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The Effect of Six Weeks of Interval Aerobic Training in Sea Level on Acute Mountain Sickness

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ARTICLE INFO	ABSTRACT
<p>Article History: Received 20 December 2018 Received in revised form 14 January 2019 Accepted 18 March 2019 Available online 23 March 2019</p>	<p>The aim of this study was to examine the effect of six weeks of interval aerobic training at sea level on acute mountain sickness (AMS). Seventeen mountaineers with a history of AMS participated in this study over a six-week period. Initially, the participants ascended to altitudes above 3,500 meters, where their peripheral oxygen saturation (SpO₂) was measured using a pulse oximeter, and the symptoms of AMS were assessed using the Lake Louise Questionnaire. The experimental group then performed interval aerobic training at sea level for six weeks, consisting of three sessions per week. After the training period, participants were re-evaluated at altitudes above 3,500 meters for AMS symptoms. The results indicated a significant improvement in the experimental group compared to the control group, reflected in increased maximal oxygen consumption (VO₂max), higher SpO₂ levels, and a reduction in heart rate ($P < 0.05$). It can be concluded that continuous interval aerobic training, even when conducted under normoxic conditions, enhances cardiorespiratory function and elevates SpO₂ levels. Moreover, exercise under hypoxic conditions can further improve VO₂max and physiological adaptation to high altitudes.</p>
<p>Keywords: Acute Mountain Sickness, Interval Hypoxia Training, VO₂max.</p>	

1. INTRODUCTION

Exposure to altitude, higher than normal, causes some physiological changes in the human body. The most basic features to the altitude, is the atmospheric pressure changes, so that with increasing altitude, the oxygen concentration is reduced [1]. Acute mountain sickness or altitude sickness, the most common serious problem related to altitude, is a syndrome consisting of non-specific symptoms such as headaches, digestive problems (anorexia, nausea, or vomiting), sleep disturbances, dizziness, malaise and fatigue in a person with less adaptation to height, who has recently been to altitude higher than 2500 meters (A group of American doctors, 2008). The incidence of sickness in studies which have done in the different mountains varies from 22% to 60% which this rate is influenced by several factors [2]. It is thought that this sickness is popular in less trained athletes, but there is no evidence to suggest

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that physical fitness can prevent the outbreak of symptoms of this sickness. It seems that an athlete who does much endurance exercises before going to higher altitude has a small amount of resistant to the effects of lack of oxygen; Because decrease percentage of in both trained and untrained individuals at altitude, is the same. Since the VO₂max decreases the participants who have the more aerobic capacity can do a specific work with less fatigue and heart – vessel pressure than those who have the less aerobic capacity at altitude [3]. Ruskoh et al. [4] showed that by training at sea level with the lack of oxygen the maximum aerobic power will rise within 25 days. Mellissa et al. [5] showed that the aerobic power of 10 men who were trained within 8 weeks with a low percentage of oxygen ???, had increased.

Schommer et al. [6] showed that appropriate training increases about 50 percent oxygen absorption of norm baric hypoxia of acute mountain sickness. But there was always this ambiguity that for each of the conditions what kind of physical activity and how much of that, is necessary for the body. To achieve aerobic fitness most researchers have concluded that exercise in less oxygen (hypoxia) can increase the capacity of athlete's cardio – pulmonary organ [7]. Karinen et al. [8] indicated that climbers who successfully maintain their arterial oxygen saturation, especially during the exercises, have the lower risk of AMS.

The results suggest that daily assessment Spo₂ during the climb, both at rest and during exercise, can help to identify individuals who are good at altitude [9]. Rupp et al. (2013) examined the effects of hypoxia and exercise on symptoms of acute mountain sickness. The results showed that by exercising during the first hours after exposure to hypoxia, acute mountain sickness was intensified [10].

According to a study which was done by Honigman et al. [11], there is no connection between the physical and normal activity at sea level and the growth of acute mountain sickness in a total population of climbers at an altitude of 3000 meters [11]. According to the first observations of Ravenhill, strong and healthy young men may completely overcome the AMS while scout people may get a headache. The precise effect of physical fitness in the development of AMS is unknown. Therefore, this study was implemented by the aim of considering combined training at sea level including hypoxic interval training method and training Fartlek methods, in the prevention of early altitude sickness at high altitudes.

2. METHODOLOGY

This study was quasi-experimental. 17 male climbers (Age: 35.94±8.05 year, Height: 176.41±6.81 cm, Weight: 79.81±10.57 kg, body mass index: 25.44±3.31) with a history of altitude sickness were selected randomly for this study. In the first stage of research, they went to the height of almost 3,600 meters. The symptoms of AMS of the subjects were investigated by using the Lake Louise Criteria [12-14].

Then, the arterial blood oxygen saturation was measured by a pulse oximetry [8, 10]. Of the 17 people, 9 of them selected in the experimental group and 8 of them selected in the control group, randomly. At first, by Bruce's test the subject's VO₂max were evaluated. Trainings conducted in 6 weeks; 3 sessions per week including 2 sessions of interval training for 30 minutes and after a short break, a practice on the treadmill with interval training was done for 15 to 20 minutes at sea level which breath retention in some exercise stages was implemented. Then a session of Fartlek training was done at the altitude of almost 1,500 meters. Mountain Medical Association in an article titled interval training system, announced an interval proposed program on treadmill which is used in this study as is shown in table 1.

In the breath retention training, the subject breathes consciously and purposefully so that him/her body faces with a gentle and subtle lack of oxygen. By this kind of exercise, a participant can be prepared for a rapid climbing and against the lack of oxygen amount without climbing readiness and being present at high-altitude [7, 15]. In this study, we tried to simulate climbing conditions so that the lack of oxygen exercises was done in these circumstances which are shown in table 2.

Table 1. Description of study protocol.

Exercise Intensity	Exercise Duration (min)	Velocity (km/h)	Slope (%)	Description of the activity
Slow	5	4	0	Warm up stage
High	1	6	6	Carrying backpacks weighing 5 kg
Medium	2	5	1	Carrying backpacks weighing 5 kg
High	1	6	6	Carrying backpacks weighing 5 kg
Medium	2	5	1	Carrying backpacks weighing 5 kg
High	1	7	3	Carrying backpacks weighing 5 kg
Medium	2	5	1	Carrying backpacks weighing 5 kg
High	1	8	2	Carrying backpacks weighing 5 kg
Medium	2	5	1	Carrying backpacks weighing 5 kg
High	1	9	0	Carrying backpacks weighing 5 kg
High	1	6	8	Carrying backpacks weighing 5 kg
Medium	3	5	0	Carrying backpacks weighing 5 kg
Slow	5	4	0	Cool down stage

Table 2. Training in low oxygen condition

	Velocity (km/h)	Slope (%)	Number of Steps	Description
1 st week	3	6	8 steps with breath retention	Carrying backpacks weighing 15 kg
2 nd week	3	8	8 steps with breath retention	Carrying backpacks weighing 15 kg
3 rd week	4	10	6 steps with breath retention	Carrying backpacks weighing 15 kg
4 th week	4	15	6 steps with breath retention	Carrying backpacks weighing 15 kg
5 th week	5	18	4 steps with breath retention	Carrying backpacks weighing 15 kg
6 th week	5	20	4 steps with breath retention	Carrying backpacks weighing 15 kg

One session at the weekend devoted to Fartlek training at altitudes of approximately 1,500 meters [15]. During this period, the participants of the control group did no exercise. After 6 weeks of combined training at sea level and two days after the last training session, the subjects’ VO_{2max} was measured again by Bruce’s test. The next day both groups were at height of almost 3,600 meters and the symptoms of altitude sickness were measured by using the Lake Louise Questionnaire and arterial blood oxygen saturation was measured by using a finger pulse oximeter.

3. RESULTS AND FINDINGS

Table 3 shows the mean and standard deviation of peak aerobic power, arterial blood oxygen saturation and heart rate in the pre-test and post-test which shows significant differences in pre-test and post-test of experimental group compared to the control group in peak aerobic power, increased arterial blood oxygen saturation and heart rate of male climbers ($P \leq 0.05$).

Table 3: Comparison of peak aerobic power, arterial blood oxygen saturation and heart rate in both groups after pre-test and post-test

Variable	Group	Stage	Standard deviation ± mean	Dependent t	P	Independent t	P-Value
peak aerobic power (VO _{2max})	experimental	Pre-test	55/90±8.85	4.842	0.001	4.424	
		Post-test	59.25±8.59*#				
	control	Pre-test	54.39±3.22	0.691	0.512		
		Post-test	54.46±3.39				
arterial blood oxygen saturation	experimental	Pre-test	83.41±1.62	8.102	0.000	4.163	
		Post-test	87.11±2.36*#				
	control	Pre-test	83.00±2.39	1.158	0.285		
		Post-test	83.76±2.70				
Rest Heart Rate	experimental	Pre-test	105.00±6.04	6.860	0.000	4.163	.
		Post-test	98.33±3.75*#				
	control	Pre-test	109.75±5.72	0.884	0.406		
		Post-test	110.62±4.71				

*significant difference with pre-test ($P \leq 0.05$).
 # significant difference with the control group ($P \leq 0.05$).

Table 4 shows the nonparametric Wilcoxon results of the questionnaires Lake Louise in two experimental and control groups which there is significant difference in the improvement of acute mountain sickness in the experimental group compared to the control group ($P \leq 0.05$).

Table 4. improvement comparison of acute mountain sickness by Lake Louise Questionnaire in two groups after pre-test and post-test

subjects	Z	Asymp.sign
Experimental group, before and after training	-2.530	0.011 *
Control group, before and after training	-1.342	0.180

*In fact, because $Z > 1.96$ and < 0.05 , improvement in acute mountain sickness is significant.

4. DISCUSSION AND CONCLUSION

The results of this study showed that after one period of Interval aerobic training at sea level and altitude, the mean VO₂max has a significant improvement. Since the greater amount of VO₂max leads to increase in the share of energy from devices with high-intensity aerobic activity, so fatigue due to the accumulation of excipients (such as lactic acid) is delayed. So, VO₂max improvement training effect on the quality and fate of climbing [16]. This result corroborates the works [4]. The physiology cause can be stated as follows. The increase in respiratory volumes is associated with VO₂max improvement. High tidal volume and respiratory rate is thereby increased the maximum ventilation. In submaximal trainings, the pulmonary ventilation flow is greater in trained people rather than untrained ones [3]. The results of this study show that the amount of SPO₂ at altitude, have had a significant improvement in trained people which corroborates the results of [6, 17-19]. Due to changes in people who practiced interval and hypoxia running which oxygen delivery system has been strengthened by this program, It can be used for athletes in the work program and facilitate the delivery of oxygen to tissues [7,9]. Training of the current study resulted in a significant increase in the amount of oxygen saturation or concentration! Which can be extracted from circulating blood. This increase in arterial venous oxygen difference (a-VO₂) is the result of the more effective distribution of cardiac output in active muscles, and also increase the capacity of trained muscle cells to receive and consume oxygen. Trained person compared to untrained ones in a mutual group, do the submaximal trainings with less cardiac output. This is probably a result of specific local changes that occur as a result of exercise. By increasing the muscle's ability to deliver, receive and consume oxygen, active tissues to meet the needs of their oxygen, needless local blood flow [1].

The result of this study shows that the heart rate at altitude in trained people has a significant decrease in comparison with untrained people which corroborates the results of Huez et al, Nourshahi et al and Bernardi et al [16,21,22]. The physiologic cause can be stated as follows. Exercise supplies the imbalance between the activity of the accelerator sympathetic and moderator parasympathetic tonic neurons to overcome favor vague. This matter occasionally occurs by an increase in parasympathetic or maybe decrease in sympathetic discharge. In addition, the exercise could decrease the inherent incentive of a node of S-A. These adaptations which are induced by decrease in heart rate is can be seen often in quite skilled endurance athletes or disabled people following aerobic exercise (Ryan, 1991). Successful adaptation to altitude leads to decrease in heart rate near to its normal level. The results in the study of acute mountain sickness symptoms before and after a workout at Lake Louise Questionnaire showed that the trained group compared to untrained one, had a significant improvement in acute mountain sickness which corroborates the results of Tadibi et al. [14], but it is in contrast to the results of Hyman et al. which showed that there is no connection between physical activity and normal growth of acute mountain sickness at sea level and climb to an altitude of 3000 meters in a total population; it can be expressed because of kind of training participants, race, subjects' genetic and environmental differences at sea level. The fact is that anyone who ascends the heights may be at increased risk of acute mountain sickness. With this type of training climbers will be able to increase their heart rate and bring it to the safe maximum rate. Then it could be brought lower at the recovery process easily. Interval training which is based on aerobic capacity planning, is one of the training programs for the development of preparation of cardio – respiratory. As an example, is interval hypoxic training that can increase people endurance fitness. In conclusion, that the combination of these exercises caused significant changes in factors of peak aerobic

power and resting heart rate. So, it can be involved in the transport of oxygen. This practice has created to further increase in VO₂max which can be used in training programs for different purposes (Ryan, 1991). Higher percentage of SPO₂ after arrival at height, physical fitness, the former compatibility with height, and the record of ascent to altitude, are the factors that decrease the AMS probability in mountaineers who want to climb to altitudes higher than 3,000 meters [12]. In the end, it is notable that the study examined the combined effect of short-term training, due to small sample size it is recommended to future researchers that evaluate long-term effects of exercise in hypoxia conditions with larger sample sizes of women.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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