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MEDICAL SUPPORT IN MOUNTAIN WARFARE

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Federal Armed Forces of Germany, Mountain Infantry Brigade, Medical Advisor



BUNDESWEHR

Stand: 26.09.2025

OVERVIEW

-  mountain warfare
-  historical aspects
-  future perspective
-  23 mountain infantry brigade
-  **medical support**


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mountain warfare



MOUNTAIN WARFARE

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 NATO STANDARD
 ATP-3.2.1.3
 CONDUCT OF LAND TACTICAL
 OPERATIONS IN MOUNTAINOUS
 ENVIRONMENT
 Edition A, Version 1
 APRIL 2024

 NORTH ATLANTIC TREATY ORGANIZATION
 ALLIED TACTICAL PUBLICATION
 Published by the
 NATO STANDARDIZATION OFFICE (NSO)
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“Military tactical activities in this environment are decisively influenced by the (often fast changing) forces of nature, the given **relief**, **elevation** and the **climatic conditions**.”





MOUNTAIN WARFARE

Table 1. Different types of warfare

	Type of Warfare	Definition
1	Mountain warfare	Elevation differentials exceeding 300 m <i>in addition to items 2, 3, 4, 5, 6, or 7</i>
2	Rugged-terrain warfare	Severely compartmented or complex terrain , with <ul style="list-style-type: none"> • mean slope angles of 45° <i>and/or</i> • difficult terrain (UIAA II^a or higher)
3	Cold-weather warfare	<ul style="list-style-type: none"> • Persistent mean snow depths of approximately 50 cm <i>and/or</i> • 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



Lechner, Küpper, Tannheimer. Challenges of Military Health Service Support in Mountain Warfare. Wilderness Environ Med 2018;29, 266–274



historical aspects



MOUNTAIN WARFARE

Alexander the Great crossed the Hindu Kush via the Khawak Pass in the spring of 329 BC



<https://warhistory.org/@msw/article/alexander-the-great-and-the-rule-of-the-macedonians-greco-bactrian-rule-in-afghanistan>



Tomáš Nečas - Eigenes Werk, CC BY 3.0,
<https://commons.wikimedia.org/w/index.php?curid=3472311>



MOUNTAIN WARFARE

- at the beginning of the 19th century, some nations recognized the need for mountain troops
 - 1872 commissioning of Italian *Alpini*
 - 1914 commissioning of *Bayerische Schneeschuhabtaillon*

<https://www.vestes-bellica.com/de/schwerpunkte/erster-weltkrieg/gebirgstruppen-im-ersten-weltkrieg>



Lechner, Staps, Hossfeld, Tannheimer. Medical Aspects of Mountain Warfare - Teaching of the Past. WMM 2021; 65(1), 2–12



MOUNTAIN WARFARE



- Austrian battery at Sextner Rotwand



Matthias Egger

- the highest gun of World War I, on a mountain peak in the Ortler Mountains at 3,850 meters

https://de.wikipedia.org/wiki/Gebirgskrieg_1915%E2%80%931918

- around 180,000 soldiers fell on the Alpine front in the Mountain War (1915–1918)
 - one-third due to natural causes such as cold, rockfalls or avalanches



future aspects

MOUNTAIN WARFARE

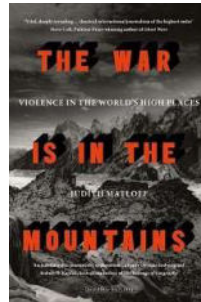
- ongoing conflicts



https://upload.wikimedia.org/wikipedia/commons/thumb/6/62/Kaschmir_umstrittene_Gebiete.svg/1280px-Kaschmir_umstrittene_Gebiete.svg.png



<https://smallwarsjournal.com/2025/06/03/mountain-warfare-fighting-the-mountain-to-fight-in-the-mountains/>



https://www.ukclimbing.com/articles/features/the_war_is_in_the_mountains-10318

MOUNTAIN WARFARE

- future conflicts



https://de.m.wikipedia.org/wiki/Liste_der_gr%C3%B6%C3%9Ften_Gebirge_der_Erde



The lessons learned from recent conflicts have highlighted the enduring relevance of mountain warfare.

Control of mountainous regions remains vital in many geopolitical contexts, particularly where these areas serve as natural barriers or hold valuable resources.

Col Leon Holc, Director of NATO Mountain Warfare Centre Of Excellence. Future Operating Environment. In: Congress Book to the 6th NATO Mountain Warfare Congress. NATO Mountain Warfare Centre of Excellence, Slovenia 2024





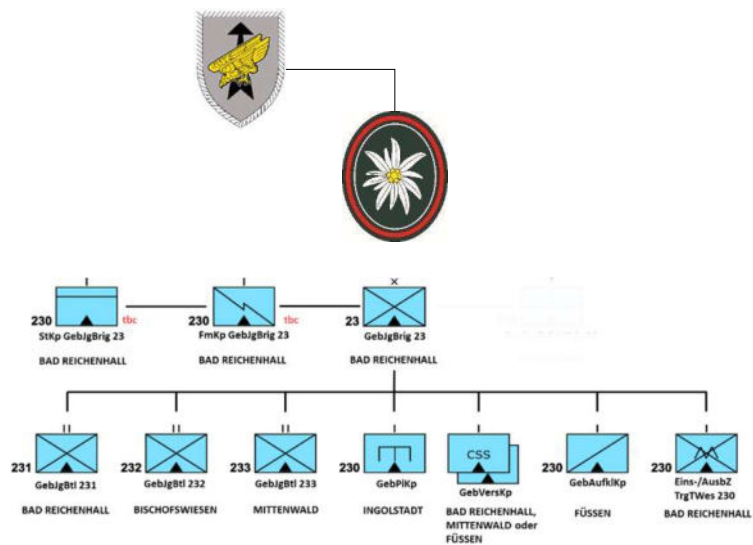
23 mountain infantry brigade

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23 MTN INF BDE



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23 MNT INF BDE

- is a highly mobile light and specialised infantry brigade that can be flexibly and **rapidly deployed (also by air) within the scope of national/collective defense, international crisis management and military evacuation** for German nationals abroad
- can be employed as a brigade with organic enabler, can sustain itself and comprises air assault capabilities
- is able to exercise command and control of multinational formations as lead brigade and act as framework brigade



23 MTN INF BDE



Combat at extremely cold conditions and in extreme climate zones, in difficult and extreme terrain, especially in the mountains and areas of great altitude differences as well as in urban areas.





medical support

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3.4.4 MILITARY MEDICAL CARE IN M

1. Mountains can pose a variety of health threats. Hypobaric hypoxia is a relevant feature in mountainous environments and in combination with other conditions it requires comprehensive and permanent force health protection.
2. Military Medical personnel in MW must focus on care under extremes, including difficult mountainous terrain, high altitude. These conditions put strain and harm on the battle worthiness and tactical elements.
3. In particular, high altitude effects must be very severely considered from tactical and the medical points of view. The rapid deployment of troops to high mountainous environments minimizes their physical and mental performance of soldiers' health. It is highly recommended that physical and mental performance of soldiers who have mountainous environments is maximized by proper preparation. Unfortunately, operational scenarios often limit the time available for preparation.
4. In addition to the classical feature of hypobaric hypoxia (low atmospheric pressure, factors such as rugged terrain, extreme solar radiation, wastelands frequently covered in snow and ice, threats for non-battle injuries and lower performance are present. Moreover, the combination of such factors negatively impacts the body to recover quickly from minor afflictions among infectious diseases and also to effectively respond to traditional sea-level trauma. Environmental illnesses (i.e. nonbattle injuries) may become a significant burden for the healthcare support system compared to traditional warfare. This publication provides a summarized overview of the most possible medical threats in mountainous environments and offers recommendations for medical support.



NATO Allied Tactical Publication - Conduct of Land Tactical Operations in Mountainous Environment ATP 3.2.1.3 Ed. A Vers. 1, April 2024


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MEDICAL SUPPORT

- Personell at Risk
- Casualty Rate
 - BC
 - KIA
 - WIA
 - MIA/CIA
 - DNBI



NATO AJP-4.10 ALLIED JOINT DOCTRINE FOR MEDICAL SUPPORT, Ed. C Vers. 1, Sept. 2019

NATO STANDARD
AJP-4.10
ALLIED JOINT DOCTRINE
FOR MEDICAL SUPPORT
Edition C Version 1
SEPTEMBER 2019

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ALLIED JOINT PUBLICATION
Produced by the
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MOUNTAIN WARFARE

EXTREME TERRAIN

COLD

HIGH ALTITUDE



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This slide features a background image of a steep, rocky mountain slope. A person is visible climbing the face of the cliff. The title 'EXTREME TERRAIN' is prominently displayed in large, bold, black capital letters within a white rectangular box. The slide is part of a 'MOUNTAIN WARFARE' presentation, as indicated by the header and footer.

MOUNTAIN WARFARE

EXTREME TERRAIN

Medical Problems

- Trauma due to terrain (rockfall, avalanches, ...)
- Trauma due to lack of specific training (fractures, TBI, ...)
- Lightning strikes
- Sunburn, Sunstroke

NATO Allied Tactical Publication - Conduct of Land Tactical Operations in Mountainous Environment ATP 3.2.1.3 Ed. A Vers. 1, April 2024

Lechner, Küpper, Tannheimer. Challenges of Military Health Service Support in Mountain Warfare. Wilderness Environ Med 2018;29, 266–274


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MOUNTAIN WARFARE

EXTREME TERRAIN

Prevention/Mitigation

- Training (skills, physical fitness)
- Equipment



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Lechner, Küpper, Tannheimer. Challenges of Military Health Service Support in Mountain Warfare. Wilderness Environ Med 2018;29, 266–274

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MOUNTAIN WARFARE

EXTREME TERRAIN

Treatment/Casualty Evacuation

- Treatment is common
- Evacuation is a great



NATO Allied Tactical Publication - Conduct of Land Tactical Operations in Mountainous Environment ATP 3.2.1.3 Ed. A Vers. 1, April 2024

Lechner, Küpper, Tannheimer. Challenges of Military Health Service Support in Mountain Warfare. Wilderness Environ Med 2018;29, 266–274

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MOUNTAIN WARFARE

COLD

Medical Problems

- Hypothermia
- NFCI/FCI
- Sunburns, snow blindness
- CO-intoxication
- Impairments of physical/neurocognitive performance
- malnutrition

Handbook in winter Service - Cold Weather Injuries. Chief of the Norwegian Army Weapons School, Oct. 2020

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MOUNTAIN WARFARE

COLD

Prevention/Mitigation

- Training (skills, physical fitness)
- Equipment

UD 6-81-1E Instruction in Winter Service - Winter Conditions, Leadership and Training, Norwegian School of Winter Warfare, Oct. 2013

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 **MOUNTAIN WARFARE**

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Treat

- Sp
- Ev



UD 6-81-1E Instruction in Winter Service - Winter Conditions, Leadership and Training, Norwegian School of Winter Warfare, Oct. 2013

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 **MOUNTAIN WARFARE**



HIGH ALTITUDE

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MOUNTAIN WARFARE


HIGH ALTITUDE

Medical Problems

- AMS
- HACE
- HAPE
- Impairments of physical/neurocognitive performance
- peripheral edema
- retinal hemorrhage
- Sleep disorders
- Impaired wound healing
- malnutrition

RTO TECHNICAL REPORT TR-HFM-146 - Review of Military Mountain Medicine - Technology and Research Barriers, Sept. 2011

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MOUNTAIN WARFARE

HIGH ALTITUDE

Prevention/Mitigation

- Acclimatization
- Therapeutic Prevention and Detection/Diagnosis of Altitude Illness

Shi et al. Closing the loop: autonomous intelligent control for hypoxia pre-acclimatization and high-altitude health management. Natl Sci Rev, 2025, Vol. 12

TB Med 505, Altitude Acclimatization and Illness Management, 2010

RTO TECHNICAL REPORT TR-HFM-146 - Review of Military Mountain Medicine - Technology and Research Barriers, Sept. 2011

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MOUNTAIN WARFARE

HIGH ALTITUDE

Prevention/Mitigation

- Acclimatization**
 - Hou C, Lin J, Lin Y et al. Chronic remote ischaemic conditioning in patients with symptomatic intracranial atherosclerotic stenosis (the RICA trial): a multi-centre, randomised, double-blind sham-controlled trial in China. *Lancet Neurol* 2022; 21 : 1089-98.
 - Li S, Han C, Asmaro K et al. Remote ischemic conditioning improves attention network function and blood oxygen levels in unacclimatized adults exposed to high altitude. *Aging Dis* 2020; 11 : 820-7.
 - Zhong Z, Dong H, Wu Y et al. Remote ischemic preconditioning enhances aerobic performance by accelerating regional oxygenation and improving car-diac function during acute hypobaric hypoxia exposure. *Front Physiol* 2022; 13 : 950086.
 - Yang J, Liu C, Du X et al. Hypoxia inducible factor 1 plays a key role in remote ischemic preconditioning against stroke by modulating inflammatory re-sponses in rats. *J Am Heart Assoc* 2018; 7 : e007589.
 - Berger MM, Macholz F, Lehmann L et al. Remote ischemic preconditioning does not prevent acute mountain sickness after rapid ascent to 3,450 m. *J Appl Physiol* 2017; 123 : 1228-34.
 - Berger MM, Köhne H, Hotz L et al. Remote ischemic preconditioning delays the onset of acute mountain sickness in normobaric hypoxia. *Physiol Rep* 2015; 3 : e12325.

Dehnert C, Böhm A, Grigoriev I et al. Sleeping in moderate hypoxia at home for prevention of acute mountain sickness (AMS): a placebo-controlled, randomized double-blind study. *Wilderness Environ Med* 2014; 25 : 263-71.

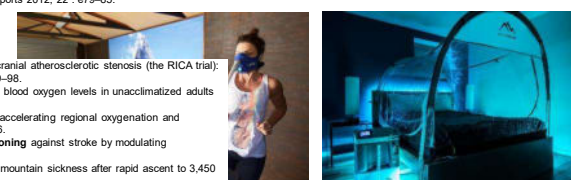
Zhang G, Zhou Y, Cao Z et al. Preliminary Intermittent hypoxia training alleviates the damage of sustained normobaric hypoxia on human hematological indexes and cerebral white matter. *High Alt Med Biol* 2022; 23 : 273-83.

Gangwar A and Pooja SM et al. Intermittent normobaric hypoxia facilitates high altitude acclimatization by curtailing hypoxia-induced inflammation and dyslipidemia. *Plügers Arch—Eur J Physiol* 2019; 471 : 949-59.

Tannheimer M and Lechner R. Rapid ascents of Mt. Everest: normobaric hypoxic pre-acclimatization. *J Travel Med* 2020; 27 : taaa099.

Foster GE, McKenzie DC, Milsom WK et al. Effects of two protocols of intermittent hypoxia on human ventilatory, cardiovascular and cerebral responses to hypoxia. *J Physiol* 2005; 567 : 689-99.

Wille M, Gatterer H, Maier K et al. Short-term intermittent hypoxia reduces the severity of acute mountain sickness. *Scandinavian Med Sci Sports* 2012; 22 : 679-85.



(IHE)

- remote ischemic preconditioning (RIPC)

Shi et al. Closing the loop: autonomous intelligent control for hypoxia pre-acclimatization and high-altitude health management. *Natl Sci Rev*, 2025, Vol. 12

TB Med 505, Altitude Acclimatization and Illness Management, 2010

RTO TECHNICAL REPORT TR-HFM-146 - Review of Military Mountain Medicine - Technology and Research Barriers, Sept. 2011

MOU

HIGH ALTITUDE

Prevention/Mitigation

- Acclimatization
- Therapeutic Prevention
- Illness

Therapeutic Prevention

- Acetazolamide
- Dexamethasone

Hydration

Xenon

54

Xenon 131.293

Xenon reduces neurohistopathological damage and improves the early neurological deficit after stroke in pigs

Neurological Critical Care

Effect of acute and chronic xenon inhalation on erythropoietin, hematological parameters, and athletic performance

Katrin A. Ellis,^{1,2} Justin S. Lawler,^{1,2,3} Hannah Gatterer,^{1,2} Erin J. Hordas,^{1,2} Satyam Surma,^{1,2} William R. Corbett Jr.,¹ Christopher M. Brown, Jr.,^{1,2} Michel Nadeau,¹ Braden Eversing,¹ Allen Shao-Wen Liang,¹ Max Reuther,¹ Thomas Pigeon,¹ Mario Thewissen,¹ Richard K. Bruck,¹ and Benjamin B. Lawler,^{1,2}

J Appl Physiol 127: 1785-1795, 2019. doi:10.1152/jap.00000.2019

Critical Care Medicine 46(10):e10000, August 2018. | DOI:10.1093/ccm/ccy000

JTS CPG 95, Altitude Emergencies in the Prehospital Environment, Mar 2024

TB Med 505, Altitude Acclimatization and Illness Management, 2010

RTO TECHNICAL REPORT TR-HFM-146 - Review of Military Mountain Medicine - Technology and Research Barriers, Sept. 2011

MOUNTAIN WARFARE

HIGH ALTITUDE

Prevention/Mitigation

- Acclimatization
- Therapeutic Prevention and **Detecti**

Clinical Study

Lung Ultrasound Is Accurate for the Diagnosis of High-Altitude Pulmonary Edema: A Prospective Study

Weibo Yang¹, Yuliang Wang², Zewu Qiu², Xuewen Huang³, Maoxia Bin Liu⁴, Dingzhou Yang⁵, Zhenhan Yang⁶, and Tingshan Xie¹

JTS CPG 95, Altitude Emergencies in the Prehospital Environment, Mar 2024

TB Med 505, Altitude Acclimatization and Illness Management, 2010

RTO TECHNICAL REPORT TR-HFM-146 - Review of Military Mountain Medicine - Technology and Research Barriers, Sept. 2011

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MOUNTAIN WARFARE

HIGH ALTITUDE

Prevention/Mitigation

- Predictive Models of Altitude Illness and Performance
- Individual Risk Prediction of Altitude Illness and Performance
- Performance Enhancement at High Altitudes

PLOS ONE

Pre-ascent measurement of hypoxia related proteins (Orexin-A, HIF-1, VEGF and Endothelin-1) where all significantly (<0.05) higher in the AMS-resistant individuals when compared to AMS susceptible individuals.

RTO TECHNICAL REPORT TR-HFM-146 - Review of Military Mountain Medicine - Technology and Research Barriers, Sept. 2011

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MOUNTAIN WARFARE

HIGH ALTITUDE

Treatment/Casualty Evacuation

- Descent
- Oxygen
- Portable hyperbaric chambers
- drugs

Drugs

- Acetazolamide
- Dexamethasone
- Nifedipin
- Hypertonic saline?

JTS CPG 95, Altitude Emergencies in the Prehospital Environment, Mar 2024

TB Med 505, Altitude Acclimatization and Illness Management, 2010

RTO TECHNICAL REPORT TR-HFM-146 - Review of Military Mountain Medicine - Technology and Research Barriers, Sept. 2011

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MOUNTAIN WARFARE



 conclusion

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