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Original article

A STUDY ON ATHLETES' HEART RATE CHANGING WHILE PERFORMING A 21 DAYS TRAINING COURSE AT AN ALTITUDE OF 2000M

MAN Maria Cristina[1], GANERA Cătălin[2]

Abstract*

Aim. It is known that athletes in the desire to obtain the best results, use exercise at altitude, which, due to lower oxygen from the air, increases the amount of hemoglobin, the carrier leading the oxygen in the blood to the muscles thus increasing capacity effort.

The research aims to achieve a significant increase in sports performance of the athletes, by changes in the heart rate (FC), favorable performance, possibly by introducing the plan to prepare an internship at altitude, after which there occur physiological and biochemical changes which are favorable to the effort capacity.

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

Results: Data analysis shows that during the phase of acclimatization FC at rest and during exercise is increased. After acclimatization FC normalises, then it begins to decline.

Conclusions: Making one or more training sessions at altitude significantly improves the performance of runners by triggering physiological and hematological changes which favors the growth performance of the athletes' body.

Keywords: altitude, aerobic capacity, heart rate.

Introduction

Cardiovascular adaptation to hypoxia

Drăgan (1977) mentions the most important modifications of the cardiovascular apparatus:

- increased cardiac output;
- increased circulating blood volume;
- increased percentage of haemoglobin and red blood cells;
- increased heart rate (tachycardia) and respiratory rate;
- slow recovery from effort;
- with altitude, the highest heart rate reached is unchanged. In these conditions this is noticed at a slower work rhythm than at sea level. The volume of blood pumped at every heartbeat (stroke volume) is decreased. Even in the case of an optimal adaptation to altitude, the maximal capacity never equals the constant capacity at sea level. This contributes to explaining the phenomenon of maximum VO2 reduced with altitude, compared to sea level. (Martin 1996);
- The blood plasma volume immediately decreases right after the arrival at altutide and it is only recovered after an adaptation period (3-4 weeks);
- if both plasma volume and red cell volume are increased, the total blood volume will therefore increase equally. If the red cell volume increases more than the plasma volume, both haemoglobin and hematocrit will have higher values than at sea level. In both cases, blood transport capacity evolves.

a) Heart rate

Heart rate (HR; bpm) is undoubtedly the physiological parameter whose changes are easiest to observe with altitude. In the first day, after settling in at altitude, at rest and during undermaximal effort HR will be increased compared to sea level. This is called "tachycardia". (Grover et al., 1976; Klausen, 1966; Vogel et al., 1967; Vogel et al., 1974; Welch, 1987). This increase of HR aims to compensate – although partially – for the decrease in O2 blood pressure (called arterial hypoxemia) and is proportional to the intensity of the hypovolemic stress (Vogel et al.,1967). This increase of HR with altitude is influenced by a strong stimulation of the sympathetic autonomic nervous system (Richalet et al., 1992; Richalet et al., 1988). After the acclimatization, the sensitivity of the myocardium decreases, therefore the initial tachycardia also

[1] "1 Decembrie 1918" University of Alba Iulia,
[2] "Nicolae Rotaru" Sports Program High School of Constanța
Email: cristinaman20@hotmail.com
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decreases. Thus, although completely acclimatized, an athlete will have a higher HR than at sea level, whether resting or making under maximal effort. (Wolfel et al., 1994).

The other way around, in the case of a maximal exercise, HR will decrease in conditions of hypoxia (Bouissou et al., 1986; Stenberg et al., 1966). This decrease in HR is determined by low density (Favret et al., 2001; Lundby et al., 2001; Richalet et al., 1992) and reduced activity (Kacimi et al., 1992), of beta-adrenergic receptors ; but also by the activity of the alpha-adrenergic receptors (Favret et al., 2001; Lundby et al., 2001) with no major modification of the sympathetic system (Richalet et al., 1992; Richalet et al., 1988a). An intensification of the activity of the muscarinic receptors (M2) involved in the regularization of the bradycardic stimuli, was stated as a subjacent mechanism of HR decrease during acclimatization in a hypoxic environment (Favret et al., 2001; Kacimi et al., 1993).

b) End-systolic volume

End-systolic volume (ESV; ml.b-1) is the blood quantity ejected by HR in systemic circulation (through the aorta) at each systole. ESV depends on several elements, like blood volume (plasma volume + red cell volume), back flow of blood, intensity and contractility of SV, pre- and post- loading. Right after the arrival at altitude, the values of ESV in rest or undermaximal or maximal exercise, are either easily decreased or identical to the ones at sea level (Hartley et al., 1973; Wagner et al., 1976; Wolfel et al., 1994). Only after several days at altitude, will the ESV value start to decrease significantly (Grover. et al., 1976; Klausen et al., 1966; Vogel et al., 1967), and this progressive decrease may last quite a long time (Vogel et al., 1967; Wolfel et al., 1994).

The Frank – Starling Law shows that the increase in the ventricular filling streches the ventricle walls, which contract even stronger to eject blood volume; there is a positive inotropic and lusitropic effect when the end-diastolic pressure volume increases. Thus, the other way around, the noticed decrease of ESV is explained by a decrease of the back flow of blood, induced, itself, through hemoconcentration and decrease in blood volume (Grover et al., 1986; Sawka et al., 2000). As a whole, the basic cause of ESV decrease is initial diminish of ventricular filling dependent on tachycardia (which diminishes the duration of the diastole) and diminish of blood volume (Reeves et al., 1987).

c) Cardiac output

Cardiac output (Q, L.min-1) is the product of HR and ESV and represents the blood volume that is ejected in the aorta per minute. As we mentioned above, altitude brings modifications in HR and ESV and, therefore, it logically also brings Q modifications. During the first days at altitude, maximum Q (Q max) is very easily modified (Ekblom et al., 1975; Klausen, 1966; Lundby & Van Hall, 2001; Stenberg, 1966; Vogel et al., 1986).

The combination between the various reactions to altitude (e.g. Increased of under maximal HR and slight decrease of ESV) explain why Q is slightlydiminished or slightly modified in the days following the arrival at altitude. It is currently admitted that this answer of an identical or easily diminished Q max. depends on a sympathetic stimulation in the conditions of an acute exposure to hypoxia (Wagner 2000; Wagner et al., 1986). Thus, after acclimatization Q max. is visibly diminished, compared to the values at sea level (Alexander et al., 1967; Sutton et al., 1988). Basically, this is explained by a significant decrease in VES (Vogel 1967; Wolfel et al., 1994). Figure 6 indicates modifications suffered by Q with an acute or chronic exposure in conditions of altitude (Wagner et al., 1986).

More hypotheses were put forward regarding mechanisms adjacent to this decrease of Q max. in conditions of altitude (Wagner, 2000).

Decreased plasma volume

Exposure to altitude leads to a decrease in plasma volume as a consequence of osmolarity modifications and fluid movements towards the outer side of the vascular compartment. Moreover, there is loss caused by increased urinary output (diuretic crisis), greater loss of vapour produced by hyperventilation and heavier sweat in conditions of altitude. (Butterfield et al., 1992; Dempsey et al., 1994; Hogan et al., 1973; Maher et al., 1975). This decrease in plasma volume leads to a diminished preload and therefore a weaker filling of the cardiac cavities, which leads to this decrease of Qmax. (Poulsen et al., 1998; Robach et al., 2000).

The importance of the filling pressure of the myocardium upon Q is debatable. For technical reasons (the need to catheterize the right cardiac segment), only little information is available (Boussuges et al., 2000; Reeves et al., 1987).

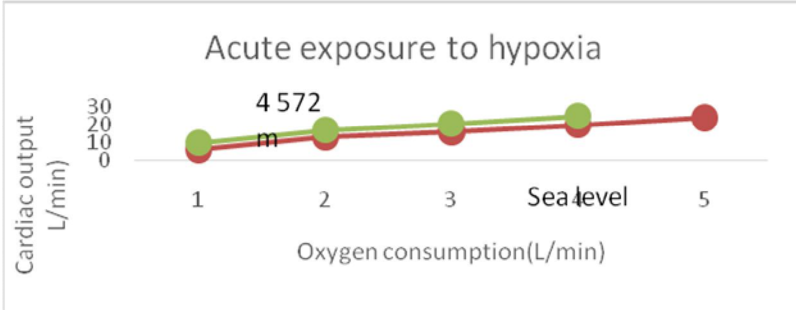

Figure no. 1 (a) – Cardiac output Q during exercise (oxygen consumption), at sea level and in a hypobaric hypoxic chamber of 430 mm Hg corresponding to an altitude of 4572 m during acute exposure applied on 8 subjects (Wagner et al., 1986)

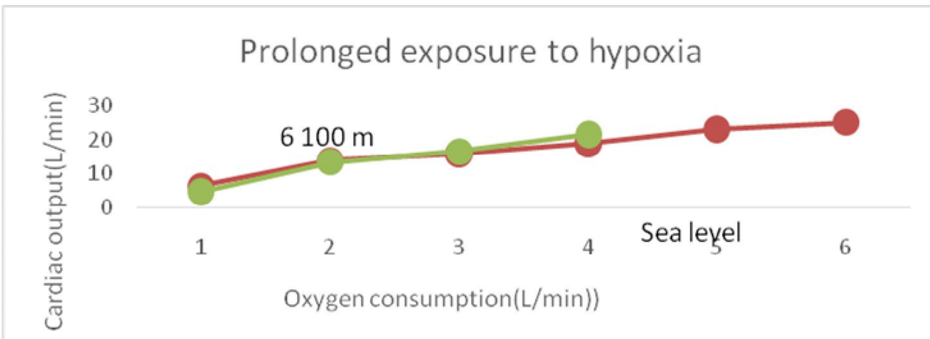

Figure nr.1 (b) – Cardiac output Q during exercise (oxygen consumption), at sea level and in a hypobaric hypoxic chamber of 430 mm Hg corresponding to an altitude of 6100 m during acute exposure applied on 8 subjects (Wagner et al., 1986)

Basically, when the plasma volume is increased, this means a very slight increase in Q max. Thus, as previously mentioned, when the plasma volume is increased, which means a decrease in blood viscosity, a slight increase in Q max is noticed. (Grover, 1965; Hartley, 1971; Wolfel et al., 1994), suggesting that variations of blood viscosity and peripheral resistance only have a minor influence on the decrease of Q max, in conditions of altitude.

Hypotheses: Including a 21 day altitude preparatory stage to release physiological and biochemical effects in the organisms of athletes, sustaining effort capacity. HR values are modified during the 21 days at altitude, which is one of the physiological parameters with beneficial potential.

Materials and 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 did a preparatory stage in Piatra Arsă at an altitude of 2000 m above the sea level.

Tests applied: Heart rate was measured

during the 21 days spent at an altitude of 2000 m, twice a day, in the morning and in the evening, with the help of the pulsoxymeter.

Results

Values of the heart rate were registered twice a day, at the same hour: 8 o'clock in the morning and 10 o 'clock in the evening, with the help of the pulsoxymeter, for 21 days.

1.MORNING HEART RATE

Experiment group

Table no1-HR values in the morning at subjects from experiment group during altitude 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.N	69	69	69	69	69	68	67	64	64	62	62	62	63	59	55	56	54	54	54	53	53
B.G.	64	64	63	59	51	55	54	52	50	53	51	54	55	56	54	54	54	49	47	47	47
C.D.	58	56	55	56	56	54	52	52	54	51	51	52	53	52	52	52	51	51	51	50	50
G.N.	65	65	64	62	61	56	55	56	55	55	54	55	56	55	54	54	54	53	54	54	53
M.V.	62	61	61	61	59	57	55	54	54	53	53	53	53	53	52	52	51	49	47	47	47
P.A.	70	70	69	69	69	68	67	65	64	61	64	64	63	59	55	56	56	55	54	54	53
P.R.	66	66	67	66	65	65	65	65	62	61	61	63	59	59	55	56	56	54	53	53	51
Z.I.	70	71	69	69	68	66	62	61	62	60	59	56	56	55	56	54	54	53	53	52	51
G.S.	71	71	70	69	69	69	68	65	64	65	64	64	63	59	57	56	55	55	54	52	51
T.D.	69	67	66	66	61	60	59	58	55	55	55	55	56	55	55	54	54	53	54	54	53

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

Heart rate during:	Average	Median	Deviation from standard	Minimum	Maximum	Amplitude	Variatioan coefficient
day 1 - day 5	65.02	65.90	4.74	56.20	70.00	13.80	7.29%
day 6 - day 16	57.77	57.45	4.16	52.27	63.09	10.82	7.20%
day 17 - day 21	52.22	53.40	2.21	48.20	54.40	6.20	4.23%

Table no3- Analysis Friedman Test morning HR experiment group

Heart rate during:	Medium ranks	Test parameters	Results
A) day 1 - day 5	3.00	N	10
B) day 6 - day 16	2.00	Chi-square	20.00
C) day 17 - day 21	1.00	Df	2
		p (Sig.)	<<0.0001

Table no.4 -Analysis Post Hoc Wilcoxon Test, morning HR experiment group

Test parameters	A vs B	A vs C	B vs C
Z	-2.803	-2.805	-2.803
p	0.005	0.005	0.005

The Friedman non-parametric test (Table no. 3) for repeated measuring shows that there are statistically significant differences between the values of the HR, measured for the three intervals for at least one pair out of the 3, p<<0.0001. According to this post hoc Wilcoxon, with the correction of Bonferroni (Table no. 4), (α = 0.05/3=0.17), the value p=0.005=< 0.017 for all the three interval pairs. This means that the heart rate measured in the morning is significantly different from any other compared intervals. Figure no. 2 illustrates the heart rates averages.

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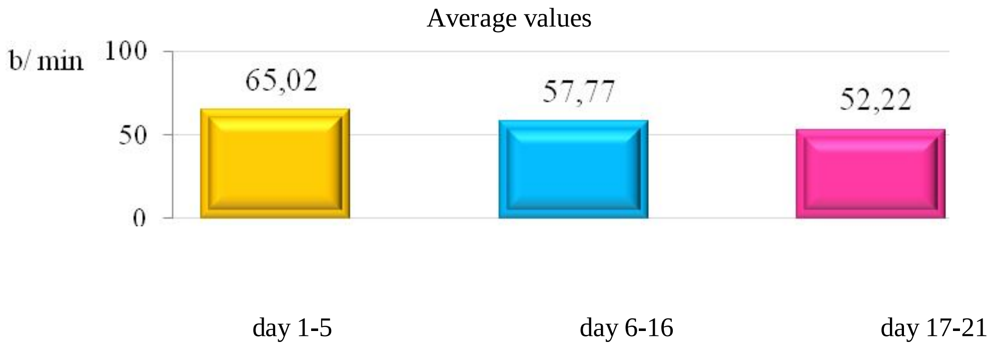

Figure no.2- *HR values in the morning, for the three test stages, experiment group*

MORNING HEART RATE

Control group

The heart rate decreased with an average of 5.50 b/ min (-8.9%), from 61.50 b/ min before the preparatory stage to 56.00 b/ min after the stage. The morning heart rate varies between 59 and 69 b/ min before the preparatory stage and between 54 and 60 b/ min at the end of the stage. At both tests, the dispersion of data around the average is homogeneous. (Table no. 5, 6).

Table no.5 -Hr values in the morning, for subjects from control group during

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.	59	59	59	59	59	59	59	59	61	65	64	59	59	59	58	58	56	56	55	55	55
D.S.	62	62	63	63	63	63	60	60	59	57	57	56	56	56	56	56	55	55	55	55	55
D.R.	59	59	59	59	58	58	58	58	58	57	57	56	56	56	56	56	56	55	55	55	55
R.A.	59	59	55	56	55	55	56	56	61	65	64	56	56	57	57	56	56	55	55	55	55
S.M.	61	62	61	62	61	60	59	56	56	57	56	54	55	56	54	54	54	54	54	54	54
S.R.	65	63	65	62	62	61	60	60	61	61	61	61	60	59	58	58	58	58	58	58	58
V.A.	69	70	68	68	67	68	67	66	66	65	65	65	66	66	65	63	63	61	60	60	60
B.M.	59	59	59	59	59	59	59	59	61	65	64	59	59	59	58	58	56	56	54	55	56
S.I.	62	63	61	62	60	60	59	59	58	58	58	58	57	56	56	56	56	55	55	55	55
L.D.	60	60	60	59	59	59	59	59	61	60	60	59	59	59	59	58	58	58	57	57	57

Table no.6- Statistic analysis of HR in the morning before and after preparatory stage

PREPARATORY STAGE	Average	Average difference	Median	Deviation from standard	Minimum	Maximum	Amplitu-de	Variation coefficient
Before	61.50	-5.50	60.50	3.27	59.00	69.00	10.00	5.3%
After	56.00	-8.9%	55.00	1.83	54.00	60.00	6.00	3.3%

Table no. 7 - Analysis Wilcoxon test morning HR, Control group

Ranks difference tests	N	Average ranks	Sum of ranks	Test parameters	Result
Negative	10	5.50	55.00	Z	-2.831
Pozitive	0	0.00	0.00	P (2-tailed)	0.005
Equals	0	0.00	0.00	Effect magnitude	0.63

According to the non-parametric ***Wilcoxon*** test, ***(Table no. 7)*** the difference attained a level of statistic significance, z = -2.831, p = 0.005 < 0.05. The effect magnitude (0.63) shows a great difference

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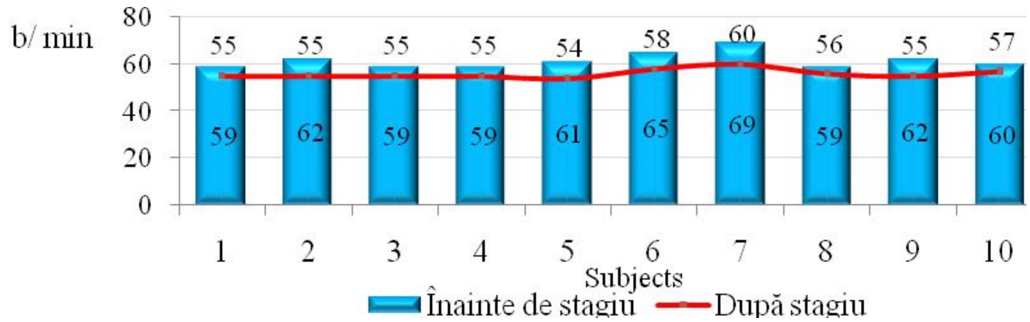
between the two tests. The null hypothesis is rejected and the hypothesis of the research is accepted, according to which the average decrease of heart rate is significant. The graphical representation of the two test of the control group is presented in ***graphic no. 1.***



Graphic no. 1 – HR values in the morning, before and after preparatory stage, control group

Experiment vs control

After preparatory stage

In the morning, the heart rate is lower, with an average of 5.10 b/min (-9.1%) at the control group, and averages of 50.90 b/min at the experiment group and 56.00 b/min at the control. In the morning, the heart rate varies between 54 and 60 b/min at the control group and between 47 and 53 b/min at the experiment group. For both tests, the dispersion of data around the average is homogeneous. **(Table no.8)**

Table no.8- Statistic comparative analysis experiment vs control groups-morning HR

Group	Average	Average difference	Median	Deviation from standard	Minimum	Maximum	Amplitude	Variation coefficient
Control	56.00	-5.10	55	1.83	54	60	6	3.3%
Experiment	50.90	-9.11%	51	2.33	47	53	6	4.6%

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

	GROUP	N	Average ranks	Sum of ranks	Test parameters	Result
MORNING HEART RATE	Control	20	15.50	155.00	Mann-Whitney U	0.00
	Experiment	20	5.50	55.00	Z	-3.830
	Total	40			P (2-tailed)	<<0.001
					Effect magnitude	0.86

According to the Mann-Whitney U non-parametric test **(Table no. 9**) between the two groups, at the end of the preparatory stage, significant statistic differences could be noticed, z = -3.830, p<0.001<0.05. The effect magnitude (0.86) shows a great difference between the two groups. The null hypothesis is rejected and the research hypothesis is accepted, according to which the morning heart rate is significantly different for the two groups. The graphical representation of the results corresponding to the two groups are presented in ***figure no. 3***

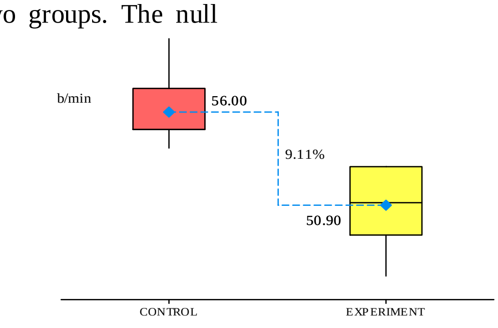


Figure no. 3 – The graphical representation of the results corresponding to the two groups – morning HR

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Evening heart rate

Experiment group

The heart rates measured in the three intervals were compared with the Friedman non-parametric test for repeated measures, which shows that there are significant statistical differences for at least one pair of the 3, p=0.0002. According to the post hoc Wilcoxon test, with the Bonferroni correction, (α = 0.05/3=0.17), the p value is p<0.017 for any of the three intervals. Therefore, the heart rate measured in the morning differs significantly for any pair compared (Table no. 10,11)

Table no.10-HR values in the evening,for subjects in the experiment group, during altitude 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.N	**85**	**70**	**79**	**78**	**71**	**69**	**71**	**74**	**70**	**70**	**71**	**71**	**70**	**71**	**69**	**69**	**67**	**61**	**65**	**64**	**64**
B.G.	**74**	**74**	**70**	**66**	**69**	**69**	**65**	**68**	**66**	**70**	**70**	**67**	**70**	**68**	**70**	**70**	**61**	**68**	**69**	**67**	**64**
C.D.	**93**	**65**	**70**	**66**	**69**	**69**	**65**	**68**	**66**	**70**	**70**	**67**	**70**	**68**	**70**	**70**	**61**	**67**	**67**	**67**	**64**
G.N.	**65**	**65**	**65**	**66**	**66**	**61**	**61**	**61**	**62**	**57**	**54**	**57**	**60**	**58**	**57**	**58**	**58**	**61**	**62**	**61**	**61**
M.V.	**74**	**65**	**70**	**66**	**69**	**69**	**65**	**68**	**66**	**70**	**70**	**67**	**70**	**68**	**70**	**70**	**67**	**67**	**67**	**65**	**64**
P.A.	**95**	**70**	**80**	**68**	**71**	**69**	**75**	**74**	**82**	**70**	**71**	**71**	**70**	**71**	**69**	**69**	**67**	**58**	**65**	**67**	**64**
P.R.	**95**	**80**	**80**	**78**	**75**	**75**	**75**	**74**	**72**	**75**	**73**	**71**	**72**	**71**	**69**	**69**	**67**	**58**	**65**	**65**	**64**
Z.I.	**72**	**74**	**70**	**68**	**67**	**66**	**67**	**61**	**62**	**59**	**58**	**57**	**58**	**58**	**57**	**59**	**57**	**57**	**57**	**56**	**56**
G.S.	**91**	**88**	**81**	**68**	**76**	**75**	**75**	**74**	**73**	**70**	**71**	**71**	**70**	**71**	**69**	**69**	**67**	**58**	**56**	**56**	**54**
T.D.	**71**	**70**	**69**	**68**	**66**	**56**	**57**	**61**	**62**	**57**	**54**	**57**	**60**	**58**	**57**	**61**	**61**	**61**	**60**	**58**	**58**

Table no. 11-Statistic analysis of evening HR,days 1-5, 6-16, 17-21 experiment

Heat rate during:	Average	Median	Dev from standard	Minimum	Maximum	Amplitude	Variety Coefficient
day 1 - day 5	73.22	71.60	5.46	65.40	81.60	16.20	7.46%
day 6 - day 16	66.88	68.45	5.63	58.18	72.36	14.18	8.42%
day 17 - day 21	62.42	64.00	3.39	56.60	66.00	9.40	5.42%

Table no.12-Friedman test analysis evening HR, experiment group

Heat rate during:	Average ranks	Test parameters	Rezult
A) day 1 - day 5	3.00	N	10
B) day 6 - day 16	1.80	Chi-square	16.80
C) day 17 - day 21	1.20	df	2
		p (Sig.)	0.0002

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

Test parameters	A vs B	A vs C	B vs C
Z	-2.803	-2.805	-2.497
p	0.005	0.005	0.013

Heart rates measured for the three intervals were compared to the Friedman non-parametric test for repeated measures which shows that there are significant differences for at least one of the three pairs, p=0.0002. According to the post hoc Wilcoxon test, with the Bonferroni correction (Table no. 13), (α = 0.05/3=0.17), value p is p<0.017 for any of the three intervals. Therefore, the heart rate measured in the morning is significantly different for any compared pair. *Figure no. 4* presents the averages of the heart rates for the three intervals.

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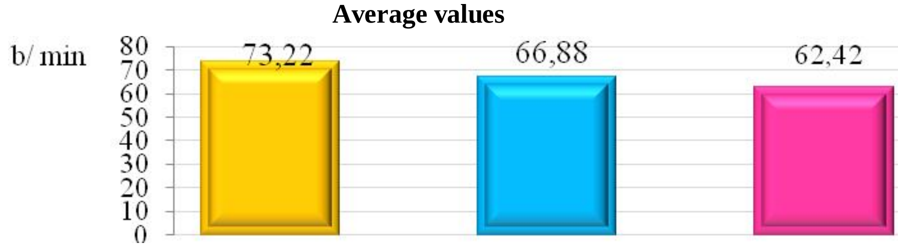


day 1-5 day 6-16 day 17-21

Figure no.4-HR values in the evening, for the three testing stages, experiment group

Evening heart rate – control group

A decrease in heart rate is noticed, by an average of 4 b/ min (-5.8%), from 69.30 b/ min before the preparatory stage to 65.30 b/ min after the programme. The evening heart rate varies between 65 and 80 b/ min before the preparatory stage and between 61 and 68 b/ min at the end of the programme. Both tests showed that the dispersion of data around the average is homogeneous (Table no.14,15)

Table no.14-HR values in the evening, for subjects in the 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.	65	65	65	66	66	68	68	65	65	67	64	67	65	67	65	66	66	68	64	65	65
D.S.	71	71	70	70	69	70	68	68	66	69	69	68	70	68	70	70	69	68	68	67	66
D.R.	74	65	70	68	69	69	67	68	66	70	70	69	70	68	70	70	69	68	69	67	66
R.A.	65	65	55	56	58	58	61	62	57	54	57	60	68	57	61	63	62	65	62	61	61
S.M.	69	67	69	69	69	69	68	68	66	69	67	68	68	68	70	70	69	68	69	68	65
S.R.	69	69	70	69	69	69	68	68	67	69	67	68	68	68	70	70	69	68	69	67	68
V.A.	80	79	80	79	72	70	75	74	74	70	71	71	70	71	70	70	69	69	65	67	65
B.M.	65	65	65	66	66	68	68	62	63	67	64	67	65	67	62	66	66	68	64	65	65
S.I.	70	68	70	69	69	69	65	68	66	70	70	68	70	68	70	70	69	68	69	67	67
L.D.	65	65	65	66	66	68	68	68	62	63	67	64	67	65	67	62	66	66	64	65	65

Table no.15-Statistic analysis of HR in the evening, before and after the training programe-control group

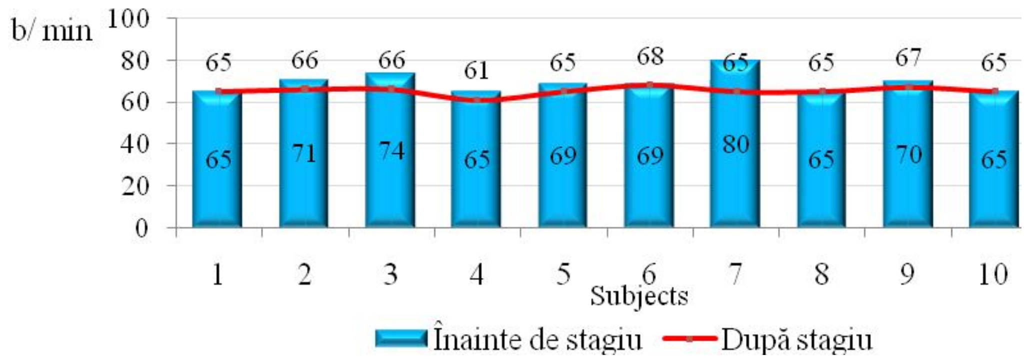
PREPARATORY STAGE	Average	Average difference	Median	Deviation from standard	Minimum	Maximum	Amplitu-de	Variation coefficient
Before	69.30	-4.00	69.00	4.88	65.00	80.00	15.00	7.0%
After	65.30	-5.8%	65.00	1.83	61.00	68.00	7.00	2.8%

Table no.16-Wilcoxon test analysis evening, control group

Ranks difference tests	N	Average ranks	Sum of ranks	Parametri test	Rezultat
Negative	7	4.00	28.00	Z	-2.371
Pozitive	0	0.00	0.00	P (2-tailed)	0.018
Equals	3	0.00	0.00	Effect magnitude	0.53

The difference attained a statistically significant level, z = -2.371, p = 0.018 < 0.05, according to the non-parametric Wilcoxon test (Table no. 16).

The effect magnitude (0.53) shows a great difference between the two tests. The null hypothesis is rejected and the research hypothesis is accepted, according to which the average decrease in heart rate is significant. The graphical representation corresponding to the two tests on the control group is presented in graphic no.2



Graphic no.2 -HR values in the evening, before and after the preparatory satage- control group

Table no.17-Statistic comparative analysis- experiment vs control groups HR evening

Group	Average	Average difference	Median	Deviation from standard	Minimum	Maximum	Amplitude	Variation coefficient
Control	65.30	-4.00	65.00	1.83	61.00	68.00	7.00	2.8%
Experiment	61.30	-6.13%	64.00	3.89	54.00	64.00	10.00	6.3%

Table no.18-Comparative analysis Mann-Whitney U test-HR evening

	GROUP	N	Average ranks	Suma ranguri	Parametri test	Rezultat
EVENING HEART RATE	Control	20	14.85	148.50	Mann-Whitney U	6.50
	Experiment	20	6.15	61.50	Z	-3.361
	Total	40			P (2-tailed)	0.001
					Effect magnitude	0.75

In the end of the preparatory stage, the results of the two groups compared with the non-parametric Mann-Whitney U test **(Table no. 18)** showed that between the two groups there are statistically significant differences, z = -3.361, p = 0.001 < 0.05. The effect magnitude (0.75) shows a great difference between the two groups. A null hypothesis is rejected and the research hypothesis is accepted, which states that evening heart rate is significantly different for the two groups. The graphical representation of the results corresponding to the two groups is presented in figure no.5

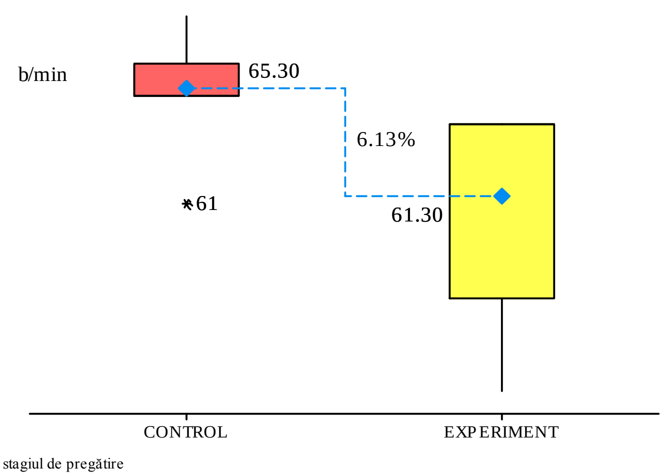


Figure no. 5- Graphical representation of the results corresponding to the two groups – HR in the evening.

Discussions

It has been suggested that after settling in at altitude, because of the decrease in the available O2, it is possible that the myocardium selflimit its contractile function (Alexander et al., 1967; Noakes, 2000). Thus, this theory has no experimental support yet. Moreover, subjects acclimatized to very high altitudes (Opération Everest Operațiunea Evrest) did not present any EMG sign of a possible ischemia or reduction of myocardium contractility (Boussuges et al., 2000; Reeves et al., 1987; Suarez et al., 1987). According to Noakes' team, during the maximal exercise in acute or chronic hypoxia, for protecting the myocardium from ischemia, the diminish of Q would basically be a consequence of the diminish of the muscular mass mobilized during the exercise, under the influence of a central neuronal control (central governor) (Noakes, 1998, 2000; Noakes et al., 2001). Otherwise, muscular mobilization would be diminished in hypoxia, joining a decrease in Q max for maintaining the oxygenation of the myocardium.

Alteration of the sympatho-vagal balance

It is well known that hypoxia stimulates autonomous nervous system (ANS), the secretion of adrenaline and non-adrenaline, which changes the peripheral muscular tonus and the cardiac function. The desensitization of the beta-adrenergic cardiac receptors (Kacimi et al., 1993) contributes to the diminish of max. HR with altitude.

Experiments on the modification of autonomous regulation show that max. HR increases with the atropine or Glycopyrrolate injection (parasympathetic tone diminishing substances), only in conditions of altitude and not at sea level (Hartley et alii, 1974). It is notable that no direct influence has been signaled upon Q.

For knowing if the decrease of HR is responsible for the decrease of Qmax. Or if it is compensated by an increase in ESV, Bogaart et alii (2002) showed, using specific blockers for the sympathetic tone (propranolol) or parasympathetic (Glycopyrrolate), that the autonomous nervous system has no significant effect upon Qmax with altitude, although changes in HR have been noticed.

Conclusions

Modifications of the cardiac physiology are noticed through monitoring of the heart activity, morning and evening pulse measurement and the following are found: In the first 5 days the average of the heart rate is 65,02 beats/min, decreasing by the end of the programme to an average of 52,22 beats/min due to acclimatization.

Heart rate is lower in the morning, with an average of 5.10 b/min (-9.1%) at the experiment group, averages equal 50.90 b/min at the experiment group, and 56.00 b/min at the control group. Heart rates vary in the morning between 54 and 60 b/min at the control group and between 47 and 53 b/min at the experiment group. At both tests, data dispersion around the average is homogeneous.

The experiment group has a generally lower evening heart rate than the control group - 4 b/min (-6.1%), averaged equal 61.30 b/min at the experiment group and 65.30 b/min at control.

Evening heart rate varies between 61 and 68 b/min at the control group and between 54 and 64 b/min at the experiment group. At both tests, data dispersion around the average is homogeneous.

In conclusion, influences of ANS activity modification upon HR does not contribute to the decrease of Q max. with altitude.

Following our theoretical and experimental research, we recommend:

1. Using altitude training as a means of improving aerobic performance capacity;
2. For a good planning and development of altitude trainings, we propose the following control parameters

Aknowledgements

We thanks to all our participants and subjects in this study.

Table no.19-Control parameters of training with hypoxia

Physiological parameters		**Sanguine parametera**	**Performance associated parameters**
Before the programme	- HR in rest - Body mass - Oxygen saturation	- Numerous sanguine values (haemoglobine, hematocrit, lymphocytes, leukocytes etc) EPO	- Test for determining VMA and VO2 max
During the programme	- HR in rest - Oxygen saturation - Cardiac variability		- Test for determining VMA and VO2 max
After the programme	- Body mass - HR in rest - Oxygen saturation - Cardiac variability	- Numerous sanguine values (haemoglobine, hematocrit, lymphocytes, leukocytes etc) EPO	- Test for determining VMA and VO2 max

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