REVIEW

ACCEPTED: October 2020

PUBLISHED ONLINE: November 2020

Küpper T, Morrison A. Mountaineers as comrade rescuers – deficiencies in First Aid knowledge, minimum physical fitness and technical requirements, and environmental exposures. Dtsch Z Sportmed. 2020; 71: 280-285. doi:10.5960/dzsm.2020.468

Küpper T[1,2], Morrison A[2,3]

1. RWTH AACHEN TECHNICAL UNIVERSITY, *Institute of Occupational & Social Medicine, Aachen, Germany*
2. MEDICAL COMMISSION OF THE UNION INTERNATIONALE DES ASSOCIATIONS D'ALPINISME (UIAA, INTERNATIONAL CLIMBING AND MOUNTAINEERING FEDERATION), *Bern, Switzerland*
3. ROYAL FREE LONDON NHS FOUNDATION TRUST, *London, U.K.*

Mountaineers as Comrade Rescuers – Deficiencies in First Aid Knowledge and Minimum Technical Requirements

Bergsteiger als Kameradenretter – mangelnde Erste Hilfe-Kenntnisse und minimale technische Anforderungen

Summary

› **Self-reliance in the mountains** requires the ability to cope with most eventualities that may arise. This includes First Aid (FA) care and rescue of a fellow mountaineer in an emergency situation that can require complex but trainable skills. This FA training should reflect the environmental conditions encountered, as these vary and add complications.

› **The minimum fitness** required by the group of rescuer has been estimated to be 3 to 3.5 W/kg body weight. Different deficiencies in FA knowledge were identified according to the climbing style, and the subjects were generally unable to judge their level of knowledge. Rescue services data on the victim's injuries inform and vary FA content according to the mountaineering activity. Data on the rescuer's mental health (e.g. acute stress management or post-traumatic stress disorder) are sparse and require further research.

› **This review summarises** the known requirements and other considerations to perform preventive specialist mountain FA courses to enable mountaineers to provide health and safety for the victim and for themselves. These skills should be periodically refreshed.

KEY WORDS:
Accidents, Emergency Medicine, Injury Care, Emergency Situation

Zusammenfassung

› **Rettungsmaßnahmen, Erste Hilfe** und Verletztenversorgung eines Bergkameraden sind extrem komplexe Situationen und Handlungsabläufe, die sowohl taktische als auch operationelle Fähigkeiten, medizinische Kenntnisse, körperliche Fitness, psychische Belastbarkeit und Aufmerksamkeit gegenüber äußeren Risiken erfordern. Dabei sind Daten über Stressmanagement und mögliches posttraumatisches Stresssyndrom praktisch inexistent und erfordern weitere Forschung.

› **Im Folgenden wird ein Überblick** über diese Anforderungen gegeben, damit es denjenigen, die in eine solche Situation geraten, möglich wird, die in Not geratene Person so gut wie es die Umstände erlauben, zu versorgen bzw. präventiv Erste Hilfe-Kurse zu organisieren, die auf die Spezifika der Zielgruppe eingehen.

› **Die minimal notwendige Leistungsfähigkeit** wurde abhängig von der Gruppengröße auf 3,0 -3,5 W/kg Körpergewicht geschätzt. Es werden auch die Faktoren berücksichtigt, die eine Gefahr für das Leben der Helfer darstellen können.

SCHLÜSSELWÖRTER:
Unfälle, Notfallmedizin, Verletztenversorgung, Notfallsituation

Scan QR Code and read article online.

CORRESPONDING ADDRESS:
Prof. Thomas Küpper, MD, PhD
Institute of Occupational & Social Medicine
RWTH Technical University
Pauwelsstr. 30
52074 Aachen, Germany
: tkuepper@ukaachen.de

Introduction

Over 50 years ago, the former Chief Physician of the Bavarian Mountain Rescue wrote, "The characteristics of an emergency in the mountains are that it always happens at altitude, it is either too hot or too cold, often windy, rainy, misty or snowing, the options are limited, it is never at a horizontal place, and sometimes the helicopter is unable to come." (42, 43). He had no data when he made this statement, but accurately described the environmental exposures of mountain rescuers. He also never mentioned the rescuer's psychological stress when caring for a comrade in an emergency situation, or indeed after (e.g. post traumatic stress disorder). The rescue may have short or long-lasting psychological effects and is explored later.

Several physical and mental factors must be considered to enable mountaineers to provide health and safety for a victim, and safety for themselves. The most important are:
- adequate alpine technical skills to move safely on the terrain
- knowledge of alpine dangers, the terrain, and the weather
- good First Aid (FA) skills specific to emergencies in the mountain
- ability to work efficiently as a team, to communicate and to set priorities, and to accept responsibility for all involved
- resilience, confidence, and peace of mind
- mindfulness, calmness and emotional intelligence to balance the expectations and limitations of the group
- adequate prevention of external risks (e.g. cold, radiation, rescue helicopter noise)
- adequate physical fitness to assist a stranded person even though there will be significant loss of stamina in the hypoxic environment at high altitude (19).

Adequate fitness in mountaineering or at altitude has been discussed in several papers since more than 140 years (e.g. (5, 41, 51)). Physiologists in the early 20's were discussing whether Mt. Everest might be possible without artificial oxygen or not (15). Recent research focused elderly people or those with pre-existing diseases (e.g. (1, 7, 8, 16, 35, 36, 46), but none ever except one group (19, 21, 30) published data about the workload and therefore minimal fitness in rescue situations.

Technical Alpine Skills

Climbing teams should not rely wholly on the FA skills of the leader as the leader may also become the victim. It's also possible to be the first responder on an accident scene and whose informed FA actions may improve the victim's chance of recovery, or save their life. Either way, it is essential that at least one other team member has sufficient knowledge, skills and fitness to handle emergency situations. Rescuers must be able to move safely if the conditions should worsen and become more difficult (e.g. wet or ice-covered rocks). The safety margin will depend on the individual tour. In Alpine rescue operation studies where a safety margin was included, the minimum climbing requirement for rescuers to operate safely on the Alpine terrain of classic routes was that they should be able to climb 50°on ice, and solo UIAA grade 3 on rocky terrain (19, 23, 30, 31).

Alpine First Aid Skills

In contrast to trekking emergencies, the spectrum of problems and diagnoses treated by comrades in the Alps has not yet been adequately investigated. There is no doubt that this spectrum is insufficiently covered by conventional FA training which focuses on urban emergencies, and excludes alpine emergencies such as altitude diseases, frostbite, and others (14, 17, 18, 19, 22, 47). However, data from rescue services informs which FA topics should be covered. In skiing, about 85% of all diagnoses were trauma-related with 26.6% located at the head or spine, 7.8% were medical or neurological problems, and 4.1% were alpine diagnoses, e.g. hypothermia or exhaustion (27). Altitude diseases - acute mountain sickness (AMS), high altitude pulmonary edema (HAPE), high altitude cerebral edema (HACE) - were rare (0.8%). Interestingly 77.5% of all diagnoses made by medically lay people with just one day FA training were correct, and another 12% were mainly correct. Most of the 10.5% of wrong diagnoses were unnoticed, or underestimated injuries of head or trunk.

Kühn (2016) found a different profile of injuries and FA knowledge on vias ferratas (18). Here exhaustion was the most important and potentially life-threatening diagnosis, followed by several minor injuries. Like others, Kühn also found that FA knowledge differed significantly from the profile of diagnoses encountered on the climb, was insufficient in general, and the subjects were unable to judge their level of knowledge (18, 32, 47).

Amongst mountaineers climbing classic routes in the Central Alps, FA knowledge was also generally poor (32). The best FA knowledge results were in relation to cardiac emergencies, altitude sickness, and hypovolaemic shock. The worst results concerned hypothermia, traumatic injuries, treatment of pain and management of emergencies. Although traumatic injuries represent about 50% of mountain accidents in the region, there was a general lack of basic knowledge on this subject. On the other hand, cold and altitude diseases are common here (28), (38). It must be concluded that the deficits in the mountaineer's FA knowledge regarding trauma do not fit with the demands in the mountains.

Amongst trekkers, altitude-related diagnoses were higher. Kühn (2019) analyzed the diagnoses of 479 inpatients (202 trekkers, 277 Nepalese workers) at Khunde Hospital in Solo Khumbu, Nepal (17). Most suffered from altitude sickness (45.5%), acute gastroenteritis (10.4%) or acute respiratory infection (8.4%). Major injuries were rare. These results were in accordance with Gschwandtl's (2019) obtained in Nepal's Solo Khumbu region where 40.5% of all trekkers experienced at least one medical incident during their trip, of which almost 50% were due to acute mountain sickness (14). Once again, FA knowledge was generally poor and did not meet the demands.

It is unrealistic to train mountaineers for all types of emergencies in all styles of mountaineering, and the psychological barriers to engage them in such training are high (9, 13, 32, 34, 44), with those at higher individual risk level being the most reluctant (27, 34). To address mountaineers as directly as possible Kühn (2016) developed a modular FA training course with a basic core training module for all disciplines, and additional modules specifically designed for the respective disciplines (18). It's pointless to train very rare diagnoses or differential diagnoses such as seizures (2, 3, 20, 37), or high altitude pulmonary edema versus pertussis (12). But for any mountaineer climbing above 2500m, the diagnosis and differential diagnosis of altitude diseases should be trained in detail because even medical professionals sometimes fail (12).

Podsiadło (2018) found that an e-learning platform was an effective tool to improve knowledge on hypothermia in mountaineers. However, when assessed a year later, the professional rescuers only partially retained this knowledge, and the volunteers dropped back to their initial level. Refresher courses are needed as unused skills tend to get forgotten (45). Data indicate that such refresher courses should be joined at least every second year, although every three years seems more realistic (32).

Mental Health

A rescue failure may be the worst case scenario which may have short or long-lasting psychological effects (e.g. acute mental stress or post-traumatic stress disorder PTSD). Except from some anecdotal case reports (e.g. (40)) there is no data demonstrating that members of ground or air mountain rescue teams suffer from PTSD more often than members of other rescue services, or indeed on what PTSD an 'uninjured' climber may suffer from when witnessing a trauma or comrade fall off the end of a rope. However, epidemiological studies have ›

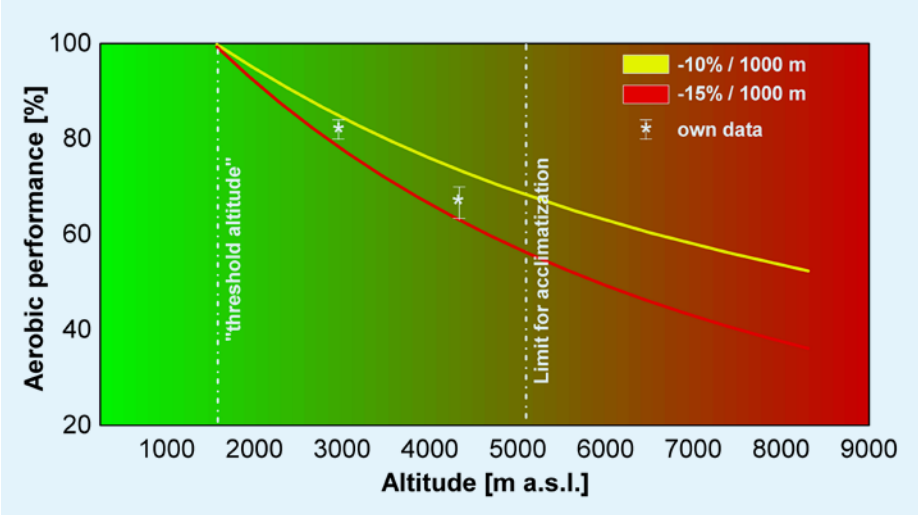

Figure 1

Decrease of Aerobic Performance with altitude. Note: Above about 7,000m rescue procedures will become impossible!

reported a lifetime PTSD prevalence rates of 13.0-20.4% for women and 6.2-8.2% for men from various causes (6). More recently the Stress Continuum developed by Marine Corps has been adapted for use by the climbing community to gauge and manage their stress in such situations in America (39). However, much more research is needed to ensure the emotional health of the mountain rescuers and comrades, and to develop preventative and therapeutic programmes.

Another problem rarely mentioned is the medical equipment. Only some mountaineers carry a FA kit, and often this kit is either insufficient or used so often that essentials are missing (18, 33, 14). Assuming the FA kit is well-equipped (e.g. a physician's kit), the next problem that may arise is that drugs may lose their potency or efficacy in different environments. Although some drugs work well even under harsh conditions, or after freezing or heat exposure, others don't (25, 26). For several other drugs, we simply don't know whether they will have an effect, and if they do, what dosage is required in a cold (centralized patient with another volume of distribution), and hypoxic environment. Drugs which cause peripheral vasodilatation (e.g. risk of hypothermia or collapse), or that have any central nervous effect, should be used with care in cold and hypoxic locations.

Physical Fitness for Rescue Operations

Decreasing oxygen partial pressure at altitude causes various physiological and pathophysiological changes in the body. Since altitude diseases (acute mountain sickness, high altitude pulmonary or cerebral edema) normally show a delay of several hours to some days they are not relevant here (11, 48).

At altitude, aerobic endurance decreases by about 10% to 15% per 1000 m, beginning at a "threshold altitude" of 1500 m (10, 19) (Figure 1). The amount of this decrease varies in literature. This is caused by different models of calculation (% over the total altitude difference or % loss related to the previous altitude (the latter would give a non-linear relation), by different collectives (highly trained persons show a more pronounced decrease than less trained ones), and probably by other factors (e.g. hydration status). To compare the workload undertaken during rescue operations at high altitude and at sea level, typical "strenuous" tasks were investigated in both conditions using telemetry in simulated rescue scenarios (19). A standard spiroergometry and a lactate analysis were performed for comparison. The same protocol was performed at sea level, and at altitudes of 3000 m (Trockener Steg / Zermatt, Switzerland) and 4560 m (Capanna Margherita, Monte Rosa / Italy) (4, 19, 30). To the surprise of the investigators, the data showed that resuscitation (CPR) can be performed aerobically, even at high altitude. However, tasks in which the patient was moved, such as transport or crevasse rescue, went far beyond the anaerobic threshold and often at the limit of the individual's maximum work capacity, and therefore these tasks could only be performed for a very limited time.

A detailed analysis of the data showed that rescue operations at altitude are limited when a rescuer's pulse work capacity at a pulse of 170/min (PWC170) is less than 3 W/kg measured at sea level. With a PWC170 of <2.5 W/kg, rescue is practically impossible. These minimal workload requirements should not prevent mountaineers from attempting comrade rescue if their fitness does not meet this criteria. They should instead be advised to go in larger groups of at least 3 to 4 persons, and to operate as team.

Rescue fitness requires muscular strength. There's no data available as to how much power is needed to pull a person out of a crevasse, or to carry him over rough terrain. If the victim is carried by a single person, then the power required will be equivalent to the victim's body weight. For a crevasse rescue, it may be more due to the rope's friction on the edge of the crevasse, or less when a sufficient technique is used (e.g. Swiss pulley, ideally with additional rolls for the carabiners). Detailed investigations are necessary to advise mountaineers especially those with individual limitations imposed by pre-existing disease because different types of muscular strength (maximal power, endurance, small vs. large muscles) show significant differences and decrease when performed at high altitude (19).

Environmental Factors

Cold

In cold mountainous environments, the risk of hypothermia or frostbite is a common problem, but knowledge on how to limit these risks and their consequences can be lacking. Detailed data on the climatic conditions at the site of alpine emergencies, and the duration on how long such conditions affect victims and his comrades, are scarce. However, conditions in the Central Alps are often harsh. In a study analysing the equivalent chill temperature (49, 50) of rescue operations over a 15-month period in the Oberwallis Region (Switzerland), Küpper et al. (2003) found that 87.1% of the operations occurred at chill temperatures >-30°C, 12.1% in the range of -30 to -45°C, and 0.8% at <-45°C (28). The lowest temperature recorded was -54.6°C during a rescue operation in February near the Grenzgipfel (Monte Rosa, 4,618m). When this data was evaluated according to the Danielson model, this resulted in 77.6% of operations without the risk of frostbite, 20.1% with >5% risk, 6% with >50% risk and 1.8% with >95% risk. According to DIN 33403.5, only 1.5% of the

operations were performed at chill temperatures warmer than cold class 1. Specifically 2.3% were class 1, 13.3% class 2, 34.7% class 3, 34.6% class 4, and 13.7% in the bitterly cold class 5. A detailed analysis of the data showed that the most important risk for the victim was hypothermia, and for the much more active rescuers it was frostbite. Sufficient cold protection is a must, especially for the victim.

Noise

Alpine helicopter rescue is a possibility in most of the mountains of industrialized countries. Most mountaineers acting as comrade rescuers will not have experience of such rescue. But the extreme noise levels of a helicopter rescue for some minutes without adequate ear protection can result in permanent hearing loss (29). Although advanced helicopters with fan-in-fin technology have significantly reduced noise emission, this is still far beyond any tolerable limit to avoid hearing loss in unprotected ears (24). Data from Zermatt showed that any exposure, even short bursts during winch operations, landing or "hot loading", is at an equivalent noise level (Leq8h) that significantly exceeds the 85 dB(A) threshold which is accepted as the highest noise level which does not cause permanent hearing loss (29). For every 3 dB(A) above this threshold, the time needed to create permanent hearing loss is reduced by half. For example, being near a helicopter with its engines running at full capacity can produce noise at about 120 dB(A), and this may cause irreversible hearing damage within 7 seconds only. With more modern helicopters producing less noise, the same hearing loss may take only a little bit longer, about 105 seconds at 107.8 dB(A). The easiest way to protect the ears without protection tools is to put a fingertip in each ear. It has been estimated that this will reduce noise levels by up to 40 dB(A). If the victim or rescuer is unable to do this, alternative ear protection should be improvised (e.g. using a hat and scarf).

Conclusion

It is unrealistic to train mountaineers for all types of emergencies in all styles of mountaineering that they do, and the psychological barriers for them to engage in such training are high. Condensed e-learning or modular FA courses are available that cater for specific types of mountaineering activity undertaken. FA training should be regularly refreshed as skills not routinely used tend to be forgotten.

Environmental and objective risks can also be minimised with alpine training and experience. Any advice concerning fitness for mountaineering should assume the worst case scenario of an emergency rescue as the fitness required will be significantly higher at altitude in hypoxic conditions. FA kits should be checked, re-stocked if required, and mountaineers bear in mind the efficacy and strength of some medications may vary in harsh environments. Data on the mental health of those involved in mountain rescue (e.g. acute stress management, posttraumatic stress disorder) is sparse and requires further research to establish preventative measures and therapeutic programmes.

Mountaineering is a sport where unique and trusting relationships are formed in challenging times, and where accidents and altitude diseases do occur. FA skills can save a comrade's life or improve their chances of recovery.

Acknowledgements

Many institutions and persons have both informed and supported the numerous studies that this review is based on. A warm "Thank you!" to the Austrian Society for Alpine and Altitude Medicine (ÖGAHM), Aachen Dental and Medical Expeditions e.V. (ADEMED), Air Zermatt AG (Zermatt / Switzerland), the enthusiastic probands and all colleagues who supported this research with their interesting discussions.

Dedicated to our fellow mountaineers and mountain rescue comrades killed in action: Reiner Schlupp, Peter Hierholzer, Andi Lambrigger, Edgar Brantschen, Gabriel Perren, Robert Baur, Denis Christin, Mark Perreten, Urs Lerien, Horst Wenerus, and Klaus-Achim Kratzsch.

Conflict of Interest

The authors have no conflict of interest.

References

(1) **ALEXANDER JK.** Cardiac arrhythmia at high altitude: the progressive effect of aging. Tex Heart Inst J. 1999; 26: 258-263.

(2) **BASNYAT B.** Seizures at high altitude in a patient on antiseizure medications. Wilderness Environ Med. 2001; 12: 153-154. doi:10.1580/1080-6032(2001)012[0153: LTTE]2.0.CO; 2

(3) **BASNYAT B, SLEGGS J, SPINGER M.** Seizures and delirium in a trekker: the consequences of excessive water drinking? Wilderness Environ Med. 2000; 11: 69-70. doi:10.1580/1080-6032(2000)011[0069: LTTE]2.3.CO; 2

(4) **BEERLAGE I, FAHNENBRUCK G.** Psychische Belastung des rettungsdienstlichen Personals]. In: Siedenburg J, Kupper T, eds. [Modern Aviation Medicine]. Stuttgart: Gentner Verlag; 2015: 487-496.

(5) **BERT P.** La pression barométrique. Paris: Masson; 1878.

(6) **BRYANT RA.** Post-traumatic stress disorder: a state-of-the-art review of evidence and challenges. World Psychiatry. 2019; 18: 259-269. doi:10.1002/wps.20656

(7) **DEHNERT C, BÄRTSCH P.** Can patients with coronary heart disease go to high altitude? High Alt Med Biol. 2010; 11: 183-188. doi:10.1089/ham.2010.1024

(8) **ERDMANN J, SUN KT, MASAR P, NIEDERHAUSER H.** Effects of exposure to altitude on men with coronary artery disease and impaired left ventricular function. Am J Cardiol. 1998; 81: 266-270. doi:10.1016/S0002-9149(97)00901-6

(9) **EVERSON G, RONDEAU E, KENDRICK M, GARZA I.** Ineffectiveness of a mass mailing campaign to improve poison center awareness in a rural population. Vet Hum Toxicol. 1993; 35: 165-167.

(10) **FULCO CS, ROCK PB, CYMERMAN A.** Maximal and submaximal exercise performance at altitude. Aviat Space Environ Med. 1998; 69: 793-801.

(11) **GALLAGHER SA, HACKETT PH.** High-altitude illness. Emerg Med Clin North Am. 2004; 22: 329-355. viii. doi:10.1016/j.emc.2004.02.001

(12) **GOEBBELS K, GIESELER U, SCHÖFFL V, KÜPPER T.** Cough and dyspnoea of an asthmatic patient at Mt. Kilimanjaro: a difficult differential diagnosis. Travel Med Infect Dis. 2010; 8: 22-28. doi:10.1016/j.tmaid.2009.11.001

(13) **GONIEWICZ M.** The ability of drivers to give first aid - testing by questionnaire. Wiad Lek. 1998; 51: 208-215.

(14) GSCHWANDTL C. Trekker and expedition climber as comrade rescuers in the Solo Khumbu-Mt.Everest Region, Nepal - development of a target group specific training concept for First Aid and risk management in remote high mountain regions - results of the ADEMED Expedition 2011. Aachen: Dept. of Occupational and Social Medicine, RWTH Aachen University; 2019.

(15) KELLAS AM. Sur les possibilités de faire l'ascension du Mount Everest. Congrès de l'Alpinisme Monaco. Paris: C.R. Seances; 1920.

(16) KEYES LE, MATHER L, DUKE C, REGMI N, PHELAN B, PANT S, STARLING J, MCELWEE M, COLE D, MCCONNELL T, PAUDEL P, SALLADE TD, SHEETS A, TWILLMAN D, YOUNG DS, BASNYAT B. Older age, chronic medical conditions and polypharmacy in Himalayan trekkers in Nepal: an epidemiologic survey and case series. J Travel Med. 2016; 23: taw052. doi:10.1093/jtm/taw052

(17) KÜHN C, APEL C, BERTSCH D, GRASS M, GSCHWANDTL C, HUNDT N, MÜLLER-OST M, RISSE J, SCHMITZ S, SHERPA K, TIMMERMANN L, VAN DER GIET M, VAN DER GIET S, WERNITZ K, MORRISON A, KÜPPER T. Inpatient treatment of trekkers and Nepalese workers in the high-altitude environment of Mt. Everest Region 1996-2011: A retrospective analysis. Travel Med Infect Dis. 2019; 31: 101356. doi:10.1016/j.tmaid.2018.11.012

(18) KÜHN J. Safety management of climbers at via ferratas in the European Alps - Incidence of inuries, First Aid knowledge and consequences for trainings. Aachen / Germany: Institute of Occupational & Social medicine, RWTH Aachen, Germany; 2016.

(19) KÜPPER T. Workload and professional requirements for alpine rescue. Aachen: Dept. of Aerospace Medicine, RWTH Aachen Technical University; 2006.

(20) KÜPPER T, CLASSEN J. Single epileptic seizures provoked by high altitude. J Travel Med. 2002; 9: 94-96. doi:10.2310/7060.2002.21498

(21) KÜPPER T, GIESELER U, SCHÖFFL V. Occupational Aspects of Alpine Helicopter Rescue Operations. Recommendation of the UIAA Medical Commission Vol. 23. Union Internationale des Associations d'Alpinisme (Medical Commission); 2015. http: / www.theuiaa.org/medical_advice.html [20th October 2020].

(22) KÜPPER T, HETTLICH C, LAMPERT F, LECHNER K, SCHARFENBERG C, HETTLICH M. Dental problems and emergencies of trekkers in the Annapurna region. High Alt Med Biol. 2014; 15: 39-45.

(23) KÜPPER T, HILLEBRANDT D, STEFFGEN J, SCHÖFFL V. Safety in alpine helicopter rescue operations—minimal requirements of alpine skills for rescue personnel. Ann Occup Hyg. 2013; 57: 1180-1188.

(24) KÜPPER T, JANSING P, SCHÖFFL V, VAN DER GIET S. Does modern helicopter construction reduce noise exposure in helicopter rescue operations? Ann Occup Hyg. 2013; 57: 34-42.

(25) KÜPPER T, MILLEDGE J, BASNYAT B, HILLEBRANDT D, SCHÖFFL V. Consensus Statement of the UIAA Medical Commission Vol.10: The effect of extremes of temperature on Drugs - With notes on side effects and use of some other drugs in the mountains. The Medical Commission of the Union Internationale des Associations d'Alpinisme (UIAA); 2008. www.theuiaa.org/medical_advice.html [20th October 2020].

(26) KÜPPER T, SCHRAUT B, RIEKE B, SCHÖFFL V, STEFFGEN J. Drugs and drug administration in extreme climates. J Travel Med. 2006; 13: 35-47. doi:10.1111/j.1708-8305.2006.00007.x

(27) KÜPPER T, STEFFGEN J, GORE C, PERREN B, ZAHND P, GORE R. Qualified rescue by ski patrols - safety for the skier. Int J Sports Med. 2002; 23: 524-529. doi:10.1055/s-2002-35071

(28) KÜPPER T, STEFFGEN J, JANSING P. Cold exposure during helicopter rescue operations in the Western Alps. Ann Occup Hyg. 2003; 47: 7-16.

(29) KÜPPER T, STEFFGEN J, JANSING P. Noise exposure during alpine helicopter rescue operations. Ann Occup Hyg. 2004; 48: 475-481.

(30) KÜPPER T, STEFFGEN J, MORRISON A, MILLEDGE J, SCHÖFFL V. Workload during cardiopulmonary resuscitation. Int Arch Occup Environ Health. 2015; 88: 175-184. doi:10.1007/s00420-014-0948-3

(31) KÜPPER T, STEFFGEN J, SCHÖFFL V. Climbing capabilities and alpine emergencies – minimal requirements for personnel of alpine rescue organizations. Wilderness Environ Med. 2007; 18: 243.

(32) KÜPPER T, WERMELSKIRCHEN D, BEEKER T, REISTEN O, WAANDERS R. First aid knowledge of alpine mountaineers. Resuscitation. 2003; 58: 159-169. doi:10.1016/S0300-9572(03)00122-9

(33) LECHNER K. Risk Management of Trekkers. Aachen: Inst. for Occupational and Social Medicine, RWTH Aachen University; 2013.

(34) LEJEUNE PO, DELOOZ HH. Why did persons invited to train in cardiopulmonary resuscitation not do so? Eur Heart J. 1987; 8: 224-228.

(35) LEVINE BD, ZUCKERMAN JH, DEFILIPPI CR. Effect of high-altitude exposure in the elderly: the Tenth Mountain Division study. Circulation. 1997; 96: 1224-1232. doi:10.1161/01.CIR.96.4.1224

(36) LUKS AM, SWENSON ER. Travel to high altitude with pre-existing lung disease. Eur Respir J. 2007; 29: 770-792. doi:10.1183/09031936.00052606

(37) MAA EH. How do you approach seizures in the high altitude traveler? High Alt Med Biol. 2011; 12: 13-19. doi:10.1089/ham.2010.1071

(38) MAGGIORINI M, BUHLER B, WALTER M, OELZ O. Prevalence of acute mountain sickness in the Swiss Alps. BMJ. 1990; 301: 853-855. doi:10.1136/bmj.301.6756.853

(39) MCGLADERY L. Traumatic Stress Injuries – immediate and long-term aid. American Alpine Club; 2019. http: //publications.americanalpineclub.org/articles/13201215174/Essentials-Traumatic-Stress-Injuries-Immediate-and-Long-Term-Aid [15th July 2020].

(40) MESSNER R. Grenzbereich Todeszone [Border area death zone]. Frankfurt, Berlin: Ullstein; 1980.

(41) MOSSO A. Der Mensch auf den Hochalpen. Leipzig: Verlag von Veit & Comp.; 1899.

(42) NEUREUTHER G. Allgemeine Unterkühlung. Paper presented at: 6. Rettungskongreß des Deutschen Roten Kreuzes, 24.-27.4.1986; Nürnberg.

(43) NEUREUTHER G. Probleme bei der Erstversorgung beim Bergunfall. MMW. 1969; 7: 332-339.

(44) PEARN J, DAWSON B, LEDITSCHKE F, PETRIE G, NIXON J. Who accepts first aid training? Aust Fam Physician. 1980; 9: 602-605.

(45) PODSIADLO P, KOSINSKI S, DAROCHA T, SALAPA K, SANAK T, BRUGGER H. The Use of E-Learning in Medical Education for Mountain Rescuers Concerning Hypothermia. High Alt Med Biol. 2018; 19: 272-277. doi:10.1089/ham.2018.0050

(46) PUEHRINGER R, BERGER M, SAID M, BURTSCHER M. Age-Dependent Health Status and Cardiorespiratory Fitness in Austrian Military Mountain Guides. High Alt Med Biol. 2020; 10.1089/ham.2020.0092. doi:10.1089/ham.2020.0092

(47) SCHARFENBERG C. First Aid Knowledge of Trekkers. Aachen: Inst. for Occupational and Social Medicine, RWTH Aachen Technical University; 2013.

(48) SCHOENE RB. Illnesses at high altitude. Chest. 2008; 134: 402-416. doi:10.1378/chest.07-0561

(49) SIPLE P, PASSEL C. Excerpts from: Measurements of dry atmospheric cooling in subfreezing temperatures. Wild Environm Med. 1999; 10: 176-182. doi:10.1580/1080-6032(1999)010[0176: FODACI]2.3.CO; 2

(50) SIPLE P, PASSEL C. Measurements of dry atmospheric cooling in subfreezing temperatures. Proc Am Philos Soc. 1945; 89: 177-199.

(51) ZUNTZ N, LOEWY A, MÜLLER F, CASPARI W. Höhenklima und Bergwanderungen in ihrer Wirkung auf den Menschen. Berlin: Deutsches Verlagshaus Bong & Co; 1906.