

## Original Article

### Effects of medium-height mountain training on the functional abilities and physical fitness of mid-distance runners

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#### Abstract:

The purpose of this study was to identify functional changes that determine the effectiveness of mountain training for athletes specializing in running medium distances, after return from mountain. Twelve elite athletes specializing in running distances of 400 and 800m participated in this study and were measured 2 times, with rest periods of 20 days between measurements. Our results show that mountain training leads to an increase in the physical performance and the level of physical fitness lasting as long as 24-25 days after returning from the mountains. However, not for all athletes training is equally effective. The most significant positive changes are observed in athletes whose adaptation to the conditions of the medium-height mountains is accompanied by moderate intensity of regulatory mechanisms and prevalence of the vagotonic type of autonomic homeostasis. Differences in reactions to hypoxia may be also due to the individual characteristics of athletes, e.g. the genetic predisposition to a favorable response to hypoxia, the type of central and autonomic nervous system, or efficiently planned mountain training. Thus it is important to split athletes into groups according to their reaction to hypoxia while planning efficient training programs at mid altitudes.

**Key words:** middle distance runners, mid-range altitude, physical abilities, functional performance

#### Introduction

The effectiveness of mountain training, as a means of improving the performance of athletes associated with the increased endurance, has been proved by many researchers [R.L. Wilber, 2007; V.N. Ilyin, 2007; M.M. Bulatova, 2008]. However, there are few publications describing the effects of mountain training on athletes engaged in sports requiring power, speed-force combination, complex-coordination, or combat wrestlers [D.V. Pyatnichuk, 2008; T.V. Boychuk, 2010].

It is known that the endurance abilities of athletes strongly depend on the type of sport they perform in. Specifically, athletes specializing in different sports engage different metabolic mechanisms and energy sources [A.S. Rovny, 2015]. We believe that currently insufficient attention is being paid to the study of individual hypoxic adaptation features that depend on the autonomic homeostasis types [V.B. Issurin, 2016].

#### Purpose of the research

To identify functional changes that determine the effectiveness of mountain training for athletes specializing in running medium distances, after return from mountain.

#### Materials and methods

We examined 12 elite athletes specializing in running distances of 400 and 800m (average age  $23.9 \pm 3.82$  years).

An assessment was made of the functional abilities determining the physical performance and the level of physical fitness. During the mountain training we determined athletes' autonomic regulation type of the physiological systems using the heart rate variability method. Depending on the type of homeostatic regulation, athletes were divided into two groups.

The first group was made up of five athletes, whose adaptation proceeded against the backdrop of increased intensity of regulatory processes at rest and strain during functional loads (the advantage in the autonomic balance of sympathetic influences). The second group included seven athletes, whose adaptation took place against the background of moderately intense regulatory processes and balanced sympathetic and parasympathetic effects or an increased parasympathetic effect [V.V. Sosnovsky, 2018].

Physical performance was determined by a bicycle PWC<sub>170</sub> test at a sea level (in Kyiv), first 2-3 days and then 24-25 days after returning from mountain training sessions. The subjects also performed exercises,

which increased in intensity stepwisefrom 50 to 250 W per minute. The following study scheme was used: 5 minutes - rest, 5 minutes - load, 10 minutes - recovery.

The gas composition of the inhaled and exhaled air was determined using a mass spectrograph MX 6202 (Ukraine), pulmonary ventilation - volumeter 45084 (Germany). We evaluated parameters of power, capacity, respiratory and cardiovascular efficiency, and aerobic and anaerobic systems. Maximum oxygen consumption (MOC, l/min) was calculated using the formula -  $(2.2 \times \text{PWC170} + 1070)/1000$ .

Before the trip to the mountains, and 24-25 days after return, the physical fitnessVariables (strength, speed, specialized endurance, and speed-strength abilities) were determined using tests for athletes who specialize in speed-power sports. The results shown in the test exercises were evaluated using the assessment scales [V.I. Bobrovnik, 2013]. We also evaluated the power, capacity and efficiency of energy systems using the functional scoresof high, average and low [A.S. Rovny, 2015].

Nonparametric statistics was used to analyze and evaluate the results [M.Yu. Antomonov, 2006].

## Results

At 2-3 days post return from mountain training, for the athletes of the first group calculated value of maximum (MOC) and specific(MOCsp) oxygen consumption were lower than the proper values (MOCpr), which indicated the functional scores of the effectiveness of aerobic performance(Table 1).

The values for the specific anaerobic and aerobic capacities corresponded to the high functional score of anaerobic capacity and higher than the average functional score of the effectiveness of aerobic performance.

Measurements conducted 24-25 days after returning from the mountains indicated a decrease in the oxygen cost of work ( $O_2$  cost of work) due to a decrease in oxygen demand for work ( $O_2$  request) and total oxygen debt (total  $O_2$  debt), which indicated an increase in athletes' efficiency.

MOC has practically reached the proper values, and the functional scores for aerobic performance increased from average to high. In contrast to measurements at 2-3 days, the anaerobic capacity has increased over the aerobic capacity, consistent with the specialization of mid-distance runners.

Functional score of anaerobic capacity and efficiency of aerobic performance corresponded to high levels.

The ratios of oxygen demand for work and total oxygen debt to the total oxygen cost of work for 2-3 and 24-25 days have not changed.

Table 1.Variables of physical performance for athletes of the first group after returning from training sessions (n = 10)

Variables	Post 2-3 days	Post 24-25 days
$O_2$ cost of work, l	9,590 (8,867; 10,009)	8,038(7,803; 8,016)*
$O_2$ workrequest, l	6,180 (4,975; 6,919)	5,157 (4,176; 5,811)*
Total $O_2$ debt, l	3,410 (2,977; 4,001)	2,881 (1,958; 3,404)*
Alactat $O_2$ debt, l	2,214 (1,956; 2,912)	2,109 (1,699; 2,459)*
Lactat $O_2$ debt, l	1,196 (0,903; 1,118)	0,772 (0,417; 0,893)*
$O_2$ work request,in % of total cost	64,4 (45,7; 74,9)	64,2 (46,9; 80,1)
$O_2$ recovery, in % of total cost	35,6 (26,7; 54,5)	35,8 (20,9; 54,3)
MOC, l/min	3,446 (2,935; 4,001)	3,820 (3,112; 4,110)
MOCspec., ml/min/kg	51 (40; 58)	56,5 (46; 63)*
MOC/MOCpr., %	92,9 (86,7; 99,5)	103,0(100,2; 105,8)
Anaer.power, kkal	56,9 (51,9; 68,4)	67,7 (66,3; 78,7)*
Spec. an. power, kkal/kg	0,59 (0,48; 0,67)	0,70 (0,68; 0,81)**
Aer. power, kkal	62,48 (52,23; 68,11)	51,7 (40,93; 52,21)**
Spec. aer. power, kkal/kg	0,65 (0,57; 0,73)	0,54(0,32; 0,70)*

Notes: median (1; 3- quartile); \* p <0,05; \*\* p <0,01; p was determined using a nonparametric rank criterion

For athletes in the second group, whose adaptation to the mountain conditions took place against the backdrop of moderatelyintense regulatory processes, measurements at 2-3 days after returning from the mountains showed a probable (p<0,05) decrease in  $O_2$  cost of work in comparison to athletes of the first group. This was due to lower values of  $O_2$ work request and total  $O_2$  debt (Table 2), while MOC and MOCspec were higher.

The functional score of the aerobic capacity of these athletes was higher than the average. The values of absolute and specific anaerobic and aerobic capacities corresponded to high functional scores.

For the athletes of the second group, measurements conducted 24-25 days after returning from the mountains, showed a decrease in oxygen cost of work, oxygen request for work and total oxygen debt, which indicated an increase effectiveness of the body's response to physical activity.

MOC and MOC/MOCpr have increased. The functional levels for the aerobic performance at these athletes have risen to high.

As with athletes of the first group, the intensity of anaerobic processes increased and intensity of aerobic processes decreased. This confirms the data showing the decrease of the relative contribution of aerobic metabolism to the wider energy supply system after 24-25 days in comparison to after 2-3 days.

Functional scores were high for the anaerobic working capacity and the effectiveness of aerobic performance for these athletes, as well as for the athletes in the first group.

According to several authors, the reduction of the relative contribution of aerobic metabolism to the wider system of energy supply increases the resilience of athletes in both groups to hypoxia experienced in mountains as well as to hypoxia experienced due to the physical load [M.M. Filippov, 2010]. This confirms the effectiveness of mid-altitude training [M.M. Filippov, 2014; V.I. Portinchenko, 2017].

Table 2. Variables of physical performance for athletes of the second group after returning from training sessions (n = 14)

Variables	Post 2-3 days	Post 24-25 days
O <sub>2</sub> cost of work, l	7,273 (6,323; 8,311)	6,113 (5,156; 7,036)*
O <sub>2</sub> workrequest, l	4,857(3,908; 5,199)	4,094 (3,439; 5,018)*
Total O <sub>2</sub> debt, l	2,416 (1,918; 3,215)	2,019 (1,619; 2,412)*
Alactat O <sub>2</sub> debt, l	1,739 (1,510; 2,293)	1,595 (1,231; 1,815)*
Lactat O <sub>2</sub> debt, l	0,677 (0,387; 1,011)	0,424 (0,296; 0,598)*
O <sub>2</sub> work request, in % of total cost	66,8 (46,3; 78,5)	67,0 (49,7; 77,3)
O <sub>2</sub> recovery, in % of total cost	33,2(21,8; 53,9)	33,0(21,8; 50,8)
MOC, l/min	3,798 (3,001; 4,09)	4,260 (3,901; 4,612)
MOCspec., ml/min/kg	54 (42; 59)	61 (50; 69)
MOC/MOCpr., %	102,4 (98,3; 105,4)	114,82(109,7;115,9)
Anaer.power, kkal	72,2 (62,3; 78,1)	80,7 (74,3; 88,1)*
Spec. an. power, kkal/kg	0,75 (0,56; 0,80)	0,84 (0,74; 0,89)
Aer. power, kkal	47,2 (38,1; 63,7)	38,8 (30,3; 62,2)
Spec. aer. power, kkal/kg	0,49 (0,31; 0,65)	0,40 (0,28; 0,69)

Notes: median (1; 3 quartiles); \* – the probability of difference is significant at the level  $p < 0,05$ ; p was determined using a nonparametric rank criterion

Our results show that mountain training leads to an increase in physical capacity lasting as long as 24-25 days after returning from the mountains. The positive effect was more pronounced in the athletes of the second group, which is consistent with the data of other authors showing that the peak of the functional capabilities and performance falls on 20-25 days after returning from the mountains [V.N. Ilyin, 2007; M.M. Bulatova, 2008].

Our results for physical fitness of athletes in both groups (Figure 1) showed that before the trip to the mountains, four athletes in the first group had an average level of physical fitness, while one had higher than the average level. The scores of physical abilities of five athletes in this group was  $2.98 \pm 0.31$  points, which corresponded to the average level.

Among the athletes in the second group, all seven athletes showed an average level of physical fitness: before the trip to the mountains, the scores were  $3.03 \pm 0.21$  points, which corresponded to a higher, than the average level.

After returning from the mountains, three athletes of the first group showed an average level of physical fitness, while two athletes scored higher than the average. The average score for the group as a whole was estimated at  $3.42 \pm 0.26$  points. Therefore, there was a tendency to improved physical fitness.

Among athletes of the second group, one athlete showed an average level of physical fitness, while four athletes scored higher than average with further two scoring high. These results indicate that athletes of this group experienced significant positive changes in physical fitness (the level of physical fitness increased from  $3.03 \pm 0.21$  to  $4.01 \pm 0.54$  points ( $p < 0.001$ )).

Thus, a comparative assessment of physical fitness indicates that the performance after training sessions improved more for the athletes in the second group who demonstrated prevalence of vagotonic influences and increased resistance to functional loads.

Our results demonstrate that the effectiveness of mountain training is not the same for all athletes. This is explained by a number of authors in different ways. Some researchers did not find any improvement in physiological parameters (hematologic, MOC or sports outcome), while others observed an increase in MOCsp and improved competitive results [M.M. Bulatova, 2008; V.B. Issurin 2016; V.N. Ilyin, 2017]. Differences in reactions to hypoxia may be due to the individual characteristics of athletes, e.g. the genetic predisposition to a favorable response to hypoxia [S.B. Drozdovska, 2015], the type of central and autonomic nervous system [Portinchenko V.I., 2017], or (in)efficiently planned mountain training [V.B. Issurin, 2016; S.B. Drozdovska, 2015; V.N. Platonov, 2019].

In conclusion, we believe that it is important to split athletes into groups according to their reaction to hypoxia while planning efficient training programs at mid altitudes.

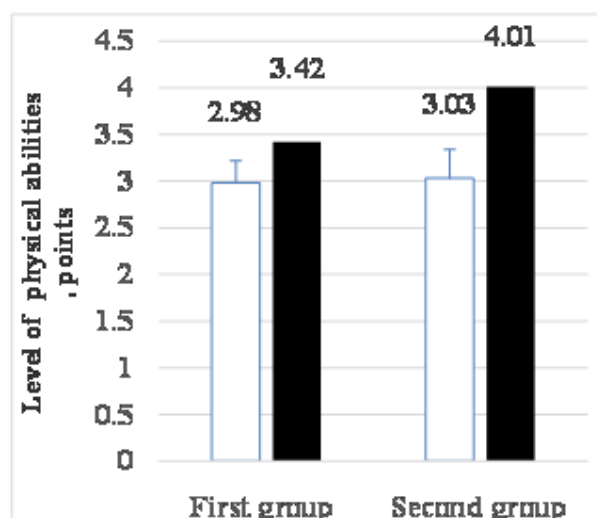


Figure 1. Levels of physical fitness before and after training at mid-altitudes: □ before training; ■ post 25-27 days.

### Conclusions

We have shown that mid-altitude training is an effective means of improving the physical fitness and functional performance of athletes specializing in running medium distances. However, not for all athletes training is equally effective. The most significant positive changes are observed in athletes whose adaptation is accompanied by moderate intensity of regulatory mechanisms and prevalence of the vagotonic type of autonomic homeostasis.

Further research is planned, which will focus on the development of criteria for assessing the adaptive effects of hypoxia on athletes' bodies, depending on the initial type of autonomic homeostasis. This will enable a prediction of the effectiveness of hypoxic training for athletes in specific sports.

**Conflicts of interest** – If the authors have any conflicts of interest to declare.

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