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Original article

STUDY ON CHANGING ARTERIAL OXYGEN SATURATION LEVEL OF ATHLETES WHILE PERFORMING A 21 DAYS TRAINING COURSE AT AN ALTITUDE OF 2000 METERS

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Abstract*

Aim. Among the scientific literature in sports training, introduction of training at altitude (2000m) in the preparation of biological competition is an acquisition as spectacular as it is efficient, disqualifying this way doping with blood (a risky method, that violates sporting ethics) and is credited with an increase of endurance of up to 7%.

The research aims to carry out monitoring changes produced at the level of oxygen saturation in arterial blood (Sp O2), which leads to a significant increase in performance of the athletes, due to changes in physiological, biochemical, hematological, favorable performance products with body exposure hypoxia.

Methods. The research was conducted on a group of 10 athletes during a training session of 21 days in the National Sports Complex in Piatra Arsa Bucegi, located at an altitude of 2000m. To conduct this research we used experimental methods, mathematical method Statico, graphical representation method.

Results. Data analysis shows that during exposure the body to hypoxia, saturation, arterial oxygen decreases, which leads to the production in the body of physiological changes and biochemical growth-enhancing sports performance, and does not return to normal levels throughout the 21 days spent at altitude.

Conclusions. Making one or more training sessions at altitude significantly improves the performance of runners by triggering physiological changes, hematological body athletes exposure to hypoxia, favorable growth performance.

Keywords: altitude, oxygen saturation, heart rate, hypoxia.

Introduction

General considerations on the altitude climate (Bucegi mountains, Fagaras, Carpathians):

- lowest altitude (subalpine climate 500 - 600 m and 1000 m);
- low altitude (1200 - 1800 m);
- medium altitude (1900 - 2400 m) - is characterized by :
- atmospheric pressure 580 - 600 mm Hg;
- partial pressure of O_2 approximately 100 - 115 mm Hg;
- temperature average 7 - 8^0 C in summer and 3 - 4^0 C in winter;
- relative humidity in air: - 75 - 85 % in summer;
- 55 - 65 % in winter;
- high density of negative ions;
- rich ozonation.

At an altitude of 2000 m, several beneficial effects on the body are noticed: improvement of the respiratory function, of the peripheral sanguine flow, thermoregulation, stimulation of the suprarenal glands. About the oxygen supply of the fibres, we mention that the circulation of the oxygen towards the fibres is due to the oxygen pressure gradient, which could be perceived as a succession of stairs. As the hypoxia is higher, a total drop of the gradient is lower. With high altitudes, as the gradient is very low, fibres cannot get a sufficient quantity of oxygen unless a series of compensatory mechanisms become active, like hyperventilation, a drop of the alveolar-arterial oxygen gradient, polycythemia. Moreover, there are the acido-basic balance, (compensated respiratory alkalosis), the decrease of the haemoglobin affinity for oxygen and the cellular adaptation for chronic exposure.

The ventilatory reactions to hypoxia are produced by several simultaneous mechanisms, which makes them hard to understand.

Pulmonary ventilation

The decrease of PaO_2, observed with

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exposure to hypoxia increases pulmonary ventilation (VE). This hyperventilation allows the partial compensation of the effects of altitude on the oxygen transport. (Wagner et al., 1986). Actually, hyperventilation is immediate when settling in at altitude and comes from the stimulation of peripheral chemoreceptors situated in carotidian bodies, sensitive to O_2 pressure decrease in arterial blood. These receptors send information to cortical respiratory centres, which regulate ventilation at a central level (Dempsey & Forster, 1982). If ventilation increase, as an initial response is directly influenced by carotidian chemo sensitivity A second phase, after several minutes, corresponds to a central inhibition of ventilator centres. This inhibition depends on PCO_2 which decreases in the cerebral extracellular fluid and will thus induce a decrease in the ventilator response. Therefore, the acute respiratory response in hypoxia is positively influenced by peripheral aortic chemo sensitivity, but also negatively by central chemo sensitivity.

This stimulation of the peripheral chemoreceptors induces an increase in the activity of the autonomous sympathetic nervous system (ANS) and in the production on catecholamine. Hyperventilation is basically due to an increase in the current volume and increases the effort of the ventilatory muscles with altitude (Dempsey & Forster, 1982). At rest, respiratory frequency only increases with very high altitudes, namely over 6000 m.

Actually, Huang et al. (1984) and Asano et al. (1997) showed that $PETCO_2$ decreases with exposure to acute hypoxia and that this decrease in $PETCO_2$ lasts for several days.

The ventilatory adaptations to chronic exposure to hypoxia are composed of three distinct phases. At the arrival at altitude, there is a rapid hyperventilation (hyperpnea), followed by a slight decrease, 20 – 30 minutes later (Easton et al., 1986; Whipp, 1994). If exposure lasts for more days, a progressive increase in VE will be noticed (Asano et al., 1997; Huang al., 1984). Therefore, Bisgard (Bisgard, 1995) showed that extended stimulation of the carotid body decreases the sensitivity of the chemoreceptors to hypoxia, which explains – at least partially – the increase in VE during the acclimatization phase.

This increase of VE and decrease of $PETCO_2$ persists even in normoxic conditions after a longer stay at altitude (Dempsey & Forster, 1982). On the other hand, after a regular too short exposure (1 – 2 hours/day), VE at rest and PETCO2 do not suffer modification at sea level (Katayama et al., 2001; Katayama et al., 2000).

Hypoxic ventilatory response

The hypoxic ventilatory response (HVR) is an indicator of ventilatory chemo sensitivity with hypoxia (harms & stager, 1995). HVR is correlated with VE and SAO_2 measured during an exercise in hypoxia (Dempsey & Forster, 1982). This increase in HVR is considered an adaptive positive response. Indeed, an increase in VE will induce an increase in PAO_2 and, therefore, in SAO_2 (Huang et al., 1984).

The increase in HVR allows an extended acclimatization, despite the inhibitory influence of respiratory alkalosis caused by hyperventilation (Dempsey & Forster, 1982). Therefore, a chronic exposure will attract an increase in HVR measured at rest (Rivera-Ch. et al., 2003; Sato et al., 1992; White et al., 1987), which is associated with an increase in VE and SAO2, at rest, as well as during exercises in hypoxia (Bei et al., 1997; Huang et al., 1984; Sch et al., 1984; Vo et al., 1974; Wo et al., 1991). Also, it is well known that HVR persists for several days after arriving back on flatland and can contribute to improving aerobic performance immediately following an altitude training camp. This high HVR tends to decrease several days after the arrival back on flatland (Sato et al., 1992; White et al., 1987). Its role in posthypoxic adaptation, on a long term, is not to be neglected, by all probabilities, but demands further investigation.

It is also known that amplitude and duration necessary to ventilatory acclimatization with hypoxia is extremely variable from one individual to another. This ventilatory variability is widely found in different responses considered (positive or negative) performance-wise (respondents and non respondents) Townsend et al. (2002).

Under the influence of the autonomous nervous system, exposure to altitude brings an instant modification of the ventilatory function. Asano et alii showed that the intensification of the activity of the chemoreceptors – which set the conditions of the ventilatory response, and partially of the acclimatization – is responsible for the development of the sympathetic activity (Asano et al., 1997). Mateika et al., (2004) highlighted an increase in the activity of this chemo reflex, following a short term exposure to hypoxia. In the same time, Mahamed et al., showed a increase of the reflex ventilatory response 3 hours after a hypoxic (and isocapnic) acute stimulus, as well as after a chronic hypoxic stimulus (14 days; 20 min/day) (Mahamed et al., 2003)

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Hypotheses: Including a 21 day long altitude preparatory stage, which brings modifications in the arterial blood oxygen saturation (Sp O_2), which leads to a significant increase in sport performance of runners practising athletics, due to physiological, biochemical, haematological modifications, favourable to performance, produced with body exposure to hypoxia.

Methods

We mention that the research protocol was done according to the Declaration of Helsinki, Treaty of Amsterdam and Directive 86/609 EEC and approved by the Ethics Commission of the Physical Education and Sports Department of the Babeș-Bolyai University of Cluj-Napoca, regarding research upon human subjects. Research procedures have been entirely explained to the participants at the study and their written agreements have been obtained before the beginning of the research.

Period and research location: Studies took place between 01.08.2014 and 22.08.2014 in the Piatra Arsă National Sports Complex from the Bucegi Mountains and the Stadium of the Blaj School Sports Cluj – Blaj, 2 Parc Avram Iancu.

The subjects: 10 endurance athletes specialized in mountain running. For 21 days, the athletes have done the same preparatory stage, had the same food regime and the same effort-sustaining treatment. The group of 10 athletes undertook a preparatory stage in Piatra Arsă, at an altitude of 2000m above the sea level.

Tests applied: Oxygen saturation (SP O_2) was measured for 21 days at an altitude of 2000m, twice a day, in the morning and in the evening, with the help of the pulsoxymeter (***Fig. no. 1)***

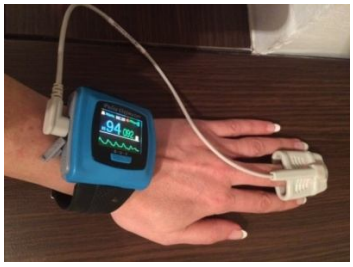

Fig. no. 1*- Pulsoxymeter OXYM 7500*

Results

The values of the oxygen saturation (SP O_2) were measured twice a day, at the same hour: 8:00 o'clock in the morning and 22:00 o'clock in the evening, with the help of the pulsomymeter, for 21 days.

The following values were noted:

1. MORNING OXYGEN SATURATION

Experiment group

The non-parametric Friedman test for repeated measures shows that there are statistically significant differences between the values of the oxygen saturation measured in the morning, at the three intervals, for al least one of the 3 possible pairs, $p=0.0003<0.05$. According to the post hoc Wilcoxon test, with the Bonferroni correction, (α =0.17), the significant differences are between A and B and between A and C, for these $p<0.017$ ***(Table no.1)***

Table no. 1 – *Values of SpO_2 in the morning, at subjects from experiment group, during altitude training camp*

Days / Name	D. 1	D. 2	D. 3	D. 4	D. 5	D. 6	D. 7	D. 8	D. 9	D. 10	D. 11	D. 12	D. 13	D. 14	D. 15	D. 16	D. 17	D. 18	D. 19	D. 20	D. 21
B.N.	94	94	94	95	94	94	94	94	95	94	95	94	94	94	96	94	95	95	96	94	95
B.G.	93	94	94	96	94	95	93	94	96	95	94	96	94	94	94	94	95	95	95	95	95
C.D.	93	93	93	93	95	95	94	94	95	95	94	93	95	95	96	94	95	93	93	93	95
G.N.	93	93	93	93	94	94	93	96	93	94	94	96	94	94	94	94	95	95	95	95	95
M.V.	93	94	94	96	94	95	93	94	96	95	94	96	94	94	94	94	95	95	95	95	95
P.A.	95	96	94	95	94	94	94	94	95	94	95	94	94	94	96	96	95	95	96	94	95
P.R.	93	93	94	93	94	94	94	94	95	94	95	94	94	94	96	96	95	95	96	94	95
Z.I.	93	93	93	93	94	94	93	96	93	94	94	96	94	94	94	94	95	95	95	95	95
G.S.	93	93	94	95	94	94	94	94	95	94	95	94	94	94	95	95	95	95	95	94	94
T.D.	93	93	93	93	94	94	93	96	93	94	94	96	94	94	94	94	95	95	95	95	95

Table no. 2 – Statistic analysis of SpO_2 in the morning, days 1-5, 6-16, 17-21 experiment group

Oxygen saturation during:	Average	Median	Deviation from standard	Minimum	Maximum	Amplitude	Variation coefficient
day 1 - day 5	93.76	93.60	0.56	93.20	94.80	1.60	0.60%
day 6 - day 16	94.38	94.41	0.15	94.18	94.55	0.36	0.16%
day 17 - day 21	94.84	95.00	0.39	93.80	95.00	1.20	0.41%

Table no. 3 – *Friedman test analysis on SpO_2 in the morning, experiment group*

Oxygen saturation during:	Average ranks	Test parameters	Result
A) day 1 - day 5	1.10	N	10
B) day 6 - day 16	2.00	Chi-square	16.20
C) day 17 - day 21	2.90	df	2
		p (Sig.)	0.0003

Table no. 4 *- Post Hoc Wilcoxon test analysis on SpO_2 in the morning, experiment group*

Test parameters	A vs B	A vs C	B vs C
Z	-2.512	-2.829	-2.098
p	0.012	0.005	0.036

Figure no. 2 presents the averages of the oxygen saturation levels in the morning, for the 3 intervals.

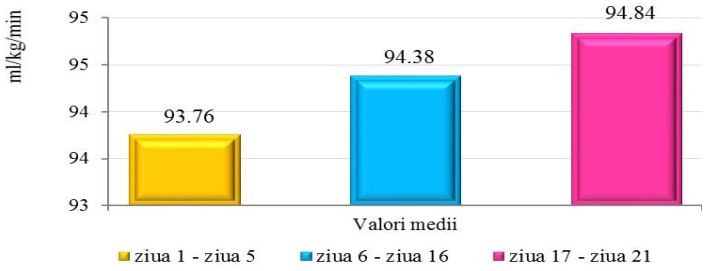

Figure no. 2 – Values of SpO_2 in the morning, at the three test stages, experiment group

Morning oxygen saturation- Control group

The oxygen saturation equals 99.40 ml/kg/min, before and after the programme. The morning oxygen saturation varies between 99 and 100 before the preparatory stage and also at its end. At both tests, data dispersion around the average is homogeneous. (Table no. 5, 6)

Table no. 5 – Values of SpO_2 in the morning, control group, during preparatory stage

Days / Name	D. 1	D. 2	D. 3	D. 4	D. 5	D. 6	D. 7	D. 8	D. 9	D. 10	D. 11	D. 12	D. 13	D. 14	D. 15	D. 16	D. 17	D. 18	D. 19	D. 20	D. 21
B.A.	99	100	100	100	99	100	100	99	100	100	100	100	99	99	100	100	100	100	100	100	100
D.S.	100	99	100	100	99	99	100	100	100	99	99	100	99	99	99	99	100	100	100	100	100
D.R.	100	99	99	100	100	100	100	100	99	99	99	99	100	100	100	100	100	99	100	99	99
R.A.	99	99	99	100	100	100	100	100	99	100	100	99	99	100	100	99	99	100	100	100	100
S.M.	100	99	99	100	100	100	99	99	99	99	100	100	99	99	99	100	100	99	99	99	99
S.R.	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
V.A.	99	100	100	99	99	100	100	100	99	99	100	100	100	100	100	100	99	100	100	100	99
B.M.	100	100	100	100	100	99	100	100	100	99	100	100	100	100	99	100	99	100	100	100	100
S.I.	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	99	100	100	100	99	99
L.D.	100	100	99	100	100	100	99	100	100	100	100	100	100	100	100	100	99	100	100	100	100

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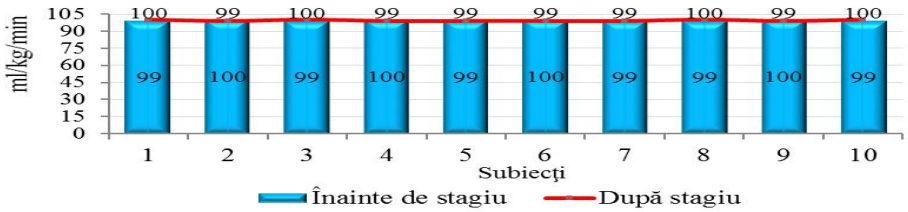
Table no. 6 – Statistic analysis on SpO_2 in the morning, before and after preparatory stage, control group

Preparatory stage	Average	Average differences	Median	Deviation from standard	Minimum	Maximum	Amplitude	Variation coef.
Before	99.40	0.00	99.00	0.52	99.00	100.00	1.00	0.5%
After	99.40	0.0%	99.00	0.52	99.00	100.00	1.00	0.5%

Table no. 7 - Wilcoxon Test analysis on HR SpO_2 in the morning, control group

Ranks difference tests	N	Average ranks	Rank sum	Test parameters	Result
Negative	4	4.50	18.00	Z	0.000
Pozitive	4	4.50	18.00	P (2-tailed)	1.000
Equal	2	0.00	0.00	Mărime efect	0.00

The non-parametric Wilcoxon test **(Table no. 7)** did not attain the statistical significance level, z = 0.000, p = 1.000 > 0.05. The null hypothesis is accepted, according to which an average decrease of the oxygen saturation is not significant. The graphical representation of the morning oxygen saturation values corresponding to the two tests of the control group is presented in ***graphic no. 1***



Graphic no. 1 – Values of SpO_2 in the morning, before and after preparatory stage, control group

EXPERIMENT vs CONTROL
AFTER preparatory stage
MORNING OXYGEN SATURATION

Morning oxygen saturation at the experiment group is generally 4.50 (-4.5%) ml/kg/min lower, averages equalling 94.90 at the experiment group, and 99.40 ml/kg/min at the control group. The morning oxygen saturation varies between 99 and 100 at the control group and between 94 and 95 at the experiment group. At both tests, data dispersion around the average is homogeneous ***(Table no. 8)***

Table no. 8 – Comparative statistic analysis experiment vs control groups - morning SpO_2

GROUP	Average	Average differences	Median	Deviation from standard	Minimum	Maximum	Amplitude	Variation coef.
Control	99.40	-4.50	99.00	0.52	99.00	100.00	1.00	0.5%
Experiment	94.90	-4.53%	95.00	0.32	94.00	95.00	1.00	0.3%

Table no. 9 – Comparative analysis Mann-Whitney U test – morning SpO_2

	GROUP	N	Average ranks	Rank sum	Test parameters	Result
MORNING OXYGEN SATURATION	Control	20	15.50	155.00	Mann-Whitney U	0.00
	Experiment	20	5.50	55.00	Z	-4.038
	Total	40			P (2-tailed)	<<0.001
					Effect magnitude	0.90

There are statistically significant differences between the two groups, z = -4.038, p<<0.001<0.05, according to the non-parametric Mann-Whitney U test ***(Table no. 9)*** taken at the end of the preparatory stage (0.90) there is a great difference between the two groups. The null hypothesis is rejected and the research hypothesis is accepted, according to which the morning oxygen saturation is significantly different at the two groups. The graphical representation of the results corresponding to the two groups are presented in **figure no. 3.**

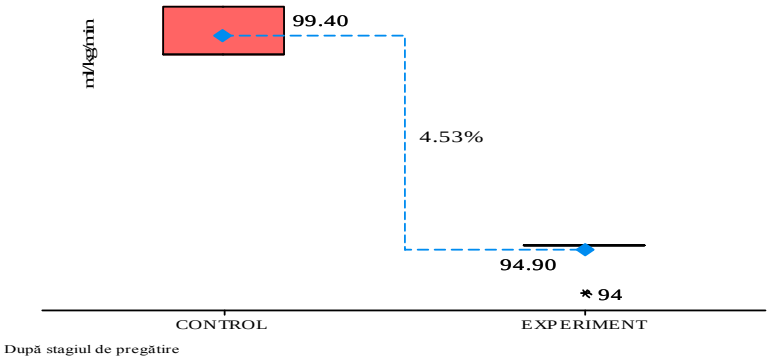


Figure no. 3- Graphical representation of the results corresponding to the two groups - morning SO_2

2. EVENING OXYGEN SATURATION

Experiment group

According to the non-parametric Friedman test for repeated measures, there are statistically significant differences between the evening oxygen saturation measured at the three intervals, for at least one of the three pairs possible, p=0.0012<0.05. According to the post hoc Wilcoxon test, with the Bonferroni correction, (α =0.17), there only exist significant differences between A and B, value p<0.017 ***(Table no. 10)***

Table no. 10 – Values of SpO_2 in the evening, experiment group, during altitude preparatory stage

Days	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.	D.
Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
B.N	94	94	94	95	94	95	95	95	94	96	96	95	95	94	95	95	96	96	96	95	95
B.G.	93	93	93	93	93	94	94	94	96	95	96	96	95	95	94	95	95	93	96	94	94
C.D.	93	93	93	93	93	94	94	94	96	95	96	96	95	95	94	95	95	93	96	94	94
G.N.	93	93	93	93	93	94	94	94	96	95	96	96	95	95	94	95	95	93	95	94	94
M.V.	93	93	93	93	93	94	94	94	96	95	96	96	95	95	94	95	95	93	96	94	94
P.A.	94	94	95	93	94	95	95	96	94	96	96	95	95	94	95	95	96	97	96	95	95
P.R.	94	94	95	93	94	95	95	94	94	95	95	95	95	94	95	95	96	97	96	95	95
Z.I.	93	93	93	93	93	94	94	94	96	95	96	96	95	95	94	95	95	93	96	94	94
G.S.	93	93	94	93	94	95	95	95	94	95	95	95	95	94	95	96	96	96	96	95	95
T.D.	93	93	93	93	93	94	94	94	96	95	96	96	95	95	94	95	95	93	96	94	94

Table no. 11 – Statistic analysis on the evening SpO_2, days 1-5, 6-16, 17-21 experiment group

Oxygen saturation during:	Average	Median	Deviation from standard	Minimum	Maximum	Amplitude	Variation coefficient
day 1 - day 5	93.36	93.00	0.51	93.00	94.20	1.20	0.54%
day 6 - day 16	94.91	94.91	0.10	94.73	95.09	0.36	0.10%
day 17 - day 21	94.30	94.40	1.70	89.80	95.80	6.00	1.80%

Table no. 12 - Friedman test on evening SpO_2, experiment group

Oxygen saturation during:	Average ranks	Test parameters	Result
A) ziua 1 - ziua 5	1.10	N	10
B) ziua 6 - ziua 16	2.70	Chi-square	13.40
C) ziua 17 - ziua 21	2.20	df	2
		p (Sig.)	0.0012

Table no. 13 - Post Hoc Wilcoxon test analysis on evening SpO_2, experiment group

Test parameters	A vs B	A vs C	B vs C
Z	-2.869	-1.826	-.517c
p	0.004	0.068	0.605

Figure no. 4 presents the averages of the evening oxygen saturation levels for the three intervals.

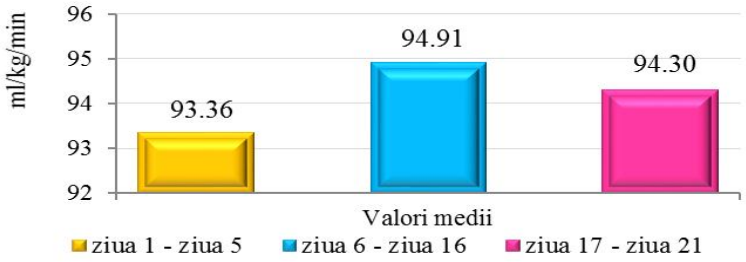


Figure no. 4 – *Values of SpO_2 in the evening at the three test stages, experiment group*

Evening oxygen saturation - control group

We notice a increase of oxygen saturation with an average of 0.70 (0.7%) ml/kg/min, from 99.10 before the programme to 99.80 after. The evening oxygen saturation varies between 99 and 100 before and after programme. At both tests, data dispersion around the average is homogeneous ***(Table no.14, 15)***

Table no. 14 – Values of SpO_2 in the evening, control group, during preparatory stage

Dayy Name	D. 1	D. 2	D. 3	D. 4	D. 5	D. 6	D. 7	D. 8	D. 9	D. 10	D. 11	D. 12	D. 13	D. 14	D. 15	D. 16	D. 17	D. 18	D. 19	D. 20	D. 21
B.A.	99	100	100	100	99	100	100	99	99	99	99	100	100	100	100	99	99	99	100	100	100
D.S.	99	99	99	99	100	99	100	100	100	99	99	99	99	100	99	99	99	99	99	99	100
D.R.	99	99	99	99	99	100	100	100	100	100	100	99	99	99	99	99	99	99	100	100	100
R.A.	100	100	100	100	100	100	99	99	99	99	100	100	100	99	99	99	100	100	100	99	100
S.M.	100	99	99	99	99	99	99	100	100	100	100	100	100	100	99	99	100	100	100	100	100
S.R.	100	99	99	99	99	100	100	99	99	98	99	99	99	99	99	99	99	100	100	100	100
V.A.	99	100	100	100	100	99	99	99	99	99	99	99	99	99	100	100	100	100	99	99	99
B.M.	100	99	99	99	99	100	100	100	100	99	98	99	99	100	100	100	100	100	100	99	99
S.I.	99	99	99	99	100	100	100	99	100	100	100	100	99	99	100	100	100	99	99	100	100
L.D.	99	99	99	99	99	99	100	100	100	100	100	100	100	100	100	99	99	100	100	100	100

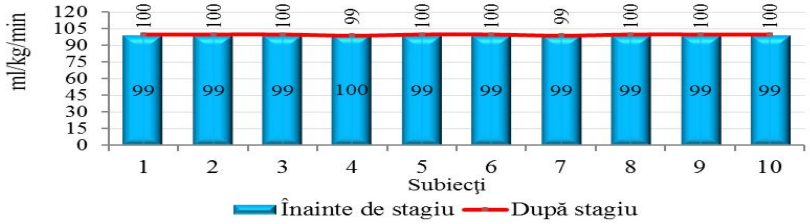
Table no. 15 – Statistic analysis of SpO_2 in the evening, before and after preparatory stage – control group

Preparatory stage:	Average	Median	Deviation from standard	Minimum	Maximum	Amplitude	Variation coefficient	Oxygen saturation during:
Before	99.10	0.70	99.00	0.32	99.00	100.00	1.00	0.3%
After	99.80	0.7%	100.00	0.42	99.00	100.00	1.00	0.4%

Table no. 16 – Analysis on Wilcoxon test HR evening SpO_2, control group

Ranks difference tests	N	Average ranks	Rank sum	Test parameters	Result
Negative	1	5.00	5.00	Z	-2.333
Pozitive	8	5.00	40.00	P (2-tailed)	0.020
Equals	1	0.00	0.00	Effect magnitude	0.52

According to the non-parametric Wilcoxon test ***(Table no. 16)*** the difference attained the statistic significance level, z = -2.333, p = 0.020 < 0.05. The effect magnitude (0.52) shows a great difference between the two tests. The null hypothesis is rejected and the research hypothesis is accepted, according to which the average increase in oxygen saturation is significant. The graphical representation corresponding to the two test on the control group are presented in ***graphic no.2***.



Graphic no. 2 – *Values of SpO_2 in the evening, before and after preparatory stage, control group*

EXPERIMENT vs CONTROL
AFTER preparatory stage
EVENING OXYGEN SATURATION

The oxygen saturation is lower in the evening, with an average of 5.40 (-5.4%) ml/kg/min at the experiment group, averages equalling 94.40 at the experiment group and 99.80 ml/kg/min at the control group. Evening oxygen saturation varies between 99 and 100 at the control group and between 94 and 95 at the experiment group. At both tests data dispersion around the average is homogeneous ***(Table no. 17)***

Table no. 17 – Statistic comparative analysis experiment vs control groups - SpO_2 in the evening

GROUP	Average	Median	Deviation from standard	Minimum	Maximum	Amplitude	Variation coefficient	Oxygen saturation during:
Control	99.80	-5.40	100.00	0.42	99.00	100.00	1.00	0.4%
Experiment	94.40	-5.41%	94.00	0.52	94.00	95.00	1.00	0.5%

Table no. 18 – Comparative analysis Mann-Whitney U test - SpO_2 in the evening

	GROUP	N	Average ranks	Rank sum	Test parameters	Result
EVENING OXYGEN SATURATION	Control	20	15.50	155.00	Mann-Whitney U	0.00
	Experiment	20	5.50	55.00	Z	-3.979
	Total	40			P (2-tailed)	0.000
					Mărime efect	0.89

Results obtained by the subjects of the two groups at the end of the preparatory stage were compared to the non-parametric Mann-Whitney U test (Table no. 18) The result showed that between the two groups there are statistically significant differences, z = -3.979, p = 0.000 < 0.05. The effect magnitude (0.89) indicates a great difference between the two groups. The null hypothesis is rejected and the research hypothesis is accepted, according to which the evening oxygen saturation is significantly different at the two groups. The graphical representation of the results corresponding to the two groups is presented in figure no. 5.

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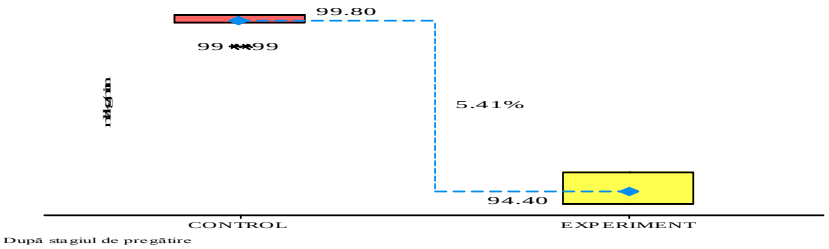

Figure no. 5 – Graphical representation of the results corresponding to the two groups SpO_2

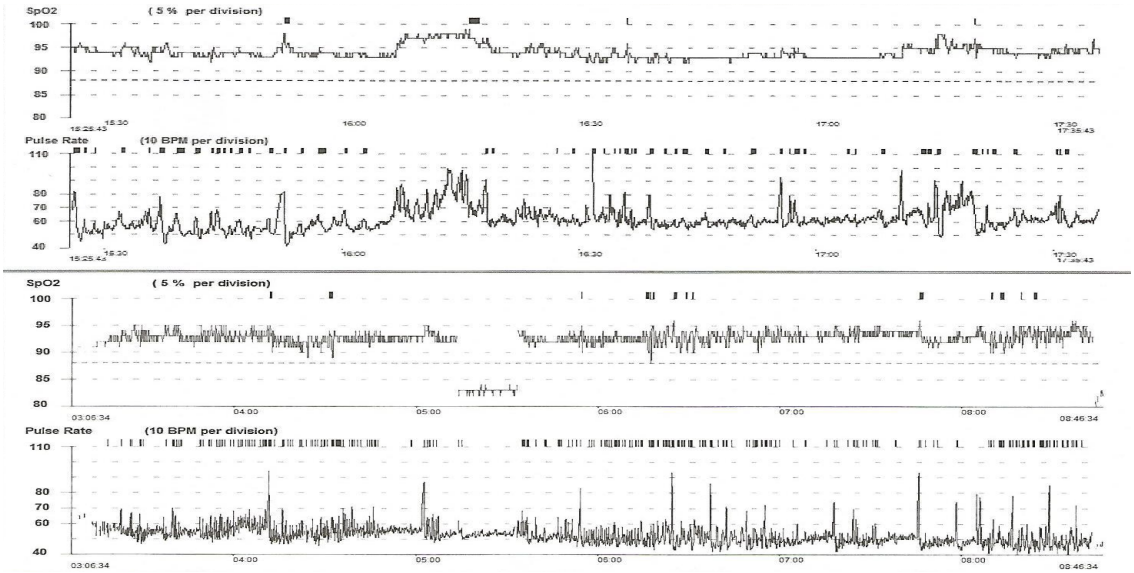

Figure no. 6 - Example of SpO_2 and HR recording during one night on two subjects

Discussions

Calbet et al. (2003) showed that for non acclimated subjects gas changes are modified: through a maximal test with a stationary bicycle (VO_2 max.), they could breathe a hypoxic gas mix (FIO_2 = 10.5%, - 5300 m). Therefore, maximal ventilation decreased with 22% in the conditions of this acute exposure to hypoxia.

This hyperventilation has two major consequences:

- higher alveolar ventilation which partially compensated for the low alveolar pressure in O_2 (PAO_2), PaO_2 and arterial saturation in O_2 (SAO_2);
- a partial decrease in CO_2 in the breathed air measured at the end of the exhalation ($PETCO_2$) (Ursini et alii, 2001). $PETCO_2$ was described as a "good indicator for acclimatization and efficient ventilation" (Ree et alii, 1993). The quoted authors showed that $PETCO_2$ measured at sea level has an inverse correlation with the amplitude of the hypoxic ventilatory response (HVR). Therefore, these authors suggested that the HVR amplitude allow determination of the ventilated level, at different altitudes, including sea level.

Katayama et al. (2005) investigated the modification of ventilatory responses during repeated acute exposures to hypoxia (e. g. 1 hour/day at 12% O_2 for 10 days – series 1). The same hypoxic protocol was repeated 1 month later (series 2), at the same subjects. The quoted authors showed that PETCO2 decreases and SAO_2 increases progressively at series 1. At series 2 $PETCO_2$ was much lower and SAO_2 higher in days 1 and 3, compared to day 1 from series 1 **(Fig. 7).** This suggests that for pre-acclimated subjects, at the second hypoxic exposure, the acclimatization phase will be faster, due to persistent ventilatory adaptations (Katayama et al., 2005).

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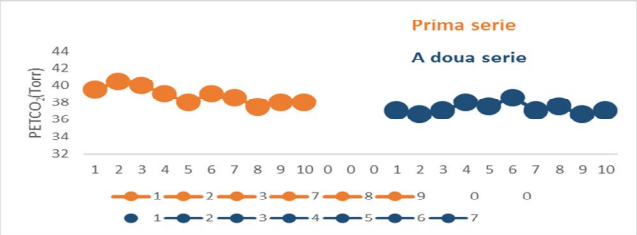

Figure no. 7 – Values of $PETCO_2$ measured in rest with hypoxia during the first two series of 10 days intermittent exposure to hypoxia. Significant differences from day 1 series 1, ($P < 0.05$) (Katayama et alii, 2005)

Townsend et al (2002) remarked a higher HVR (hypoxic ventilatory response) in the first 2 days after the end of the training for cyclists and triathlon athletes who slept for 20 days (8 hours/day, at a simulated altitude of 2650 m).

Having analysed different specialists' studies, one can draw the conclusion that exposure to hypoxia, no matter the method, leads to a progress in the performance capacity of athletes. Trainers and athletes can choose, according to their competitional objectives and physiological particularities, the most appropriate method of altitude training.

Conclusions

At the end of the experiment, we reached the following conclusions:

Concerning the physiology of respiration, after measures made with the help of the pulsoxymeter, a major decrease in oxygen concentration is noticed, from 100% to values of 93,76% easily increasing by the end of the preparatory stage due to the acclimatization phenomenon, at the experiment group.

Morning oxygen saturation, at the experiment group is lower, with an average of 4.50 (-4.5%) ml/kg/min, averages equalling 94.90 at the experiment group and 99.40 ml/kg/min at the control group. Morning oxygen saturation varies between 99 and 100 at the control group and between 94 and 95 at the experiment group. At both tests, data dispersion around the average is homogeneous.

Evening oxygen saturation is lower, with an average of 5.40 (-5.4%) ml/kg/min, averages equalling 94.40 at the experiment group and 99.80 ml/kg/min at the control group. Evening oxygen saturation varies between 99 and 100 at the control group and between 94 and 95 at the experiment. At both tests, data dispersion around the average is homogeneous.

The main physiological modifications, regarding respiration physiology with hypoxia are:

VARIABLES	CHANGE	OBSERVATIONS
Ventilation	↑	Almost instant ventilation increase, extended for several days
Oxygen saturation	↓	Low oxygen pressure attracts a reduced number of oxygen molecules, bound in haemoglobin At sea level saturation is ~90% during intense exercises. With altitude, SpO_2 decreases down to 80% for runners and mountain runners

Table no.19 – Basic physiological modifications with hypoxia

Due to ventilatory modifications and changes of the oxygen saturation values with hypoxia, which leads to other physiological and biochemical modifications favourable to performance, we propose the following training plan, within an altitude preparatory stage:

Training plan proposal for a preparatory stage of 21 days at medium altitude

Table no. 20 The proposed training plan for a preparatory stage of 21 days at medium altitude

21 days					
1----2---	**3---4---5---6**	**--7----8----9----10**	**---11----12----13---14**	**---15---16---17---18---**	**19---20---21**
6 MICROCYCLES					
2 days	**4 days**	**4 days**	**4 days**	**4 days**	**3 days**
4 phases					
2 days	**8 days**		**8 days**		**3 days**
Acclimatization	**General training** - aerobic training -training for speed development -training for force development		**Specific training** - aerobic training -anaerobic training - training for speed development -training for force development		**Recovery**

Aknowledgements

For all of our participants from my study I want to say thank you.

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