroke hospitalizations during the past 22 years. British military forces have suffered a high incidence of non-freezing cold injuries (hands and feet) in training and operations; while U.S. Special Forces are believed to suffer many unreported non-freezing cold injuries to hands. In addition, global warming has melted polar ice, resulting in increased energy exploration and trade routes through these extreme cold areas, which have had associated security concerns.

NATO RTO RTG HFM-187 determined that: a) current thermal management capabilities are not fully utilized by NATO forces to educate military leaders on optimizing troop health and performance sustainment; b) significant scientific and capability gaps exist regarding thermal illness and injury susceptibility, early diagnosis and treatment; c) significant scientific and capability gaps exist regarding thermal management for operational effectiveness. NATO RTO RTG HFM-187 reviewed thermal management policies for NATO nations and produced both a technical report on thermal management for leaders and medical personnel, and low-tech information brochures on thermal (heat and cold) management. These products represent 'best practices' and can be translated into the languages of NATO Nations and allied forces.

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