WILDERNESS & ENVIRONMENTAL MEDICINE (2018) **29,** 266–274

REVIEW ARTICLE

Challenges of Military Health Service Support in Mountain Warfare

Raimund Lechner, MD; Thomas Küpper, MD, PhD; Markus Tannheimer, MD

From the Department of Anesthesiology and Intensive Care, Bundeswehr Hospital Ulm, Ulm, Germany (Dr Lechner); the Institute of Occupational and Social Medicine, RWTH Aachen University, Aachen, Germany (Dr Küpper); the Medical Commission of the Union Internationale des Associations d'Alpinisme (UIAA MedCom), Bern, Switzerland (Dr Küpper); and the University Hospital Ulm, Department of Sports and Rehabilitation Medicine, Ulm, Germany (Dr Tannheimer).

Introduction—History is full of examples of the influence of the mountain environment on warfare. The aim of this article is to identify the main environmental hazards and summarize countermeasures to mitigate the impact of this unique environment.

Methods—A selective PubMed and Internet search was conducted. Additionally, we searched bibliographies for useful supplemental literature and included the recommendations of the leading mountain medicine and wilderness medicine societies.

Results—A definition of mountain warfare mainly derived from environmental influences on body functions is introduced to help identify the main environmental hazards. Cold, rugged terrain, hypoxic exposure, and often a combination and mutual aggravation of these factors are the most important environmental factors of mountain environment. Underestimating this environmental influence has decreased combat strength and caused thousands of casualties during past conflicts. Some marked differences between military and civilian mountaineering further complicate mission planning and operational sustainability.

Conclusions—To overcome the restrictions of mountain environments, proper planning and preparation, including sustained mountain mobility training, in-depth mountain medicine training with a special emphasize on prolonged field care, knowledge of acclimatization strategies, adapted time calculations, mountain-specific equipment, air rescue strategies and makeshift evacuation strategies, and thorough personnel selection, are vital to guarantee the best possible medical support. The specifics of managing risks in mountain environments are also critical for civilian rescue missions and humanitarian aid.

Keywords: history, acute mountain sickness, medical support, acclimatization, preventive measure

Introduction

It is not possible to identify a specific event as the starting point of mountain warfare. However, the challenges of mountain warfare are not a modern phenomenon. As early as 500 BC, Sun Tzu expressed considerable respect for mountainous terrain in relation to war.[1] Many famous military leaders such as Alexander the Great, Hannibal, Napoleon, José de San Martín, and Simón Bolívar experienced the hardships of mountainous terrain during their campaigns.[2,3] Despite sophisticated technology and growing knowledge, mountainous environments still influenced military campaigns in the 20th century—for example, during World War I and the ongoing Indian-Sino-Pakistan border conflicts.[2–5] Currently, the ongoing war against terrorism has brought mountain warfare once more into the focus of military planning. According to the North Atlantic Treaty Organization, mountainous terrain provides sanctuary for hostile forces, particularly terrorist organizations.[6]

The aim of the present review is to help leaders identify the main environmental hazards by introducing a definition of mountain warfare, understand how mountainous environments affect daily life and warfare, and

Corresponding author: Raimund Lechner, MD, Department of Anesthesiology and Intensive Care, Bundeswehr Hospital Ulm; e-mail: raimundedgarlechner@bundeswehr.org.

Submitted for publication July 2017.

Accepted for publication January 2018.

Presented in part as a lecture at the 8th European Hypoxia Symposium, September 10, 2016, Poljče, Slovenia.

summarize countermeasures to mitigate the impact of mountainous environments.

Methods

A selective PubMed and Internet search was conducted using the keywords (individually and in any combination) "military," "history," "mountain warfare," and "high altitude." Additionally, we searched bibliographies for useful supplemental literature and included the recommendations of the leading mountain medicine and wilderness medicine societies.

Definition of mountain warfare

We have developed a definition of mountain warfare, adopted from Pierce, that will assist military leaders in identifying environmentally challenging battle spaces in mountain areas or similar regions (Table 1).[7] Mountain warfare should be regarded as fighting in terrain with elevation differentials of at least 300 m *and* additional characteristics, such as complex and rugged terrain, low temperatures, or challenging altitude. To emphasize the challenges of the particular terrain, the terminology used should include all characteristic fields (eg, high-altitude, cold-weather, rugged-terrain mountain warfare). Warfare with any elevation differentials but no additional characteristics should be referred to as normal warfare because no special equipment or training is needed, and every soldier should be able to deal with that topography. Naturally, gray zones and transition zones exist.

By comparison, severely compartmented terrain as well as snow and low temperatures do require special equipment and skills. We suggest considering these types as rugged-terrain warfare and cold-weather warfare to clearly emphasize the tactical, behavioral, and logistic challenges.

Arctic warfare and (high) altitude warfare are 2 extreme variations of environmentally challenging warfare. We define arctic warfare as fighting with constant windchill factor (not air) temperatures of –30°C. In such conditions, there is an increased risk of frostbite in exposed facial skin within 10 to 30 min for most people.[8] An environment of this kind cannot be compared with a normal winter. Extra training and equipment are essential.

Above 2500 m, there is a risk of altitude sickness for nonacclimatized individuals.[9] Above 5500 m, no permanent human habitation is possible.[10] However, the effects of hypobaric hypoxia can already be observed in the form of a reduction of maximum aerobic capacity and endurance even at 1500 m.[11] We have established the categories "moderate-altitude," "high-altitude," and "extreme-altitude" warfare to give consideration to the major influence of altitude on warfare.

Health service support in mountain warfare and lessons from the past

Much information exists on mountain warfare in general, but publications which cover the health service support requirements are very limited.[5] Until World War I specialized mountain warfare units were rare.[12] Therefore, no specialized mountain warfare health support units existed. During World War I, the German Empire and Austria-Hungary were still not prepared for mountain warfare from a medical point of view, despite the foundation of mountain warfare units. Also, the Wehrmacht mostly had to improvise when evacuating casualties during mountain warfare, despite intensive progress in technical mountain rescue and the purchase of special medical equipment suitable for mountain operations in the 1930s.[5] Many additional casualties

Table 1. Different types of warfare

	Type of Warfare	Definition
1	Mountain warfare	**Elevation differentials** exceeding 300 m *in addition to items **2, 3, 4, 5, 6,** or **7***
2	Rugged-terrain warfare	Severely compartmented or complex **terrain**, with • mean slope angles of 45° *and/or* • difficult terrain (UIAA II[a] or higher)
3	Cold-weather warfare	• Persistent mean snow depths of approximately 50 cm *and/or* • Persistent ambient air temperatures below 0°C
4	Arctic warfare	Persistent ambient **windchill factor temperatures** below –30°C
5	Moderate-altitude warfare	Heights between 1500 m and 2500 m above sea level (**normobaric conditions**)
6	High-altitude warfare	Heights that exceed 2500 m above sea level (**hypobaric hypoxia**)
7	Extreme-altitude warfare	Heights that exceed 5500 m above sea level (**extreme hypobaric hypoxia**)

UIAA, Union International des Associations d'Alpinisme (International Climbing and Mountaineering Federation)

[a] UIAA II requires the movement of one limb at a time and a proper setting of the movements.[51]

Table 2. Casualties from mountainous environment in selected mountain warfare campaigns

Campaign	Casualties from environmental factors	Main environmental factors
Alexander's crossing of Khawak Pass[2]	Up to 50% of fighting forces killed	Hypoxia, cold, malnutrition, avalanches
Alexander's assault of the Sogdian Mountain Citadel[2]	10% of assault force killed	Falls in difficult terrain
Hannibal's crossing of the Alps[2,3,14]	Approximately 50% of fighting forces killed	Falls in snowy terrain, cold, malnutrition
San de Martín's crossing of the Andes[2]	33% of fighting forces and 50% of pack animals killed	Cold, hypoxia, difficult terrain
World War I front line in the Alps[2,5]	Considerably deviating numbers, probably 150 000–180 000 killed, approximately two thirds of casualties due to environmental factors	Hygiene, malnutrition, cold avalanches
Sino-Indian War[2]	More casualties from mountain conditions than from enemy action; up to 20% of Indian forces with AMS of which approximately one third died	Hypoxia, cold
Indian-Pakistan War[4]	90% of the 2000 dead and 12,000 injured Indian soldiers	Hypoxia, cold
Operation Anaconda[20]	15% AMS and 25% orthopedic injuries of coalition casualties	Hypoxia, terrain
Trainings and exercises[14]	10-fold higher compared with same training in non-mountainous terrain	Various reasons

AMS, acute mountain sickness.

occurred due to accidents during the improvised evacuation efforts and the long duration of evacuation.[5]

However, the lessons of history give us some important characteristics of mountain warfare that are essential for health service support (Table 2). As early as 550 AD, Mogul Mirza Mohammed Haidar complained severely about performance decrements, weakness, dyspnea, and hallucinations to the point of death during his campaign on the Tibetan Plateau.[13] However, any incidence of losses due to mountainous environments is difficult to estimate.[5]

Numbers are ideally based on the experiences of past mountain campaigns.[14] Alexander the Great lost half of his fighting men while crossing the Khawak Pass due to a combination of hypoxia, cold, hunger, and dehydration, making this campaign one of the costliest in mountain warfare. During his assault on the Sogdian mountain citadel, approximately 10% of his assault force died due to difficult rock terrain.[2] Also, Hannibal lost roughly 50% of his men while crossing the Alps.[2,3,14] San Martín lost approximately one third of his troops and half of his pack animals during his 3-week crossing of the Andes, and Bolívar also suffered great losses.[2] During World War I, more soldiers died of environmental causes and poor hygiene than because of hostile actions.[2,5]

In addition to the huge losses of men and material, past campaigns are full of examples that illustrate the hardships of mountain warfare. Alexander the Great experienced the importance of adequate nutrition and Hannibal the effect of poor supply lines and casualty handling on strategic decisions.[2,15] During World War I, World War II, the Korean War, the Indian border conflicts, the Falkland War, and Operation Anaconda, the effects of poor equipment and insufficient resupply repeatedly limited combat strength and caused devastating cold injuries because the effects of mountain environments were simply underestimated.[2,5,7,16,17] To summarize, the most frequent causes of morbidity and mortality were cold, terrain, malnutrition, subacute hypoxic exposure, and most often a combination and mutual aggravation of these factors.[18]

Except for the last 50 years, the effects of altitude hypoxia were probably minimal because of acclimatization during the slow advance of the soldiers, especially during Younghusband's campaigns in Tibet and during World War I.[2] In recent decades, however, ever-increasing mobility has led to rapid deployments to high altitudes by vehicles or helicopters (vertical maneuver), emphasizing one aspect of mountain warfare that is of special importance: acute altitude hypoxia.[19]

During the Sino-Indian war, mountain sickness was prevalent in up to 20% in some companies, and one third of the casualties are reported to have died.[2] India suffered 14,000 casualties, 2000 of whom died in the conflict with Pakistan at the Siachen Glacier; 90% are estimated to have died as a result of altitude and

cold.[4] During Operation Anaconda the 274th Forward Surgical Team treated 96 coalition forces casualties, of which 15% suffered from acute mountain sickness (AMS) and 25% from orthopedic injuries that were caused by the rugged terrain.[20] As a general rule derived from training exercises, the number of soldiers who need evacuation has to be calculated more than 10-fold for mountain operations compared with the same maneuvers conducted at low altitude.[14]

However, the most important lesson from the past is that mountain warfare is increasing in frequency.[7] In 2002, 23 of the 27 ongoing armed conflicts in the world were being fought in mountain areas.[18]

Influence of mountains on warfighting

In addition to terrain, it is commonly agreed that extreme temperatures, wind, ultraviolet radiation, and snow and ice, but also wastelands and especially hypoxia make mountain warfare especially difficult.[18] These environmental factors influence the 6 warfighting functions: movement and maneuver, fire, sustainment, intelligence, command and control, and force protection (all preventive measures to minimize the vulnerability of personnel, facilities, and equipment to conserve the force's fighting potential).[7] From a healthcare point of view, movement, logistics, command and control, and force protection are the most significant.

Movement is restricted by cold, snow, wind, terrain, and human performance decrement due to altitude. This is even more significant with regard to casualty evacuations. Helicopters currently facilitate evacuation; however, due to the high operating altitude, poor landing zones, poor visibility, wind, and hostile anti-aircraft defenses, helicopter use is not guaranteed.[7,21] In addition, due to the scarcity of roads, vehicle evacuations cannot be guaranteed either.

Mountain environments hinder logistics simply by restricting movement. Therefore, the delivery of supply goods can be challenging. Additionally, the logistical requirements are far above average, and special mountain equipment may be necessary.[7,10] Furthermore, environmental parameters can alter the operation of (medical) equipment and change maintenance requirements.[14]

Leadership is one of the key factors when conducting operations in a mountainous and cold-weather environment.[2,7] Hydration, nutrition, proper use of cold equipment, and regular buddy checks are key factors for successful health maintenance.[4] Close supervision and strong (self-) discipline are required by everyone. This is aggravated by cognitive impairments at high altitudes, which additionally impair leadership ability.[22]

Table 3. Most common health threats in mountain warfare and their underlying causes

Main underlying factor	Health threat
Low atmospheric pressure/ hypobaric hypoxia	Acute mountain sickness High altitude cerebral edema High altitude pulmonary edema Sleep deprivation Performance decrements Cognitive decrements
Cold, dry air	High altitude pharyngitis
Rugged, steep and exposed topography Rock and ice fall Landslides Avalanches Crevasses	Lightning injury Trauma Suspension trauma
Wide temperature ranges Wind	Freezing cold injury Nonfreezing cold injury Hypothermia Heat injuries
Ultraviolet radiation	Snow blindness Sunburn Sunstroke
Combination of above factors	Constricted hygiene Hypohydration Malnutrition/Hypoglycemia

Adapted and amended.[2,14,21]

The most critical function definitely is medical force protection. Mountains can pose a variety of health threats, most of which increase with altitude (Table 3).[14] Hypobaric hypoxia is unique to mountain environments and is therefore the most distinctive environmental factor.[18] In addition, military personnel are more susceptible than civilian mountaineers to impairments caused by hypobaric hypoxia due to the distinctive differences between military and civilian mountaineering (Table 4).

Military tactics determine military medicine—solutions for an inevitable challenge

Military commanders decide, on the basis of tactical considerations, where and how military operations are conducted. Therefore, military tactics dictate military medicine and the avoidance of healthcare challenges in military mountain operations by avoiding mountain

Table 4. Differences between civilian and military high altitude mountaineering

Objective	Civilian	Military
Preparation time	Long preparation time	Potentially at short notice
Preacclimatization	Freedom of movement	No freedom of movement
Acclimatization	Individual	Team approach
Rate of ascent	Individual	Team approach Tactical requirements Potential helicopter or car usage (vertical maneuver)
Time at maximum altitude	Short (summit)	Potentially long (mission accomplishment)
Abortion criteria	Own choice	Mission accomplishment
Performance required	"Easy going" possible	Full combat strength needed
Equipment	As lightweight as possible	Additional military equipment
Harassments	Nature	Nature and hostile forces
Chain of evacuation	Established in commercial expeditions	Limited

Adapted and amended.[4,19,21]

ranges is not an option. In fact, proper planning and preparation enhance the probability of being able to cope in mountainous environments and of ensuring optimal efficacy of the deployed troops. Several fields of predeployment planning and preparation have to be addressed for mountain warfare (Table 5). Above all, the battle space has to be analyzed according to Table 1, and the main environmental hazards have to be identified.

Preventive measures are intensive mountain mobility training, including physical fitness, rope and climbing techniques, and skiing or snow shoe mobility to mitigate the influence of rugged terrain and snow. Only with high levels of motor skills, proprioception, and body demeanor can high injury rates due to complex terrain be reduced.[20] Behavioral training, experience, and substantial self-discipline are necessary to deal with the harshness of low temperatures. According to estimations, 10 or more years are required to become a truly capable mountain soldier.[21]

Table 5. Summary of preventive measures to mitigate the influence of mountainous environment

Personnel selection
Mountain mobility training
Use of acclimatization protocols
Use of adapted time calculations
Use of pack animals
Providing adequate hydration
Providing carbohydrate rich diet
Providing special mountain equipment
Training in treatment of mountain specific diseases
Training in prolonged field care
Training in air rescue techniques
Training in alternative evacuation techniques

To deal with the challenges of altitude, acclimatization protocols and adapted time calculations are necessary. A mathematical model predicts that the risk of experiencing AMS increases roughly 4.5-fold for every 1000 m increase in altitude, with AMS severity almost doubling every 1000 m.[23] In simpler terms, the incidence of nonacclimatized or poorly acclimatized individuals with severe AMS can be as high as 10% between 2500 and 3000 m with an additional 10% every 500 m.[10] Soldiers affected by AMS or high altitude pulmonary edema or high altitude cerebral edema are "medically non-effective."[14] Data from civilian mountaineering show that if individuals are acutely exposed to an altitude of 4560 m, the prevalence of AMS is approximately 60%.[24–27] However, the prevalence of AMS depends on several factors, with the most important being (pre-) acclimatization, individual susceptibility, altitude, time at altitude, and high (anaerobic) activity.[23,27] Therefore, a reliable prevalence is hard to predict.

To counteract altitude-related performance deficits, acclimatization strategies are necessary. Civilian recommendations state that above 2500 to 3000 m, sleeping altitude should only be increased by 300 to 500 m per night with a rest day every 3 to 4 days. If larger gains are necessary, an additional rest day is strongly recommended.[9,28] Recommendations for military personnel limit the increase of sleeping altitude to 300 m per night from 2400 m onward.[10] However, for tactical and logistical reasons, these rules cannot always be observed, and reactions to hypobaric hypoxia are highly individual.[9] A rule of thumb is that the larger the group and the lower the experience, the more defensive the ascent protocol should be.

In addition to a graded ascent, another solution to reduce the risk of altitude sickness is preacclimatization. The optimal methods for preacclimatization have not been fully determined yet, but in general the degree of acclimatization is proportional to the altitude attained and the duration of exposure.[9,29] Due to the limited data and highly individual reactions to altitude, it is not appropriate to give exact recommendations. A possibility for preacclimatization other than exposure to natural heights is through intermittent hypoxic exposure under hypobaric or normobaric conditions (chambers, tents, or breathing masks), which is practiced extensively by the Indian Armed Forces and increasingly by civilian mountaineers.[4,10,30] Pharmacologic prophylaxis with acetazolamide and/or dexamethasone may be considered as well, especially if the operation does not allow time for proper preacclimatization (eg, rescue mission, quick reaction force).[9,14]

In addition to triggering high altitude illnesses, hypobaric hypoxia reduces maximal aerobic capacity and endurance. Consequently, the time needed to perform (sustained) physical tasks increases with higher altitude. The percentage increase can be estimated with predictive models to determine the duration of the actual task at altitude compared with sea level.[31–33] However, exact adaptations are difficult to predict due to additional factors, such as fitness level, altitude sickness, terrain, weather, additional clothing, and equipment.[10,34]

As a rule of thumb, anaerobic and short-duration activities are less affected than aerobic and long-duration activities.[32] Some tasks with high-energy output will no longer be physically possible due to the altitude-induced performance decrement (10–15% reduction per 1000 m altitude, beginning at 1500 m).[11,14,32,34] In general, adapted planning with an increased amount of time allowed to complete a task, reduced pace or intensity of performed tasks, and/or more and longer breaks are essential.[10,14,34,35] In our opinion, the most pivotal factor for sound leadership in mountain warfare is the military leader's personal experience with mountain environments, especially altitude, which is essential to estimate their impact on military tactics. However, history shows that many leaders considerably underestimate the difficulties of mountain warfare.[19,36]

A further important coping strategy to reduce the impact of high altitude is the use of pack animals for transportation of personnel and material. Because physical exertion is thought to contribute to the severity of high-altitude symptoms, a reduction in physical effort is believed to be beneficial.[10] Additionally, adequate hydration and a carbohydrate-rich diet (approximately 70% carbohydrate content of the diet) with small but frequent ingestion will make food rations more palatable, keep physical performance at the highest level possible for a given altitude, and may reduce altitude sickness susceptibility.[4,10,14]

Furthermore, personnel selection can reduce the risk of medical problems in mountain environments. This applies to combatants as well as noncombatants. A positive history of a previous episode of AMS or cold injury and all medical conditions that affect respiration and oxygen transport should be given special consideration.[14] Several tests exist that support estimation of the individual risk of AMS and/or the degree of acclimatization.[14,37–39] However, it must be pointed out that all these tests have so far shown a limited positive predictive value and should therefore be used conservatively. To date, the most valid data with regard to future altitude tolerance is the individual's altitude history.[40]

Fighting and surviving in mountain terrain requires special equipment.[14] For certain operations, mountaineering and ski equipment is indispensable. Procurement from the civilian marketplace should be advocated by medical personnel if the equipment is not available in the normal military supply chain.[14] Supply and resupply of special medical equipment such as portable hyperbaric chambers; economical inspiration-triggered oxygen systems; oxygen concentrators; medications for typical health problems; and provisions for adequate water, nutrition, and field sanitation are necessary as well.[9,14] Of course, briefing and training in the correct application is a prerequisite.

Current data from high altitude conflicts suggest that high altitude illnesses and cold injuries have a considerable share in preventable deaths as well as disease and nonbattle injuries in mountain operations.[2,4,20] Therefore, surveillance, assessment, implementation, and monitoring of field strategies for all mountain-specific diseases (Table 3) and hygiene, skincare, and maintenance of hydration and nutrition have to be part of regular medical training for mountain operations.[4,14] Because most casualties die before reaching a medical treatment facility, and because trained nonmedical personnel have proven to significantly reduce preventable combat deaths, proper training of medical and nonmedical personnel is required.[14,41,42] High altitude diseases and nonfreezing and freezing cold injuries especially have to be addressed, in accordance with the latest guidelines and international recommendations.[9,28,43–48] Experience from civilian mountain medicine courses shows that a minimum of 2 weeks of intensive training is necessary for medical personnel to achieve basic mountain medicine capability. However, to achieve acceptable mountain mobility, a minimum of 10 weeks of training seems appropriate.[21]

Air rescue should be conducted whenever possible because it is generally the fastest and most gentle possibility of extraction. However, to be proficient in mountain air rescue, special training is imperative for ground and air personnel as well, namely identification of landing zones, special flying, and casualty hoisting and extraction techniques. However, air transportation is often limited by weather conditions, tactical considerations, enemy threat, a lack of landing zones, and altitude-ceiling limitations for many helicopters.[14]

To mitigate the impact of long evacuation times, special emphasis has to be placed on training in prolonged field care. In addition, strategies to improve and speed up evacuations must be developed and trained —for example, technical rope access maneuvers, traditional mountain rescue techniques, ground transportation by pack animals, or simple hand carriage.[14,21,49,50] Close cooperation between medical and nonmedical personnel is essential because all ground evacuation techniques require significant time and personnel.

Finally, history has shown that mountain warfare is conducted in small, rather disconnected units according to the superior tactical plan, because mountain topography limits the ability of large units to maneuver.[7,14] Medical assets have to be configured to support those small elements.[14] Additionally, intensive cross-training in all fields mentioned is required to replace losses and guarantee the sustainability of an operation.

Conclusions

Mountain environments present numerous challenges for military operations with hypobaric hypoxia, cold and rugged terrain being the most critical factors. Underestimating environmental influence has decreased combat strength and caused thousands of casualties in past conflicts. Medical personnel have to know these limitations and their countermeasures to give competent advice to military leaders and guarantee medical support is at its best while also contributing to operational success. Thorough planning and preparation are necessary years before mountain operations are launched to build up a solid mountain competency. The specifics of managing risks in mountain environments are not critical for military operations alone but also for civilian rescue missions and humanitarian assistance.

Author Contributions: Study concept and design (RL, MT); acquisition of the data and literature search (RL, MT, TK); analysis of the data (RL, MT, TK); drafting of the manuscript (RL); critical revision of the manuscript (RL, MT, TK); approval of final manuscript (RL, MT, TK).

Financial/Material Support: None.

Disclosures: None.

References

1. NATO Mountain Warfare Centre of Excellence. General about mountain warfare. In: Blaznik B, ed. *Mountain Warfare within NATO-Initial Study*. Poljče, Slovenia; 2016:6–9.
2. Houston CS. Selected military operations in mountain environments: some medical aspects. In: Pandolf KB, Burr RE, eds. *Medical Aspects of Harsh Environments Volume 2* Washington, DC: Office of the Surgeon General, Department of the Army, USA; 2002:619–43.
3. Paton BC. Cold, casualties, and conquests: the effects of cold on warfare. In: Pandolf KB, Burr RE, eds. *Medical Aspects of Harsh Environments*. Vol 1. Washington, DC: Office of the Surgeon General, Department of the Army, USA; 2001:313–49.
4. Rodway GW, Muza SR. Fighting in thin air: operational wilderness medicine in high Asia. *Wilderness Environ Med.* 2011;22(4):297–303.
5. Müllerschön A. Medical equipment and evacuation during mountain warfare in the First and Second World War [in German]. *Wehrmed Monatsschrift.* 2017;61(2–3):50–4.
6. Task Group HFM-146. Introduction. In: NATO Research and Technology Organisation, *Review of Military Mountain Medicine Technology and Research Barriers* France: Neuilly-sur-Seine Cedex; 2011:1–2.
7. Pierce SW. Mountain and cold weather warfighting: critical capability for the 21st century-a monograph. Kansas, KS; 2008.
8. Castellani JW, Young AJ. Human physiological responses to cold exposure: Acute responses and acclimatization to prolonged exposure. *Auton Neurosci.* 2016;196:63–74.
9. Luks AM, McIntosh SE, Grissom CK, Auerbach PS, Rodway GW, Schoene RB, et al. Wilderness Medical Society practice guidelines for the prevention and treatment of acute altitude illness: 2014 update. *Wilderness Environ Med* 2014;25(4 Suppl):S4–14.
10. Headquarters Department of the Army. TB MED 505: Altitude acclimatization and illness management. Washington, DC: 2013.
11. Küpper T. *Workload and Professional Requirements for Alpine Rescue [Dissertation; in German]* Aachen, Germany: RWTH Aachen University; 2006.
12. Buhrmester HD. The origin of mountain units-a search [in German]. *Gebirgstruppe.* 2016;62(3):36–8.
13. Houston CS. Mountain sickness. *Sci Am.* 1992;267(4):58–62.
14. Rock PB, Iwanyk EJ. Military medical operations in mountain environments. In: Pandolf KB, Burr RE, eds. *Medical Aspects of Harsh Environments*. Vol 2. Washington, DC: Office of the Surgeon General, Department of the Army, USA; 2002:854–69.
15. Delbrück H. *History of the Art of War. Volume I: Warfare in Antiquity. Book V: The Second Punic War. Chapter III: The Strategic Prologue of the War in Retrospect [in German]* Berlin: Georg Stilke Publishing; 1920.
16. Midla GS. Lessons learned: Operation Anaconda. *Mil Med.* 2004;169(10):810–3.

17. Thomas JR, Oakley EHN. Nonfreezing cold injury. In: Pandolf KB, Burr RE, eds. *Medical Aspects of Harsh Environments*. Vol 1. Washington, DC: Office of the Surgeon General, Department of the Army, USA; 2001:467–90.
18. Rock PB. Mountains and military medicine: an overview. In: Pandolf KB, Burr RE, eds. *Medical Aspects of Harsh Environments*. Vol 2. Washington, DC: Office of the Surgeon General, Department of the Army, USA; 2002: 613–9.
19. Tannheimer M. Military missions at high altitudes [in German]. *Alpinmedizinischer Rundbr.* 2012;46(1):8–11.
20. Peoples GE, Gerlinger T, Craig R, Burlingame B. The 274th Forward Surgical Team experience during Operation Enduring Freedom. *Mil Med.* 2005;170(6):451–9.
21. Truesdell AG, Wilson RL. Training for medical support of mountain operations. *Mil Med.* 2006;171(6):463–7.
22. Yan X. Cognitive impairments at high altitudes and adaptation. *High Alt Med Biol.* 2014;15(2):141–5.
23. Beidleman BA, Tighiouart H, Schmid CH, Fulco CS, Muza SR. Predictive models of acute mountain sickness after rapid ascent to various altitudes. *Med Sci Sports Exerc.* 2013;45(4):792–800.
24. Basnyat B, Subedi D, Sleggs J, Lemaster J, Bhasyal G, Aryal B, et al. Disoriented and ataxic pilgrims: An epidemiological study of acute mountain sickness and high-altitude cerebral edema at a sacred lake at 4300 m in the Nepal Himalayas. *Wilderness Environ Med.* 2000;11 (2):89–93.
25. Maggiorini M, Buhler B, Walter M, Oelz O. Prevalence of acute mountain sickness in the Swiss Alps. *BMJ.* 1990;301 (6756):853–5.
26. Graham LE, Basnyat B. Cerebral edema in the Himalayas: too high, too fast!. *Wilderness Environ Med.* 2001; 12(1):62.
27. Schneider M, Bernasch D, Weymann J, Holle R, Bartsch P. Acute mountain sickness: influence of susceptibility, preexposure, and ascent rate. *Med Sci Sports Exerc.* 2002;34(12):1886–91.
28. Küpper T, Gieseler U, Angelini C, Hillebrandt D, Milledge J. Consensus Statement of the UIAA Medical Commission Vol 2: *Emergency Field Management of Acute Mountain Sickness, High Altitude Pulmonary Edema, and High Altitude Cerebral Edema*. 3rd ed. Bern, Switzerland: UIAA, 2012.
29. Muza SR, Beidleman BA, Fulco CS. Altitude preexposure recommendations for inducing acclimatization. *High Alt Med Biol.* 2010;11(2):87–92.
30. Tannheimer M. Intermittent simulated hypoxia for pre-acclimatization. *Sleep Breath.* 2010;14(3):185–6.
31. Péronnet F, Thibault G, Cousineau DL. A theoretical analysis of the effect of altitude on running performance. *J Appl Physiol (1985)* 1991;70(1):399–404.
32. Fulco CS, Rock PB, Cymerman A. Maximal and submaximal exercise performance at altitude. *Aviat Space Env Med* 1998;69(8):793–801.
33. Beidleman BA, Fulco CS, Buller MJ, Andrew SP, Staab JE, Muza SR. Quantitative model of sustained physical task duration at varying altitudes. *Med Sci Sports Exerc.* 2016;48(2):323–30.
34. Fulco CS, Cymerman A. Physical performance at varying terrestrial altitudes. In: Pandolf KB, Burr RE, eds. *Medical Aspects of Harsh Environments*. Vol 2. Washington, DC: Office of the Surgeon General, Department of the Army, USA; 2002:689–724.
35. Chatterjee T, Bhattacharyya D, Pramanik A, Pal M, Majumdar D, Majumdar D. Soldiers' load carriage performance in high mountains: A physiological study. *Mil Med Res.* 2017;4:6.
36. Naylor S. *Not a Good Day to Die: The Untold Story of Operation Anaconda*. New York, NY: Berkley Books; 2005.
37. Canouï-Poitrine F, Veerabudun K, Larmignat P, Letournel M, Bastuji-Garin S, Richalet JP. Risk prediction score for severe high altitude illness: A cohort study. *PLoS ONE.* 2014;9(7):e100642.
38. Tannheimer M, Albertini N, Ulmer HV, Thomas A, Engelhardt M, Schmidt R. Testing individual risk of acute mountain sickness at greater altitudes. *Mil Med.* 2009; 174(4):363–9.
39. Tannheimer M, Buzzelli MD, Albertini N, Lechner R, Ulmer HV, Engelhardt M. Improvement in altitude performance test after further acclimatization in pre-acclimatized soldiers. *Mil Med.* 2013;178(5):507–10.
40. Bärtsch P, Grunig E, Hohenhaus E, Dehnert C. Assessment of high altitude tolerance in healthy individuals. *High Alt Med Biol.* 2001;2(2):287–96.
41. Kotwal RS, Montgomery HR, Kotwal BM, Champion HR, Butler FK Jr, Mabry RL, et al. Eliminating preventable death on the battlefield. *Arch Surg Chic Ill. 1960* 2011;146 (12):1350–8.
42. Eastridge BJ, Mabry RL, Seguin P, Cantrell J, Tops T, Uribe P, et al. Death on the battlefield (2001–2011): implications for the future of combat casualty care. *J Trauma Acute Care Surg.* 2012;73:S431–7.
43. Zafren K, Giesbrecht GG, Danzl DF, Brugger H, Sagalyn EB, Walpoth B, et al. Wilderness Medical Society practice guidelines for the out-of-hospital evaluation and treatment of accidental hypothermia. *Wilderness Environ Med.* 2014;25(4):425–45.
44. Paal P, Gordon L, Strapazzon G, Brodmann Maeder M, Brodmann Maeder, Putzer G, Walpoth B, et al. Accidental hypothermia–an update: the content of this review is endorsed by the International Commission for Mountain Emergency Medicine (ICAR MEDCOM). *Scand J Trauma Resusc Emerg Med.* 2016;24:111.
45. McIntosh SE, Opacic M, Freer L, Grissom CK, Auerbach PS, Rodway GW, et al. Wilderness Medical Society practice guidelines for the prevention and treatment of frostbite: 2014 update. *Wilderness Environ Med.* 2014;25 (4 Suppl):S43–54.
46. Sachs C, Lehnhardt M, Daigeler A, Goertz O. The triaging and treatment of cold-induced injuries. *Dtsch Aerzteblatt Online.* 2015:741–8.
47. Donegani E, Paal P, Küpper T, Hefti U, Basnyat B, Carceller A, et al. Drug use and misuse in the mountains: a UIAA

MedCom Consensus Guide for medical professionals. *High Alt Med Biol.* 2016;17(3):157–84.
48. Küpper T, Gieseler U, Milledge J. Consensus Statement of the UIAA Medical Commission Vol 3: Portable Hyperbaric Chambers. 3rd ed. Bern, Switzerland: UIAA, 2012.
49. Mountain warfare. *J R Army Med Corps* 1951;96(6):391–3.
50. Tannheimer M. Craniocerebral injury during expedition climbing. *Medicina Sportiva.* 2014;18(3):120.
51. International Climbing and Mountaineering Federation. UIAA grades for rock climbing. Available at: http://theuiaa.org/mountaineering/uiaa-grades-for-rock-climbing/. Accessed December 14, 2016.