THE EFFECT OF HYPOXIA ON EXERCISE TOLERANCE AND MORPHOLOGICAL PARAMETERS OF BLOOD IN MALE AFTER ACUTE CORONARY SYNDROME TREATED WITH ANGIOPLASTY

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Abstract

Background: Currently there is little documented research evaluating the effect of high-mountain environment on patients with ischemic heart disease.
The main aim of the study was to assess the effect of no normobaric hypoxia on exercise tolerance and blood parameters in patients diagnosed with stable coronary disease.
Methods: 22 men aged 37 to 72 (55,68 ± 9,86 years of age) with coronary disease were qualified. Pre-study, in normobaric normoxia environment each patient underwent: resting ECG, spiroergometric test using a treadmill, laboratory tests (lipid profile, morphology, gasometric parameters and lactate level, electrolite). The patients stayed in the cabinet for 3 hours at the: 1. normoxia , 2. hypoxia (2000 m a.s.l), 3. hypoxia (3000m a.s.l.) levels. After the 3-hour period patients underwent a spiroergometric exercise tolerance test combined with blood lactic acid concentration test. Venous blood and capillary blood was drawn for gasometry testing purposes.
Results: Under 2000 and 3000m hypoxia a significantly shorter duration of the exercise test, distance travelled, MET values, VO_{2peak}, $VO_{2peak/kg.}$ Increase in resting blood pH and decrease of resting and peak pCO_2 and pO_2 were observed. There were no significant changes in morphology parameters and electrolytes.
Conclusion: As a result of exposure to normobaric hypoxia exercise tolerance of patients after acute coronary syndrome decreases.

***Key words**: normobaric hypoxia, rehabilitation, exercise tolerance, blood parameters, coronary artery disease*

Introduction

Due to the fact that increasingly more persons decide to spend their free time skiing or mountain hiking it is to be accentuated that basic safety measures need be taken. These measures apply especially to patients with cardiovascular disease. Patients suffering from coronary disease constitute the largest group of cardiovascular patients and therefore are at the highest risk of reacting to temperature and air pressure changes related to altitude. A study conducted in the Alps in 2011 showed that persons with a history of stroke, hypertension or coronary disease engaging in sport activities such as skiing and high-mountain climbing were more likely to experience cardiac arrest while staying in high-altitude environment [Windsor et al 2010, Bärtsch et al 2007, Cheuk-Man et al. 2003] . Nevertheless, it was recommended that the patient undergoes a 3-5 day adaptation period after reaching each a new height before progressing to any type of physical exercise, especially sports and recreational activities [Donegani et al 2014, Anderson et al 2011, Naeije 2010, Faeh et al 2009, Al-Huthi et al 2006]. Moreover, UIAA Medical Commission summarizes that patients with stable, well controlled CAD without residual ischemia who participate in unrestricted physical activity at sea level are probably safe to travel up to 3000 to 3500m with minimal increased risk. Information on the risks to those who with CAD ascend to altitudes above 5000m is lacking, although there are plenty of anecdotal examples of individuals with stable CAD performing well at these altitudes[Donegani et al 2014] . It should be remembered, that if a person suffering from coronary disease experiences any type of pain during the exercise test then surely this pain is also expected to occur after reaching even low altitudes, which disqualifies the participant from activities in high-mountain environments [Messerli-Burgy et al 2009, Kjaergaard et al 2006, Cheuk-Man et al 2003]. It should also be mentioned that this limitation should avoid the person to visit moderate altitude just to enjoy the scenery without significant physical activity[Mieske et al 2010, Morgan et al 1990]. The altitude tolerance of such patients may be tested by breathing hypoxic air at rest in well supervised conditions (e.g. doctor's practice) [Donegani et al 2014]. The first three days of staying in the hypoxia conditions have an impact on the athletes' ability to exercise, as well as people with functional limitations [Gabrys et al 2019, Millet et al 2016, Zoll et al 2006]. Especially such limitations should be expected during physical activity of patients with coronary artery disease in hypoxia conditions.

Recommendations regarding physical exercise, including the type of exercise, its intensity, frequency and workload for optimal safety of the patient can be found ESC guidelines [Guazzi et al 2012]. However, in the aforementioned guidelines no indications can be found regarding staying in higher-temperature and humid environments or in environments where changes in temperature and air pressure occur, such as the mountains. Information regarding this topic are of high priority and are more useful than indications regarding physical exercise alone. Physical training has already been widely discussed and its benefits on the cardiovascular system have been well proven.

Most recommendations regarding staying at high altitudes for this group of patients remain experimental and are not based on scientific evidence. There is a minor amount of reports, mainly from the late 1990s, including results of studies conducted directly at high altitudes on a very limited number of cardiac patients [Agostini et al 2000, Erdmann et al 1998, Levina et al 1997, Pokan et al 1994, Morgan 1990]. So far the most comprehensive survey and recommendations have been given by the Medical Commission of the Union Internationale des Associations d'Alpinisme (Intercational Mountaineering and Climbing Federation, UIAA) [Donegani et al. 2014]. These recommendations are as evidence based as possible.

Despite the fact that the above mentioned studies were at a significant risk of complications promising results were obtained. Considering the fact, that conducting this type of research requires adequate preparations and medical backup such as using proper diagnostic equipment, selecting a suitable group of patients, as well as significant financial means due to travelling to mountainsides or constructing a hypoxic cabinet in order to conduct the study in laboratory environment,the amount of reports on the topic is exiguous, which in turn makes the reports difficult to reach. Accordingly, the aim of the following study was to evaluate the effect of normobaric hypoxia on exercise tolerance in patients with coronary artery disease after acute coronary syndrome treated with coronary stent implantation.

Methods

To the study enrolled patients with coronary disease after acute coronary syndrome treated with angioplasty combined with coronary stent implantation was performed (Table 1).

Table 1. Coronary angioplasty with stent implantation in study participants after acute coronary syndrome.

Artery	Number of patients
LM	5 (22.73%)
RCA	2 (9.1%)
LAD	8 (36.38%)
Cx	3 (13.63%)
D1	1 (4.54%)
OM1	1 (4.54%)
LAD+RCA	1 (4.54%)
OM1+Cx	1 (4.54%)

LM- left main coronary artery, RCA- right coronary artery, LAD- left anterior descending artery, CX-circumflex artery, D1- first diagonal, OM1- first obtuse marginal

To keep the potential risk for the volunteers as low as possible only patients with stable coronary disease treated with model A cardiac rehab (Table 2) were qualified for the experiment. Cardiac rehabilitation of the participants was applied at least 3 months after acute coronary syndrome episode.

Table 2. Model A cardiac rehabilitation of patients with coronary diseas

Model	Risk	Exercisetolerance	Type of training	Frequency	Total time	Intensity
A	low	>7 MET >100W	Continuous endurance training on a cycloergometer or treadmill, resistance training, general fitnessexercises	5 days a week	90 minutes a day	60% to 80% of heart rate reserve or 50% to 70% of maximum heart rate

Inclusion criteria were:

- patients after acute coronary syndrome and angioplasty with stent implantation,
- patients with stable coronary disease,
- men aged 35-75 years,

- patients who underwent type A cardiac rehabilitation at least 3 months after the occurrence of acute coronary syndrome,
- patients who gave their consent to partake in the study

Exclusion criteria were:

- unstable coronary disease,
- chronic heart failure during periods of exacerbation,
- resistant hypertension,
- abnormal exercise test results,
- peripheral arterial occlusive disease,
- venous thromboemoblism,
- COPD,
- anemia,
- disorders of locomotor system disabling the patient to take the exercise test,
- lack of consent to partake in the study.

As a result of the above described method of enrolment 22 patients with diagnosed and clinically documented coronary disease aged 37-72 (55,68 ± 9,86 years of age) were qualified for the study. Pre-study, in normoxia environment, each patient underwent the following tests:

1. resting ECG,
2. exercise test combined with spiroergometric test using a treadmill in accordance with the traditional seven-grade Bruce Protocol,
3. gasometric test
4. morphology
5. electrolytes

Each participant entered the hypoxia cabinet three times for a period of 3 hours. The testing took place at the Cardiovascular Performance Testing Laboratory. The experiment was conducted in varying oxygen pressure environments:

- normoxia resembling the air pressure of 350 m above sea level
- hypoxia resembling the air pressure of 2000 m above sea level
- hypoxia resembling the air pressure of 3000m above sea level

  In accordance with the study protocol the patients staying in the hypoxic cabinet were not informed about the air pressure they were exposed to (single blind design).

After the 3-hour cabinet experiment each of the participants underwent a spiroergometric test using a treadmill, laboratory tests (lipid profile, morphology, gasometric parameters and lactate level, electrolite). In order to ensure safety of the participants during the experiment a medical rescue team took part in the study.

Exercise tolerance was evaluated with the use of electrocardiographic submaximal stress test, during which the 7- grade Bruce Protocol was applied.

As established in the study protocol, the pharmacological treatment of patients qualified for the study was optimized and accordant with the guidelines for coronary disease management (Table 3).

Table 3 . Pharmacological treatment of male participants

Type of medication	Number of patients
β-blockers	15
Clopidogrel	5
Acetylsalicylicacid (ASA)	16
Atorvastatin	2
α-blockers	1
Vitamin K antagonists	4
Angiotensin II receptor blockers (ARB)	3
Metformin	3
Calcium channel antagonists	2
Angiotensin II converting enzyme inhibitors (ACEI)	8
Diuretics	3

A permission of the Bioethics Committee No. 9/2014 was granted for conducting the study.

Data acquisition:

During the spiroergometric exercise test the following exercise tolerance values were assessed: duration of trial [min], distance travelled [m], metabolic equivalent [MET], peak oxygen consumption [VO_{2peak}], peak oxygen consumption [VO_{2peak}] per kilogram of bodyweight, peak minute ventilation [VE], resting and peak heartrate (spiroergometric parameters were determined with The CORTEX portable METAMAX 3B gas analyzer) .

Gasometric test and lactic acid concentration: pH, pO_2, pCO_2. Morphology parameters: WBC(white blood cells), RBC (red blood cells), HGB (hemoglobin), HCT (hematocrit), PLT (platelets). Morphology parameters was determined with a Sysmex model K400 device.

In order to perform a blood gasometry and lactic acid test the nurse drew approximately 200 μl of blood from fingertip. Test material for gasometry was collected in the hypoxia cabinet twice – first time at rest and then after the exercise tolerance test. The blood gasometry test was performed using the Bayer Diagnostics Rapidlab284 device.

Statistical analysis

In order to perform statistical analysis for the study OpenOffice 4.0.1, StatSoftStatistica 10 and GraphPad Prism 6.07 software was used. The Shapiro-Wilk test and histograms depicting frequency distribution of the studied variable were used in order to evaluate the compatibility of empirical distribution of the studied variables. The homogeneousness of variances was measured pre-analysis using the Brown-Forsyth test. The statistical tools used for verifying the statistical hypotheses were:

- parametric variance analysis with repetitive measurements for variables which distribution is compatible with normal distribution and the variances of the studied groups are homogenous,
- Friedman's non-parametric variance analysis with repetitive measurements for variables which distribution is not compatible with normal distribution or the variances of the studied groups are not homogenous.

For statistically significant results suggesting that median changes in parameter values at varying altitudes differ the post-hoc Turkey's test for variables of normal distribution and homogenous variances and the Dunn-Bonferroni test for variables exhibiting different than normal distribution and non-homogenous variances were used. Accepted level of significance for the verification of statistical hypotheses amounted to α=0,05.

Results and discussion

In both hypoxic and normoxic environments corresponding to the altitude of 2 000 and 3 000 meters a.s.l. none of the patients suffering from coronary disease exhibited adverse symptoms requiring that the experiment be aborted.

Exercise tolerance

In a hypoxic environment responding to the altitude of 2 000 and 3 000 meters a.s.l. (Table 4) in comparison to normoxia patients with coronary disease exhibited a statistically significant decrease in exercise tolerance test duration, distance travelled, MET values and VO_{2peak} per kilogram of bodyweight. Additionally, a statistically significant decrease in MET values and VO_{2peak} per kilogram of bodyweight was noted in hypoxia responding to the altitude of 3 000 meters a.s.l. in comparison to hypoxia resembling the height of 2 000 meters above sea level. However, no similar differences were observed as far as exercise tolerance test duration and travelled distance during the spiroergometric test are concerned.

Table 4. Spiroergometric test results (median±standard deviation) in patients examined in normoxic and hypoxic environments responding to the altitudes of 2 000 and 3 000 meters above sea level.

	I	**II**	**III**	**P value**		
	Normoxia 350 (metersASL - Katowice)	**Hypoxia 2000 (metres ASL)**	**Hypoxia 3000 (meters ASL)**			
	X ± SD	**X± SD**	**X ± SD**	**I vs II**	**I vs III**	**II vs III**
Test duration [min]	10,70±2,31	9,53±1,72	9,31±2,11	**0,001**	**0,000**	0,711
Distance [m]	589,03±199,89	502,70±171,25	467,61±164,13	**0,000**	**0,000**	0,498
MET [ml/kg/min]	8,52±1,80	7,10±1,33	6,65±1,27	**0,000**	**0,000**	**0,034**
VE [1/min]	81,92±22,54	74,09±21,29	72,80±21,04	0,244	0,174	0,847
VO_{2peak} [l/min]	2,51±0,64	2,06±0,52	1,86±0,47	**0,001**	**0,000**	**0,034**
$VO_{2peak/kg}$ [ml/min/kg]	29,63±6,44	26,27±8,14	22,04±4,91	**0,029**	**0,000**	**0,042**
Lactates 1 [mmol/l]	1,86±0,77	1,97±0,62	1,50±0,41	0,588	0,059	0,064
Lactates 2 [mmol/l]	5,49±2,47	5,30±2,04	4,81±2,09	0,786	0,322	0,432
HR_{rest} [1/min]	69,86±9,08	68,36±8,35	68,27±8,61	0,851	0,822	0,978
HR_{peak} [1/min]	139,68±15,86	137,40±11,30	134,77±13,04	0,584	0,266	0,475

VE – minute ventilation, MET – metabolic equivalent, HR_{rest} – resting heart rate, HR_{peak} – peak heart rate; 1 – at rest; 2 – at peak physical effort

No statistically significant changes in ventilation, resting and intra-workout lactate concentration, as well as resting and intra-workout heart rate were observed (Table 4).

Gasometry

Blood pH values increased in a statistically significant manner in hypoxic environment responding to the altitudes of 2 000 and 3 000 meters above sea level. No statistically significant changes were observed in blood pH values between hypoxic environments of 2 000 meters a.s.l. in comparison to those of 3 000 meters above sea level. No statistically significant effects of hypoxic environments of 2 000 and 3000 meters a.s.l. on peak physical effort blood pH values during the spiroergometric test were noted (Table 5).

No statistically significant effects of hypoxic environment of 2 000 meters a.s.l. on both resting and intra-workout pCO_2 values were observed. However, in hypoxic environment of 3 000 meters a.s.l. a statistically significant decrease in both resting and peak pCO_2 values in comparison to normoxic and hypoxic environments of 2 000 meters a.s.l. were observed. Resting and peak physical effort values of pO_2 decreased significantly in hypoxic environments of 2 000 and 3 000 meters above sea level. Moreover, significantly lower resting and peak pO_2 values were noted in hypoxic environment of 3 000 meters a.s.l. as compared to the environment responding to altitude of 2 000 meters a.s.l. (Table 5)

Table 5. Results of gasometric test in patients observed in normoxic and hypoxic environments of 2 000 and 3 000 meters a.s.l. (median±SD)

	I	**II**	**III**	**P value**		
	Normoxia 350 (meters ASL - Katowice)	**Hipoxia 2000 (meters ASL)**	**Hipoxia 3000 (meters ASL)**			
	X ±SD	**X ±SD**	**X ±SD**	**I vs II**	**I vs III**	**II vs III**
pH1	7,37±0,03	7,40±0,02	7,41±0,01	**0,001**	**0,001**	0,288
pCO_2 1 [mmHg]	37,55±4,38	37,17±2,98	35,37±3,02	0,744	**0,018**	**0,004**
pO_2 1 [mmHg]	69,20±7,35	56,20±4,95	51,26±3,77	**0,000**	**0,000**	**0,000**
pH 2	7,30±0,06	7,33±0,05	7,31±0,09	0,174	0,741	0,512
pCO_2 2 [mmHg]	35,20±3,41	34,20±2,88	32,75±2,86	0,298	**0,001**	**0,036**
pO_2 2 [mmHg]	88,64±13,80	72,43±7,73	62,35±7,62	**0,000**	**0,000**	**0,000**

1 – at rest; 2 – at peak physical effort

Morphology

Table6. Results of morphology test in patients observed in normoxic and hypoxic environments of 2 000 and 3 000 meters a.s.l. (median±SD)

	I	**II**	**III**	***p***		
	Normoxia 350 m a.s.l	**Hypoxia 2000 m a.s.l**	**Hipoxia 3000 m a.s.l**			
	$\bar{X}$ ±SD	**$\bar{X}$ ±SD**	**$\bar{X}$ ±SD**	**I vs II**	**I vs III**	**II vs III**
WBC	9,21±2,33	8,40±3,52	9,26±1,65	*0,377*	*0,945*	*0,302*
RBC	4,95±0,39	4,85±0,37	4,94±0,27	*0,411*	*0,921*	*0,387*
HGB	15,77±1,26	15,45±1,15	15,87±0,79	*0,384*	*0,754*	*0,166*
HCT	44,11±3,04	45,70±9,60	44,45±2,23	*0,465*	*0,674*	*0,555*
PLT	202,36±50,72	211,30±43,26	217,36±49,29	*0,532*	*0,323*	*0,671*

WBC- White blood cells, RBC- red blood cells, HGB- hemoglobin, HCT- hematocrit, PLT- platelets

There were no significan changes in morphology parameters.

Electrolytes

Table7. Concentration of electrolytes observed in normoxic and hypoxic environments of 2 000 and 3 000 meters a.s.l. (median±SD)

	I	**II**	**III**	***p***		
	Normoxia 350 m a.s.l	**Hypoxia 2000 m a.s.l**	**Hipoxia 3000 m a.s.l**			
	$\bar{X}$ ±SD	**$\bar{X}$ ±SD**	**$\bar{X}$ ±SD**	**I vs II**	**I vs III**	**II vs III**
Sodium	142,09±4,31	143,81±3,40	142,40±2,80	*0,144*	*0,774*	*0,144*
Potassium	4,92±0,45	4,86±0,44	4,90±0,33	*0,665*	*0,823*	*0,784*
Chlorides	105,44±2,10	99,43±22,39	102,70±1,080	*0,200*	*0,325*	*0,482*

There were no significan changes in morphology parameters.

DISCUSSION

The evaluation of the organisms' reaction to progressively increased physical effort is one of the most important elements of cardiac rehabilitation diagnostics. The stimuli in the form of increasingly more demanding physical exercise may incur various disease symptoms such as early symptoms of heart failure, heart ischemia indicators or cardiac arrhythmia.

The comparison of exercise tolerance test results performed in normoxic environment of 350 meters a.s.l. (Katowice) and those performed in hypoxic environment of 2 000 and 3 000 meters a.s.l. showed various reactions of the participants' organisms, adequate to given circumstances. Resting heart rate values, regardless of the air pressure in the cabinet, were similar. The above may have been a result of the applied pharmacological therapy. As the altitude increases the oxygen partial pressure – and therefore also in tissues of the body – is reduced, which may cause decreased exercise tolerance, especially in patients with cardio-vascular disease [Strapazzon et al 2011]. Beyond the altitude of 1 500 meters a.s.l. peak exercise tolerance is reduced by 1% with each 100 meters travelled [Kupper 2006, Fulco et al 1998, Buskirk et al 1996, West 1990, Jackson and Sharkey 1988, Buskirk et al 1967]. The above thesis has also been proved by proprietary research. During the exercise test with each new altitude reached the duration of the test, as well as distance travelled, METand peak oxygen uptake dropped significantly in comparison to normoxic environment. An increase of heart rate related to altitude is one of the organisms' reactions to reduced oxygen supply [Schmid et al 2006]. This phenomenon was noted also in proprietary studies – the patients reached the destined (submaximal) heart rate quicker with each new height above sea level. Although the differences were not statistically significant, the general tendency of the alterations was consistent with the observations of other researchers [Morgan 1990, Schmid et al 2006, Dehnert and Bartsch 2010].

Another observed parameter, depicting exercise tolerance level of a participant is peak oxygen uptake (VO2) during submaximal physical effort. At high altitudes a gradual decrease in the human organisms' oxygen uptake capability occurs. In some persons, this phenomenon can be observed even at low altitudes (circa 1 400 – 1 600 meters above sea level). Beyond the aforementioned heights this effect occurs in a linear manner: circa 11% with each 1 000 meters above sea level, while at eight-thousanders peak oxygen uptake amounts only to 20% of the value occurring at sea level [Vogt and Hoppeler 2010], beginning above the "threshold altitude" ob 1,500m [Kupper 2006, Buskirk et al 1996, West 1990, Jackson and Sharkey 1988].

In a study conducted on a group of skiers a negative correlation was noted between muscle oxidative metabolism indicators (mitochondrial density, intracellular lipid content) and VO2max and maximum effort power indicator evaluated with the use of progressive exercise test in hypoxic environment [Angermann et al 2006]. Roberts et al (1998) aimed at explaining the causes of the decrease of VO2max in hypoxemic environment is of interest. In purposefully induced conditions in hypobaric-hypoxemic cabinet the effect of a few factors likely to impact exercise tolerance with rising hypoxemia were studied. The performed analysis showed that parameters such as sea level VO2max value cause a significant decrease of VO2max in hypoxemic environment. It was stated that the greater the initial VO2max level, the greater its decline afterwards. Lactate threshold reached at sea level shows an inversed relation – the greater the initial value, the smaller the decline. This finding is somehow difficult to explain. The so-called "lactate paradox" can be excluded since this effect has been observed at extreme altitudes far beyond 7,000m only [Hochachka 1988]. The indicator causing its decrease during exercise until failure is hemoglobin oxygen saturation (SaO2) in hypoxemia; as far as this indicator is concernedthe greater its reduction, the greater decrease of VO2max [Buskirk et al 1967].

In proprietary studies VO2peak given as l/min and ml/min/kg showed statistically significant changes between all levels at which the studies were conducted. The achieved results confirm the thesis that VO2max declines as oxygen pressure decreases. Similar results were reached in other studies showing a 7-9% decrease in VO2max with every 1 000 meters a.s.l. [Schmidt and Prommer 2010]. A 19% drop in peak VO2max was noted in comparison to the initial value at 540 meters above sea level. It is to be accentuated that the methodology was similar in these studies in comparison to the proprietary studies: the experiments were conducted once and the patients exposure to hypoxic environment was constant. In turn, different results were reached in cases of exposing the participant to hypoxic environment in intervals [Shatilo et al 2008].

It also needs to be noted that there are reports in which no significant changes in oxygen uptake in comparison to initial circumstances (normoxia) were noted [Neya et al 2007, Julian et al 2004, Katayama et al 2004]. Moreover, some authors achieved results according to which peak oxygen uptake increased [Shatilo et al 2008, Burtscher et al 2004]. Such disparities in study results were caused by choice of methodology, time of the patients' exposure to hypoxic environment and physical effort intensity applied in hypoxic environment.

During the patients' stay in the hypoxic cabinet lactate concentration at rest, before the stress test and 4 minutes after stress test was assessed. During intense physical exercise significant amounts of lactates are produced (except at extreme altitudes far above of 3,000m where our actual study was performed ("lactate paradox", see above)). Maintaining a productive exercise metabolism relies on efficient transportation of the produced lactate and H+ ions [Hochachka 1988]. Lower lactate concentration in working muscles reduces the feeling of fatigue and facilitates longer periods of physical effort.

According to reports the ability to regulate pH levels (H+ ion concentration) in muscle tissue depends on the amount of buffering alkali [Mizuno et al 2008]. A higher level of buffering alkali may be a part of a fundamental exercise tolerance enhancing mechanism as result of high-altitude training. A study aiming at evaluating the effect of normobaric hypoxia on Finland national sprint team was conducted. It was observed that a 16 to 17-hour stay in an environment responding to 2 200 meters a.s.l. causes raised blood pH levels. After leaving the cabinet the members of the group, as well as members of the control group underwent exercise tolerance tests which showed significant differences in blood lactate concentration. The athletes presented lower blood lactate concentration levels in comparison to the control group (7.0 mmol/L and 5 mmol/L respectively) [Numella and Rusko 2000]. The achieved results remain fundamentally in accordance with the results obtained by other authors conducting studies involving athletes [Astrand et al 2003, Billat et al 2003]. At moderate and high altitude anaerobic metabolism is activated during relatively less intensive activity.

Resting concentrations may be increased in all clinical conditions causing the decrease of oxygen availability in the system, increased lactate production and/or hindered lactate elimination. The same process is true for patients diagnosed with coronary disease. Decreased oxygen availability in hypoxic environment combined with limited blood supply to the locomotor muscles may bring about declined energetic activity and may also induce the preference of anaerobic metabolism. Exposure to lower oxygen environments may cause increased lactate production, at least at a local level (muscle).

In proprietary studies the only statistically significant differences in blood lactate levels were noted during experiments at altitudes of 2 000 and 3 000 meters above sea level. Participants of the study simultaneously took part in a cardiac rehab program. Most of the patients also engaged in relatively intense physical activity on their own (Nordic walking, cycling, vivid marching, one of the participants was even a parachute jumper) and remained professionally active. It is therefore suggested that higher blood lactate concentration may have been a result of physical activity undertaken a few hours before the testing

Küpper reports mean resting values of 1.3 mmol/l (+/-0.74). a.s.l. while at 3,000m a tendency to higher concentrations was measured (1.5 mmol/l (+/-0.36; $p = 0.0758$)) and the increase was higly significant at 4,560m 2.2 mmol/l (+/-0.74; $p = 0.0015$) [Kupper 2006]. It is suggested that persons inhabiting low or plain regions, planning to visit high-altitude terrains should develop at least some degree of adaptation through pre-exposure to hypoxic environment corresponding to 1 500 meters above sea level. This pre-exposure may be performed in a constant manner, as well as using the IHE method (Intermittent Hypoxic Exposure) [Rusko et al 1995]. The IHE method was first introduced in the studies on Finnish athletes as a means of utilizing the ability of human organism to adapt to hypoxia without the need of burdensome and costly travelling. According to these authors the degree of acclimatization incurred by this method is directly dependent on the altitude a.s.l. as well as the duration of the stay. As much as 1 to 2 days spent at the altitude of 2 200 meters a.s.l. or a 1.5 to 4 hours exposure to hypoxic environment (cabinet) equivalent to the altitude of 4 000 meters a.s.l. using the IHE method causes the human respiratory system to adapt. During the IHE procedure patients remain in hypoxic rooms with reduced oxygen. The air is attenuated with nitrogen, filtrated or turned into a hypoxic gas mixture, which in turn resembles the circumstances equivalent to 2 500 to 3 500 meters above sea level. Vogt et al. (2010) observed an increase in total mitochondrial density as result of consistent cycloergometric training in hypoxic environment corresponding to the height of 3 850 meters a.s.l.. The training was performed for a total of 30 minutes a day, 5 days a week for 6 weeks. Moreover, increases in maximal power and VO2max were also noted. However, the latter might be an effect of any kind of exercise in a sedentary collective.

Peripheral blood gasometry was another studied parameter. Blood was drawn twice: at rest and at peak physical effort. Significant changes were noted between resting blood pH in normoxic environment of 2 000 and 3 000 meters above sea level.

It is deemed that the human organisms' adaptation to high-mountain hypoxia is associated with increased ventilation and simultaneous reduction of blood plasma volume which results from increased water excretion during intensive breathing. Increased ventilation prevents further decrease of partial blood oxygen pressure (pO2) and blood oxygen saturation (SaO2), causes the decrease of partial pressure of carbon dioxide (pCO2) and normalizes arterial blood pH during the initial phase of the patients' high-mountain stay [Luks 2009].

What is more, proprietary research showed that resting and peak effort pO2values decreased significantly in hypoxic environment of 2 000 and 3 000 meters above sea level. Moreover, a significant decrease in resting and peak effort pO2values at the altitude of 3 000 meters a.s.l. were noted in comparison to the measurements taken at the altitude of 2 000 meters above sea level. These results remain in accordance with the aforementioned reports. A significant decrease in partial oxygen pressure was noted starting with the altitude of 1 500 – 2 000 meters a.s.l. and did not affect the health of the studied group. Similar results were achieved in both the control group and in the group of patients diagnosed with coronary disease[West 2004].

Results can be found in literature on the topic pointing to minor decrease of partial oxygen pressure in our study group. The reason for such a result was the short duration of the stay in hypoxic environment (lasting only 2,5 hours). Analogous results pertained to partial pressure of carbon dioxide (pCO2).

As in proprietary studies, Neya et al. and Katayama et al. showed that analyzing the body's response at 3000m above sea level there are no differences between hemoglobin concentration in red blood cells [Neya et al 2007, Katayama et al 2004].

Both conventional and artificially training of healthy people can significantly increase hemoglobin only if the following conditions are met: exposure to hypoxia corresponding to more than 2100m above sea level will last for more than 14 hours a day for at least 3 weeks [Schmid et al 2006] . In our own research, the hypoxia effect was shorter than in the mentioned authors. It should also be taken into account that the stay in certain conditions took place only once, with a one-week break. Therefore it can be assumed that the study group spent too little time under hypoxia conditions to allow significant changes in blood morphology parameters.

A longer stay in conditions of chronic hypoxia, causes cellular dehydration - release of potassium from the cell into the extracellular space and, consequently, an increase in its serum concentration. In our own studies, increases in potassium in plasma were observed, however, they were too small to be statistically significant. It is only the upward trend. The same situation occurs with the concentration of sodium ions in the blood plasma. The results may suggest no significant effect of short-term hypoxia on the body's dehydration. Changes in chloride concentration, unrelated to changes in the sodium range, take place in the case of disturbances of the acid-base balance. Hypochloremia condition is only when the concentration of chloride ions in the blood serum is <102 mmol / l. Such situation occurred in our own research, during the stay of the group of subjects under conditions, corresponding to the height of 2000 m above sea level and 3000 m above sea level.

Conclusion

As a result of a 3-hour exposure to normobaric hypoxia exercise tolerance of patients after acute coronary syndrome treated with angioplasty combined with coronary stent implantation decreases. There is no clear information for patients weather high mountain conditions are safe for them. Presented researches were some kind of introduction to wider and more thorough experiments that can result in practice information for patients.

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