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FOREWORD

Dear participants, colleagues and friends!

Welcome to the 8. European Hypoxia Symposium. In next three days we will participate in scientific and professional presentations related to four main topics, following:

High altitude and severe hypoxia session will show recent experience of authors related to different aspects of living and exercising (alpinist climbing) at high-altitude or in normobaric hypoxic conditions. For the first time some presentations will related to topics of possible differences in hypoxic adaptations in children and adults. Finally, certain clinical issues will be presented.

Mountains warfare session will relate to recent and historical reviews of mountain warfare, definitions of mountains related to warfare specific conditions, and specific experience how to prevent mountain sickness in soldiers. Estimation of specific performance of soldiers during marching in mountains will be present too.

Moderate altitude and altitude training will be topic of the third session. It will give us information about several strategies how to improve specific sport performance, specific adaptations related to intense endurance training and living in different environmental conditions.

Other topics related to altitude will combine different topics starting from technical issues related to normobaric hypoxia technology and to technical testing of climbing ropes quality. Specific interest will be focus to possibility of marking relative exertion during walking in mountains. Very interesting and rare topic will related to diving at high altitude.

On behalf of the Scientific Commettee I wish you pleasant stay here in Poljče and in Slovenia, especially for you, who are for the first time, here.

prof. dr. Anton Ušaj

HIGH ALTITUDE AND SEVERE HYPOXIA

HYPOXIA

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HYPOXIA

Hypoxia is PiO_2 less than normal (1).

- Hypoxia, induced.by enhanced terrestrial altitude.
- Breathing normobaric hypoxic gases (reduced FiO_2).

HYPOXEMIA

Hypoxemia is decrease of arterial blood oxygen pressure (P_AO_2) below 10.7-13.3 kPa as it is normal in arterial blood (1).

- Exercise induced arterial hypoxemia.
- Enhanced terrestrial altitude induced arterial hypoxemia.
- Hypoxemia influenced breathing normobaric hypoxic gases (reduced FiO_2).

ADAPTED CELL HYPOXIA

Adapted cell hypoxia means an intracellular PO_2 less than in absence of stress but sufficient to maintain O_2 and ATP flux because of adaptive changes in redox and phosphorylation (1).

DYSOXIA

Dysoxia is an O_2 limited cytochrome turnover, an O_2 deficiency or PO_2 at which deficiency occur (1).

WHAT IS HAPPENING DURING EXERCISE

Transport of O_2 molecules from air by breathing, blood, muscle cells to mitochondria, decreases their PO_2 from the air (21.3 kPa) to about 13.3 kPa in arterial blood, to about 4 kPa in muscle (2,3). During maximal exercise close to Vo_2max and in red muscle (predominantly ST fibres) this valued reaches extremely low 0.4-0.5 kPa (2).

Increase of exercise intensity (for example during incremental test) accompanying an increase in Vo_2 on cellular and mitochondrial level and whole body level. At cellular level the PO_2 decreases too in a linear manner. During low cellular Vo_2, for example at 50%, decrease of PO_2 is small but still adequate for maintaining ATP flux. Further increase of Vo_2, decreases PO_2 additionally for maintaining increased ATP flux, however with additional metabolic adaptations (adapted cell hypoxia) (1). Usually the upper limit of this range reached Vo_2max. The PO_2 is the lowest possible, necessary for realizing the highest oxygen consumption and ATP flux from aerobic metabolism. Further decrease of Po_2 should impair mitochondrial Vo_2. Such low Po_2 assure adequate difference in Po_2, force which makes possible successful diffusing of O_2 to mitochondria (1, 3). Additionally low Po_2 is stimulus for enhancement of maximal perfusion (1, 3).

To understand how decrease of PO_2, especially in mitochondria is connected to increase of Vo_2 it should be understanding that the highest possible ATP flux realized by aerobic metabolism must be reached by larger possible difference between Po_2 in inspired air and mitochondrial values (3). Decreasing of PiO_2 by increasing altitude (hypoxia) decreased mitochondrial PO_2 below 0.3 kPa. This influence on decreasing mitochondrial Vo_2 and reduce power of ATP resynthesis by aerobic metabolism named dysoxia (1, 3).

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CIRCADIAN RHYTHM OF SpO_2 AT HIGH ALTITUDE

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INTRODUCTION

Oxygen saturation (SpO_2) is frequently measured at high altitude to determine acclimatization status. We could show that SpO_2 increases during the night. Therefore diurnal decrease becomes indispensable otherwise a continuous increase would occur.

METHODS

To prove this hypothesis we analyzed SpO_2-course during two different studies at high altitude; nocturnal (SpO_{2N}) during an expedition in Peru (10 male; 3050-6354m), diurnal (SpO_{2rest}) during a stay in the area of Mont Blanc (15 male; 3731 – 4808m). Using non-invasive pulse oximeters SpO_{2N} was continuously measured and two 2h-periods during the first (N1) and second part (N2) of individual sleep duration were averaged, SpO_{2rest} was measured at three different time points (7:00 a.m., 8:30 p.m., 12:00 p.m.).

RESULTS

In Peru SpO_{2N} significantly increased from 83.4% (N1) to 86.3% (N2) during the first night at 3050 m. The magnitude of this increase at the same altitude was reduced with time spent at altitude which is a relative change of 4.7% (night 1) and 2.0% (night 21), respectively. In contrast SpO_{2N} decreased in persons suffering from severe AMS. At similar altitude of 3371m in the area of Mont Blanc SpO_{2rest} decreased from 92% at 7.00 a.m. to 88% at 8.30 p.m. down to 85% at 12.00 p.m.

CONCLUSSIONS

Even though these are two different studies each principal finding supports the result of the other study as well as our hypothesis that SpO_2 shows a circadian rhythm. We conclude that the time point of SpO_2 measurement is of utmost importance for SpO_2 interpretation. Furthermore data suggests that nocturnal SpO_2 time course might be a valuable indicator of individual acclimatization, more specifically the failure to increase nocturnal SpO_2 might indicate insufficient acclimatization.

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COMPARING THE EFFECT OF LOAD CARRIAGE ON ENERGY EXPENDITURE AND HEART RATE IN HYPOXIA WITH NORMOXIA.

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INTRODUCTION

The effect of carrying a load is well documented at sea level (SL), as are the effects of exercising at altitude, yet there are very few studies to date that have combined the two; examining the changes in physiological responses to load carriage at altitude. The aim was to investigate whether the unloaded to loaded relationship experienced at SL is mirrored, exaggerated or reduced during acute hypoxia (H).

METHODS

- 10 participants (6 males, 4 females) took part in the study (mean ± SD age: 23 ± 3.77 years; $\dot{V}O_{2max}$: 56.21 ± 11.87 $ml.min^{-1}.kg^{-1}$).
- All tests were conducted in the environmental chamber at Leeds Beckett University. Tests were performed at SL (20.9% F_iO_2) and 4300m (~11.8% F_iO_2).
- Participants undertook a maximal exercise test to exhaustion at H and SL. One a separate day, particiapnts rested for 15 mins followed by ~30 min of unloaded walking,~30 min of loaded walking (18.2 kg), and a second unloaded bout (~10 mins). Bouts were separated by 10 min rest periods. Trials incorporated different gradients (-10%, 0% and 10%) and speeds, absolute (3 and 4 $km.hr^{-1}$) and relative (35, 40 and 50% $\dot{V}O_{2max}$).
- Expired air was analysed by the online gas analyser (Cortex 3B Metalyzer, Germany). Heart rate (HR) was measured using a Polar T31 coded™ transmitter (Kempele, Finland).
- Data were analysed using IBM SPSS 22, with significance denoted as $p \leq 0.05$, using a repeated measures ANOVA. Post-hoc testing consisted of paired t-tests with Bonferroni adjustment and Cohen's D for effect size.

RESULTS

$\dot{V}O_{2max}$ was significantly reduced during H (37.49 ± 8.33 $ml.kg^{-1}.min^{-1}$) compared to SL (56.21 ± 11.87 $ml.kg^{-1}.min^{-1}$) ($p < 0.001$, d = 1.83). HR_{max} was also reduced (172 ± 11 $beats.min^{-1}$) compared to SL (187 ± 14 $beats.min^{-1}$, $p < 0.001$, d = 1.19). Table 1 shows that H caused a significantly greater $\Delta\%\dot{V}O_{2max}$, ($p < 0.001$, $\eta_p^2 \geq 0.887$) when load was added. At relative exercise intensities, the magnitude of change was similar between environments.

According to (3) when walking at absolute speeds at SL, average HR remained in recovery zone (<55%HR_{max}) and zone 1 (55-75%HR_{max}) whereas at H, HR fluctuated between zones 1 to 3 (80-90%HR_{max}). In addition, H caused individuals to perform at a significantly higher %HR_{max} at speeds representing 35% and 40%$\dot{V}O_{2max}$, ($p \leq 0.001$, d = 0.675).

*Table 1. Mean ± SD Δ%$\dot{V}O_{2max}$ from unloaded to loaded at absolute speeds (3 $km.hr^{-1}$ and 4 $km.hr^{-1}$ combined) and %HR_{max} when loaded at absolute speeds * significantly different to SL values.*

Variable	Gradient	SL	4300m
Δ%$\dot{V}O_{2max}$	-10%	2.06±1.22	5.40±3.45*
	0%	4.11±2.08	9.33±3.18*
	10%	7.58±1.97	10.23±3.78*
%HRmax (loaded)	-10%	46.24±4.78	59.21±8.77*
	0%	47.71±5.14	67.26±8.76*
	10%	63.5±6.75	85.88±5.85*

CONCLUSIONS

$\dot{V}O_{2max}$ was reduced by ~33% upon acute exposure to H, this is in agreement with previous findings (2). To the authors knowledge, this is the first study to show that the difference in %$\dot{V}O_{2max}$ when going from unloaded to loaded walking is greater in H than at SL. This finding can be attributed to the reduced $\dot{V}O_{2max}$ causing a larger disturbance in homeostasis, triggering greater physiological and metabolic changes (2). It has been previously reported (1) that absolute sub-maximal $\dot{V}O_2$ during load carriage remains similar to SL values (2). Due to the reduced $\dot{V}O_{2max}$ at H, walking at a given speed is performed at a higher %$\dot{V}O_{2max}$ (2). Therefore the same absolute change in $\dot{V}O_2$ from unloaded to loaded will manifest itself as a greater difference when at altitude.

The finding of similar changes in %$\dot{V}O_{2max}$ associated with load at relative exercise intensities, highlights the importance of reducing speed when at altitude. This ensures that the effects of load do not exceed responses seen at SL. The knowledge of HR responses with respect to HR zones when loaded will inform training and preparation practices.

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CORTISOL RESPONSES TO INTERMITTENT NORMOBARIC HYPOXIC EXPOSURE WITH AND WITHOUT EXERCISE.

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INTRODUCTION

Cortisol is a stress hormone that may contribute to fluid retention at high altitude[1]. Fluid retention has been strongly associated with susceptibility to acute mountain sickness (AMS)[2]. Preacclimatisation techniques such as intermittent hypoxic exposure (IHE) or training (IHT) may be beneficial in reducing the cortisol response to hypoxia and therefore may reduce susceptibility to AMS on subsequent high altitude exposure.

METHODS

Three comparison groups comprised: IHE (8 male, 2 female, height, 175±7cm, mass, 80±12kg & age 33±12 years), IHT (8 male, 1 female, height, 178±8cm, mass, 75±8kg & age 22±2 years), Sea Level Control (SLC)(7 male, 3 female, height, 175±10cm, mass, 75±12kg & age 22±2 years). All were non smoking, lowlanders and had not been to altitudes >1500m in the previous 3 months. The three groups completed 5 consecutive days of testing ($5h.day^{-1}$ at 18°C and 45% relative humidity). IHE & IHT groups were exposed to 4800m (normobaric 10.9%-11.1% O_2) on days 1, 4 & 5 and 4300m (11.7%-11.9% O_2) on days 2 & 3. SLC were blinded to conditions of 20.9% O_2. Four venous blood samples were collected at consistent times of day in session 1 and 5 (T1 = 0hrs, typically between 06:30am-08:00am, with T2 at 1hr45min, T3 at 4hrs, and T4 at 5hrs). IHT and SLC groups walked for 90 mins from 2hr30mins at 10-15% incline carrying 10kg (10 mins at 40%, 60 mins at 50%, 10 mins at 60% & 10 mins at 70% of altitude specific $V0_{2MAX}$). Data were analysed using SPSS 22 and tested for normality. Differences were evaluted using a repeated measures (RM) ANOVA with *post hoc* testing performed using t-tests with Bonferroni adjustment.

RESULTS

SLC showed a consistent typical diurnal decrease in Cortisol concentration across the two sessions (Table 1). In contrast, IHE & IHT produced significantly elevated Cortisol responses across session 1 compared with session 5 (RMANOVA, Session*Time*Group, p=0.016). Exercise in IHT significantly (t-test, p=0.006) elevated the Cortisol response in session 1 (T3), however, this increase was significantly reduced in session 5 (t-test, p=0.023). Using area under the curve, cortisol response for IHT from session 1 to 5 showed a greater magnitude of decrease than for IHE (37314± 18512 vs. 9120± 36862 $nmol.L^{-1}.min$), which approached significance (t-test, p=0.051).

Table 1: Cortisol responses ($nmol.L^{-1}$) in SLC, IHE and IHT groups (mean and SD).

		Session 1			
		T1	T2	T3	T4
SLC	Mean	593	475	380	376
	SD	274	235	165	129
IHE	Mean	394	301	385	424
	SD	82	114	243	206
IHT	Mean	472	464	657*	536
	SD	133	173	87	149
		Session 5			
SLC	Mean	564	409	387	316
	SD	185	148	78	80
IHE	Mean	424	328	288	275
	SD	99	97	111	77
IHT	Mean	473	365	455$	339
	SD	66	91	104	85

(IHT: * = significantly higher than T2 in session 1; $ = significantly lower than T3 in session 1).

CONCLUSION

Both IHE and IHT produced favourable responses in Cortisol concentration consistent with acclimation and therefore have potential to decrease AMS susceptibility. Findings suggests that exercise (IHT) has a more favourable effect on acclimation in comparison to rest (IHE) alone.

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ADRENERGIC MECHANISMS IN THE ADAPTATION TO HYPOXIA

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INTRODUCTION:

The aim of the adaptation to hypoxia is to ensure sufficient oxygen supply for the organism. The haemodynamic situation is characterised by hypoxia-induced pulmonary vasoconstriction and systemic vasodilation. In addition, hypoxic stimulation of peripheral chemoreceptors induces release of catecholamines (CA). In the present study, we investigated the role of alpha- and beta-adrenergic mechanisms in the acute cardiopulmonary adaption to hypoxia.

METHODS:

All experiments were performed on female Sprague Dawley rats. The animals were exposed to normoxia (N) or normobaric hypoxia (10% O_2 in N_2, H) for 1.5 or 6 h. The animals received intravenous infusion (1 ml/h) with one of the following treatments: 0.9% NaCl (N-Ctrl, H-Ctrl); norepinephrine 0,1 mg kg^{-1} h^{-1} (N-NE, H-NE); prazosin 0.1 mg kg^{-1} h^{-1} (H-PZ); propranolol 1 mg kg^{-1} h^{-1} (H-PR); prazosin 0.1 mg kg^{-1} h^{-1} + propranolol 1 mg kg^{-1} h^{-1} (H-PZPR).

At the end of the exposure time we measured the systolic pressure of the right (RVSP) and the left (LVSP) ventricle, the diastolic aortic pressure (PdAo), the index of cardiac output (CI) and the total peripheral resistance (TPR). Blood was drawn from the aorta to quantify the concentrations of NE and epinephrine (Epi). Tissue from the right lung was taken for histological analysis.

RESULTS:

No significant changes in haemodynamic parameters were observed after the short-term (1.5 h) exposure to hypoxia. Treatment with H-PZPR significantly decreased LVSP and PdAo by 20 – 30 mmHg compared to H-Ctrl. Prolonged (6h) exposure to hypoxia significantly reduced LVSP and PdAo compared to normoxia. While PZ, PR and PZPR did not further reduce these parameters, NE showed the tendency to normalise them. Neither NE infusion in normoxia nor exposure to hypoxia induced significant changes in the serum concentrations of NE and Epi whereas combination of hypoxia with NE infusion significantly increased the NE level.

CONCLUSION:

During the first 1.5 h of hypoxia, the haemodynamic function of the systemic circulation remained stable. The drop of LVSP and PdAo after alpha- and beta-adrenergic blockade indicates that adrenergic mechanisms play a crucial role in the acute adaptation to hypoxia. The findings of the 6-h-experiments demonstrate that this CA-dependent cardiovascular adaptation becomes less effective with prolonged exposure to hypoxia.

EFFECTS OF NORMOBARIC HYPOXIA AND EXERCISE ON PSYCHOMOTOR FUNCTION IN ADULTS AND CHILDREN

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INTRODUCTION

Exposure to altitude and/or normobaric hypoxia can result in subtle neurological dysfunctions, such as reductions of fine-motor and cognitive function (Hornbein et al., 1989). These dysfunctions might reduce the safety of individuals during mountaineering or skiing at higher altitudes. The aim of this study was to investigate the influence of age, physical exercise and normobaric hypoxia on psychomotor function.

METHODS

Twenty-six healthy, low-altitude residents (adults, N=13, age= 40(4) yrs.; children, N=13, age= 8(2) yrs.) were tested in normoxia (FiO2=0.209; PiO2=134(0.4) mmHg; 940m) on Day 1 and normobaric hypoxia (FiO2=0.162±0.003; PiO2=105(0.6) mmHg; ~3000 m) on Day 2 following an overnight hypoxic acclimation (≥12-hrs). The psychomotor function of the participants was assessed in normoxia and hypoxia, before and after physical exercise using a simple visual reaction time (SVRT), positioning speed test (PST) and Trial making test (TMT) A and B. The tests were conducted from less (VSRT) to more (TMT-B) complex tasks with the same order in both conditions.

RESULTS

In comparison with children, adults achieved significantly ($P<0.01$) better results in all tests in both, normoxic and hypoxic environment. Participants of both groups improved the results in all tests after exercise in both normoxic and hypoxic condition. Adults significantly improved results in PST and TMT-B and children in TMT-A and TMT-B tests ($P<0.01$).

CONCLUSIONS

Contrary to the majority of previous investigations, our results do not indicate that the tested level of normobaric hypoxia (~3000 m simulated altitude) induces psychomotor dysfunction in either adults or children. Improvement in tests results could be attributed to learning effects (Beglinger et al., 2005) and physical exercise (Nanda et al., 2013).

The authors would like to thank the Foundation for sports which enabled the realization of the project KidSki (RR-2015-5228-11659).

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EFFECTS OF HYPOXIA EXPOSURE ON CUTANEOUS THRESHOLDS FOR WARMTH AND COLD SENSATION: COMPARISON BETWEEN ADULTS AND CHILDREN

Miroljub Jakovljević[1], Tadej Debevec[2], Jernej Kapus[3], Anton Ušaj [3], Adam C McDonnel [2], Janez Vodičar[3], Peter Najdenov[4], Polona Jaki Mekjavić[5], Igor B Mekjavić[2]

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INTRODUCTION

One of the non-thermal factors, which can affect thermoregulation, is hypoxia. It may affect perception of temperature, particularly the threshold for cold sensation (Golja et al., 2004) and may influence the zone of thermal comfort (Golja & Mekjavic, 2003). The aim of the study was to investigate the effect of acute hypoxia on thermotactile sensation in adults and children.

METHODS

Twenty-six healthy, low-altitude residents (adults, N=13, age= 40(4) yrs., body mass: 73(12) kg; children, N=13, age= 8(2) yrs., body mass: 29(7) kg) were tested in normoxia (Nor: FiO2=0.209; PiO2=134(0.4) mmHg; 940m) on Day 1 and normobaric hypoxia (Hyp: FiO2=0.162±0.003; PiO2=105(0.6) mmHg; ~3000 m) on Day 2, following an overnight hypoxic acclimation (≥12-hrs). Thermal stimuli were produced by computer driving Biomed T-sensy (MAK Elektronik, MAK d.o.o., Škofja Loka, Slovenia). Warm sensory perceived thresholds (WSPT), cool sensory perceived thresholds (CSPT) and interthreshold interval (II) were obtained by method of alternate level stimuli (Klopčič & Jakovljević, 2009) in the middle point of the volar side of left forearm.

RESULTS

There were no significant differences in WSPT, CSPT and II between adults and children in both conditions. In addition, no significant changes were established in WSPT, CSPT and II between normoxia and hypoxia

CONCLUSIONS

We confirmed the results of Malanda and coworkers (2008) that hypoxia does not affect cutaneous sensation threshold for either warmth or cold detection, not only in adults, but also in children. It is possible that in the acral parts of extremities hypoxia affects thresholds for the cold sensation (Daanen & van Ruiten, 2000) which is not possible to observe on proximal parts of extremities.

The authors would like to thank the Foundation for sports which enabled the realization of the project KidSki (RR-2015-5228-11659).

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WORKLOAD AND PULMONARY ARTERY PRESSURE AT HIGH ALTITUDE (5150M) – ECHOCARDIOGRAPHIC RESULTS OF THE ADEMED EXPEDITION 2011 (MT. EVEREST REGION, NEPAL)

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INTRODUCTION

Increased systolic pulmonary artery pressure (PAPs) is considered as one of other risk factors for high altitude pulmonary edema (HAPE). However, data about PAP in real situation(s) like high altitude, workload by speed of walking or heavy load are missing.

METHODS

27 trekkers (20 to 65 years; 13 male, 14 female) climbed Kalar Patthar (5675m) from Gorak Shep (5170m). Ascent was controlled for speed and load (0.1 to 0.3 kg/kg body weight). Three participants climbed up to 11 times with different loads and speeds at consecutive days. All subjects were evaluated by echocardiography immediately after arrival at the summit. PAPs was estimated by measuring the maximal regurgitation speed (v_{max}) at the tricuspidal valve. Individual data, preexisting conditions and altitude profile (acclimatization) were registered by a questionnaire.

RESULTS

PAPs and v_{max} increases with altitude in almost all subjects (mean differences between Ghorak Shep and the summit: v_{max} 0.22 m/s, PAPs 4.39 mmHg; $P<0.01$). A significant number of participants showed pulmonary hypertension after arrival at the summit. The pressure was correlated with age and inverse correlated with acclimatization. It was independent from gender and BMI. Surprizingly it was also independent from load and speed of the current ascent.

Preacclimatization in isobaric hypoxia prior to the trip causes lower PAPs. Prophylactic use of acetazolamid increases the mean values at Gorak Shep and a further but less pronounced inrease of PAPs and V_{max} at the summit.

No subject showed abnormalities of the right ventricular systolic function (measured by TAPSE). No subject showed any sign of HAPE at the summit.

CONCLUSSIONS

Obviously neither the actual load nor the actual ascent speed is of sigificant influence on PAPs and v_{max}. Surprizingly also acetazolamide did not reduce PAPs – it increased it. The most important factor to keep the increase of PAP under control is perfect acclimatization, especially by an adequate ascent profile. This may also be performed by isobaric hypoxia prior to the trip. Individuals with preexisting cardiopulmonary diseases or hypertension may be at higher risk. This should be investigated in a specific study.

SHORT-TERM CARDIORESPIRATORY ADAPTATION TO HYPOXIA IN CHILDREN AND ADULTS: The KidSki study

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INTRODUCTION

Acute altitude exposure significantly affects aerobic capacity (1) as well as orthostatic tolerance (2) and induces a number of compensatory mechanisms that counteract the reduced O_2 availability (3). However, the influence of maturation on altitude/hypoxic acclimatization is currently unclear. The present study aimed to compare cardiorespiratory responses during rest, simulated skiing exercise and orthostatic test in normoxic and hypoxic conditions between adults and children.

METHODS

Thirteen children (age= 8±2 yrs, body mass= 29±7 kg) and 13 adults (age= 40±4 yrs, body mass= 73±12 kg) underwent testing in normoxia (Nor: F_iO_2=0.209; P_iO_2=134±0.4 mmHg; altitude=940m) on Day 1, and in normobaric hypoxia (Hyp: F_iO_2=0.162±0.003; P_iO_2=105±0.6 mmHg; altitude ~3000 m) on Day 2 following an overnight (≥12-hrs) hypoxic exposure. Resting morning heart rate (HR) and capillary oxyhemoglobin saturation (SpO_2) measurements were performed using finger pulse oximetry. Participants also completed a simulated skiing protocol on a Pro Ski simulator (3 bouts of 2-min) and a head-up tilt test (3-min supine, 6-min 60° tilted). HR and SpO_2 were measured continuously as described above. Minute ventilation (V_E) and oxygen uptake (VO_2) were recorded continuously during the ski protocol using a calibrated metabolic cart. Data relative to body mass from the third skiing bout were used for analysis.

RESULTS

Resting SpO_2 was lower in hypoxia (Nor: 97±1%; Hyp: 91±2%; P<0.01), with no differences between groups (Fig. 1). Higher resting HR in hypoxia, compared to normoxia was only noted in children (Fig. 1; P<0.05). While greater HR during hypoxic vs. normoxic skiing, was noted in children than adults (Nor: 155±19; Hyp: 167±13) beats/min; P<0.05), V_E and VO_2 were comparable.

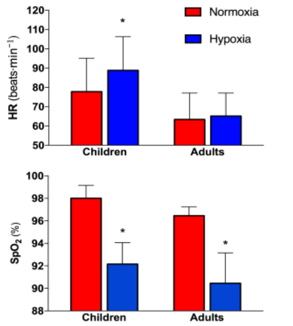

Fig. 1 Resting morning heart rate (HR) and capillary oxyhemoglobin saturation (SpO_2) in children and adults in normoxia and hypoxia.

HR and SpO_2 responses during the tilt test were comparable between groups. The HR responses were significantly higher throughout the hypoxic tilt test in children only (P<0.01).

CONCLUSSIONS

These data indicate similar cardiorespiratory responses in children and adults during simulated hypoxic skiing, and orthostasis. The greater resting and exercise HR responses to hypoxia observed in children compared to adults, without a concomitant increase in other measured cardiorespiratory parameters, bring into question the usefulness of HR as an index of short-term altitude adaptation in children and warrants further investigation.

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VENTILATION AND MUSCLE OXYGENATION DURING HYPOXIC EXERCISE IN CHILDREN AND ADULTS

Tadej Debevec[1], Jernej Kapus[2], Adam C. McDonnell[1] Janez Vodičar[2], Peter Najdenov[3], Miroljub Jakovljevic[4], Polona Jaki Mekjavic[5], Milan Žvan[2], Leja Dolenc Grošelj[5], Igor B. Mekjavic[1], Anton Ušaj[2]

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INTRODUCTION

Maturation significantly influences ventilatory control during exercise (1). However, it remains unclear if exercise ventilatory response to hypoxia is similar in children and adults (2). To that end, we compared the ventilation and muscle oxygenation at the ventilatory threshold during exercise performed in normoxic and normobaric hypoxic conditions between children and adults.

METHODS

Thirteen adults (Males, N= 7; BM= 80±8 kg; AGE= 38±4 yrs & Females, N=6; BM= 65±11 kg; AGE= 41±3 yrs) and 13 prepubertal children (BM= 29±7 kg; AGE= 8±2 yrs; 6 females) performed two incremental tests (40W·3min^{-1}) on a cycle ergometer in normoxia (NOR, F_iO_2=0.209; P_iO_2 = 134±0.4 mmHg; 940m) and hypoxia (HYP, F_iO_2=0.162±0.003; P_iO_2=105±0.6 mmHg; ~3000 m). The HYP tests were performed following an overnight hypoxic acclimation (≥12-hrs). Minute ventilation (Ve) and ventilatory threshold (VT) were determined using a metabolic cart (CPET, Cosmed). Near infrared spectroscopy (Oxymon MK III, Artinis) was employed to assess vastus lateralis muscle oxygenation (O_2Hb).

RESULTS

Absolute power outputs at VT were higher in males than in children both in NOR (120±32 W; 72±23 W) and HYP (134±18 W; 59±14 W; P<0.005). Relative power outputs values at VT (W·kg^{-1}) were similar in both conditions.

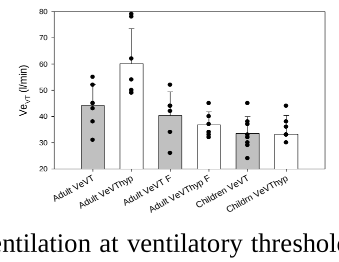

Fig. 1 Ventilation at ventilatory threshold in males, females (F) and children during the normoxic and hypoxic (Hyp) tests.

As noted in Figure 1, signficantly higher Ve at VT in HYP compared to NOR was observed in males, with no differences noted in females and children (P<0.05). Similarly, O_2Hb at VT in HYP was only increased in males (P<0.05) with a tendency for an increase in females and no difference observed in the children group (Figure 2).

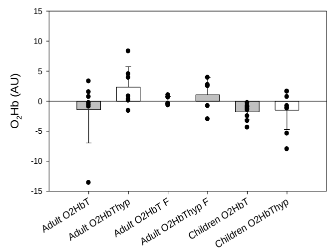

Fig. 2 Muscle oxygenation (O_2Hb) at ventilatory threshold in males, females (F) and children during the normoxic and hypoxic (Hyp) tests.

CONCLUSSIONS

The observed increases of Ve and O_2Hb in male adults during hypoxic compared to normoxic tests suggest an advantage in both ventilatory response and muscle oxygenation in relation to females and children during hypoxic exercise. The obtained data however suggest that these adaptations might not translate into endurance performance advantage in hypoxic conditions due to similar relative power outputs achieved at ventilatory thresholds in both conditions.

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AEROBIC EFFICIENCY AT SEA-LEVEL PREDICTS PHYSICAL PERFORMANCE IN HYPOXIA

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INTRODUCTION

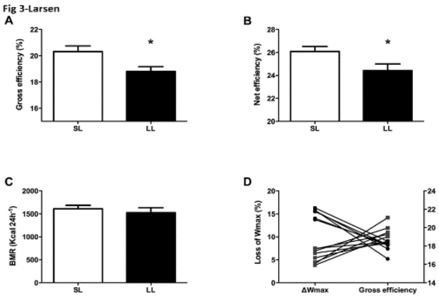
Aerobic performace inevitably decreases in parallel with decreasing oxygen availability. In several studies higher whole-body aerobic efficiency (AE) has been found in highland compared to sea-level natives (1). Moreover, improved AE during exercise have been observed after short-term hypoxic exposure (2). Other studies have demonstrated mitochondrial rearrangements after more severe hypoxic exposure (3). However, this subject is controversial with many seemingly contradictory findings (4). The intent of this study was to test if AE as measured on a cycle ergometer at sea-level was an indicator of the tolerance to hypoxia.

METHODS

- 14 well-trained men participated in this study.
- AE was measured by indirect calorimetry both at sea-level and in normobaric hypoxia (16% O_2). Physical performance was measured by an incremental exercise test to exhaustion.
- Subjects were grouped into two categories; those that showed a large loss (LL) and a small loss (SL) of performance in hypoxia (LL).

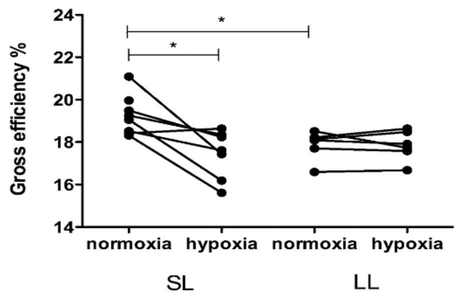
RESULTS

Fig 3-Larsen



Whole body metabolic efficiency is higher in subjects better able to maintain exercise performance in hypoxia. Gross efficiency (GE) (A) and net efficiency (NE) (B) bot not BMR (C) was significantly higher in the SL group when measured at workloads of 100 and 150 watts in normoxia. Gross efficiency at 100 watts in normoxia was associated with the relative reduction in Wmax in hypoxia (D).

Fig 4-Larsen



Acute decreases in gross efficiency in subjects better able to maintain performance in hypoxia. Gross efficiency was calculated at a workload of 100 watts, first in normoxia (FiO_2 20.94%) and at a separate occasion in hypoxia (FiO_2 16 %). In normoxia gross efficiency was significantly higher in the SL group (n=7) but decreased in this group upon hypoxic exposure to the same level as the LL group (n=6).

CONCLUSIONS

This study shows that subjects with a high level of AE at sea-level can better maintain their physical performance in hypoxia. Subjects that responded well to hypoxia showed a reduction in AE when exposed to hypoxia, possibly as an adaptive response to liberate more free energy towards power production.

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INTERMITTENT HYPOXIA AGAINST PREDIABETES: THE ROLE OF O_2-REGULATED GENE EXPRESSION

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INTRODUCTION

More than 20 years ago Ukrainian scientists have proved that intermittent hypoxic training (IHT) reduces risk factors in diabetic animals, increases blood insulin level, inhibits the islet destruction, provides new formation of beta-cells in acinar tissue (1). Later on, it was shown that hypoxia modulates lipid and carbohydrate metabolism in rats through the changes in expression of HIF-1α and its target genes that play a key role in the regulation of glucose homeostasis (2). This study aimed to explore for effects of a two-week adaptation to IHT on mRNA expression of HIF-1α and its target genes: pyruvate dehydrogenase kinase (PDK1), insulin receptor (INSR), facilitated glucose transporter - solute carrier family-2 (SLC2A1), and transient potassium channel (KCNJ8) in healthy humans and patients with prediabetes.

METHODS

Seven healthy volunteers of 44-68 years old (Gr I) and 15 prediabetic patients of 48-70 years old (Gr II) participated in the study. Gr II included subjects who had impaired fasting glycemia, glucose intolerance, or their combination. They were divided into two sub-groups: Gr IIa – experimental IHT group (11 subjects), and Gr IIb – sham IHT group (4 subjects). All participants were studied before IHT, after 3rd and 14th days of IHT program and in a month after IHT termination. Every IHT session consisted of four 5 min bouts/d of breathing 12% O_2 with 5 min breaks. In dynamics of IHT, mRNA expression was determined in blood leukocytes using real-time PCR.

RESULTS

Two-week IHT course reduced significantly fasting and 120 min post-OGTT glycemia in Gr IIa, this reduction was maintained through a month after IHT termination. Acute hypoxic test (AHT) (3) revealed a significant increase in tolerance to hypoxia. Shortened recovery time, more effective functioning of respiratory and cardiovascular systems during AHT was also registered in patients of Gr IIa. Initial levels of mRNA expression of HIF-1α, SLC2 and KCNJ8 were the same in Gr I and Gr II, however, PDK1 and INSR were 2-fold higher in Gr II. IHT resulted in 4-fold (Gr I) and 6-forld (Gr IIa) increase in HIF-1α during 3rd (Gr I) or 14th (Gr IIa) days of IHT, the latest remained twice higher in a month. A similar pattern was observed with respect to PDK1. The greatest increase in INSR, SLC2 and KCNJ8 expression in both groups was observed in a month after IHT termination. Correlation analysis showed that higher expression of HIF-1α, INSR and SLC2 determines a higher resistance to hypoxia.

CONCLUSSIONS

Thus, pilot study has shown that oxygen-dependent transcription factors are actively involved in adaptation to IHT in healthy individuals and patients with metabolic disorders.

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THE INFLUENCE OF HIGH-MOUNTAIN HYPOXIA ON EFFORT TOLERANCE IN PATIENTS WITH STABLE CORONARY ARTERY DISEASE.

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INTRODUCTION

There are only few documented researches assessing influence of hypoxia on patients with coronary artery disease (CAD) (1,2). It is very important to monitore closely and take appropriate precautions patients with CAD because every year more and more people goes high mountain trekking or practice some winter sports (3).

METHODS

- 22 patients in aged 37-72 years old (55,68 ± 9,86 years) with CAD after acute coronary syndrome, rehabilitated in ambulatory care.

- 3-hour stay in the artificial hypoxia cabin imitating 300 (placebo), 2000 and 3000 m.a.s.l conditions. There were cardiac stress test, morphology blood test, gasometric and lactate analysis done.

RESULTS

There were significant changes in parameters: gasometric analysis (pH p=0.002, pO_2= 0.000, pCO_2= 0.011), sodium level (p= 0.000), decrease of effort capacity during cardiac stress test (time p=0,044, distance p= 0,031, MET p= 0,000, VO_2= 0,011).

CONCLUSSIONS

There is no significant danger of stay in hypoxia conditions for patients with CAD.

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DOES SLEEP WITH INCREASED UPPER-PART OF THE BODY REDUCE ACUTE MOUNTAIN SICKNESS? – ECHOKARDIOGRAPHIC STUDY DURING ADEMED EXPEDITION 2011 AT 5150M (GORAK SHEP, MT. EVEREST REGION, NEPAL)

Grass, M.; Apel, C.; Bartz, N.; Bertsch, D.; Gschwandtl, C.; Kühn, C.; Müller-Ost, M.; Risse, J.; van der Giet, M.; van der Giet, S.; Schmitz, S.; Timmermann, L.; Wernitz, K.; Küpper, Th.

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INTRODUCTION

Exclusively in German literature the advice can be found quite often that sleep with elevated upper body is of advantage for AMS and probably HAPE. A detailed follow up oft he references showed that this is based on an individual person who did never have any data (personal communication). He made an empiric transfer conclusion from patients with cardiac insufficiency in intensive care facilities.

METHODS

44 trekker were included (19 f/ 25 m; 42.9 ± 15.9 y; BMI 23,76 ± 3,47 kg/m²). They were randomized into 2 subgroups (with / without 5° increased upper body during sleep). All individuals underwent echocardiography before sleep and before standing up next morning (PAPs, vmax, TAPSE, RVID). After clinical check Lake Louise AM Score was obtained (evening and morning). Individual data, preexisting conditions and altitude profile (acclimatization) were registered by a questionnaire. Study locations were Gorak Shep (5170m) and Pheriche (4280m).

RESULTS

Mean ascent from Lukla to Gorak Shep was 8,9 ± 2,9 days, corresponding to less than 500m of altitude / day. However, 17/44 subjects (38.6%) showed symptoms of AMS (evening: 16, morning 9). Total AMS prevalence was 38.6% with 60% in Gorak Shep and 20.8% Pheriche. A decrease of symptoms was found in both subcollectives (f>m). However, the reduction of symptoms was more pronounced when people slept in 5° position.

Mean PASP was 36.1 ± 7.7mmHg in the evening and 37.0 ± 7.8mmHg in the morning. Acetazolamid reduced PASP from 37.2 ± 9.9 in the evening to 35.6 ± 7.5mmHg in the morning (N=9). Without acetazolamid the respective values were 35.8 ± 7.2 and 37.4 ± 8.0mmHg. Overall 30/44 subjets (68.2%) showed a PASP of more than 36mmHg at least a tone measurement. With increased body position the portion of subjects with pathological PASP increased by 33.3% over night. In contrast it decreased by 14.3% in the group who slept in flat position.

CONCLUSSIONS

Although there are many different sleeping patterns in several subgroups sleep with inreased upper body seems to reduce AMS prevalence and severity of symptoms. However, the price may be an increased risk caused by increased PASP. Here further studies are necessary.

MUSCLE SYNDROMES AND MUTATION IN MOUNTAIN MEDICINE.

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The most common muscle syndromes in mountain medicine are cramps, fatigue and elevated CK. Muscle pain is a complex multifactorial disorder, that might lead to fiber muscle necrosis and reactive macrophage reaction. Also in some peripheral nerve conditions such as CMT hypoxia can precipitate central or pheripheral oedema. There is contraindication for most muscle patients to acces high altitude or trecking, in addition over 5000 meters the occurrence of both muscle atrophy/ autophagy can occur. Enviromental hypoxia can induce: 1) a loss of mitochondria mass 2)substrate switch from fatty acid toward glucose, amino acids, ketone bodies. Can adeguate nutrition prevent this? While much it is know on muscle metabolism and oxygen utilisation by mitochondria, few is know about how to prevent such symptoms. A loss of mithocondria may be driven by mithophagy and upregulation of authophagy. For highlanders experiments have demonstrated a shift toward optimal utilisation of substrate, myopathies of high altitude show that an adaptation over certain limits is inadeguate. Mitochondria and selection of revelant metabolic pathways is a limit of adaptation to altitude and hypoxic exercise. The signalling mechanism are molecular i.e. HIF, ROS and need investigation since ROS are know to stabilise HIF.

Enviromental hypoxia does induce a selective attenuation of fatty acid metabolism while glucose uptake is maintained to support glycolisys.

MEDICAL CONTRAINDICATIONS FOR MOUNTAINEERING OR FLYING IN HYPOXIA – INTRODUCTORY CONSIDERATIONS

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INTRODUCTION & RESULTS

David Hillebrandt showed during his presentation at the Tatra-symposium (2013) "*Diabetes – Personal practical experience of management in the field*" a photo from Kinabalu (Borneo) with 13 medical contraindications for climbing: "Do not climb if you have a history of suffering from the following ailments". He gave a very impressive example for a diabetic typ 1 in mountaineering and climbing, however. – A similar photo was taken by Markus Tannheimer in the Kilimanjaro-region, more specific, however. "Points to remember: 1. Hikers should be physically fit. 2. If you have a sore throat cold or breathing problems, do not go beyond. 3. Children under 10 years of age are not allowed above 3000 meters a.s.l. 4. If you have heart or lung problems do not attempt the mountain at all without consulting your doctor. 5. Allow plenty of time for the body to acclimatize by ascending slowly".– Thomas Küpper demonstrated a photo from a police station in the region of Chin-an (China), advising travelers and mountaineers: "Hikers on this path should be aware of the high risk of accidents; the elderly, woman, children, and the drunken are prohibited from climbing".

– A case report by Thomas Küpper: A passenger with a moderate problem of pulmonary gas exchange contacted his doctor who sent a MEDA sheet to Air Berlin to organize oxygen just to be on the safe side. The airline did not respond, but they did not allow the passenger to enter the aircraft when he arrived at the gate. – Grounding of pilots, caused by medical decisions, has severe consequences for pilots and airlines. Therefore a special regulation exists to give special physicians by single-case examination the possibility to prolong the license.

An explorative questioning of Carolin Chladek of 107 mountaineers (German alpin club) about frequency of asthmatics showed no problems with mountaineering of the 13 cases with asthma (12 %). Another former student Solveig Pisarz examined thoroughly the dangerous nightly hypoglycaemia of diabetics after endurance activities at afternoon or evening, caused by glycogen depletion during endurance activities and filling up during sleep in the night. She asked consulters for diabetics and looked in documents for consulting diabetics, guidelines and scientific literature. *Result:* This dangerous effect during sleep is known in literature and in consulters for diabetics (69 % of n = 16), but not distinctly enough written in documents and guidelines, especially not the special recommendation of measuring the glucose-value at least once during the night after endurance activities. This example shows, how special instructions can improve consultations for patients.

CONCLUSSIONS

Most of the described recommendations might have a forensic background to exclude liability claims. But what should patients do? Consequences for patients and physicians should be discussed and documented, based on own experience of the lecturers.

MOUNTAINS WARFARE

BRIEF HISTORY OF MOUNTAIN WARFARE AND ITS IMPACT ON MEDICAL SUPPORT OF MILITARY OPERATIONS IN THE MOUNTAINS

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INTRODUCTION

Aim of this lecture is to give a brief overview on history of mountain warfare, to carve out the specific characteristics of fighting in a mountainous environment and finally outline its influence on medical care on the battlefield.

METHODS

A selective Medline and internet search was done with the keywords "military", "history", "mountain warfare" and "high altitude". Additionally a backward literature search was done and our own experience as physicians, soldiers and military mountain guides was evaluated.

RESULTS

There have always been battles in rough terrain, for example the Battle of Thermopylae or the Battle of the Teutoburg Forest. But in general difficult terrain was studiously avoided during the ancient time of line tactics and the medieval times with its heavy encumbered knigths. Even General Clausewitz writes that mountain-positions are little suited for decisive defensive battles and recommends to avoid mountains with the principal mass of force.[1] Only with the beginning of mountaineering (first ascent of Mount Ventoux 1336 and Mont Aiguille 1492) and mobility becoming the chief quality of armies with the revolutionary armies of General Bonaparte, battles in mountain ranges were possible.[2] During the last 100 years the importance of mountain warfare has greatly increased and battles in mountainous regions were part of most major conflicts (World War I and II, Falkland Wars, OEF). Nowadays conflicts increasingly occur in a mountain/ cold weather environment. [3] Mountain environment (terrain, altitude, weather) declines considerably movement and maneuver, fire support, logistics, air support, command and control, communications and increases the importance of (medical) force protection. [3]

CONCLUSSIONS

Mountain and cold weather warfare has a long history, and that history clearly demonstrates that those who ignore it are doomed to fail when fate places them in such an environment. Special organized, trained, equipped and sustained units are necessary to mitigate those challenges.[3] This also refers to all supporters including the medical service. In addition specific mountain related diseases and injuries, demanding casualty handling, delayed Medical Evacuation and the necessity to perform prolonged field care are ubiquitous and require forward looking planning. Therefore, tailored medical and mobility training is required for mountain infantry and medical personnel as well.

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MILITARY MISSIONS AT HIGH ALTITUDE

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INTRODUCTION

Mountainous terrain provides sanctuary for hostile forces, in particular for terrorist organizations. Therefore regular forces are frequently engaged at high altitude in asymmetric warfare. We want to outline the differences between military missions and civilian climbing ventures and prove that soldiers are at higher risk of developing acute mountain sickness (AMS) than mountaineers.

METHODS

As active military medical officers and military mountain guides with more than 400 days being deployed in military missions the authors are responsible for the course»high altitude medicine« in the German Army. They held responsible positions for all medical affairs in the German Mountain Infantry and Special Forces and accompanied the training programme 'tactical altitude medicine' including military expeditions to 8000 m peaks.
They give an overview over their own experience in military missions at high altitude with regards to the current literature.

RESULTS

The incidence of AMS is significant higher (nearly doubled) in soldiers compared to civilians at similar altitudes. Even in severe firefights a significant number of combat related casualties is caused by AMS (14.3%) or alpine traumatic injuries (24.5%). As this issue is not aware in the military hierarchy substantial attempts have been already made to improve the knowledge in military high altitude medicine (i.e. special education courses for military leaders, NATO task groups and meetings, research and investigation …)

CONCLUSSIONS

Missions above 2000 m on short notice require special attention. In case of guaranteed short-term mission the latency of AMS (6-36 h) can be used. Longer deployments require proper acclimatization otherwise the soldiers are not fully operational and significant casualties may occur.

Normobaric hypoxic chambers offer a smart possibility to acclimatize soldiers and to keep them acclimatized even under the conditions of an ongoing mission in remote areas, as it is demonstrated i.e. by the Indian army.

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STRATEGIES TO PREVENT ACUTE MOUNTAIN SICKNESS IN MILITARY OPERATIONS: IDENTIFICATION AND PRE-ACCLIMATIZATION OF SUSCEPTIBLE INDIVIDUALS

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INTRODUCTION

International military operations including exposures to altitudes > 3000 m became more frequent during the last decades, e.g. in Afghanistan (4). Ascents to altitudes > 2500 m are associated with the risk of altitude illnesses, of which acute mountain sickness (AMS) is the most common. AMS incidences range up to more than 60 % depending on the absolute altitude, the degree of acclimatization (i.e. the rate of ascent), the level of physical exertion, and the individual susceptibility (3) Several small re-acclimatization studies applied a combination of real and simulated altitude and the authors reported a shortened acclimatization time during a Mount Everest expedition after normobaric pre-acclimatization (5).

Two important questions arise for military operations at high altitude:

1) Is it possible to detect AMS-susceptible individuals with a high sensitivity by applying a simple screening procedure?

2) Are there strategies without side-effects to reduce the AMS risk, i.e. pre-acclimatization, in AMS-susceptible individuals?

METHODS

300 Infantrysoldiers will be exposed to a simulated altitude of 3500 m (normobaric hypoxia) and after 30 minutes SaO_2 is measured. Based on the SaO_2 values AMS susceptibility is assumed (2). To guarantee a high sensitivity persons with a SaO2 < 89 % (cut-off value) are predicted to develop AMS during the subsequent exposure to real high altitude. Subsequently, subjects are transported to an altitude of 3500 m where AMS incidence and severity (1) are assessed after 3, 6, 12, and 24 hours. Sensitivity and specificity, as well as positive and negative predictive value of the screening method are calculated. Part 2: Participants who developed AMS during the high-altitude exposure are considered as AMS susceptible comprise the study population of the second part. The participants are randomly assigned (double-blinded) to one of 4 hypoxia groups (HG1 to HG4) or the placebo group (PG).The pre-acclimatization programs of the HG1 to HG4 consist of 7 to 14 passive hypoxic sessions (4500 m simulated altitude) with an increasing hypoxic dose from HG1 to HG4. The PG also completes a program in the chamber breathing normoxic air. The participants are transported to a real altitude of ca. 3500 and AMS incidence and severity are assessed after 3, 6, 9, 21, 30, and 45 hours of high-altitude exposure. Comparisons of AMS incidences and severity between groups at the different time points are conducted.

CONCLUSSIONS

The proposed project aims to evaluate the prognostic value of resting SaO_2, determined after 30 minutes of exposure to normobaric hypoxia, for the development of AMS at real high-altitude and to test 4 pre-acclimatization protocols, applying different hypoxic doses, for their AMS-preventive effect in persons susceptible to AMS.

Potential impact

Especially among AMS susceptible individuals more than 50 % develop AMS 8 (). An effective strategy to identify those susceptible and consequently prevent or lower AMS symptoms by time-efficient pre-acclimatization in hypoxic chambers, shortly before deployment or within the mission area, could improve impact of military forces. Additionally the project will significantly contribute to science based recommendations for AMS prevention by pre-acclimatization.

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PERFORMANCE OF SOLDIERS DURING MARCHING IN MOUNTAINS

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INTRODUCTION

Soldier's performance during mountains marching can be estimated from their characteristics measured during march. Such characteristics should be selected according to their prediction power of performance, determined as distance, reached during self-paced marching. To ascertain which combination of predictors estimated the largest variance in performance was the aim of the study.

METHODS

Members of the 132. Mountain Regiment of Slovenian Armed Forces and NATO Mountain warfare Centre of Excellence (N=14; AGE= 28±7 yrs., BH= 176±5 cm; BW= 79±12 kg) performed prolonged march in mountains, consisted of uphill terrain with two characteristicall slopes (Fig. 1). Each member was equipped with military personal gear of total weight 33 kg (backpack, weapon, helmet). All may have drink water et.libitum.

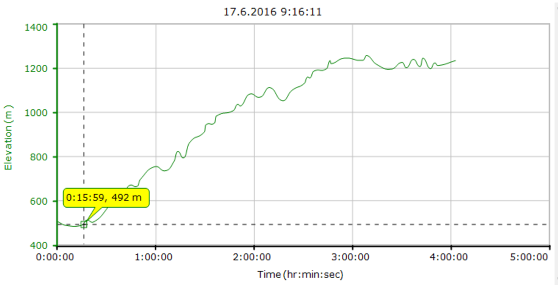

Fig. 1
The configuration of marching terrain. Two characteristically slopes were identified.

Marching velocity, position, altitude and heart rate were continuously measured by Garmin Forerunner GPS system. Aerobic metabolism was estimated by Vo2, Vco2 and Ve, by using metabolic chart K4b during 10 min intervals, every hour. The 4 temperature sensors measured head, chest, forearm and leg skin temperature (2). Blood lactate, glucose, hematocrit and hemoglobin were measured every hour. Urine specific gravity was measured before and after march. Additionally BW was measured every hour. The specific energy cost (Cw) for uphill walking was calculated (1). For estimation, how different combinations of characteristics predicted the distance reached by 4 hrs. marching, the multiple linear regressions were calculated.

RESULTS

The performance was estimated by distance reached in 4 hrs. The correlations of used characteristics with this distance were used for selection of the strongest prediction candidates: the ΔHR (the difference in HR between the initial horizontal and last hour marching) ($r=0.90$; $p<0.01$), the Cw (energetic cost during last hour of marching) ($r= -0.72$; $p<0.01$) and Vo_2 during 2nd hour of marching ($r= 0.60$, $p=0.03$). Furthermore, the best predictive combination of multiple linear regressions was selected. It used a combination of the Vo_2 and Cw at the end of march ($R^2 = 0.86$, $P < 0.001$).

CONCLUSSIONS

Results show that using a linear combination of Vo_2 measured during last hour of marching and energetic cost of walking during same time interval was the strongest prediction combination for estimating performance during selected configuration of mountain marching. Additionally, also increase of HR from the horizontal (initial) interval of marching and final HR seems to be a strong predictor. These variables will represents background for construction the model and standards for performance characteristics of mountain soldiers on selected testing route.

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SERUM ANGIOTENSIN I-CONVERTING ENZYME PROFILE AT HIGH ALTITUDE

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INTRODUCTION

The high altitude environment (>2500m) is a physiologically challenging setting that requires the angiotensin I-converting enzyme (ACE) mediated renin-angiotensin-system (RAS) as a compensatory mechanism through its pressor and diuretic actions (Woods & Montgomery 2001). Despite the importance of ACE in the RAS very little is known about how its action influences adaptation to high altitude (HA) (Milledge & Catley 1987). Furthermore, few prior studies have investigated the realtionship between serum ACE levels and the effect of HA.

METHODS

This was a dual phase investigation. All participants were British military personnel.

Phase 1- Participants (n=12) were subjected to a sub-maximal exercise protocol in a normobaric chamber (The Carnegie Institute) over 5 days to examine the effect of acute hypoxic exposure.

Phase 2- Participants (n=11) took part in the British Services Dhaulagiri Medical Research Expedition 2016 to the Himalayas which involved 14 days of trekking and exposure to terrestrial HA.

For both phases baseline blood samples were taken at sea level and at different points during the HA exposure for analysis and comaprison of serum ACE and aldosterone levels. ANOVA was used to compare the mean percentage change in serum ACE levels between the time points for statistical significance ($P<0.05$).

RESULTS

Phase 1- The exposure group saw no significant percentage change in serum ACE values ($P=0.973$). Aldosterone levels were seen to be suppressed on exposure to HA and increased by sub-maximal exertion.

Phase 2- There was no significant percentage change in serum ACE values on the expedition ($P=0.619$). Aldosterone was significantly suppressed at HA ($P=0.013$). This was supported by decreasing plasma osmolality with increasing altitude ($P=0.057$).

CONCLUSIONS

There was no significant alteration in serum ACE values on exposure to acute and chronic hypoxia. Although a suppression of aldosterone levels was observed following chronic hypoxia. Correlations of ACE levels with peripheral oxygen saturations indicate a potential inverse correlation.. ACE is not affected by hypoxia and is thus independent of the RAS modulated acclimatisation pathways. ACE also does not mediate aldosterone change on exposure to HA. This infers that aldosterone levels are directly suppressed by high altitude, possibly due to the inhibition of aldosterone synthase though future reserach should aim to establish this mechanism.

This negative effect with regards to serum ACE at high altitude is a novel finding and is important to understanding how the RAS functions in acclimatisation to HA.

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This scientific work was conducted as part of a Master of Research degree which itself was part of a wider study into pre-acclimatisation conducted by Mark Cooke, Leeds Beckett University in conjunction with the Defence Medical Services.

GLOBAL CLASSIFICATION OF MOUNTAINS

The study has been prepared by the NATO MW COE, which currently consists of experts from five countries (**AUT, CRO, DEU, ITA** and **SVN**). They contribute their knowledge and experiences to all MW COE products.

INTRODUCTION

Deploying military capabilities to mountainous environment requires a detailed assessment in preparation, pre-deployment phase. Clear terminology is essential in providing common understanding.

The main purpose of the study is raising issues that should be taken into consideration when planning military operations in the mountains.

Classification of mountains is dealt with in many geographical sources, but in most cases they are presented in a general way and therefore in most cases of limited use for military purposes. Authors are initiating further discussions on a standardized classification, a tool which would assist in the planning and conducting of future military mountain operations. This study does not set a specific standard.

METHODS

- Descriptive method serves as a basis for the study presented.
- Comparisons of already existing solutions and approaches have been introduced while conducting the research.
- Synthesis and generalization of relevant national approaches is complex but needed, when preparing doctrinal documents for NATO.

RESULTS

The study results in a proposal of mountain classification, which might be used in the process of terrain analysis before deployment of troops. Terrain effects on troops are influenced by altitude, relief, climate and type of land exploitation. Deploying capabilities above certain altitude in mountains is affected by many factors. Some are related to hypoxia and must be included into planning of operations due to high risk for soldiers' health and their performance.

Classification of mountains into five classes, three categories of mountains and three levels of affects represents an assisting option in this process.

Especially commanders and staff personnel, who were not involved in mountain operations in their previous deployments need essential facts presented in a short and simple way to find them useful and to incorporate them into plans. In addition, such a tool should make decision makers better aware of the specifics of mountainous environment.

Of course, additional discussions are necessary within NATO and Partnership community to reach final goal.

CONCLUSIONS

Starting point for further discussions, connected with military terminology and other specifics of mountainous environment is established with this and some other initial studies.

Community of interest is welcome to provide responses and additional proposals, relevant for future development of mountain warfare within NATO.

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MODERATE ALTITUDE

AND

ALTITUDE TRAINING

NONHEMATOLOGICAL ADAPTATIONS USING TRAINING AT MODERATE ALTITUDE

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INTRODUCTION

Living-high and training-low (LHTL) method influences hematological (2) and non-hematological (1) adaptations which may enhances endurance at sea level. However, by increasing training altitude to about 1500 m (moderate altitude) while living altitude remain similar (LHTM), method became ineffective at already trained subjects (3). The reduced training intensity in such conditions was possible reason for this phenomenon (2).

To ascertain whether the reduction of living (sleeping) hypoxic dose from high (LHTM) to moderate, while training dose remain similar, moderate; (LMTM), may remove previously presented ineffectiveness of LHTM, was the aim of the study. Namely, if this would be true, then reduced training intensity should not be the single important player in this story.

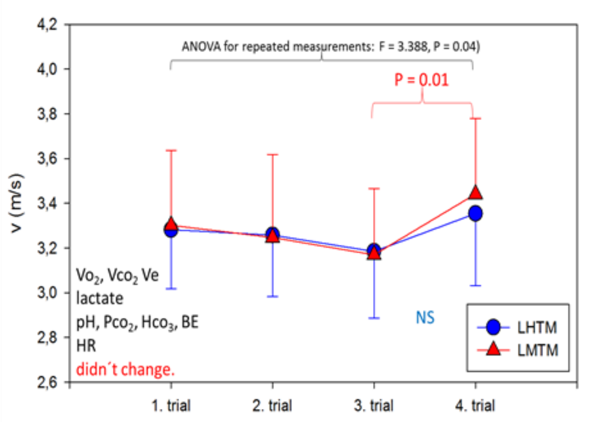
METHODS

A 5 members of XC-ski running national team performed training at 1500-1600m and have slept at additional normobaric hypoxia (FiO_2= 0.18) at altitude of 1500m (LHTM). A 7 other member of the same team performed training at the same altitude but have slept at 1500m (LMTM). Both groups performed a maximal 7 km trial using XC-ski rollers and submaximal test. It consisted of 10 min 100W warm-up, 3 min 100W hypoxic interval (FiO_2=0.15), 3 min normoxic interval and 3 min 3.5 W/kg submaximal exercise before and after 3 wks. training period.

RESULTS

In contrast to believe that lower training intensity during LHTM was the dominant reason for ineffectively of LHTM training (2) our results (Fig

1) showed that the reduction of sleeping hypoxic dose has significant influence. Namely both groups have trained similarly and have similar training hypoxic dose. But sleeping hypoxic dose was reduced in LMTM group which actually increased its performance (Fig. 1). The increase of trial velocity was accompanied by reduced muscle blood perfusion; decreased muscle blood deoxygenated hemoglobin and reduced ventilation observed at similar absolute exercise intensity.



CONCLUSSIONS

Reducing the sleeping hypoxic dose and not training hypoxic dose from LHTM to LMTM seems to enhance performance at low altitude by typical nonhematological effects, even in already trained subjects.

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EFFECT OF REPEATED SPRINT TRAINING UNDER HYPOXIA ON REPEATED SPRINT AND EDURANCE PERFORMANCE.

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INTRODUCTION

Repeated sprint training has been reported to enhance repeated sprint ability via improved oxygen utilisation and anaerobic glycolysis. In addition, simulated altitude training has been shown to enhance many of the limiting factors associated with repeated sprint ability. The use of repeated-sprint training and hypoxia, therefore may be two methods to achieve increased adaptation and improved performance in athletes. However, the performance benefits of such training are equivocal (1-3). The aim of this research was to investigate the effectiveness of a rugby-specific sprint training protocol under hypoxia on repeated sprint ability and endurance in rugby players.

METHODS

Nineteen rugby players from Canterbury, New Zealand were matched on baseline repeated sprint performance into 2 groups and given 3 weeks of repeated sprint training under either normoxia (F_IO_2 = 20.9%) or hypoxia (F_IO_2 = 14.5%) with a subsequent 3-week post-intervention period (Post 1-3). A second 1-week repeated sprint training block followed in which all players completed repeated sprint training under hypoxia (F_IO_2 = 14.5%), followed again by a 2-week post-intervention period (Post 4-5). Training consisted of 2 sessions a week of four sets of 5 reps of 5-s maximal cycle ergometer sprints with 25 s of passive recovery between reps and 5 min of active recovery between sets. Repeated sprint fatigue and Yo-Yo endurance performance was analysed in the Statistical Analysis System (Version 9.3, SAS Institute, Cary NC) using Proc Mixed.

RESULTS

Fatigue during a repeated sprint test (8x20-m) was comparable in both groups prior to training and improved similarly the first week after the intervention (Post1, see Table 1). However, unlike the normoxic group, the hypoxic group's performance continued to improve (Post2-5, Table 1). Yo-Yo performance was similar in both groups at baseline and remained similar between groups throughout the study (Table 1).

Table 1. EFFECTS OF REPEATED SPRINT TRAINING UNDER HYPOXIA OR NORMOXIA ON REPEATED SPRINT AND ENDURANCE PERFORMANCE.

	Repeated Sprint Fatigue (%)		Yo-Yo Intermittent Recovery Test (m)	
Time	Hyp	Norm	Hyp	Norm
Pre1	5.8±3.4	5.5±2.3	1200±384	1100±426
Pre2	6.1±2.3	5.9±1.8	1305±440	1187±447
Post1	4.1±2.4*	4.3±2.2*	1480±544	1418±583*
Post2	3.8±1.1*	4.8±2.3	1573±497	1458±485*
Post3	3.7±2.2*^	5.5±1.7	1600±424*	1354±608
Post4	4.1±0.6*^	6.1±1.7	1765±392*	1490±561*
Post5	4.8±2.4*^	6.2±2.3	1733±495*	1547±737*

Data are mean±SD, *Substantially different from mean of Pre1+Pre2. ^Substantially different between groups. Hyp; hypoxia, Norm; normoxia.

CONCLUSIONS

Compared to training under normoxic conditions, repetitive sprint training under hypoxic conditions substantially improved repeated sprint, but not endurance performance, in well-trained rugby players.

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THE RELATIONSHIPS BETWEEN INTERNAL AND EXTERNAL TRAINING LOADS DURING CYCLING TRAINING IN HIGH-ALTITUDE HYPOXIA CONDITIONS

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INTRODUCTION

Determining the relationship between internal and external training loads, is of vital significance when conducting sports training. (Weaving et al. 2014). This relationship depends on a number of factors, among which, the conditions of the effort carried out, are of crucial importance. High-altitude hypoxia is a factor used in training in order to obtain the competitor's internal load while applying a lower external load value. (Hahn, Gore 2001, Saunders et al. 2009) The aim of the study carried out, was to determine the range of the possible external load decrease, which would trigger off the body's internal load, reflecting standard external load conditions in the cyclists' basic training measures.

METHODS

The participants of the study were mountain bike cyclists, members of The Russian and Polish Nationals Teams (women n=9, 25.4/2.1year, 50.3/2.2kg, 160.3/5.5cm). At the altitude of 170 MAMSL (Lonato del Garda, Italy), and 2250 MAMSL(Livignio-Trepale Italy), the participants of the study underwent 3 effort tests: 1. Graded Incremental Exercise Test (GXTs – determining internal load values VO_2, VE, VCO_2, HR on the external loads level (P, W/kg), from 50 to 100% taking lactate threshold (LT), and anaerobic threshold into account 2. Strength on Bicycle Test: 6x1'min. exercise P=80%Pmax with breaks, repetition 1' with 50%Pmax 3. Power on bicycle 6x (4'/P 70%Pmax +4'with 50%Pmax) high cadence 110-120 RPM, In the course of the effort the following were measured: VO_2, VE , VCO_2 (K4b2, Cosmed Italy), LA (Biosen S-line, EKF, Germany), and HR (Polar V650, Polar Finland).

RESULTS

On the basis of GXTs, it was proved that the parameters of the efforts carried out in the conditions of high-altitude hypoxia cause changes in the range of internal loads. The changes are at the following LT levels, and directed as follows: P↓, VO_2↑, VE↔, HR↔, O_2HR↑, on AT: P↔; VO_2↑; VE↑; HR↑; O_2HR↑ and on Pmax: P↓; VO_2↑; VE↑; HR↑; O_2HR↑. As far as strength on bicycle is concerned, there is a 20% decrease, and power on bicycle is decreased by 10-12%, while maintaining the same internal load values in high- altitude hypoxia conditions, as those registered in normoxic conditions.

CONCLUSSIONS

Obtaining the same internal load values of the mountain bike cyclist's body both in the conditions of high- altitude hypoxia, and in those of normoxia is possible at external loads of lower power values. In the event of the shaping of strength on bicycle, external loads are decreased by 20%, and power on bicycle is decreased by 10-12%. During constant efforts on the aerobic, and anaerobic threshold levels, the power necessary to obtain internal loads is 10, and 15 % lower than in normoxic conditions.

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INTERMITTENT HYPOXIC EXPOSURE AS PERFORMANCE ENHANCER - FACT OR FICTION?

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INTRODUCTION

Intermittent hypoxic exposure (IHE) has become increasingly popular among athletes for augmenting their sports performance. Market has reacted fast and various devices for IHE, such as hypoxic tents, hypoxicators etc., are nowadays available to athletes. However, despite its popularity the evidence for IHE efficiency is scarce or absent. Thus, the aim of the present study was to evaluate the effects of IHE on cycling performance and key cardiovascular and hematologic parameters.

METHODS

Seven well trained, male junior cyclists participated in the control, and seven in the experimental group. The experimental group performed IHE one hour daily, five days per week, for four weeks. During IHE the subjects inspired hypoxic gas mixture (FiO_2=11.4%; simulated altitude of ≈4500 m) in repetitive bouts of seven minutes, followed by three minutes of normoxic breathing. The control group did not perform any IHT.

For all subjects, the following physiological parameters were obtained: oxygen saturation (SaO_2;%) during every bout and every session of IHT; haematological parameters (haemoglobin, hematocrit, erythrocytes, reticulocytes, S-Fe, S-ferritin) before and after the four weeks; oxygen consumption (VO_2;ml/min·kg) including VO_2max, oxygen saturation (SaO_2;%), heart rate (HR;bt/min), ventilation (L/min), and ratings of perceived exertion (modified Borg's scale) during incremental cycle ergometry at sea level and at simulated altitude of 3000 m (FiO_2=13.3%) performed in balanced manner; blood lactate (L;mmol/L) and maximal work load (WLmax;W) determined at the end of cycle ergometry.

Data were analysed with multifactorial ANOVA for repeated measures on one factor and the level of $p<0.05$ was adopted as statistically significant.

The protocol of study was approved by the Medical Ethics Committee of the Republic of Slovenia.

RESULTS

Six subjects of the experimental and four of the control group completed the entire study protocol. All of the observed parameters remained practically unchanged in both, control and experimental groups. Thus, no performance enhancing effects of IHE were noted.

CONCLUSSIONS

According to the results of the present study and the state-of-the-art overview of literature (1,2), performance enhancing effects of IHE are not supported by evidence. A threshold dose of hypoxic exposure (severity × time) is indispensably required to induce any long-term physiological adaptation. The majority of the existing IHE protocols obviously fail to reach this threshold.

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LOW INTENSITY INTERMITTENT HYPOXIC RESISTANCE EXERCISE IS NOT EFFECTIVE IN AUGMENTING QUADRICEPS MUSCLE CAPACITY

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INTRODUCTION

Low-intensity resistance exercise with restricted muscle blood flow (i.e. ischemic exercise) has been shown to induce gains in muscle mass and strength comparable to standard high-intensity exercise (1). It has also been proposed to enhance muscle endurance and oxygen delivery (2,3), which may be useful for muscle conditioning when joint tolerance for mechanical loading is reduced. However, vascular occlusion with cuffs can only be applied to extremities and may also augment oedema formation, compress nerves and induce discomfort. Thus we hypothesised that inhalation of normobaric hypoxic gas mixture during resistance exercise can give similar results with fewer hindrances.

METHODS

The study protocol was approved by the Medical Ethics Committee of the Republic of Slovenia. Six healthy males performed knee-extension exercise for four weeks (4 sessions weekly) at 15% of one repetition maximum (1RM). Subjects trained one leg (H-leg) while inhaling hypoxic gas mixture (FiO_2=12%), whereas the other leg (N-leg) was trained in normoxic conditions. A test of maximal voluntary isometric contraction (MVIC) torque at 90° of flexion, two endurance tests (normoxic and hypoxic test) of knee extensions at 15% of 1RM to failure, and MRI of quadriceps f. cross-sectional area (CSA) were performed prior to and after the training intervention. Surface EMG and tissue oxygen kinetics (NIRS) were acquired from quadriceps f. muscle during all tests. Data were analysed with ANOVA for repeated measures on one factor where $p<0.05$ was adopted as statistically significant.

RESULTS

Average mixed blood oxygen saturation during training sessions in hypoxic and normoxic condition were 84±2% and 97±1%, respectively. After the intervention, no significant increases in quadriceps f. MIVC torque and CSA on either of the two legs were observed. In contrast, number of repetitions increased ($P<0.01$) by 28±5 % in H-leg and by 34±5 % in N-leg in the normoxic test, and by 22±6 % in H-leg and 26±5 % in N-leg in the hypoxic test. Smaller ($p<0.025$) decrease in oxygenated haemoglobin concentration with concomitant increase ($p<0.025$) in total haemoglobin concentration was observed in both legs during normoxic test after the intervention. Also, a transient increase ($p<0.05$) in RMS EMG amplitude of rectus f. only was noted in both legs during the normoxic test after the intervention.

CONCLUSSIONS

In conclusion, inhaling hypoxic gas mixture during low-intensity resistance exercise does not enhance muscle mass, performance, activation, or oxygen delivery to a greater extent than exercise performed in normoxia. Exercise stimulus for long-term muscle adaptation during intermittent hypoxic exercise training thus appears to be much smaller than the stimulus during ischemic exercise of equal training volume (2). Differences in level of tissue hypoxia and local metabolite accumulation induced by the two types of exercise training most likely play the key role.

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THE INFLUENCE OF HIGH – ALTITUDE HYPOXIA ON THE CHANGES IN WORKOUT VALUES IN INTENSITY ZONES DETERMINED BY MEANS OF METABOLIC THRESHOLDS IN ALPINE SKIERS.

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INTRODUCTION

In alpine skiing, training sessions, and sporting events are often carried out on glaciers, in conditions of high-altitude hypoxia, above 3200 MAMSL. Starting at the attitude of 2500 MAMSL, defense reactions of the body to excessive loads occur. (Saibene et al. 1985)Internal training loads of an alpine skier are the sum total of physical effort, and high-altitude hypoxia. (Prieur et al. 2005)The aim of the study was to evaluate the influence of high-altitude hypoxia (1450 MAMSL, and 3250 MAMSL) upon the changes in the values of the workout performed in intensity zones determined by means of metabolic thresholds. (Gross et al. 2009)

METHODS

The participants were the members of The Polish National Alpine Ski Team. Group A (n=5,22±1.3 years old), and group B (n=6, 17±1,6 years old). Everyone examined carried on cyckloergometer a test GTX (Graded Exercise Test). The study was carried out at the following altitudes: 260 MAMSL (Warsaw), 1450 MAMSL (Hintertux Dorf), 3250 MAMSL- The Hintertux Glacier. The LT threshold was determined by means of the Beaver *et al.* method, the AT threshold was determined by means of the IAT method (1985). Three workout zones were determined: up to LT (I), LT-AT (II), and above AT (III),

RESULTS

The influence of the altitude on the quality of the workout carried out in each of the three zones differed in groups A, and B. In zone III an increase in altitude influenced a decrease in workout in group A by 26% (1822 J/kg 260 MAMSL / - 1620 J/kg /1450 MAMSL - 1346 J/kg /3250 MAMSL, in group B by 56% (1733- 1156 - 761 J/kg). In zone II, respectively: group A 44% (1963 – 1667- 1105 J/kg, group B 17% (1572 – 1432 - 1304 J/kg), and in zone I, respectively: group A 44% (822 -787- 461 J/kg), group B 38% (829 – 785 - 513 J/kg).

CONCLUSSIONS

The changes in external load, in response to internal load are not directly proportional (do not progress linearly) to the increase in high- altitude hypoxia. In zones I, and II, they are relatively small – 4.5%, and 15% (A), and 6.5% and 9% (B), respectively The greatest interaction strength occurs after the external load, classified in intensity zone III has been surpassed. Changes in hypoxic conditions cause, in zones I, and II of the loads, a weaker reaction in younger competitors, in comparison to older ones, while the reaction in zone III of the loads is much stronger. Internal training loads should be the indicators of correcting external training load values in high- altitude hypoxia conditions, whereas, age will be the factor that changes the range of the corrections of loads, depending on intensity zones.

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THE DIRECTION, AND SCOPE OF THE CHANGES IN INTERNAL, AND EXTERNAL LOAD INDICATOR VALUES AT AT, AND ANT THRESHOLDS IN CYCLISTS IN HIGH- ALTITUDE HYPOXIA CONDITIONS

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INTRODUCTION

High- altitude hypoxia is a training load intensity regulator in cycling. It regulates external loads (power, speed), and internal loads (HR, lactate concentrations) Intensity zones regulated by means of metabolic thresholds (aerobic, and anaerobic), are also influenced by this external factor (Casas et al. 2000) The aim of the research carried out was to establish the direction, and scope of the changes in internal, and external load indicator values in cyclists, men , and women, in high- altitude hypoxia conditions.

METHODS

The participants of the study were mountain bike cyclists, members of Russian and Polish Nationals Teams (women n=11, 23.4/2.6 year, 55.3/2.5kg, 165.7/4.2cm, men n=9, 24.1/3.3 year, 72.6/3.6kg, 177.4/5.1cm). At the altitude of 170 MAMSL (Lonato del Garda, Italy), and 2250 MAMSL(Livignio-Trepale Italy), the participants of the study underwent Graded Incremental Exercise Test (GXTs – determining internal load values VO_2, VE, VCO_2, HR on the external loads level (P, W/kg). In the course of the effort the following were measured: VO_2, VE , VCO_2 (K4b2, Cosmed Italy), and HR (Polar V650, Polar Finland). Effort intensity was determined at ventilators thresholds VE1 (AT), and VE2 (AnT).

RESULTS

Research results are presented on fig 1. In the men group, the widest range of changes is visible as far as internal load values at AeT and AnT thresholds, are thresholds. In women, the scope of changes is far narrower, and concerns internal load indicators from 7 to 11 %.

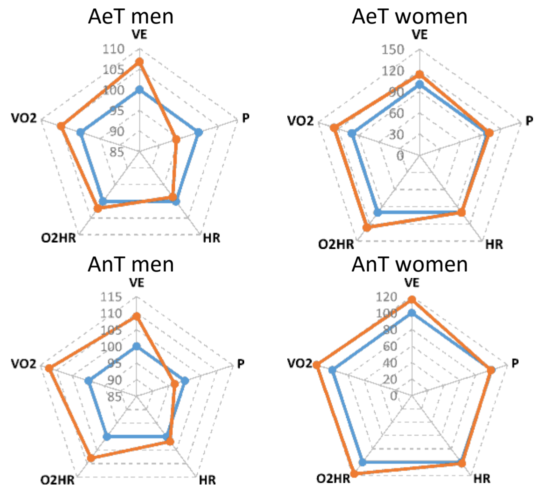

Figure 1. The structure of the differences between internal, and external load indicators in normoxia , and high- altitude hypoxia conditions, in cyclists, men, and women, at AeT, and AnT.

CONCLUSSIONS

The scope of the changes in internal load indicator values is at metabolic thresholds , is narrower in men, than in women. In women , there is a significant decrease in VO2, and VE, and P ,which is consistent with Mohan et al. (1997) observations. HR is the least sensitive to high-altitude hypoxia conditions, of all the load indicators,. It does not undergo significant changes due to hypoxia at the AeT, and AnT thresholds.

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THE EFFECTS OF CLASSIC LIVE HIGH TRAIN HIGH ALTITUDE TRAINING ON HEMOGLOBIN AND RED BLOOD CELLS IN ROWERS – PRELIMINARY STUDY

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INTRODUCTION

This is part of the study comparing effects of natural altitude training and simulated altitude method of training.

METHODS

12 elite rowers (11 men, 1 woman) participated in a 3-week altitude training camp at 2000 m. All have undergone equivalent training program. Blood samples were taken four times- before (pre), at the end of the camp (camp) and twice thereafter - on first week and on 3-th week after descending.

RESULTS

The main parameters are presented in the Table1.

Table 1. Blood tests results

	pre	camp	1 week	3 week
Hb [g/l]	148,00	154,67	145,36	148,17
RBC [T/l]	5,00	5,34	4,93	4,97
Hct [l/l]	0,44	0,45	0,43	0,43
Ret [0/00]	18,17	28,42	11,75	10,17
Fe [mcmol/l]	18,60	18,33	15,02	15,42
TIBC [mcmol/l]	57,36	60,83	56,84	52,98
Total protein [g/l]	58,5	66,5	60,8	59,5

Hemoglobin (Hb) has a significant increase at the end of the camp with 6,67 g / l (+/- 3,87, p <0,001), and then decrease significantly with -9,30 g / l (+/- 4,92, p <0.001) eight days after descending.

Erythrocytes (RBC) also has increased at the end of the camp with 0,34 T / l (+/- 0,14, p <0,001) and consequently decreased with -0,41 T / l (+/- 0,15, p <0,001).

Similar changes was seen in haematocrit (Hct), reticulocytes count (Ret) and total iron-binding capacity (TIBC), but was not statistically significant. This dynamic was observed in all athletes. Serum iron (Fe) also decreased and remained at lower level.

CONCLUSSIONS

After 3 weeks of natural hypoxic exposure we do not observe lasting changes in Hb and Erythrocytes. It is notable rapid return of the parameters to the before exposure values. Although there is evidence of stimulated hemopoiesis – rise of reticulocytes and decrease of iron. It is possible that this fast dynamics is associated with the observed haemodilution (1). Proof of that is change in hematocrit and total protein. Future investigations are needed to clarify this question.

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DYNAMICS OF INDIVIDUAL CHANGES IN FUNCTIONAL CAPACITY AND BLOOD PARAMETERS (UREA AND URIC ACID) DURING REAL AND SIMULATED ALTITUDE TRAINING OF HIGH PERFORMANCE ROWERS.

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INTRODUCTION

In endurance type of sports performance is mainly determined by the rate of oxygen transport and oxygen utilization which in most of the cases reach plateau after several years of training. Thus performance improvements of 1% or 2% are a major challenge. Simulated altitude training now is one of the most effective ways for further development of functional capacities and it is an inseparable part of the modern high performance training system (2). The overall objective is to compare the classical altitude training (Live High – Train High) and modern (Live High – Train Low) by the use of High Altitude Sleep System (MAG-20, Higher Peak, USA) in high performance Bulgarian rowers.

METHODS

Subjects: 16 subjects from the U18 Men Bulgarian National Rowing Team were recruited .
Training Protocol: Subjects completed two training camps (3 weeks each) according to their annual training plan. The first one (RL) at 2100 m sea level (Belmeken Bulgaria) and the second training camp (SM) was set at 400 m sea level during which athletes slept at 2400 – 2800 m using High Altitude Sleep System (MAG-20, Higher Peak, USA).
Performance test and Blood Sampling: Each subject performed an incremental test – 4 stages/40 W apart x 3 min with 30 sec rest periods (2) on Concept-2 (USA) rowing ergometer. The test was conducted 18 day before (I), at the end (II) and on the 7th (III) and 18th day after (IV) each of the training camps.
During the test 10 µl ear blood samples were collected for blood lactate concentration and Anaerobic Threshold determination (4 mmol/l) (Lactate Pro 2, Japan). In addition, PWC_{170} and VO2max (l/min) were determined using regression equations described elsewhere (2). Venous blood samples (5 ml) were obtained for urea and uric acid concentration.
Statistics: Functional parameters and blood indices were assessed with ANOVA and Bonferroni post-hoc test

RESULTS AND CONCLUSSIONS

No significant difference was found pre and post LHTH training camp in PWC170 and power at Anaerobic Threshold. Result from LHTL training camp are still analyzing because of the fact that this period is still running.

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Stage	Weight	P_{AnT}	HR_{AnT}	PWC170/kg	VO2max (PWC170)
	kg	W/kg	bpm	W/kg	ml/min/kg
RL-I	81.45 ± 7.39	3.87 ± 0.37	178.36 ± 9.49	3.61 ± 0.46	67.12 ± 6.43
RL-IV	78.93 ± 5.52	4.1 ± 0.31	182.47 ± 10.43	3.7 ± 0.51	60.45 ± 20.6
SM1	80.53 ± 7.17	3.83 ± 0.36	180.48 ± 10.92	3.47 ± 0.55	64.84 ± 8.42
P_{AnT} – power at anaerobic threshold ; HR_{AnT} – heart rate at anaerobic threshold					

Table 1. Functional parameters from real (RL) and simulated (SM) (Average ± SD) altitude training camp

OTHER TOPICS RELATED TO ALTITUDE

EXERTION RELATED FEEDBACK FOR WALKING AND MOUNTAINEERING BY %-MARKINGS DURING THE WAY

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INTRODUCTION

Exertion during endurance activities is to arrange between start and end point: If the metabolic intensity is too high, inadequate fatigue or exhaustion will occur before reaching the end point, if the intensity is to low, the end point cannot be reached in the desired time. This is not only valid for endurance athletes, but also for walkers or mountaineers, because going uphill is heavy work.

So arrangement of exertion is an important tactical aspect for all intensive eandurance activities – intensive means in relation to the individual fitness. This arrangement depends on psychophysiological feedback (1) and it requires experience: one reason of the advantage of somewhat older compared to younger mountaineers with their best values for laboratory fitness (2). But not only engaged mountaineers need such tactical arrangement of exertion. but also tourists, looking for recreation. If they are interested to reach an attractive viewpoint, they must adjust their intensity of exertion – probably with a reduced state of fitness – over an unknown timespan until end point and they have to save time for return.

Therefore we conceived a system for exertion related external feedback by installing boards during the way with steps in percentages of the total exertion until the end point.

<u>Aim of abstract</u>: To present tactical aspects of walking/mountaineering and possibilities to optimize/train psychophysiological feedback

METHODS

A very experienced mountaineer walked uphil with a constant exertion until summit Hirschkaser (Ramsau/Berchtesgaden, 1391 m), ascent of + 470 m. Interval times were marked during the ascent. In relation to the total time percentages of exertion could be calculated and by this bords in steps of 20% could be placed.

RESULTS

At the start place a board informed about the sense of the percentage-boards. Figure 1 shows two examples of the placed boards in the forest of the increasing trail.

Figure 1: Examples for the %-boards

Concerning acceptance e found until today some orientating, but not systematic observations.

CONCLUSIONS

In future we plan to evaluate the acceptance of this psychophysical feedback for 1. Leisure tourists with different status of fitness, 2. Recreation/ rehabilitation people, refering to return early enought before reaching the goal in case of relevant fatigue 3. sporting engaged people (endurance-tactics-trainig, e.g. in combination with BORG's scale).

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EES: EXTREME ENIVRONMENT SIMULATOR

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INTRODUCTION

Field-based investigation of human physiology in extreme environmental conditions represents a major challenge for research. Nevertheless, studies of healthy individuals under extreme physiological stress are crucial to providing further clinical insight in applicable translational research models. The combination of climatic conditions found in areas such as: high mountain regions, Antarctic ranges, and desert plateaus are often at the limit of human physiological endurance. The logistics necessary to establish effective laboratories capable of consistent, accurate assessment of human physiological response to such extreme conditions are hugely challenging and rarely standardisable. Therefore, in an attempt to partially solve these problems and push the boundaries of applicable clinical research, many institutions invested in environmental chambers; enabling the development of more accessible, controlled, comparative research. Early chamber studies [1, 2] have striven to set the precedent in hypobaric hypoxia for strategic adaption of basic science research concepts to applied clinical investigation. The EES will facilitate the complex simulation of multiple environmental factors, thus ensuring an enhanced capability to fully investigate this research concept (Fig.1).

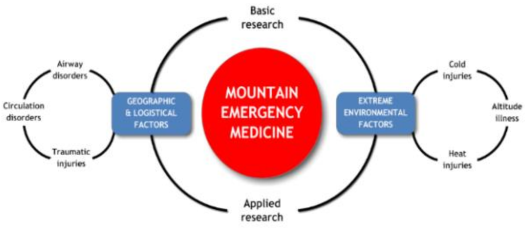

Figure 1. EES research concept

Environmental Factors	from	to	unit
Temperature	-40	+60	°C
Atmospheric pressure (altitude)	1013 (0)	300 (9000)	mbar (m)
Wind speed	0	30	m/sec
Relative humidity (≥4°C)	10	95	%
Rain	0	60	mm/h/m²
Snowfall	0	5	cm/h

Table 1. Technical specification of EES chamber

METHODS

The unique multi-functionality, size and range of controllable target variables will set the EURAC EES facility apart. Specifically, the ability to control barometric pressure from sea level down to 300mbar, whilst simultaneously controlling multiple climatic parameters (Table 1). The EES will consist of a large test chamber (12m L x 6m W x 6m H), complete with ambulatory chamber and toilet/ showering facilities (Fig. 2). Capable of accommodating ≤15 individuals and programmable to run consecutive test protocols for up to 45 days without interruption.

RESULTS & CONCLUSSIONS

The construction and operation of this EES facility will enable new perspectives in the field of emergency medicine and alpine technologies. A primarily international focus, interdisciplinary co-operation and professional management structure will offer the possibility of collaborative innovation and enhanced research expertise. Bolzano is ideal for the establishment of this facility due to its central location in the Alps, close connectivity to partner EURAC research institutes and established links with other European leads in applied clinical research.

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Figure 2. EES chamber design

HEALTH AND SAFETY OF EMPLOYEES IN ISOBARIC HYPOXIA FACILITIES

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INTRODUCTION

About 1000 facilities with isobaric hypoxia are in use worldwide (industrial faclilities only, training facilities not included) with an estimated number of 6000 employees exposed to conditions between 17.0% and 14.0% O2, corresponding to an altitude of about 1700m to 2750m. Although such moderate altitude is well known as safe environment except for people with severe cardiopulmonary diseases (NYHA III+), many HSE officers and governments are worried and assume increased risk for employees.

RESULTS

The review will summarize the physiological factors which define work in such facilities, gives an overview how UIAA MedCom recommends to care for health and safety of the respective employees and how the different countries manage the task.

CONCLUSIONS

Summarized any person who is well trained in altitude medicine should emphasize the safety of the facilities which have – in contrast to „real“ altitude – the special advantage that anybody who might not feel well will always be able to leave into normal atmosphere.

INVESTIGATING SAFETY OF CLIMBING ROPES

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INTRODUCTION

Quality of climbing ropes is determined by two parameters, i.e. climber safety and rope's durability (1). Durability in this case does not mean just failure of a rope, but rather deterioration of its time-dependent response when exposed to an impact force. Both parameters are governed by time-dependent properties of the material from which ropes are manufactured. The UIAA (Union Internationale des Associations d'Alpinisme) has established standard testing procedures to measure how ropes react to drops (2), that are not geared to analyze the time-dependent deformation process of the rope, which causes structural changes in the material and affects the functionality and durability of the rope itself.

Using self-developed Experimental-Numerical-Analytical (ENA) methodology (3) we can study (time-dependent) dynamic behavior of tested ropes, and consequently safety of climbers.

METHODS

Details of experimental setup and measuring methodology are described elsewhere (4). Within this paper we have tested four "dry" and four "wet" specimens prepared from the same commercial rope. Tested rope was single rope made out of polyamide fibers. The length of all samples was the same: diameter 9.7 mm, and weight per meter 63 g. The set of "dry" ropes were then kept at room condition, whereas the "wet" samples were immersed in water for 96 h. Each rope was then exposed to 10 consecutive impact loadings (drops) with the time interval of 5 min between each drop.

RESULTS

From the shown results on Fig. 1, we may observe that "dry" and "wet" ropes behave significantly different. The difference in $F_{\max}$ at the first drop is not so large, however, with the increased number of drops the maximum force for "wet" ropes increases much faster than that of "dry" ropes. In fact, already at the second impact loading the maximum force of "wet" ropes exceeds the maximum force that is reached with "dry" ropes after ten consecutive drops. Thus, one could as well say that the life-time of "wet" ropes is ten times shorter than that of "dry" ropes! For climbers this is definitely information that should be considered very seriously.

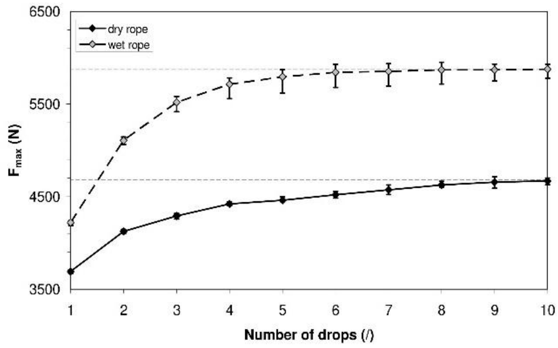

Figure 2. MAXIMUM FORCE ACTING ON "DRY" AND "WET" ROPES

CONCLUSSIONS

Using ENA we have showed that moisture has a significant effect on the functionality and durability of ropes. In brief, "wet" ropes create larger maximum force. Using wet ropes can lead to the change in (de)acceleration which exceeds the critical safety limit and endanger the user of the rope. These results also indicate that mechanical properties of ropes are governed mainly by the time dependency of the material, from which the rope is manufactured.

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PHYSIOLOGICAL RESPONSES TO APNEA AT SEA LEVEL COULD PREDICT SaO_2 AT HIGH ALTITUDE

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INTRODUCTION

The study aimed to identify individual physiological markers predicting altitude sensitivity, by evaluating whether responses to apnea at sea level (330m) correlated with SaO_2 when exposed to simulated altitude by normobaric hypoxia (5300m). We hypothesized that the apnea induced diving response (1) and spleen response (2) could predict sensitivity to high altitude.

METHODS

Thirteen volunteers (24±4 years) performed the following protocol: 10 min rest breathing room air at 330 m altitude, 1 min apnea, 2 min rest, two maximal-effort apneas separated by 2 min, and 20 min rest. The subject then entered a chamber simulating 5300 m (10.7 % O_2) for 30 min, followed by 10 min eupnea at sea level. Spirometric measurements included vital capacity (VC), forced vital capacity (FVC), peak expiratory flow (PEF), and maximal voluntary ventilation (MVV). Arterial oxygen saturation (SaO_2) and heart rate (HR) were continuously monitored using pulse oximetry. Minimum SaO_2 during 5300 m exposure was defined as the minimum average for every 5 min period. The diving response bradycardia was calculated as the reduction in HR during the apnea from the pre-apnoeic HR value. Spleen diameters were measured from ultrasonic images every minute before and after each apnea (2). Finger capillary blood samples were taken for hemoglobin (Hb) and lactate concentration before and after each apnea. Pearson's correlation analysis was used and $P<0.05$ was considered significant.

RESULTS: A positive correlation was found between the minimum SaO_2 during 5300 m exposure and the Hb concentration with spleen contraction; both immediately after the last maximum apnea ($r=0.537$ $P=0.048$) and 3 min post apnea ($r=0.614$ $P=0.026$). Spleen volume was significantly reduced after last apnea execution compared with resting values (238±77 vs. 186±80mL; $P=0.005$). A tendency for correlation was found between the minimum SaO_2 at 5300 m and duration of the last maximal apnea ($r=0.508$ $P=0.064$) and the diving bradycardia ($r=0.473$ $P=0.088$). Other variables recorded at sea level did not correlate with minimum SaO_2 at 5300 m.

CONCLUSION

We concluded that the physiological responses to apnea at sea level; mainly the spleen contraction induced Hb elevation and possibly also the cardiovascular diving response, both known to enhance apnea performance (3), could predict SaO_2 at high altitude. These responses should be explored further for designing a test predicting individual altitude sensitivity.

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WHICH ARE THE INFLUENCING FACTORS OF NECK PAIN DURING BELAYING HIS CLIMBING PARTNER?

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Bachelor thesis to attain the degree Bachelor of Science within the department of therapy sciences at the SRH University in Heidelberg, Germany.

INTRODUCTION

Many of the injury and overuse problems have been investigated in different studies and interventions have been developed to mitigate the injury risk. For these studies the focus was on the climber because the climbers reviewed were in midpoint at climbing competitions. My research has highlighted that there are missing basic studies whose focus is on neck pain during belaying. Before developing compensation measures it is essential that the causes of neck pain are identified and known. Especially those, related to constant body position habitually preferred during belaying, it is not an ergonomic posture therefore it causes an overuse and pain at the cervical spine and shoulder girdle structure.

METHODS

A questionnaire has been developed and 100 climbers in the Rhein-Neckar region have been surveyed in order to figure out if the cause of the pain is muscular, articular or vestibular. Complementing this, the spine form, Spurling test and ULTT1 assessments have been carried out by the examiner and the result has been included in the questionnaire too. The assignment to group with or without neck pain in this clinical trial has been based on the answer to the question: “Do you have pain during belaying?” All data have been prepared in Excel and the calculation has been generated by the statistical program STATA.

RESULTS

Participants in the group with neck pain are climbing $\bar{x}$ = 2.37 hours / week longer than climbers in the group without neck pain. Participants with positive Spurling and therefore tight facet joints tend to increased neck pain. Prior spine injuries result in higher prevalence of neck pain during belaying.

The pain quality was described as cramped and tensed up in a way that indicates it is of a muscular origin (0.86 ± 0.36) caused by unilateral pressure. The back shape seems to have no influence on the neck pain at all, neither the position at work or the neurological reaction test what has been expected. The longer the belayer has to observe the climber the higher is the prevalence of neck pain during belaying. Nor the spine shape, neither the professional activity had any influences, what has originally been expected.

CONCLUSSIONS

In order to mitigate pain resulting from belaying, avoid the muscular tensions and following articular and vestibular limitations. It would be better to belay with the coordinated belaying posture or climbing glasses than with the habitual belaying posture currently adopted by most climbers. Belayers who already have a muscle Dysbalance would be classified into chronical neck pain. They should train the cervical spine and thoracic spine muscles in order to stabilize and strengthen them.

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