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11th European Hypoxia Symposium, Training Centre of the German Federal Police, Kührointalm / Berchtesgaden (Germany), 26th–28th September 2025

Thomas Küpper

Symposium President

Conference reports

About the Meeting

The meeting continues a long tradition since some colleagues have organized the first one in 2002 in Slovenia. Hundreds of lectures followed and after a short break during the COVID-19 period the Czech team continued at Kladno and now it takes place again at the Training Centre od the German Federal Police near Berchtesgaden.

As usual colleagues were invited to contribute to all aspects of hypoxia. In addition to mountain medicine, there is diving medicine, intensive care medicine, aviation medicine, working in extreme conditions, training, and many more. There was also a special invitation to young scientists and students to present their theses.

The presented abstracts are listed in alphabetical order of the first author.

Keywords

- hypoxia
- medicine
- conference
- abstracts

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Neuromuscular system and CNS mechanism of adaptation in hypoxia

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Introduction: Reduced oxygen levels can impair mitochondrial function and lead to a shift in cellular metabolism. In response to hypoxia, the mitochondria undergo several adaptations to optimize energy production and maintain cellular homeostasis. One key adaptation is an increase in the number and size of mitochondria. This increase, known as mitochondrial biogenesis, is regulated by various signaling pathways, such as the hypoxia-inducible factor (HIF) pathway.[1]
Objectives: Additionally, in hypoxic conditions, the mitochondria may switch to alternative metabolic pathways to generate ATP. For example, anaerobic glycolysis becomes more prominent, producing ATP but with a lower efficiency compared to oxidative phosphorylation. Mitochondrial damage is often present and leads to the "lactate paradox", fatigue, and sarcopenia. Moreover, mitochondria play a crucial role in the production of reactive oxygen species (ROS), which are byproducts of oxygen metabolism. In hypoxic conditions, the imbalance between ROS production and clearance can occur, resulting in oxidative stress. This oxidative stress can damage the mitochondria and other cellular components, leading to various physiopathological consequences and changes in neurotransmitters, which might change the mood, toward depression or euphoria. The mitochondrial adaptations aim to maintain cellular energy production and homeostasis under low oxygen, as in the MELAS[2] condition.
Results: A Team of researchers, including physicians, neurologists, neuroanatomists, biochemists, and molecular biologists, studied cases of fatigue and myoglobinuria due to excessive MELAS syndrome, fatigue, or toxic drugs (cocaine). Using the Lake Louise Scale, in a Nepal trekking and expedition in Capanna Margherita,[3] we examined the effects of diuretics and exercise to prevent Acute Mountain Sickness, as well as the dangerous effects on muscle and brain.
Conclusion: Hypoxia can directly affect mitochondrial function in neurons, muscle, and hormones. Mitochondrial oxidative phosphorylation may be compromised, leading to reduced ATP production and impaired energy metabolism. Mitochondrial dysfunction may disrupt neuronal signaling, induce paranoid ideas, alter synaptic transmission, and overall CNS function,[4] while CNS and diaphragmatic weakness and lack of NOS in myofibers[5] alter the sleep rhythms, contributing to sleep apnea episodes.
Acknowledgement: Research supported by Everest K2, CNR, Eurobiobank, and Eurac.

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Cardiopulmonary effects of normobaric hypoxia and sympathetic activation, and subsequent normoxic recovery in rats

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Introduction: Short-term exposure (6h) to normobaric hypoxia (10% O_2 in N_2) impairs left ventricular (LV) inotropic function in rats. In previous studies, LV systolic pressure (LVSP) and LV contractility (LV dP/dt max) decreased to 68% and 55% of normoxic values, respectively. After 24 hours a slight recovery of LV function was observed.[1] The deterioration of LV function was paralleled by the occurrence of pulmonary edema (PE).[1,2] Moreover, sympathetic blockade worsened both LV dysfunction and the PE.[3]

Objectives: This study aimed to determine whether prolonged normobaric hypoxia (72 hours) would induce acclimatization, hence improve LV function and resolve PE. We also examined whether sympathetic stimulation via norepinephrine (NE) could counteract the hypoxia-induced LV dysfunction. Additionally, we investigated the extent of recovery following an additional 72 hours under normoxic conditions.

Methods: Rats (n = 130) were exposed for 72 hours to either room air or to normobaric hypoxia (10% O_2 in N_2) inside a chamber. During this period, animals received intravenous NaCl (control groups) or NE. After the hypoxic exposure, a subset from each group were moved to normoxic conditions with NaCl infusion for further 72 hours (recovery group). At the end of the experiment, all rats underwent heart catheterization to evaluate hemodynamic function. Finally, lung tissue was harvested for histological analysis.

Results: After 72 hours of hypoxia, LV dP/dt max and LVSP remained significantly reduced with about 80% of normoxic values. Interestingly, NE infusion further decreased both parameters in normoxic animals and to even greater extent in hypoxic ones compared to the corresponding controls. After a 3-day recovery under normoxia, both values returned to baseline. Hematocrit levels were elevated after hypoxia and stayed high even after 72 hours of normoxic recovery. PE developed during hypoxic exposure and resolved only partially after 3 days of normoxia. NE infusion induced formation of PE even in normoxia but aggravated it only slightly under hypoxic conditions.

Conclusions: Although left ventricular function was still depressed after 72 hours of hypoxia, full recovery was observed after additional 3 days under normoxic conditions. Nonetheless, PE was still present. NE failed to counteract the hypoxia-induced depression of LV inotropic function and did not alleviate the PE. However, the normalization of LVSP and LV dP/dt max after recovery indicates a reversible impairment.

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Treatment recommendations for frostbite: A narrative overview

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Introduction: Frostbite is a cold-induced injury caused by tissue freezing, leading to significant morbidity, especially in exposed extremities such as fingers, toes, ears, and nose. Although rare in the general population, incidence increases in specific professions (e.g., military personnel) and outdoor activities (e.g., mountaineering, ice climbing). Severe frostbite can cause long-term disability, particularly when hands are affected.

Objectives: This review aims to summarize current evidence-based recommendations for the treatment of frostbite injuries, based on the latest guidelines from the Wilderness Medical Society (2024) and the American Burn Association (2024).

Methods: A narrative review of two major clinical practice guidelines was conducted, focusing on diagnostic approaches, pre-hospital care, hospital management, and advanced therapies. Pathophysiology and therapeutic interventions, including thrombolysis and Iloprost, were critically examined.

Results: Effective frostbite management prioritizes early recognition, protection from further cold exposure, and rapid rewarming in warm water (37–39°C). Ibuprofen is recommended for its anti-inflammatory and anti-thrombotic effects. In the hospital, wound care with Aloe Vera, analgesia, and tetanus prophylaxis are essential. In severe cases, early (<24 h) thrombolytic therapy (rt-PA) and Iloprost within 24–72 hours post-rewarming may reduce amputation rates. Imaging techniques support clinical decisions but should not delay treatment. Antibiotics are reserved for signs of infection. Hyperbaric oxygen therapy shows potential but lacks sufficient evidence for routine use.

1. Prioritise treatment of hypothermia and/or serious injury/illness.
2. Rapid rewarming in a warm water bath (37–39°C) until the affected areas are soft (if not already performed in the prehospital setting or if spontaneous warming of the extremities has been ruled out). Analgesia should be started as required
3. Clinical examination to determine the severity of frostbite.
4. Administration of ibuprofen (12 mg/kg bw/day, divided into two single doses).
5. Tetanus prophylaxis and antibiotics if infected wounds are suspected.
6. Debridement: selectively relieve clear blisters, e.g. by needle aspiration, leave haemorrhagic blisters in place.
7. Dressing change: 2 × daily with topical aloe vera gel under sterile conditions. Additional application of dry, generous dressings. Elevation (prevention of oedema) and splinting of the extremities.
8. Ensure systemic hydration (by mouth or intravenously if necessary).
9. Consider thrombolytic therapy for deep, extensive frostbite within the first 24 hours after rewarming in combination with heparin or LMWH for 3–5 days.
   - Intravenous thrombolysis: 0.15 mg/kg bw for 15 min, followed by 0.15 mg/kg/hr for 6 hours. Use angiography prior to thrombolysis and to monitor progress if available.
   - Intra-arterial thrombolysis after vasodilatation with e.g. nitroglycerin or iloprost a bolus of 2–4 mg followed by 1 mg/hr/catheter/upper limb in 6 hours.
10. Iloprost therapy: Consider within 72 hours of thawing in cases of deep frostbite. Dosage: Day 1–3: 0.5 ng/kg/min, increase by 0.5 ng/kg/min every 30 min to max. 2 ng/kg/min for 6 hours/day. Day 4–5: start with the highest tolerated dose, max. 6 ng/kg/min for 6 hours/day, duration of therapy: 8–(10) days; note side effects such as nausea, headache, flushing, hypotension, bradycardia and myocardial ischaemia.

Conclusions: Frostbite is a vascular emergency requiring structured and timely intervention. Early rewarming, anti-inflammatory treatment, and consideration of advanced therapies such as thrombolysis and Iloprost can significantly improve outcomes. Multidisciplinary care, including wound management and psychological support, is essential. Further research is needed to strengthen the evidence base for specific interventions.

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Cognitive decline and therapeutic hypoxia in post--myocardial infarction patients

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Introduction: Cognitive dysfunction following myocardial infarction (MI) is an increasingly recognized yet underexplored condition. Up to 30% of post-MI patients experience measurable cognitive deficits, particularly in executive functioning, within weeks after the event. Pathological hypoxia resulting from MI, stroke, or heart failure—together with neuroinflammation and cerebral hypoperfusion—can disrupt the blood–brain barrier (BBB) and impair white matter integrity. This pathophysiology reflects the concept of the heart–brain axis, where cardiovascular pathology contributes to neurological decline.

Objectives: The aims of this study are to:

Describe the mechanisms linking cardiac ischemia, hypoxia, and cognitive impairment.

Assess diagnostic tools for neurocognitive monitoring, particularly the Stroop test.

Present initial clinical observations on normobaric therapeutic hypoxia as a potential neuroprotective strategy.

Methods: A narrative review was conducted on post-MI cognitive impairment, hypoxia-induced brain injury, and neurovascular signaling. Diagnostic tools—including

neuropsychological tests and inflammatory biomarkers—were evaluated. A pilot clinical intervention was also initiated using moderate normobaric hypoxia (equivalent to 2500–3000 m above sea level) combined with ergometric training. Sessions were conducted in a specialized hypoxic room, and patients underwent cognitive, immunological, and endothelial assessments. Each participant completed 20 supervised sessions under medical oversight.
Results: Pathological hypoxia promotes BBB disruption, increases pro-inflammatory cytokines (TNF-α, IL-6), and impairs executive functions. The Stroop test effectively detects early cognitive decline and is suitable for tracking recovery. While pharmacological treatment offers limited benefits, non-pharmacological strategies—especially physical training under hypoxia—show potential.
Preliminary results from the pilot study suggest favorable adaptations in cytokine profiles, endothelial function, and cognitive performance. These findings will be presented during the conference.
Conclusions: The early post-MI period is critical not only for cardiac but also for cognitive rehabilitation. Precisely controlled intermittent normobaric hypoxia may activate adaptive, anti-inflammatory, and neuroprotective mechanisms. This strategy could represent a shift from heart-focused rehabilitation toward integrated cardioneurological care. Preliminary findings are promising and support the need for further interdisciplinary research into therapeutic hypoxia as an innovative tool in managing cognitive complications after cardiovascular events.

Table 1. Comparison of pathological vs. therapeutic hypoxia

Feature	Pathological Hypoxia	Therapeutic Hypoxia
Source	Stroke, heart failure, MI	Controlled hypoxic training (2500––3000 m simulated altitude)
Character	Chronic, often uncontrolled	Acute, supervised and dosed
Cytokine profile	↑ IL-6, ↑ TNF-α (proinflammatory)	↓ TNF-α, ↑ IL-10 (anti-inflammatory)
Effect on BBB	Damage to endothelial integrity, permeability ↑	Stabilization of BBB, repair – enhanced tight junctions
Cognitive impact	Decline inexecutive function, memory loss	Improvement in attention, working memory, processing speed

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Falling to death: Hiking fatalities on angels landing trail

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Introduction: Hiking in mountainous and other wilderness environments is a popular outdoor activity in U.S. National Parks (NPS). Unfortunately, hiking-related injuries account for 48% of all search and rescue (SAR) operations and 10% of deaths in National Parks. The Angels Landing Trail in Zion National Park (Utah) is considered one of deadliest hiking trails in national parks. Only 8 km long, the Angels Landing Trail is steep, ascends 454 m, and is known as a narrow trail with slippery edges, steep drop-offs, 21 switchbacks, and chain railings. The trail has been considered synonymous with overcrowding and has at least 18 confirmed deaths. Most deaths are associated with falls off the trail but little is known about the factors contributing to the deaths.
Objectives: To identify the factors contributing to hiking-related deaths on Angels Landing Trail in Zion National Park.

Methods: Following a freedom of information request for incident records, a case study approach was used to review NPS 10-343 and 10-344 forms for all hiking fatalities on the Angels Landing Trail. The reports contain information about the date, time, location, and nature of each incident. The reports also include information about all involved hikers and a detailed narrative describing the emergency response, a summary of investigative actions, and witness statements.
Results: Seven hiking deaths were reported in NPS records. Hiking behavior played a major role in five of the seven recorded deaths, pre-existing health conditions was a factor in two of the deaths. Environmental factors (social and physical environment) contributed to each death. Falls from height were the final cause of death in six of the seven fatalities.
Conclusions: In April 2022, Zion National Park instituted a permit system designed to prevent overcrowding on Angels Landing Trail. While designed to prevent overcrowding, the permit system also intends to increase hiker safety and the overall hiking experience. One falling death has occurred since the permit system was instituted.

Medical aspects of field experiments studying breathing under avalanche snow

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Introduction: Field experiments simulating breathing under avalanche snow are essential for informing international rescue and resuscitation guidelines and for guiding the design of safety equipment intended to protect individuals at risk of burial. However, the methodology of these studies varies substantially, and the medical aspects associated with such experiments have not been comprehensively described.
Objectives: This work aimed to summarize current knowledge of gas exchange in avalanche burial victims, review experimental studies conducted worldwide, present the results of research performed at the Czech Technical University, and analyze the medical considerations relevant to such field experiments.
Methods: We reviewed data collected during three outdoor experimental studies [1–3] and analyzed them with particular attention to medical safety and monitoring aspects.
Results: Study participants were exposed to pathophysiological conditions mimicking those of avalanche burial victims. The primary challenges included the triad of hypoxia, hypercapnia, and, in some cases, hypothermia. Each of these states carries a potential risk of arrhythmias, which poses a significant safety concern. Furthermore, physicians supervising the experiments must often rely on intensive care monitoring devices. However, under field conditions, such devices may provide misleading or unreliable results, even when operated strictly according to manufacturer instructions. This discrepancy underscores the limitations of transferring ICU technology into extreme outdoor environments.
Conclusions: Medical concerns in avalanche breathing experiments primarily arise from the combined effects of hypoxia and hypercapnia experienced by participants. Ensuring participant safety requires meticulous monitoring—not only to safeguard subjects but also to provide reliable study endpoints and datasets for subsequent analysis. Continuous clinical assessment by an experienced physician remains indispensable and cannot be replaced by monitoring devices alone.
Acknowledgement: This work was supported by the Grant Agency of the Czech Technical University in Prague, Grant No. SGS23/198/OHK4/3T/17.

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Dynamic changes of peripheral saturation and perfusion index during rapid desaturation

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Introduction: Pulse oximetry is widely used for non-invasive monitoring of blood oxygenation. Its reliability, however, is questioned during periods of rapid desaturation, when known limitations such as motion artifacts or low peripheral perfusion may significantly impair accuracy.[1,2] The perfusion index (PI), derived from the plethysmographic waveform, reflects changes in peripheral tissue perfusion and is calculated as the ratio of the pulsatile to the non-pulsatile component of the infrared signal. PI values typically range from 0.02 to 20, with higher values indicating better perfusion. Since PI is computed from a 3–5 s pulsatile amplitude relative to a 30 s average of the non-pulsatile component,[3] rapid fluctuations in perfusion may be masked.

Objectives: This study aimed to investigate dynamic changes in peripheral oxygen saturation (SpO_2) and PI during rapid desaturation in an experimental model simulating breathing under avalanche snow.

Methods: We conducted a prospective randomized double-blind crossover field experiment involving 13 healthy male volunteers. Participants breathed either into natural snow or into an artificial snow simulant. Each subject was monitored simultaneously with five different pulse oximeter probes, applied under carefully standardized conditions with meticulous thermal insulation of the fingers.

Results: The duration of breathing episodes varied between subjects and materials, with a total recording time per experiment of 419.5 ± 92.4 s (range 230–620 s). Across all recordings, SpO_2 values displayed substantial variability between the five pulse oximeters, particularly in the onset of desaturation, the nadir of SpO_2, and the time course of resaturation. The mean baseline PI was 1.54 ± 1.01. During progressive hypoxia and hypercapnia, no significant decline in PI was observed (1.25 ± 0.71). In contrast, upon termination of the breathing challenge and return to ambient air, PI demonstrated a rapid surge accompanied by increased variability (3.92 ± 3.36).

Conclusions: Breathing into avalanche snow or its simulant induced concomitant hypoxia and hypercapnia, conditions under which SpO_2 readings varied considerably between different pulse oximeters. This variability is unlikely attributable to inadequate peripheral perfusion, as baseline PI values in this study were within the expected range for clinical conditions and did not significantly decline during hypoxia. The sharp increase in PI observed during the resaturation phase may reflect vasodilatory effects of elevated carbon dioxide on vascular tone. These results suggest that peripheral perfusion remains sufficient during experimental avalanche burial, and therefore low perfusion states are not a major contributor to pulse oximetry inaccuracy under these conditions.

Acknowledgement: This work was supported by the Grant Agency of the Czech Technical University in Prague, Grant No. SGS23/198/OHK4/3T/17.

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Health and safety for heavy duty work at extreme altitude: Construction of the Fred Young Telescope at 5700 m

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Background: While HSE administrations in numerous countries are still debating whether working in isobaric hypoxia (15%, corresponding to an altitude of 2500 m) poses a risk or not, other, much more difficult questions have long since arisen in the reality of the working world. Many people around the world work at high and extreme altitudes, often without the opportunity to acclimatize. There is still no reliable way of predicting an individual's tolerance to altitude, except for medical history: if someone has been at a comparable altitude before and tolerated it well, they will probably do so again.

The **current concept** for selecting and supporting employees for extreme altitudes is presented using the example of the construction of the Fred Young Telescope (5700 m). This is in accordance with the national regulations of Chile and Germany. It includes:

1. Preliminary examination including laboratory tests (complete blood count, spirometry, ergometry and hypoxia test (20 min at 10% O_2).
2. If the SaO_2 falls below 70% at rest, the SaO_2 is additionally measured at 80W on a bicycle ergometer, assuming a distribution and ventilation disorder in a seated position.
3. At altitudes above 5000 m, it is mandatory to use a light-weight O_2 demand system, which can be set to 2 to 6 l/min depending on the severity of the work. Regular SaO_2 measurements are taken and blood pressure is measured at the start in accordance with Chilean regulations. The work shift is limited to 2 hours on the first day and 4 hours on the second day. From the third day onwards, full shifts can be worked.
4. The sleeping altitude is generally 2400 m above sea level.

Conclusion: In individual cases, employees complained of mild, diffuse headaches on the first few days. To date, no cases of clinically relevant AMS have been identified, and as expected, no cases of HAPE or HACE have been reported. The strategy should be feasible also for other work places at extreme altitude.

Borg's rating of perceived exertion—what does it measure and does it work at altitude?

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Background: So far exercise tests are not validated for isobaric hypoxia or hypobaric hypoxia (altitude training). Borg's rating scale for perceived exertion is a well established procedure to control the level of exercise during training. There are different scales for endurance and for strength training. For exercise training it may be assumed that pulse rate (HR) or increase of breathing indicates the body the actual level of load. But with both, HR and breathing, being increased by any kind of hypoxia a bias should be expected when the scale is used at altitude. Surprisingly, despite its widespread use, the scale has never been examined to determine which factor indicates the current level of stress to the user and whether a shift in the scale must be taken into account when using it in hypoxia.

Material and methods: Sixteen healthy individuals underwent a stress test (spiroergometry) at sea level, at 3,000 metres (Trockener Steg, Zermatt, Switzerland) and at 4,560 metres (Margherita Hut, Monte Rosa, Zermatt). For each stress level, the assessment had to be given according to the Borg scale.

Results: All Borg ratings at altitude were according to those from sea level. The correlation of load and HR or breathing volume was low. The highest correlation between load and physiological data was found for the increase of systolic blood pressure.

Conclusion: Borg scale for perceived exertion during endurance exercise can be used to control workload at altitude without a correction factor. Contrary to expectations, the increase in heart rate or respiratory minute volume appears to play a minor role (if any) in the perception of exertion level. The most important trigger for this appears to be the exertion-dependent increase in systolic blood pressure.

Hypoxic inter-effort recovery during sprint interval training exercise enhances oxygen uptake at the onset of efforts while maintaining exercise tolerance

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Introduction: Sprint interval training (SIT) in association with hypoxia is well known to enhance physiological adaptations improving exercise performance.

Notably, compensatory vasodilation, increased erythropoietin, and higher erythrocyte/hemoglobin mass are components of the O_2 transport system that may be improved with repeated exposures to hypoxia. However, exercise intensity can be reduced when performed under continuous hypoxia, we recently argued[4] and found evidence[1,2,3] suggesting that adding hypoxia exclusively during the recovery periods between efforts in interval training sessions [i.e., inter-effort hypoxia recovery (IEH)] could be a more effective approach than performing the entire training session under hypoxia to avoid decreases in external training load.[3,5] This study aimed to compare the acute effects of oxygen consumption ($\dot{V}O_2$), muscle oxygenation (SmO_2), and exercise tolerance during a session of SIT in normoxia (NOR), continuous hypoxia (HYP) and IEH conditions.

Methods: The single-blind randomized crossover experimental design involved 12 recreational runners (age of 24 ± 5 years old; body mass of 74.1 ± 14.5 kg; height of 174.5 ± 8.9 cm; $\dot{V}O_{2peak}$ of 49.8 ± 5.3 mL/kg/min) tested on a treadmill. Participants completed a graded exercise test in normoxia, followed by SIT sessions under three conditions: NOR (effort and recovery, FiO_2: 0.21%), HYP (effort and recovery, FiO_2: ~0.13%) and IEH (effort FiO_2: 0.21% and recovery: ~0.13%) on different days and random order. Oxygen consumption, ventilatory variables and muscle oxygenation in the vastus lateralis were assessed during SIT sessions consisting of ten 1-min efforts (at 120% of maximal treadmill running speed from the graded test), with 2-min passive recoveries.

Results: Compared to normoxia, IEH recovery caused significant hemoglobin desaturation (between 95% to 88%) and a ~14% decrease in $\dot{V}O_2$ during recoveries. During efforts, particularly in the first 30 seconds, $\dot{V}O_2$ was significantly increased by approximately 7% in the IEH condition compared to NOR. Notably, exercise task completion was nearly identical between NOR (87 ± 24%) and IEH recovery conditions (87 ± 18%), but significantly lower in continuous HYP (44 ± 27%), along with impaired indexes of O_2 metabolism. Additionally, IEH recovery resulted in a significantly lower pulmonary O_2 diffusion gradient at a given $\dot{V}O_2$, suggesting a compensatory increase in blood flow.

Conclusion: In conclusion, IEH recovery reduces O_2 availability in arterial blood and active skeletal muscle, significantly lowering $\dot{V}O_2$ only during recovery. However, $\dot{V}O_2$ is increased and muscle oxygenation is maintained at control levels during efforts. Notably, enhanced aerobic metabolism during efforts was associated with preserved exercise tolerance in the IEH condition, an advantage over HYP during SIT exercise.

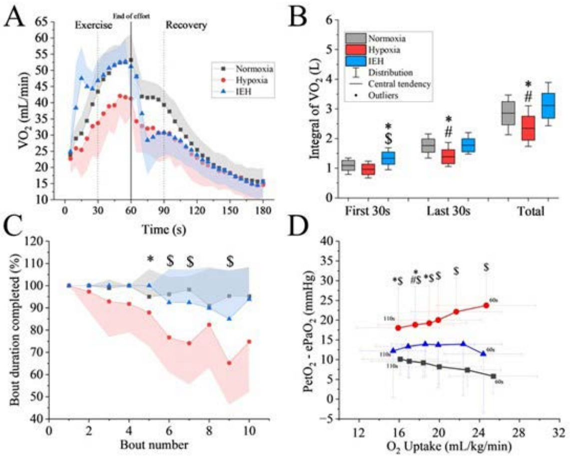

Figure 1. The averaged time courses of $\dot{V}O_2$ (A), O_2 uptake integral across different fractions of the effort (B), exercise tolerance of each effort completed (C), and efficiency of oxygen transport and utilization in relation to the alveolar-arterial oxygen gradient (D).

* Difference between IEH and hypoxia; difference between IEH and NOR; $ difference between HYP and NOR.

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Which altitude is better? Under which artificial hypoxic condition is training more effective for patients after a myocardial infarction?

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Introduction: In light of the latest scientific research, the use of artificial hypoxic conditions can effectively accelerate and improve the rehabilitation process of patients after a myocardial infarction.[1,2] Unfortunately, the parameters that should be used to ensure these specific conditions are as safe and optimal as possible for patients have not yet been fully studied or described.[3] Therefore, we compared all the studies we have conducted so far to determine which hypoxic conditions were most beneficial for patients.
Objective: Which hypoxic conditions (2000 or 3000 meters above sea level) during which interval training was performed on a cycle ergometer proved to be the most effective in terms of exercise test results and echocardiographic parameters of the heart?
Methods: Cardiopulmonary stress test CPET, echocardiography, blood parameters tests, blood saturation
Results: Significant differences were observed in exercise test parameters:

- 2000 m a.s.l. vs normoxia: test duration ($p = 0.012$), distance ($p = 0.009$);
- 3000 m a.s.l. vs normoxia: duration ($p = 0.007$), distance ($p = 0.005$), MET ($p = 0.008$), RER ($p = 0.033$).

Echocardiography with tissue Doppler imaging:

- 2000 m a.s.l. vs normoxia: LVEDd ($p = 0.016$), e' lateral ($p = 0.045$), e' septal ($p = 0.032$);
- 3000 m a.s.l. vs normoxia: E wave ($p = 0.033$).

No significant differences were found in other parameters (blood, oxygen saturation) with regard to the 2000 m and 3000 m a.s.l. conditions.
Conclusion: The obtained results indicate a better training effect at an altitude of 3000 m a.s.l.; however, from a practical point of view, training at 2000 m a.s.l. was better tolerated by the patients and allowed for the use of higher training loads at this altitude.

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Assessment of hypoxemia while climbing Mount Kilimanjaro (5985 m)

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As the highest mountain in Africa the Mount Kilimanjaro reaches 5985 m at its highest point (Uhuru peak) and is a member of the seven summits. The famous snow-covered volcano is fairly easy to climb and with long climbing seasons and a good infrastructure the mountain is a magnet for annually more than 50,000 trekkers. Surprisingly only 53–61% reach the summit and a high incidence of over 75% of acute mountain sickness (AMS) has been recorded.[1,2] Fast ascend profiles and a lack of acclimatisation is often blamed for these numbers. However, the hypoxemia during the ascend of Kilimanjaro hasn't been investigated yet.

In order to get a full description of the hypoxemia during the ascent of Mount Kilimanjaro, a group of five trekkers were monitored for six days via the most popular Marangu Route. Therefore we continuously measured the oxygen saturation (SpO_2) during sleep and trekking phases as well as conventional two-minutes SpO_2 measurements at rest every morning. Simultaneously the participants completed daily Lake Louise Scores for AMS symptoms. Our main goal was to record and describe the phases of hypoxemia during the ascend of Mount Kilimanjaro and show SpO_2 trends during sleep and exercise in high altitude.

Our results show a decline of SpO_2 with increasing altitude (see Figure 1). The lowest mean SpO_2 during exercise was recorded during the summit trek ($B5SpO_2$ = 68.8%). The lowest mean SpO_2 during sleep was recorded on Kibo Hut (4700 m) ($N5SpO_2$ = 77.6%). Additionally, the measurements at altitude during sleep ($NSpO_2$) have shown to be significantly lower than the conventional measurements at rest ($RSpO_2$) in the morning.

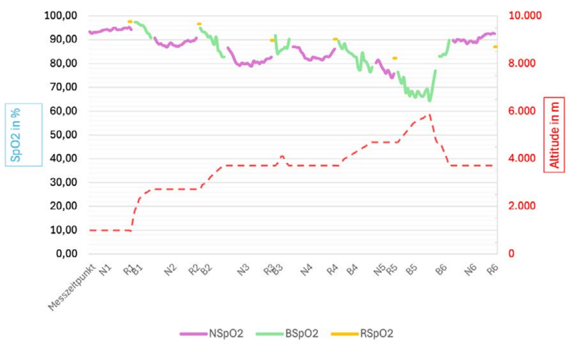

Figure 1. Continous SpO_2-measurement during the ascend of Mt Kilimanjaro

Especially the observation of SpO_2 trends give a detailed picture of the amount of desaturation during sleep and exercise. Effects of acclimatisation could be shown through significant increases of nightly SpO_2 when the three nights on Horombo Hut (3720 m) were compared ($N3SpO_2$ = 81.2%, $N4SpO_2$ = 83.5%, $N6SpO_2$ = 86.6% $p = 0.042$).

For direct links of continuously measured SpO_2 at night or exercise to AMS symptoms larger sample sizes are required. Our participants have all shown symptoms of AMS during their ascend. The big elevation gain and fast ascend profile at Mount Kilimanjaro seem to be a real physiological challenge.

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Expedition Denali: Challenges at altitude and in the cold

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Introduction: High-altitude medical knowledge and the application of appropriate tactics are the essential basis for successful operations at altitude and in cold conditions. In practice, however, one often encounters challenges that require a practical decision based on various factors.

Objectives: During a US Army expedition in 2017, the 23th Mountain Infantry Brigade was represented by two military mountain guides. The aim of the German participants was to gain experience with altitude and cold and to test new equipment (clothing, tents, stoves, etc.). The lecture will illustrate the difficulties that arise in practice and that theory is necessary but does not replace practical.

Methods: During the expedition, practical findings were evaluated in the sense of "lessons learned / lessons identified".

Results: Meticulous planning and preparation for any operation at altitude and in the cold conditions is necessary. That means:

- precise temporal and material planning with reserves;
- previous process training and testing of the material in a simpler environment;
- know the skills of the partners/group beforehand;
- a high level of physical fitness is essential, even if this has nothing to do with altitude adaptation;
- in practice, the human factor is the highest priority;
- the prophylactic use of altitude medicines is misleading and dangerous.

Conclusions: Good preparation and high fitness are the basis for success at altitude and in cold conditions. In addition to a reasonable altitude adjustment, sensible decisions must be made depending on the situation, even if the goal cannot be achieved.

Teaching remote First Aid in the UK

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First aid instructor, UK

Any place in the UK that is more than two hours away from the arrival of emergency services is considered a remote environment. It is now a requirement that anybody who works in a remote area needs to hold a valid and up to date First Aid Certificate because the knowledge of basic first aid can save lives. Workers in forestry, agriculture and outdoor activities need to have such a certificate.

I would like to present my experience in teaching Remote First Aid in the UK including the protocols we have for major emergencies as advised by the Resuscitation Council. The majority of the participants to these courses do not have prior medical knowledge and this is a challenge for us who need to explain in very simple terms what is sometimes a critical situation. We use practical scenarios to reinforce the knowledge and it is important to make the teaching interactive to allow for questions and informal assessment. At the end of the course there is an evaluation and the certificate will be released with a pass score. Whatever the setting, I found that the participants of the course are always interested and willing to learn if we present the information in a format that is accessible to all. We hope that, by making first aid knowledge more widespread in the UK, it will be possible to make a difference and avoid a preventable deterioration of a casualty.

Acknowledgements: Peter Cook, ProTraining Ltd, Diploma of Mountain Medicine, British Mountain Medical Society.

Non-invasive assessment of individual hypoxia tolerance in elite athletes: Flow Mediated Skin Fluorescence (FMSF) as an effective diagnostic tool

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Introduction: Individual hypoxia tolerance is a key factor determining the effectiveness and safety of training under conditions of reduced oxygen levels. Many tools exist for rapid, non-invasive, and objective assessment of an athlete's individual response to hypoxia, but they focus on the effect, rather than the cause. This often leads to inaccurate conclusions, and in practice, means making arbitrary training decisions, often leading to overload or ineffective adaptation. The proposed method focuses on the microvascular response following exposure to hypoxia.

Objectives: The aim of this pilot study was to evaluate the diagnostic potential of the Flow Mediated Skin Fluorescence (FMSF) technique in assessing hypoxia tolerance in endurance athletes and predicting the effects of hypoxic training.

Methods: Ten elite cyclists underwent a three-stage research protocol: (1) the FMSF test (under normoxia and after a 3-minute brachial artery occlusion), (2) one IHT (Intermittent Hypoxic Therapy) session (60 minutes: alternating cycles of 5 minutes of hypoxia/5 minutes of normoxia), (3) a repeat FMSF test after IHT. Microvascular parameters (HS, VM, RHR, IRmax, HRmax, PSD) and microvascular oscillatory activity at rest, divided into endothelial, neurogenic, and myogenic components, were recorded.

Results: The conducted study allowed for the practical application of the FMSF technique as an objective tool for assessing microcirculatory reactivity and adaptation to hypoxia. Distinct patterns of microcirculatory response were identified that demonstrated a potential association with hypoxia tolerance. Significant individual differences were observed in microcirculatory parameter values, which may be predictors of adaptation to hypoxia. Repeated FMSF measurement after IHT revealed dynamic changes in the oscillatory components of the microcirculation.

Conclusions: The FMSF technique enables a non-invasive, quantitative assessment of hypoxia tolerance, which could revolutionize the approach to hypoxic training planning. This tool allows for the objective identification of athletes who can benefit from high-altitude training and those who are at risk of overload. FMSF fills a long-sought diagnostic gap and represents a breakthrough in assessing the risk associated with hypoxic training.

Acknowledgements: This study was conducted without external financial support.

Assessment of hypoxia tolerance and determination of the optimal hypoxic training altitude in elite cyclists—a pilot study

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Introduction: The effectiveness of hypoxic training depends on the individual compensatory and adaptive capacity of the body to hypoxic conditions and the correct selection of the hypoxic dose and training loads. Determining training zones in a classic performance test does not provide information on whether the training zones will be maintained under hypoxic conditions. The new approach allows for both the assessment of hypoxia tolerance and the precise determination of the optimal training altitude that would not require a reduction in exercise intensity, which is one of the most important aspects from the point of view of the effectiveness of hypoxic training.

Objectives: The aim of the pilot study was to analyze the relationship between the results of the FMSF (Flow Mediated Skin Fluorescence) test, which assesses the microvascular and metabolic response to hypoxia following occlusion, and the results of a modified performance test assuming progression of simulated altitude at constant exercise intensity.

Methods: Ten elite cyclists first underwent the FMSF test, which assessed parameters such as Hypoxia Sensitivity (HS), Vasomotion (VM), Reactive Hyperemia Response (RHR), and other microcirculatory oscillations. Each athlete then completed a cycle ergometer performance test (at a constant workload corresponding to the ventilatory threshold (VT1)), with simulated altitude progression of approximately 100 m every 1–1.5 min to exertion or to a simulated altitude of 3000 m, whichever came first. Physiological variables were recorded: SpO_2, HR, SmO_2, V'E, BF, and ventilatory equivalents. The correspondence of the microvascular response (FMSF) to exercise tolerance at a given simulated altitude was analyzed.

Results: The developed procedures allowed for the simultaneous assessment of microvascular adaptation potential and the precise determination of the optimal training altitude at which the athlete can train without the need to reduce workloads. Physiological patterns were observed suggesting a possible correlation between FMSF results and the modified performance test results, providing a starting point for further validation of the method.

Conclusions: For the first time, two complementary diagnostic methods—FMSF and a modified performance test—have been integrated to fully assess adaptability to hypoxia and determine the individual's optimal training altitude for a given exercise intensity. This approach has the potential to transform hypoxic training protocols, better understand physiological responses to hypoxia, improve athlete safety, and maximize training effectiveness.

Acknowledgements: This study was conducted without external financial support.

Medical challenges in mountain warfare

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Introduction: Historically, there is much evidence of the influence of mountainous environment on warfare. The aim of this presentation is to answer the question if we now have to be prepared for mountain warfare in present or future times and to give an overview which environmental hazards have implications on medical care and evacuation.

Methods: A selective PubMed and Internet search was conducted. In addition, own experiences were included in the preparation of the presentation.

Results: There are still ongoing conflicts in areas with mountainous terrain or extreme climatic challenges, especially cold. Reasons for actual or potential conflicts are various. With regard to the influencing environmental factors, three different main aspects must be considered in more detail in mountain warfare:

- difficult and extreme terrain, especially in the mountains, as well as with large differences in altitude;
- high altitudes;
- extreme cold.

Conducting operations in this environment results in numerous casualties which, in addition to the casualties caused by combat, are of a magnitude that should not be underestimated.

Each aspect, either individually or in combination, has relevant implications for medical care. Not only the tactical approach to care, but also specific clinical pictures and specific pathophysiological changes pose a challenge for medical personnel.
Conclusions: Mountain warfare—military operations in this extreme environment—is still an issue we need to think about. All considerations for medical support in such kind of operations must be based on a very specific knowledge and training.

Descent of 2000 m within 5 minutes—Hyperbaric Rescue Bag

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Introduction: Portable hyperbaric chambers are used as emergency treatment for mountaineers suffering from altitude illness. At high altitude the overpressure generated inside these chambers simulates a physiological "descent" for the patient. Under standardized conditions in a hypobaric chamber, the effectiveness of this elegant physiological therapy principle is demonstrated to participants of the German Army training course "High Altitude Medicine for Medical Personnel".
Materials and methods: In the altitude and climate simulation chamber of the German Air Force in Königsbrück, course participants are exposed to an altitude of 15,000 ft (4,572 m). The use of a hyperbaric altitude rescue bag (CertecBag) is taught. Manual pumping creates an overpressure inside the CertecBag, regulated by a pressure valve. A barometric altimeter is placed inside the bag, and a pulse oximeter (Nonin PalmSat 2500) is attached to the test subject to visualize the effect.
Results: A rapid descent of 2000 m is achieved within 5 minutes. The subject's SpO_2 significantly increases from 72% to 99%. No pressure equalization problems occurred in the subject, though such issues are described in the literature.
Conclusion: The principle of the hyperbaric rescue bag is elegant, as it does not consume limited resources such as bottled oxygen. The therapy is highly effective and can be responsibly administered by mountaineering groups after brief training. In cases of altitude illness, symptom improvement should be used to facilitate immediate descent.

The brain-gas interface: The chemosensitive serotonergic system

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The serotonergic system (5-hydroxytryptamine, 5-HT) is a fundamental regulator of brain homeostasis, integrating classical neurotransmission with intrinsic chemosensory capabilities. Serotonergic neurons—particularly those within the brainstem raphe nuclei—exhibit sensitivity to fluctuations in arterial carbon dioxide (CO_2), pH, and oxygen (O_2) levels, enabling dynamic adaptation of brain function to environmental and physiological stressors. While traditionally recognized for its role in respiratory regulation, emerging evidence underscores its broader influence on pain modulation, neuroplasticity, and cerebral hemodynamics, particularly under conditions of hypocapnia or hypercapnia and hypoxia encountered during high-altitude exposure, aviation, diving, and acute stress.

Hyperventilation, a compensatory response to hypoxia, commonly observed at altitude and under acute psychological stress, induces hypocapnia and respiratory alkalosis. This shift suppresses the activity of chemosensitive serotonergic neurons, resulting in decreased central 5-HT availability. The downstream effects include reduced descending inhibition of nociceptive pathways, potentially increasing vulnerability to headache and somatic pain, frequently reported in altitude illness and aviation fatigue. Moreover, serotonin is critically involved in supporting synaptic plasticity and stress resilience; its attenuation during hypocapnia may impair cognitive flexibility, memory consolidation, and adaptive neural responses.

Serotonin also plays a pivotal role in cerebral blood flow (CBF) regulation through receptor-mediated vasodilatory mechanisms. Hypocapnia-induced cerebral vasoconstriction, compounded by reduced serotonergic input, may lead to transient cerebral hypoperfusion, manifesting as cognitive impairment, dizziness, or even syncope—clinical features particularly relevant to aerospace physiology and mountain medicine.

Conversely, acute hypoxia typically enhances serotonergic neuronal activity, facilitating arousal, sympathetic activation, and autonomic regulation. However, chronic or severe hypoxic exposure, such as in alpinists or professional divers, may disrupt serotonergic function, undermining its neuroprotective, cognitive, and vascular roles. Such dysregulation has been implicated in neurocognitive decline, affective disturbances etc.

In conclusion, the chemosensitive serotonergic system constitutes a vital interface between gas exchange dynamics and brain function. Its modulation of nociception, neuroplasticity, and CBF under extreme environmental conditions highlights its clinical and operational significance in aviation, diving medicine, and high-altitude physiology.

Oxygen supply for parachuters at operational altitudes--laboratory tests and their usefulness in extreme and real environments

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Introduction: The data determined in the laboratory is complicated to transfer to the real environment. Often, different results are obtained in real-world environments, leading to an incorrect assessment of human performance. In particular, environmental influences must be taken into account in the overall physiological assessment. In addition, field measurements are not easy to carry out because the measurement options available to date are either invasive and therefore unusable, the instruments are too heavy, or the parameters are misinterpreted without considering the environment.

Methods: For parachuters, a setup was used that primarily incorporates environmental influences into the assessment. Sensors and the measuring location were integrated into the study preparations to gain a comprehensive understanding of the physiological conditions. In particular, the data collection to be carried out in the future was included in the setup from the outset in order to collect valid data under the adverse conditions experienced by high-altitude parachuters.

Results: Over the last 10 years, outstanding results were achieved in over 300 jumps during actual jumps. An interesting trend was observed in oxygen saturation levels, which showed significant desaturation even during the approach to the target. Additionally, core body temperature and skin temperature data were recorded, and notable values were also measured in this case. The peripheral skin temperatures showed significant reductions, whereas the central temperature showed an increase.

Discussion: It appears that measurements of physiological data in the environment yield different results than those found in the laboratory. In particular, the selection of sensors and the inclusion of environmental parameters show that complex processes are at work that influence human performance. In this long-term study, it was possible to demonstrate the feasibility of data collection in the real environment and to record interesting data that could not be obtained in laboratory settings. It is therefore always advisable to verify the consistency and reliability of laboratory results in real-world conditions. With the mobile physiological laboratory and, in the future, with the developed smart textile (mobPhysioLab®—SmTx), such studies become manageable, and additional research opportunities arise that facilitate the assessment of individual performance and endurance in extreme environments.