TER Report HFM-255

"Cold Extreme Environmental Operations"
Optimizing Warfighter Performance in Extreme Cold

Dr. Stefan M. Pasiakos
US Army Research Institute of Environmental Medicine
15 Kansas Street, Bldg. 42
Natick, MA
USA

stefan.pasiakos@us.army.mil

ABSTRACT

In October, 2014, about 40 international cold-weather experts, including physiologists, NATO military commanders, and physicians gathered at the Norwegian Defence Research Establishment (FFI) in Kjeller, Norway to participate in a Workshop to discuss military operations in extreme cold-weather. The workshop combined the history, etiology, and physiology of cold-weather injuries, cold-weather protection, performance optimization, and operational insight from Warfighters from various NATO and Partnership for Peace (PfP) countries. The intent of the Workshop was to identify research and development (R&D) opportunities to improve operational effectiveness in cold-weather extremes. R&D priorities were identified in the following areas: 1) pharmacological, nutritional, and technological approaches to maintain peripheral blood flow, 2) improved cold-weather clothing and equipment optimization and requirements, 3) establishment of normative, longitudinal cold-weather data to assist with the identification and classification of those with heightened susceptibility to cold-weather injury, 4) development of a standardized cold-weather injury reporting tool, first responder medical policy for treatment of injuries, and development of a leadership decision aid tool to mitigate risk during cold-weather operations, and 5) cold-weather field-feeding optimization in cold-weather environments. The Workshop concluded and all participants recognized the value of continued NATO collaborations on these topics with a specific R&D focus that directly addresses the pragmatic needs of the Warfighter.

KEYWORDS

Acclimatization, Adaptation, Behavior, Clothing, Cold-Weather Injuries, Combat Rations, Equipment, Frostbite, Infrared Thermography, Interoperability, Non-Freezing Injuries, Leadership, Nutrition, Peripheral Blood Flow, Pharmaceutical, Risk Prediction, and Training

EXECUTIVE SUMMARY

The HFM-255 Workshop on "Cold Extreme Environmental Operations – Optimizing Warfighter Performance in Extreme Cold" was held at the Norwegian Defence Research Establishment (FFI) in Kjeller, NOR, from Tuesday, 28 October through Thursday, 30 October 2014. The Workshop consisted of 4 keynote presentations and 8 mini-symposia, which were presented primarily by cold-weather physiologists and NATO military personnel with experience operating in cold-weather extremes. Moderated round table discussions were held at the conclusion of days 1 and 2 to stimulate interaction between scientists and military personnel and identify capability gaps. R&D topics were then formulated and prioritized.

The workshop addressed:

(1) The history, incidence, and registration of cold-weather injuries during military operations, and the physiological basis of cold-weather injuries, and
(2) Human biological responses to cold, including behavior, neuromuscular function, and dexterity, and current cold-weather exposure limits and standards for protection, and
(3) Technological, training, protection, subsistence and medical treatment approaches to mitigate the operational challenges and performance decrements that plague cold-weather operations.

The combination of experienced NATO military personnel in cold-weather operations with scientific subject matter experts on human physiological and behavioral responses to cold-weather was the single most important factor for the success of this Workshop. The idea to use real-world experiences to guide scientific discussions for future R&D created an environment that inspired realistic collective thinking about the future challenges and approaches to improve cold-weather operations and Warfighter safety.

The capability gaps identified and deserving of NATO R&D exploration were:

(1) Peripheral cold-weather injuries continue to plague Warfighters. A comprehensive review of the peer-reviewed, scientific literature should be performed to determine the efficacy of pharmacological, nutritional, and technological approaches to sustain peripheral blood flow during cold-weather.
(2) Explore the interactive effects of clothing and equipment on physiological and behavioral responses to cold to determine minimal usage standards that achieve interoperability, optimize thermoregulation, mitigate cold-weather injury risk, and sustain performance.
(3) Establishment of a normative database that documents and allows study of longitudinal cold-weather responses of different demographic populations of NATO service personnel.
(4) Development of: a) a standardized, interoperable reporting tool for use by medical treatment personnel to document cold-weather injuries; b) first responder medical treatment policy for cold-weather injuries and c) a military leadership decision aid to assist with risk management during cold-weather operations.
(5) Examine current NATO cold-weather field-feeding policies, procedures, rations and equipment in order to identify new ways to optimize field-feeding during cold-weather training and operations. Organizing an exploratory group to evaluate the need for a NATO standardization agreement (STANAG) for cold-weather field-feeding was discussed.

1. INTRODUCTION

1.1 Purpose and Scope

Military operations are performed in climatic environments ranging from extreme hot (40°C) to extreme cold (-40°C) conditions. Work has recently been focused on optimizing operational effectiveness and Warfighter performance in hot environments (e.g., Iraq, Afghanistan), with much less effort directed at persistent issues associated with operating in the cold. However, given that the next military conflict may very well involve deployments to countries with cold and snow it is important that Warfighters can operate effectively and safely in cold-weather conditions. Studies performed within the NATO HFM RTG187 identified that thermal management capabilities are not fully utilized by NATO force military leaders and gaps in education and knowledge exist regarding thermal illness/injury susceptibility, early diagnosis and treatment in cold environments. NATO HFM168 identified that R&D must address combat clothing, testing and classification of clothing, treatment of cold-weather injuries and hypothermia, nutrition, differences amongst sexes and races, and cold water survival strategies and challenges for the soldier such as weapons handling. NATO HFM RTG 154 reviewed nutritional requirements for NATO general purpose individual combat rations, but did not address requirements for special purpose rations such as rations for use during extreme cold operations. This Workshop aimed to further the results obtained in RTG187 and RSY168 by identifying specific persisting problems and recommending future R&D to protect the Warfighter in the extreme cold.

The objectives of this Workshop were:

(1) To define successful approaches for retaining NATO Warfighter performance in cold extreme environments, and

(2) To identify human factors-related limitations and constraints on Warfighter performance during NATO cold-weather operations, and

(3) To identify strategies to minimize risk for cold-weather injuries and sustain NATO operational effectiveness, and

(4) To identify future R&D to address capability gaps.

1.2 Workshop Program & Participation

The HFM-255 Workshop on “Cold Extreme Environmental Operations – Optimizing Warfighter Performance in Extreme Cold” was held at (FFI) in Kjeller, NOR, from Tuesday, 28 October through Thursday, 30 October 2014.” The technical part of the program consisted of 4 keynote presentations and 8 mini-symposia, which were primarily presented by military personnel from multiple NATO countries with extensive experience operating in cold-weather extremes. Moderated round table discussions were held at the conclusion of days 1 and 2 to stimulate interaction between the scientists and NATO military personnel. A final discussion moderated by the Technical Evaluator was held on the final day of the Workshop to capture the lessons learned and establish a consensus for future NATO R&D activities specific to cold-weather operations. This discussion is the basis for this report. The final Workshop announcement and program are provided in Appendices A and B. About 40 individuals from a range of NATO and PfP nations and affiliations participated in the Workshop.

2. OBSERVATIONS

My impressions of the Workshop are presented below.

2.1 Organization

The organizers of this workshop (Drs. Gunderson, Young, Castellani, Blatny, Madslien, Mrs. Teien and Mr. Martini) should be commended for creating a focused and collegial atmosphere, which were essential towards achieving the Workshop objectives. Attendees and speakers included senior scientists from academia and military institutes, physicians, industry leaders, and, importantly, the user, which in this case, were experienced cold-weather Warfighters from various NATO and PfP nations. The format of the Workshop was conducive to creative and pragmatic discussion. The round-table discussions were particularly effective, as the moderators navigated through critical discussion issues and spurred the generation of new ideas by asking targeted questions. A unique, and particularly effective, facet of this Workshop was the successful execution of an operationally relevant meeting focused on the needs of the Warfighter without allowing the meeting to evolve into a purely academic exercise. As a result, capability gaps were identified and R&D priorities were established which, if executed, are likely to provide tangible benefits for NATO forces operating in cold-weather extremes.

2.2 Strengths and Limitations of the Workshop

The objectives and structure of the Workshop were clearly articulated. Each day began with welcoming and administrative remarks followed by Keynote presentations. The content of these presentations ranged from a historical perspective of cold-weather military operations, with experiences and lessons learned, to human physiological and psychological responses to cold and their effects on injury risk and operational performance. A contemporary analysis of training optimization for cold-weather operations and a prioritization of Warfighter capability gaps was also presented by NATO forces Commanders from SWE, NOR, and USA. Mini-symposia were focused and shorter in duration and included presentations on cold-weather field-feeding, protective clothing and equipment, neuromuscular function and dexterity, and the impacts of cold-weather extremes on medical support of military operations. Moderated, round-table discussions concluded each day of the Workshop.

The strengths of this Workshop included the location and hospitality of the host nation (NOR), and the organizing committee's identification of appropriate and effective topical area speakers. The presentation by CWO Scott (Northern Warfare Training Center, US Army, Alaska) regarding field feeding during cold-weather operations is an excellent example of matching the appropriate speaker to a topic. He identified critical challenges that have increased injury prevalence and limited operational effectiveness during cold-weather field feeding operations (carbon monoxide poisoning, falls, inability to safely operate equipment, such as mobile kitchens and potable water systems). The scientific community, in general, is not familiar with the realities of military operations. Such discussions provided the necessary operationally relevant information for the attending scientists to discuss new R&D.

Although the Workshop was overall a success, there were limitations. Mainly, not all of the presentations met the intended objective set by the organizing committee. For example, the historical brief was primarily scientific and not what the organizing committee had intended it to be. Behavioral responses to cold-weather extremes were also not adequately discussed and training for optimized winter warfare was not presented in sufficient detail. Perhaps greater oversight during the production of the presentations by the organizing committee (or an independent review board) would have ensured that the topics identified as priorities were discussed appropriately. Budget may also have constrained the overall effectiveness of

some presentations, as many top tier scientists who could have been invited (and some were) would not consider participating without remuneration for travel and participation. Future NATO Workshops should be provided a larger working budget for support of participants.

Despite these limitations the Workshop was productive. Several critical areas for future R&D were identified and are discussed in greater detail below.

3. IDENTIFIED RESEARCH GAPS

3.1 Maintaining peripheral blood flow in the cold

The pathophysiology of cold-weather injuries, particularly non-freezing cold-weather injuries, caused, in part, by vasoconstriction and concomitant diminished peripheral blood flow, was discussed in detail by the Keynote speakers on day 1 of the Workshop. Dr. Tipton discussed the pathophysiology of non-freezing cold-weather injuries and presented data to suggest that cold exposure diminishes nitric oxide production and augments vascular smooth muscle contractility resulting in increased vasoconstriction, particularly in the fingertips. Dr. Giesbrecht suggested that cold-weather injury risk can be mitigated by sustained exposure to cold to reduce vasoconstriction in favor of vasodilation. The validity of this idea (cold-induced vasodilatation as a trainable process) was heavily debated with discussion regarding whether this response represents acclimation or training, per se. Other factors introduced as potential mitigation strategies against non-freezing cold-weather injury, included pharmacologic, nutritional, and technological approaches to maintain peripheral blood flow. Nutrients such as niacin and arginine, and pharmacologic cyclooxygenase inhibitors, were discussed as possible non-invasive approaches to mitigate risk and maintain peripheral blood flow, although the magnitude that these approaches would augment vasodilation is unknown. Improvements in clothing were also discussed.

The panel strongly recommended that a contemporary and comprehensive analysis of the scientific literature be performed by experts in the field to identify approaches to maintain peripheral blood flow during cold-weather. The end-product of this analysis would be a peer-reviewed publication that identifies candidate strategies to mitigate peripheral cold injury risk.

3.2 Injury risk mitigation and performance sustainment strategies

Several strategies to mitigate cold-weather injury risk and sustain performance in the cold were discussed by the panel. Some were rather simplistic and intuitive and some are currently in use, like improved education and awareness of exposure limits. Performing exercise to increase core temperature before cold exposure and limiting periods of low activity or rest during cold-weather operations were also highlighted as simple risk mitigation strategies in the cold to prevent hypothermia. Other ideas would require additional R&D in laboratory and operational settings. In this category were studies on novel cold-weather clothing concepts for sustaining warmth and assisting performance. More specifically, occupational tasks that require Warfighters to work with their hands require protection that allows for the greatest level of dexterity while providing the adequate level of injury prevention. Other high-tech solutions that would allow for cold-weather clothing to be modified, adjusted, and layered on-the-go and based on workload during training and operations were identified as R&D needs. Refinement of cold-weather exposure tables and standards to include the points at which dexterity and operational effectiveness are

impacted by variations in cold-weather extremes was also identified for R&D.

3.3 Longitudinal normative data

There was considerable discussion regarding pre-screening/predictive tools to identify individuals with heightened cold-weather injury susceptibility. Infrared thermography and cold-water finger immersion were suggested as potential pre-screening tools. Others suggested more sophisticated approaches including behavioral and genetic testing to predict cold-weather susceptibility. The military leadership in attendance appreciated this concept but expressed concern over the utility of such assessments when applied to larger, operational scale (company, battalion, brigade, etc.). Some leaders stated desire for more simplistic ways to identify those prone to injury and ways to mitigate their risk; including pre-screening for a medical history of cold-weather injuries.

Dr. Castellani presented US Army data suggesting that military occupation, home of record geographical location and, particularly, race influence susceptibility and incidence of cold-weather injuries. The data, which were generated using military hospital records and medical surveillance tools, indicate that the prevalence of injuries is highest during organized military training. There is limited data on cold-weather injuries during actual combat operations in theatre or risk over time. Thus, it is difficult to determine the impact of these potential predictive factors on injury susceptibility in actual combat operations and over the course of a career. There was consensus among the participants that longitudinal studies were needed to determine whether race (in particular), military occupation, and home of record are predictors of cold-weather injury risk, and other individual risk factors over the course of a military career. It was acknowledged that such studies are logistically challenging, lengthy, and costly. Another limitation is the lack of normative data in similar demographical populations for proper comparison. Several members of the HFM panel suggested a need to explore financial and logistical mechanisms to conduct collaborative large-scale longitudinal studies between NATO countries to establish normative data sets describing cold-weather injuries. Executing these studies, while also conducting additional studies to further our understanding of the various military-specific factors (e.g., combat deployment vs. training) associated with heightened cold-weather injury risk, would allow for more targeted interventions and approaches to reduce the incidence of injury.

3.4 Cold-weather injury reporting, medical support and leadership risk mitigation aid

Interestingly, there is no standardized cold-weather injury reporting and first-responder medical support system for use by NATO forces. A standardized cold-weather assessment tool and injury reporting and registry system was repeatedly discussed as an imminent need for cold-weather operations. Re-evaluating first responder medical care and determining inconsistences between assessment and reporting strategies across NATO countries was deemed critical in an effort to standardize care. Developing an international registry for cold-weather reporting and injury incidence would provide valuable information to characterize the extent to which cold-weather injuries and risk mitigation strategies modulate operational performance.

The concept of developing a user-friendly decision aid to identify Warfighters prone to cold-weather injuries and stratify the severity of risk was repeatedly promoted by LTC Adams from the Northern Warfare Training Center, US Army, Alaska. Such a system should use mobile technology, and possess tools to mitigate risk and maintain operational effectiveness during cold-weather operations (e.g., clothing needed based on environment and mission). The panel agreed

with LTC Adams and the other military leaders present, and given the likelihood that NATO forces will act jointly in cold-weather environments in future operations, felt risk identification and mitigation strategies should be an immediate R&D effort, and the tool should be designed for interoperability across NATO and PfP nations.

3.5 Optimized field feeding in the cold

The implications of nutrition and challenges of field feeding are often overlooked when planning for operational effectiveness during cold-weather operations. The detrimental impact of inadequate nutrition on physiological status, physical and behavioral performance during military operations is well described. Several NATO countries have a R&D initiative to improve field feeding policies, technologies, and combat ration development. For example, technological advances such as the containerized kitchen, field sanitation center, potable water trailer, and multi-temperature refrigerated containerized system are improving field feeding capabilities. Despite the advances in technology and ration development, however; logistical challenges and environmental obstacles persist that diminish the effectiveness of operational field feeding during cold-weather operations.

Challenges to optimal field feeding were summarized by CWO Scott. Surprisingly, US military units have difficulties procuring the appropriate cold-weather ration during training and operations in cold-weather conditions (i.e. the most readily available rations are not compatible with extreme cold). CWO Scott identified operator safety during field feeding as a persistent problem, particularly slips and falls by both diners and food service personnel. These occur because large-scale food preparation systems produce steam and the condensation leads to freezing and ice formation on the floors and stairs of the mobile kitchen units. Securing and transporting mobile equipment is also difficult in the cold. Perhaps the most dangerous and life-threatening safety concern expressed by the CWO (and others) was incidence of carbon monoxide poisoning inside the enclosed food service areas.

A separate topic of interest was individualized nutrition. One size fits all prescriptions for nutrition requirements ignore the fact that nutritional demands created by the environmental and operational situation are likely different Soldier to Soldier. Although this concept is, to an extent, academic given the limited feasibility of designing individualized feeding policies and combat rations on an operational scale, the panel agreed that this concept warrants future R&D efforts or, at the very least, a follow-on cold-weather field feeding and combat ration NATO RTG.

These topics generated significant discussion and presented a logical opportunity for an exploratory NATO panel to determine optimization of field feeding policy.

4. CONCLUSIONS & RECOMMENDATIONS

In conclusion, the HFM-255 Workshop titled “Cold Extreme Environmental Operations – Optimizing Warfighter Performance in Extreme Cold” was a well-organized and productive meeting. The objectives of the workshop were met, and despite weaknesses in some presentations, the persisting challenges of cold-weather operations were identified. The panel stressed the need for R&D efforts that provide tangible and pragmatic benefits to the Warfighter and mitigate risk and sustain operational effectiveness. Five thematic areas for R&D were identified including: 1) a systematic evaluation of pharmacological, nutritional, and technological approaches to maintain peripheral blood flow, 2) re-evaluation of cold-weather exposure limits and development of clothing and equipment that provide protection and sustain

performance, 3) identify means to conduct longitudinal cold-weather exposure studies to establish normative data and populations at risk, 4) development of tools for standardized cold-weather injury reporting, first responder medical treatment of cold-weather injuries, and leadership decision aids to mitigate risk during cold-weather operations, and 5) explore ways to optimize cold-weather field-feeding. The panel urges NATO HFM management to support and encourage the establishment of follow-on NATO sponsored activities organized to address these identified R&D needs.

APPENDIX A: ORIGINAL WORKSHOP MEETING ANNOUNCEMENT TEXT

COLD EXTREME ENVIRONMENTAL OPERATIONS
OPTIMIZING WARFIGHTER PERFORMANCE IN THE COLD

Military operations are performed in temperatures ranging from extreme hot (40°C) to cold (-40°C). Based on possible future operations in arctic environments and environments that may cause non-freezing injuries, increased research and education/training is needed to enhance soldier performance sustainment in cold conditions. Studies performed within the NATO HFM Research Task Group187 recognized that thermal management capabilities are not fully utilized by NATO forces to educate military leaders and that gaps exist regarding thermal illness/injury susceptibility, early diagnosis and treatment in extreme temperatures. NATO HFM Research Symposium 168 identified that future research and development must, among others, address good combat clothing, common testing and evaluation of clothing, treatment of frostbites, addition of minerals /amino acids to nutrition, treatment of hypothermia, cold water survival strategies and challenges for the soldier such as weapons handling. Cold stress is imposed by the combination of environmental, mission, and individual risk factors and may lead to physiological and/or psychological consequences, thereby reducing physical and cognitive soldier's performance capabilities and a decrease in manual dexterity.

The Workshop aims to take further the results obtained in RTG187 and RSY168 to identify needs and recommend future R&D approaches for optimal protection and behavior of the soldier in cold environments, as well as treatment of cold injuries. The objective is to define appropriate measurements/approaches for retaining soldier/human performance in cold extreme. Special attention will be on reducing the main risks for cold injuries and keeping the soldier fit for operational effectiveness. The workshop will also have a focus on identifying future research activities.

APPENDIX B: DETAILED WORKSHOP PROGRAM

Tuesday, 28 October 2014

Cold Weather Injuries: Occurrence, Diagnosis/Registration and Prevention (Session Chair: Per-Kristian Opstad, FFI, NOR)

- 1000-1200 Registration and Reception
- 1200-1215 Welcome and Opening Remarks (Yngvar Gundersen and Janet Blatny, FFI, NOR)
- 1215-1230 Introducing the Workshop (Rear Admiral Jan Sommerfelt-Pettersen, Joint Medical Services, NOR)
- 1230-1315 Keynote Speaker 1: Hypothermia, Frostbite, Non-Freezing Cold Injuries. Definitions and Mechanisms (Gordon Giesbrecht, University of Manitoba, CAN)
- 1315-1330 Break
- 1330-1415 Keynote Speaker 2: Cold Weather Military Operations. Experiences from the Past Lessons for the Present (Mike Tipton, University of Portsmouth, GBR)
- 1415-1515 Incidences of Cold Weather Injuries Occurring in NATO Military Forces from an Operative and Scientific Perspective (Harald Østby, Norwegian School of Winter Warfare, NOR and John Castellani, USARIEM, USA)
- 1515-1530 Break
- 1530-1700 Moderated Round Table Discussion to Identify Difficulties of Registration of CWI, Primary Injury Treatment, Modifiable Risk Factors and Strategies for Injury Prevention During NATO Cold Weather Operations (Moderator: John Castellani, USARIEM, USA)

Wednesday, 29 October 2014

Warfighter Performance during Cold Weather Operations

- 0900-0915 Administrative remarks

Human Biological Responses to Cold Exposure (Session Chair: Andrew Young, USARIEM, USA)

- 0915-1000 Keynote Speaker 3: Cold Weather Physiology. Consequences for Performance (John Castellani, USARIEM, USA)
- 1000-1030 Cold and Multifactorial Stress. Behavioral Aspects (Per-Kristian Opstad, FFI, NOR)
- 1030-1040 Break
- 1040-1110 Cold Exposure and Neuromuscular Function. Effects on Task Performance and Manual Dexterity (Hein Daanen, TNO, NLD)
- 1110-1140 Human Exposure Limits and Protection Standards for Cold Weather (Hannu Rintamäki,

University of Oulu, FIN)

- 1145-1245 Lunch

Warfighter Performance, Limitations and Training for Mastering Cold Challenges (Session Chair: Svein Martini, FFI, NOR)

- 1245-1330 Keynote speaker 4: Training for Optimizing Winter Warfare Skills (Mats Forsmann, SWECWO, SWE)
- 1330-1400 Training Individual Warfighters to Function and Survive During Military Operations in Extreme Cold Conditions (Jørgen Eriksen, Norwegian School of Sports Sciences, NOR)
- 1400-1430 Impact of Cold Weather on Medical Support of Military Operations (Erik Fosse, University of Oslo, NOR)
- 1430-1445 Break
- 1445-1515 Cold-Protective Clothing and Equipment. Development and Operative Impact (Walter Øverland, NFM Holding, NOR)
- 1515-1545 Impact of Cold Weather on Field Feeding and Subsistence during Military Operations (CW Elbert Scott, US Army, Alaska, USA)
- 1545-1700 Operative Leaders meet the scientists. Moderated round table discussion to identify mission critical military task degradation during cold weather operations and strategies for mitigation (participants from USA, Canada, Scandinavia, UK, and Continental Europe, Moderator: Andrew Young, USARIEM, USA)

Thursday, 30 October 2014

Workshop Summary: Discussion, Draft Report Preparation and Path Forward (Session Chair: John Castellani, USARIEM, USA)

- 0900-0910 Administrative remarks
- 0910-0955 Near and Long-Term Prioritizations of Research and Capability Gaps. A Synopsis of the Key Points from the Previous Speeches (LTC Mark Adams, Northern Warfare Training Center, Alaska, USA)
- 0955-1100 Final Discussion and Consensus for Final Report (Moderators: Mike Tipton, University of Portsmouth, GBR /Stefan Pasiakos, USARIEM, USA)
- 1100-1130 Closing remarks (Yngvar Gundersen)