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Original article

A STUDY ON THE INFLUENCE OF TRAINING AT ALTITUDE (2000m) ON THE MAXIMUM AEROBIC VELOCITY IN ATHLETICS (MOUNTAIN RACE)

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Abstract

Premises: The interest in altitude training is part of the current questions which we must answer in connection with the competitive sport, at the intersection of the adaptation to altitude training and the acclimatization to hypoxia.

Objectives: The research aims to achieve a significant increase of sports performance of the athletes practicing athletics, the sports branch –mountain race, by increasing the maximum aerobic velocity (MAV) which is possible by introducing in the training plan a preparatory stage at altitude, after which physiological and biochemical changes occur that are favourable to sustain effort capacity.

Methods: The research was carried out on a group of 10 competitive athletes during a training stage of 21 days in the"Piatra Arsă" National Sports Complex of the Bucegi Mountains, situated at an altitude of 2000 m. In order to carry out this research we have used the experimental method, the static-mathematical method and the graphical representation method. For the determination of the MAV (maximum aerobic velocity) and the VO_2max (maximum volume of oxygen), the TMI test (le Train Maximal Impose) has been used.

Results: The data analysis has shown a significant increase in the maximum aerobic velocity and in the maximum volume of oxygen in terms of performing the training stage at altitude.

Conclusions: Performing one or more altitude training stages, significantly improves the aerobic performance of the runners.

Keywords: altitude, aerobic capacity, hypoxia, maximum aerobic velocity, maximum volume of oxygen.

Introduction

Hypoxia is a pathological condition which involves an insufficient oxygen supply to the body. It may appear at the level of the whole body (*generalised hypoxia*), or at the level of the tissue (*tissue hypoxia*). The hypoxia situation is a stress which we impose on the body, a stimulus that triggers physiological changes inside it. Although we hope these physiological changes to be favourable to sports performance, they might generate body fatigue which should not be neglected and which is most of the time harmful.

Biologically, the hypoxic condition appears at the level of the tissues because the amount of oxygen molecules brought to their level is insufficient for producing energy thus allowing the reconstruction of ATP molecules *(Schumacker & Cain, 1987).*

The physiological functions of the body under hypoxic stress will change in long-term (immediately), medium-term (a few days) and long-term (a few weeks). Two successive phases are characteristic: a period of acute stimulation followed by a period of chronic hypoxia acclimatization to hypoxia.

1. **The acute adaptation phase to hypoxia**

This period lasts between eight and ten days. Since the beginning of exposure to hypoxia, the carotid and aortic chemoreceptors are sensitive to the *pressure of oxygen in ambient air* ***(PO_2)*** and to the *oxygen saturation at arterial level* ***(SaO_2)*** which will trigger the compensating adaptation in lack of oxygen in the arterial blood. As a result, in short-term the exposure to hypoxia induces a hyperventilation which is an indicator of adaptation to hypoxia.

At rest and during exercise this slight increase in *heart rate* ***(HR)*** and the alveolar ventilation allow the partial increase of ***SaO_2***, however this adaptation is limited to endurance athletes who have an increased respiratory volume at sea level.

Due to hyperventilation the lower oxygen pressure is limited to the pulmonary alveoli level ***(PAO_2)*** and allows eliminating excess carbon dioxide ***(CO_2)*** produced by low anaerobic metabolism, resulting in increased concentration of ***H^+*** ions thus making the blood pH to rise.

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In the first 3-5 days there can be noticed a visible decrease in the capacity of endurance.

It can also be observed an early lactate production as a result of an anaerobic metabolic stress during exercise intensity, lower than the sea level.

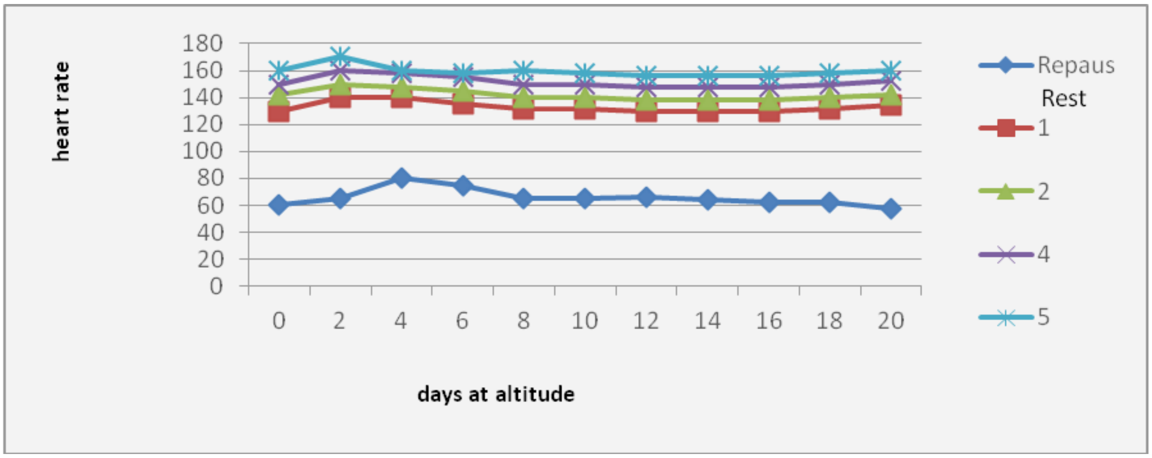

Figure no. 1 The heart rate during a 4 times 4 min. test with a slope inclination of 1, 2, 4 and 5 degrees constant submaximal intensity on the treadmill. The test has been conducted every 3 days at an altitude of 2300m on cross-country skiers of international level *(Rusko, 2003)*.

Days at altitude (2300m)

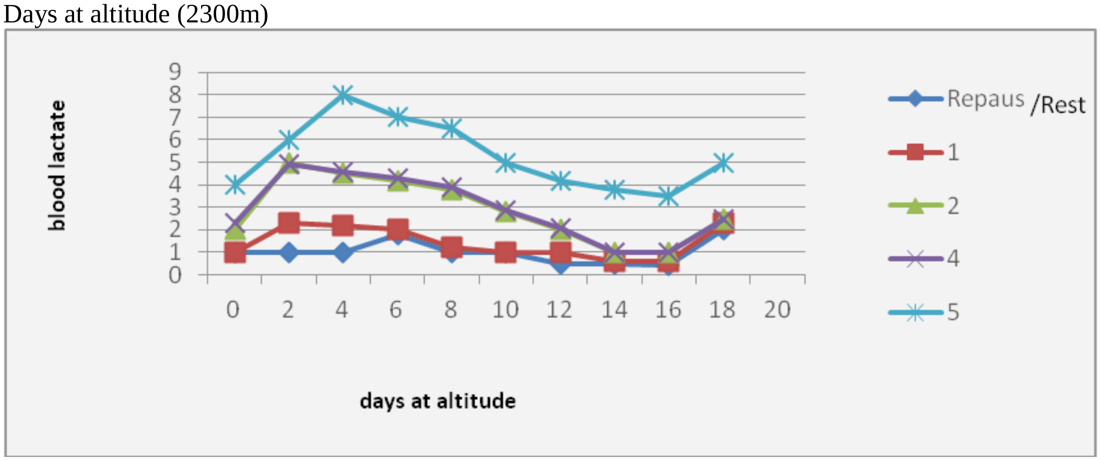

Figure no. 2 The blood lactate during a 4 times 4 min. test with a slope inclination of 1, 2, 4 and 5 degrees constant submaximal intensity on the treadmill. The test has been conducted every 3 days at an altitude of 2300m on cross-country skiers of international level *(Rusko, 2003)*

2. **The acclimatization phase in hypoxia**

This phase installs starting with the 8th day of stay at altitude. It is characterized by a slow and gradual increase of the hemoglobin. In addition, a state of dehydration takes place, which leads to increased blood viscosity. The increase in total mass of red blood cells is due to *erythropoietin (Berglud, 1992; Boutellier et al, 1990).* The body's cells possess an O_2 cellular detector called *Hypoxia Inducible Factor 1alpha* (HIF-1α) *(Wiener and others, 1996),* which locate the state of hypoxia and lead to the production of certain transcription factors. HIF(-1alpha) stimulates the production of *erythropoietin* (EPO).

The erythropoietin is a hormone responsible for the differentiation and proliferation of red blood cells. The erythropoietin is produced mainly by the kidneys (90%), but also by the liver (10%). It acts on the erythroblastic cells of the bone marrow, located at the origin of the red blood cells.

In the long term (after four weeks) it can also be observed the weight loss *(Westerterp, 2001)* and the decrease of some muscle protein *(Hoppeler & Desplanches, 1992).* This muscle loss allows easy access of O_2 to mitochondria *(Ward and others 1989).*

Maximum aerobic velocity (MAV) – Maximum volume of oxygen (VO_2 max)

VO_2 max represents the maximum volume of oxygen the human body can absorb and use during a physical effort. This volume is expressed in milliliters/kilogram body/minute.
The VO_2max term (maximum absorption of oxygen) was defined for the first time in 1920 by *Hill and Herbst*. They have issued the following theory:
1. There is an upper limit to the absorption of oxygen
2. There are inter-individual differences in VO_2 max
3. An increased value of VO_2 max is a prerequisite for increasing endurance performance
4. VO_2 max is limited by the cardio-respiratory capacity, system to carry oxygen to the muscles.

Today it is universally accepted that, physiologically, there is an upper limit of the body to consume oxygen. The VO_2 max is an accurate indicator to an athlete's physical skills. Its values differ according to gender, weight, cardiovascular capacity, etc. The VO_2 max values of the female athletes are lower than those of male athletes due to the fact that they have a lower muscle mass.

The VO_2 max is achieved during a maximum of 4-8 minutes of running. This speed is called the **Maximum Aerobic Velocity (MAV)** and is directly influenced by the VO_2 max values of each athlete.

Specialized studies have shown different methods for the development of the *maximum aerobic velocity* and implicitly the VO_2max, one of these being *the altitude training* (training in hypoxia).

There are several methods of training in hypoxia, namely:
LH+TH: lives and trains at altitude
LH+TL: lives at altitude and trains at the base
LHTLH: lives at base and trains at altitude
IHE: intermittent hypoxia exposure
IHT: intermittent hypoxia training
IHIT: intermittent hypoxia at interval training

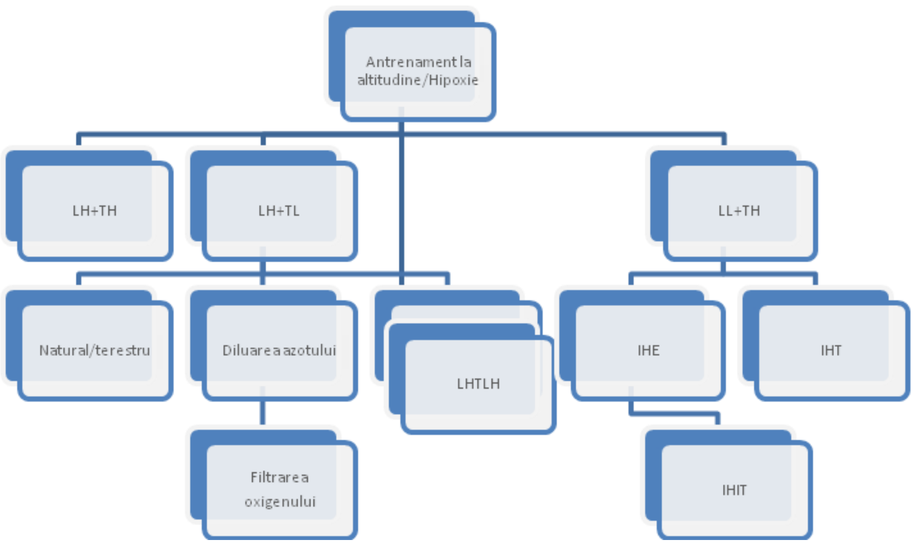

Figure no.3 Different training methods in hypoxia (real or simulated altitude) *(Millet et al, 2010)*

Each method has its advantages and disadvantages in increasing sports performance.

The VO_2 max is determined by a number of central factors and peripheral factors. *Fick's equation* describes the relationship between these factors:

$$VO_2\,max = O_2\,supplied \times O_2\,used$$
$$= Q \times (CaO_2 - CvO_2)$$
$$= (HR \times VES) \times [\beta b \times (PaO_2 - PvO_2)]$$

where:
- CaO_2,CvO_2 represents *the arterial and venous contents of the* O_2 (ml O_2.kg^{-1}.min^{-1});
- β represents *the procentage of the O_2 dissociate curve*;
- ***Pa*** and ***Pv*** represents *the arterial and venous partial pressure of the O_2* (mmHg).

According to the equation of *Fick*, the product of $Q(L.min^{-1})$ and the arterio-venous difference in the O_2 is the equivalent of VO_2 expressed in absolute values $(L\ O_2.min^{-1})$ or relative $(ml\ O_2.kg^{-1}.min^{-1})$ and it is divided into the muscle mass of the subject.

The knowledge about the mechanisms and what determines the VO_2 max are limited even at sea level. The O_2 transport has several stages staring from the ambient air, reaching the mitochondrial level and it is the convective factor for the cardiovascular transport of O_2, usually presented as being the main limiting factor of the

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VO_2max *(Di Prampero, 1985; Di Prampero & Ferretti, 1990)*. Among these ***Q*** is definitely a key factor *(Barclay & Stainsby, 1975).* The chain of transport or the cascade of O_2 must be designed as a series of resistances with a degree of increased pressure in order to overcome ***i.e.*** (interstitial fluid), with a decrease in ***PO_2*** (the oxygen pressure from ambient air), resistances that have a chronological order (***table no. 1***) *(Di Prampero, 2003):*

The resistances encountered in the transport of oxygen from the ambient air to the mitochondrial level

- ventilatory resistance ***(RV):*** the alveolo-capillary diffusion depends on *the degree of pressure* ***(PA-Pa)*** the *pulmonary diffusion capacity* of O_2 and to the same extent on the *VA/Q report - VA is the alveolar ventilation level.*
- *cardio-circulatory resistance* ***(RQ):RQ=1/(Qmax X βb)***, with ***βb*** being the average percentage of dissociation curve of O_2. The influence of ***RQ*** on the VO_2max is dependent on the ambient conditions (***i.e***., normoxia, hypoxia), which directly influences the ***βb*** as a result, the content of O_2 as well.
- *tissue resistance* ***(Rt):*** this corresponds to the diffusion of O_2 from the blood capillaries to the mitochondria. These resistances are influenced by the surface section of the muscle which is a means of assessing the distance between capillaries and mitochondria. ***Rt*** is inversely proportional to the peripheral diffusion.
- *mitochondrial resistance* ***(Rm)***: these resistances are inversely proportional to the mitochondrial oxidative activity which can be estimated by the activity of the main oxidative enzymes from ***i.e.*** succinate deshydrogenase (SDH).

Table no. 1 Limitative factors for maximum oxygen consumption (VO_2 max) during the practice of some physical exercises for a large muscle mass and a low one at sea level and at altitude (5500m). The relative importance of the factors outside pulmonary circulation is indicated in parantheses *(Di Prampero, 2003)*

PARAMETERS	SEA LEVEL				ALTITUDE
	BIG Muscle mass		SMALL Muscle mass		
R_V *(ventilatory resistance)*	0,36		0,36		0,36
R_Q *(cardio-circulatory resistance)*	0,50	(0,75)	0,32	(0,50)	0,30
R_t *(tissue resistance)*	0,07	(0,125)	0,16	(0,25)	0,17
R_m *(mitochondrial resistance)*	0,07	(0,125)	0,16	(0,25)	0,17

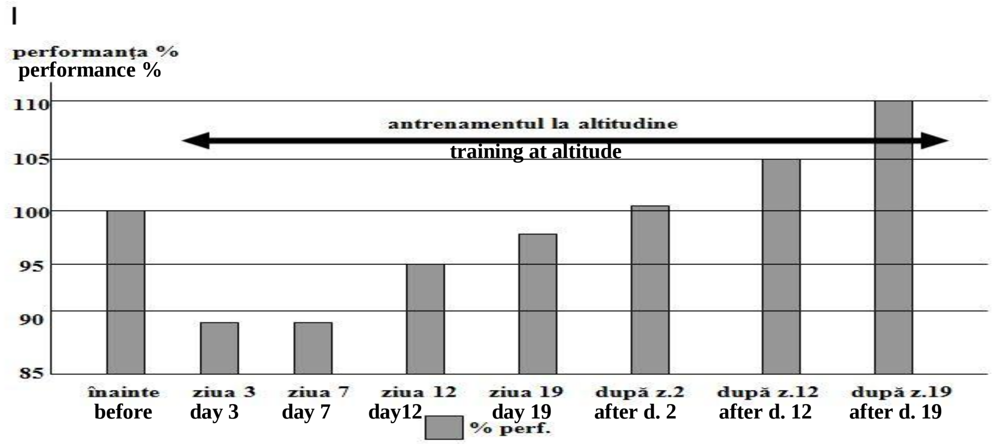
Once we have presented the factors that limit the VO_2 max values, we can say that by changing their values we increase the VO_2 max. The contribution of each central or peripheral resistance, as a limiting factor for the VO_2 max, it is particularly important to understand how we can improve the aerobic metabolism.

In the classical conception it was considered that the VO_2 max is set mainly by the cardio-circulatory factors ***i.e., Q_{max}*** and ***the blood transport capacity of the O_2***. This is correct if the exercises are performed at sea level and on major muscle groups (***R_Q:75% in table no. 1***). For the exercises at altitude it has been chosen a smaller muscle, thus the limitations are better distributed and the contributions of the more important ventilatory, tissue and mitochondrial resistances *(Di Prampero, 2003).*

As a result of the physical exercises at sea level with the training of a large muscle mass: e.g.: cycling or running races, the main limiting factor ***VO_2 max corresponds to R_Q (70-75%).*** In other words and described by *Fick*'s equation, the VO_2max is mainly set by ***Q_{max}*** and the artero-venoaus differences in O_2. As a result, an increase of 10% of one of these factors, for example the increase of hemoglobin concentration ***(Hb)*** due to increased concentration of erytropoietin ***(EPO)*** may lead to an *increase of 7% of VO_2max.*

A rate of 25-30% of the complementary limitative factors of VO_2 max, are located mainly at the peripheral level and distributed between the muscle perfusion/difussion ***(R_t)*** and the mitochondrial resistance ***(R_m).*** An increase of 10% of these factors leads to an increase of about 3% of VO_2 max. At sea level, the ***R_V*** is insignificant, in hypoxia the ***R_v*** and the peripheral resistance, the ***R_t*** and the ***R_m*** are significantly increased, as a result the ***R_Q*** is low *(Di Prampero, 2003).*

In 1990, *Fuchs* has presented the evolution of aerobic performance capacity before, during, and after a stint of 19 days of training at altitude *(Fuch & Reiss, 1990).* In the early stage of training, the aerobic performance capacity values are low, they grow at altitude once with the acclimatization of athletes and the maximum amount of aerobic capacity is reached after 19 days after returning to the base.



The ***Figure no. 4*** schematic representation of the aerobic performance capacity before, during, and after a training stage at altitude *(Fuch&Reiss,1990).*

Wilber has conducted a study which resulted in increased performance (time) for the acclimatized runners at an altitude of 2000m.

Table no 2. Performance increase (time) for athletes at 2000m altitude (acclimatized runners) *(Wilber, 2004)*

RACE DURATION	PERFORMANCE INCREASE (TIME) AT 2000m ALTITUDE
3 minutes	1,4 seconds
5 minutes	3,6 seconds
10 minutes	14,4 seconds
20 minutes	40,8 seconds
40 minutes	1minute 46,1 seconds
60 minutes	3 minutes
2 hours	7 minutes

Hypotheses: Including an altitude training stage of 21 days that triggers in the runners' body physiological and biochemical effects favourable to support effort capacity and increase the maximum aerobic values, by default the VO_2 max. Among physiological parameters with a benefic potential in endurance sports performance, the maximum oxygen consumption (VO_2max) has long been presented as decisive.

Materials and methods: We note that the research protocol was in accordance with the Helsinki Declaration, the Amsterdam Protocol and the Directive 86/609/CEE and approved by the Ethics Commission of the Physical Education and Sports Department of the Babeş-Bolyai University of Cluj-Napoca, with regard to the research on human subjects. The research procedures were fully explained to the participants in the study and their written agreements have been obtained prior to the commencement of research.

Period and place of research: The studies have been carried out in the following period: 01.08.2014-22.08.2014 in the 'Piatra Arsă' National Sports Complex of the Bucegi Mountains and the Stadium School Sports Club of Blaj - 'Avram Iancu' Park no. 2, Blaj.

Subjects: 10 competitive athletes specialized in the sports branch – mountain race. The athletes have done for 21 days the same workout program, they had the same diet and have received the same effort-sustaining medication. The group of 10 athletes has done a training stage in 'Piatra Arsă' at an altitude of 2000m above sea level.

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Tests applied: At the beginning and at the end of the preparatory phase it was determined the maximum aerobic speed for each athlete using the ***TMI*** test *(Le train Maximal Impose)* which consists in running at maximum capacity for 5 minutes, at the end, the distance achieved x 12/1000 and we obtain ***the maximum aerobic speed*** measured in km/h and for determining ***the maximum volume of oxygen*** it was used ***Merciel's formula*** –VO_2max =VMA x 3,5 and it is expressed in miligram/kilogram body/minute.

Results:

The values of the maximum aerobic speed and of the maximum volume of oxygen were determined at the beginning of the training stage, after 7 days, after 14 days, at the end of the training stage, and 21 days, after 7 and days after returning from an altitude of 2000m.
The following values have been recorded:

1.**MAXIMUM AEROBIC VELOCITY (MAV)**

Experiment group

Table no. 3 The MAV values, on subjects of the group experiment, before and after the altitude training stage

No.	Name and first name	MAV km/h Before the training stage	VMA km/h After the training stage
1.	**B.N.**	19,39	20,35
2.	**B.G.**	19.90	20,89
3.	**C.D.**	20,05	21.00
4.	**G.N.**	19,10	20.24
5.	**M.V.**	18,90	20,03
6.	**P.A.**	19,05	20.00
7.	**P.R.**	19,30	20,26
8.	**Z.I.**	18,25	19.16
9.	**G.S.**	18,90	19.84
10.	**T.D.**	19,65	20.53

Table no. 4 MAV statistical analysis before and after the training stage, experiment group

TRAINING STAGE	Average	Average difference	Median	Standard deviation	Minimum	Maximum	Amplitude	Coef. of Variation
Before	19.25	0.98	19.20	0.53	18.25	20.05	1.80	2.8%
After	20.23	5.1%	20.25	0.53	19.16	21.00	1.84	2.6%

The maximum aerobic speed has increased in average with 0.98 km/h (5.1%), from 19.25 km/h, before the training stage, at 20.23 km/h after the stage. The maximum aerobic speed varies between 18.25 and 20.05 km/h before the training stage and between 19.16 and 21.00 km/h at the end of the stage. At both trials the data dispersion around the average is homogeneous.

THE WILCOXON TEST

Table no. 5 *The Wilcoxon test analysis MAV experiment group*

Ranks difference tests	N	Average ranks	Sum of ranks
Negative	0	0.00	0.00
Positive	10	5.50	55.00
Equal	0	0.00	0.00

Test parameters	Result
Z	-2.807
P (2-tailed)	0.005
Effect size	0.63

The nonparametric Wilcoxon test demonstrates that the difference for the maximum aerobic speed recorded before and after the training stage has reached the threshold of statistical significance, z = -2.807, p =

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0.005 < 0.05. The effect size (0.63) indicates a big difference between the two tests. The null hypothesis is rejected and it is accepted the research hypothesis according to which the maximum aerobic speed increase is significant. The graphical representation of the results corresponding to those two checks from the experimental group is shown in ***chart no. 1***.

MAXIMUM AEROBIC SPEED

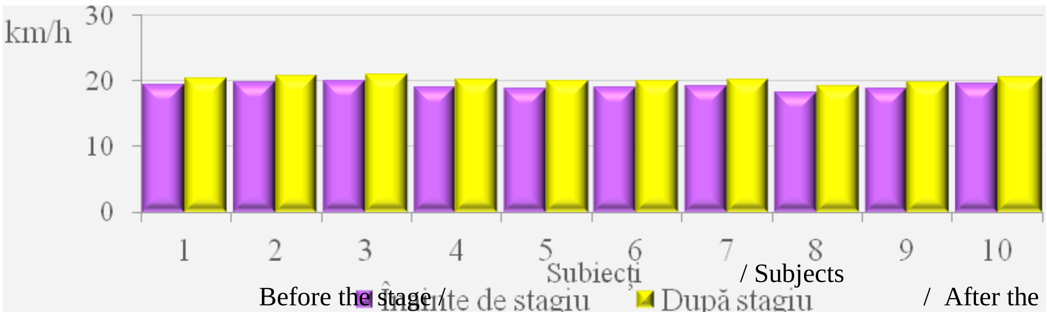

Chart no. 1 MAV values before and after the altitude training stage, experiment group

Table no. 6 MAV statistical analysis for 5 verification moments experiment group

VERIFICATION MOMENT	Average	Median	Standard dev.	Minimum	Maximum	Amplitude	Coef. of variation
Day 7	18.77	18.90	0.51	18.02	19.55	1.53	2.73%
Day 14	18.95	19.10	0.52	18.16	19.65	1.49	2.76%
Day 21	20.23	20.25	0.53	19.16	21.00	1.84	2.62%
Day 7 after	19.29	19.44	0.56	18.41	19.93	1.52	2.88%
Day 14 after	20.23	20.25	0.53	19.16	21.00	1.84	2.62%

THE FRIEDMAN TEST

Table no. 7 The Friedman test analysis experiment group

MAV values after	Average ranks
A) 7days	1.00
B) 14 days	2.00
C) 21 days	4.45
D) 7 days after finishing the stage	3.10
E) 14 days after finishing the stage	4.45

Test parameters	Result
N	10
Chi-square	39.42
df	4
p (Sig.)	<0.0001

THE POST HOC WILCOXON TEST

Table no.8 The Post Hoc Wilcoxon test analysis experiment group

Test parameters	A vs B	A vs C	A vs D	A vs E	B vs C	B vs D	B vs E	C vs D	C vs E	D vs E
Z	-2.812	-2.803	-2.805	-2.803	-2.807	-2.809	-2.807	-2.670	0.000	-2.670
p	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.008	1.000	0.008

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The nonparametric *Friedman* test results for repeated measurements show that the MAV values measured at those 5 moments, during and after the training stage period, differs significantly statistically, $p<0.0001<0.05$. Between the MAV values for the 5 moments there are at least a couple of the 10 possible combinations for which the difference is meaningful. According to the post hoc Wilcoxon test, applying the Bonferroni correction (α = 0.05/10), all the compared pairs have the value of p = 0.005, except for the comparisons of C vs E and of D vs E. In conclusion, MAV differs significantly for any pairs of moments, except for those two. In the chart of fig. we present the VMA averages at the 5 moments at which they were determined.

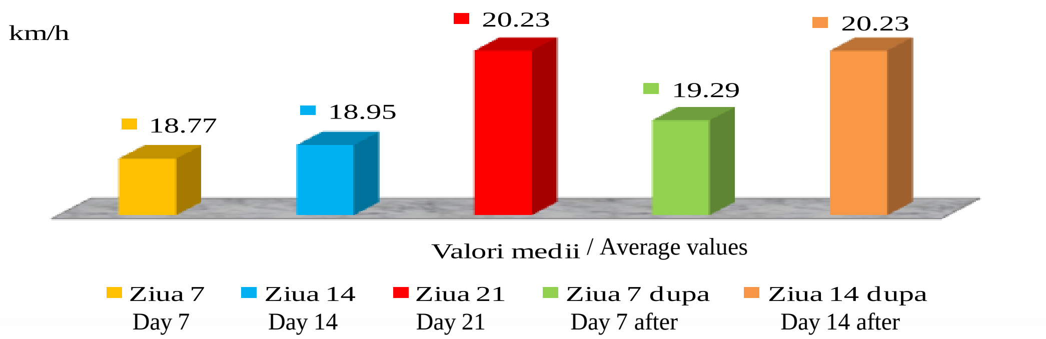

Chart no. 2 The graphical representation of the results corresponding to the stages of testing – MAV

2. MAXIMUM VOLUME OF OXYGEN (VO_2max)

Table no.9 The VO_2max values, on the subjects from the group experiment, before and after the altitude training stage

No. crt.	Name and first name	VO2max ml/kg/min Before the training stage	VO2max ml/kg/min After the training stage
1.	**B.N.**	67,86	71,22
2.	**B.G.**	69,65	73,11
3.	**C.D.**	70,17	73,50
4.	**G.N.**	66,85	70,84
5.	**M.V.**	66,15	70,10
6.	**P.A.**	66,67	70,00
7.	**P.R.**	67,55	70,91
8.	**Z.I.**	63,87	67,06
9.	**G.S.**	66,15	69,44
10.	**T.D.**	68,77	71,85

Table no. 10 VO_2max statistical analysis before and after the training stage experiment group

TRAINING STAGE	Average	Average difference	Median	Standard deviation	Minimum	Maximum	Amplitude	Coef. of variation
Before	67.37	3.43	67.20	1.86	63.87	70.17	6.30	2.8%
After	70.80	5.1%	70.88	1.85	67.06	73.50	6.44	2.6%

The maximum volume of oxygen increased in average with 3.43 ml/kg/min (5.1%), from 67.37 ml/kg/min before the training stage to 70.80ml/kg/min after the stage. The maximum volume of oxygen varies between 63.87 and 70.17 ml/kg/min before the training stage and between 67.06 and 73.50 ml/kg/min at the end of the stage. At both trials the data dispersion around the average is homogeneous.

THE WILCOXON TEST

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Table no. 11 The Wilcoxon test analysis VO_2 max experiment group

Ranks difference tests	N	Average ranks	Sum of ranks
Negative	0	0.00	0.00
Positive	10	5.50	55.00
Equal	0	0.00	0.00

Test parameters	Result
Z	-2.807
P (2-tailed)	0.005
Effect size	0.63

The difference between the maximum volume of oxygen measured before and after the training stage, according to the nonparametric Wilcoxon test, it has reached the threshold of statistical significance, z=-2.807, p = 0.005 < 0.05. The index of the effect size (0.63) shows a large difference between the two tests. The null hypothesis is rejected and it is accepted the the research hypothesis according to which the increase of the maximum volume of oxyen is significant. The graphical representation of the results corresponding to those two checks from the experimental group is shown in ***chart no. 3***.

MAXIMUM VOLUME OF OXYGEN

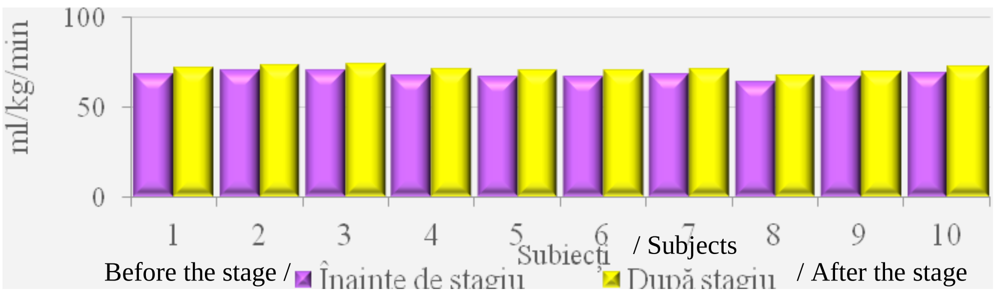

Chart no. 3 The VO_2max values before and after the altitude training stage, experiment group

Table no. 12 The VO_2 max statistical analysis for 5 verification moments experiment group

VERIFICATION MOMENT	Average	Median	Standard dev.	Minimum	Maximum	Amplitude	Coef. of variation
Day 7	65.68	66.15	1.79	63.07	68.42	5.35	2.73%
Day 14	66.33	66.85	1.83	63.56	68.77	5.21	2.76%
Day 21	70.80	70.88	1.85	67.06	73.50	6.44	2.62%
Day 7 after	67.50	68.04	1.94	64.43	69.75	5.32	2.88%
Day 14 after	70.80	70.88	1.85	67.06	73.50	6.44	2.62%

THE FRIEDMAN TEST

Table no. 13 The Friedman test analysis experiment group

MAV values after	Average ranks
A) 7 days	1.00
B) 14 days	2.00
C) 21 days	4.45
D) 7 days after finishing the stage	3.10
E) 14 days after finishing the stage	4.45

Test parameters	Result
N	10
Chi-square	39.42
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THE POST HOC WILCOXON TEST

Table no. 14 The Post Hoc Wilcoxon test analysis experiment group

Test parameters	A vs B	A vs C	A vs D	A vs E	B vs C	B vs D	B vs E	C vs D	C vs E	D vs E
Z	-2.812	-2.803	-2.805	-2.803	-2.807	-2.807	-2.807	-2.666	0.000	-2.666
p	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.008	1.000	0.008

The nonparametric *Friedman* test results for repeated measurements show statistically significant differences between the VO_2 max values to those 5 moments for at least a couple of the 10 possible combinations, $p<0.0001<0.05$. The post hoc Wilcoxon test with the Bonferroni correction, according to which the error threshold admitted $\alpha = 0.05/10 = 0.005$ shows that the resulting p value is euqal with 0.005, except for the comparisons of C vs E and of D vs E. In conclusion, the VO_2 maxim value differs significantly for any pairs of moments, except for those two. In ***chart no. 4*** we present the VO_2 max averages of those 5 moments at which they were determined.

MAXIMUM VOLUME OF OXYGEN

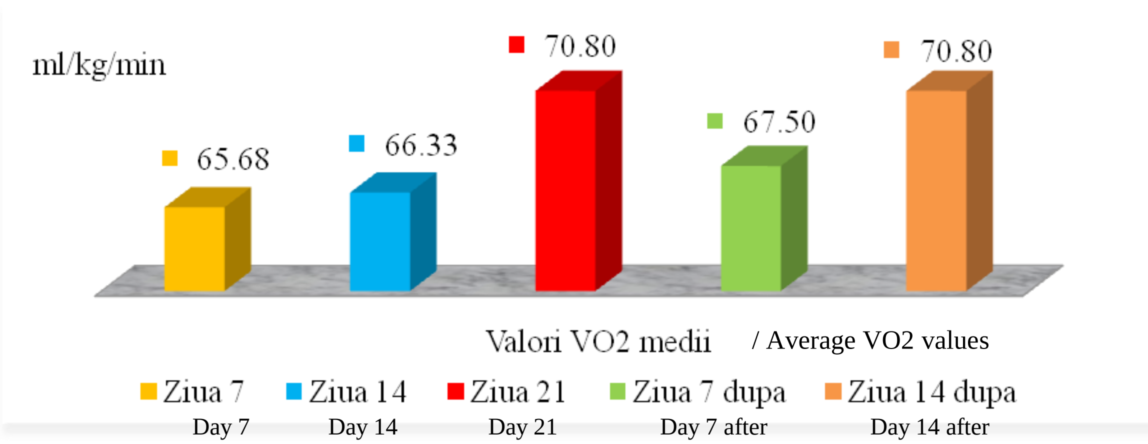

Chart no. 4 The graphical representation of the results corresponding to the stages of testing - VO_2max- experiment group

Discussions:

At present, internationally, there are numerous studies with regard to preparing at altitude with its various methods:
- LH+TH: lives and trains at altitude;
- LH+TL: lives at altitude and trains at the base;
-LHTLH: lives at base and trains at altitude;
- IHE: intermittent hypoxia exposure;
- IHT: intermittent hypoxia training;
- IHIT: intermittent hypoxia at interval training, in which there are presented their advantages and disadvantages in increasing sports performance.

For the LH+TH method: lives and trains at altitude

- *Bailey and others, 1998* in a study conducted on 14 elite runners, for 4 weeks at an altitude of 2000m after 10 days the MAV values were insignificantly modified and after 20 days they have fallen by 23%;
- *Gore and others, 1997*, a study on 13 runners, 28 days at 1740m, has shown increases of 1% of the VO_2 max at the end of the 28 days, and another study on 8 runners, 28 days at 2500m, has shown increases of 1,1% of the VO_2 max in the end;
- *Levine and Stray-Gundersen, 1997*, a study on 13 runners 28 days, 2500m, has demonstrated the VO_2 max increase by 4,9% after 4 days;
- *Daniels and Oldridge, 1970*, a study on 6 elite runners, 14 days at 2300m, shows increases of 5% of the VO_2max at the end of the altitude training stage;

For the LH+TL method: lives at altitude and trains at the base

- *Wehrlin and others, 2006*, a study on 10 orienteering runners, 24 days at 2500m, shows an increase of 3,5% of the VO_2 max at the end of the training stage;
- *Brugniaux and others, 2006*, a study on 5-6 elite runners, 18 days at 2500m-3000m altitude. Results after

15 days, the VO_2max increases by 3,4%. The maximum aerobic power increases by 4,7%;

- *Stray-Gundersen and others, 2001,*a study conducted on 22 elite runners, 27 days at 2500m altitude, shows an increase of the VO_2 max by 3%.

After analyzing various specialized studies, it can be concluded that exposure to hypoxia regardless of the method chosen is a factor of progress in terms of performance capacity of athletes. Coaches and athletes can choose according to their competitive objectives and physiological features, the most appropriate method of training at altitude.

Conclusions:

After performing the preparatory training stage at an average altitude of 2000m the MAV values increase; from an average of 19,29 km/h obtained in initial testing there has been recorded an increase of 4,86% reaching a value of 20,23km/h. During the training stage, the MAV values oscillate as follows: during the first 7 days there has been recorded a big drop from an average of 19,29km/h to 18,77km/h, a decrease due to exposure to hypoxia. After 10 days the MAV values begin to rise, once with the accommodation to altitude, up to 18,95 km/h on day 14 and 20,23 km/h on day 21. At the time of descent from altitude, the MAV values are increased, they decrease in the first 7 days to an average of 19,29 km/h after which they increase reaching maximum values of 20,23 after 14 days after descending from altitude. The same thing happens with the maximum volume of oxygen that has increased by 5,1% from an average of 67,37 mml/kg/min to 70,80 mml/kg/min. On day 7 after climbing to altitude, the VO_2 max has low values 65,68 mml/kg/min, day 14 - 66,33 mml/kg/min. The maximum values are reached in day 21 - 70,80 mml/kg/min. As well as the MAV, the VO_2 max increases during the first 7 days after descending from altitude, its values reaching 67,50 mml/kg/min, after which these values increase again reaching 70,80 mml/kg/min .

As a result of theoretical and experimental research, allow us to make the following recommendations:

1. Using the preparatory training stage at altitude – as a means of improving aerobic performance capacity;
2. In order to increase aerobic performance at athlete practioners of sports branch – moinaint race, we recommend taking two stages of training at altitude. The first stage should be in spring before the European and Balkan Championships and the second one in August before the national and world Championships.
3. For the athletes who have carried out several training stages at altitude and for whom the acclimatization is made much easier, we recommend a training plan of 21 days divided into 6 microcycles and 4 phases, the training plan presented in the table below:

<u>Training plan proposal for a preparatory stage of 21 days at medium altitude</u>

Table no. 15 The proposed training plan for a preparatory stage of 21 days at medium altitude

<table>
<tr><th colspan="6">21 days</th></tr>
<tr><th colspan="6">1----2---3---4---5---6---7----8----9----10----11----12----13---14---15---16---17---18---19---20---21</th></tr>
<tr><th colspan="6">6 MICROCYCLES</th></tr>
<tr><td>2 days</td><td>4 days</td><td>4 days</td><td>4 days</td><td>4 days</td><td>3 days</td></tr>
<tr><th colspan="6">4 phases</th></tr>
<tr><td>2 days</td><td colspan="2">8 days</td><td colspan="2">8 days</td><td>3 days</td></tr>
<tr><td>Acclimatization</td><td colspan="2">General training
- aerobic training
-training for speed development
-training for force development</td><td colspan="2">Specific training
- aerobic training
-anaerobic training
- training for speed development
-training for force development</td><td>Recovery</td></tr>
</table>

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