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The influence of altitude training on the manifestation of muscle force in the lower limbs and aerobic endurance on students specializing in ski

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Abstract

Aim and purpose: It has been widely accepted in the athletic community that altitude training can increase performance at sea level, therefore this study aims to analyze the influence of altitude training on the manifestation of muscle strength in the lower limbs and aerobic endurance in students participating at in-depth training course in a branch of sports- skiing, on the "living high-training high" model.
Material: This study included 9 students from the Physical Education and Sports Faculty of Timisoara, who took the in-depth training course in a branch of sports- skiing, taking part in the program and activities specific to this course, as well as in the training carried out at altitude.
Method: The batch was evaluated in two moments (T0 and T1), using the following assessment tests: Yo-Yo, Roman seat in isometry, high jump evaluated via the OPTOJUMP device, long jump test. The data was processed in Excel (v2205) and the statistical processing was performed using the Student T-test. It was considered that the results are statistically significant for values of $p < 0.05$.
Results: The progress recorded was quantified by normalizing the absolute values and was expressed as a percentage as follows: Yo-Yo= -1% ± 0.08 STD; RS= + 168% ± 1.26STD; HJ-Squat Jump= -4% ± 0.16STD; HJ-countermovement jump= -2% ± 0.14STD; HJ- countermovement jump-free arms = + 2% ± 0.14STD; LJ= + 6% ± 0.04STD; LJ SLJ R= + 9% ± 0.08STD; LJ SLJ L= + 10% ± 0.08STD.
Conclusions: From the evaluations performed at sea level, at T0 and T1, a noticeable improvement in the muscular strength of the lower limbs has resulted via the following tests: the Roman seat in isometry, long jump with bilateral support, long jump with unilateral support on either the left or right side; registering a significant statistical (p). However, there was no significant improvement noticed on the rest of the tests.

Keywords: *altitude training, skiing, sports performance*

Rezumat

Scop: Influenţa antrenamentelor desfăşurate la altitudine asupra performanţei sportive reprezintă un subiect de interes, fiind cercetat la scară largă. În comunitatea sportului s-a acceptat faptul că antrenamentele desfăşurate la altitudine pot îmbunătăţi performanţa de la nivelul mării, astfel, acest studiu are scopul de a analiza influenţa antrenamentelor la altitudine asupra manifestării forţei musculare la membrele inferioare şi rezistenţei aerobe la studenţii de la cursul de aprofundare într-o ramură sportivă-schi, pe modelul "living high- training high".
Material: În acest studiu au fost incluşi 9 studenţi de la Facultatea de Educaţie Fizică şi Sport din Timişoara (vârstă= 25.12± 7.39 ani; distribuţia pe gen: 1 subiect de gen feminin/ 8 subiecţi de gen masculin; fiecare participant având un istoric sportiv

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şi activ), care au urmat cursul de aprofundare într-o ramură sportivă-schi, luând parte la programul şi activităţile specifice acestui curs, precum şi la antrenamentele desfăşurate la altitudine.
Metodă: Lotul a fost evaluat în două momente (înainte- T0 şi după perioada de antrenament-T1), folosind următoarele teste de evalaure: testul intermitent Yo-Yo (Yo-Yo Intermitent Recovery Test Level 1- YYIRT1), scaunul roman în izometrie, testul săriturii în înălţime evaluat prin intermediul dispozitivului OPTOJUMP, testul săriturii în lungime. Parametrii evaluaţi au fost: nivelul (nivel) de dificultate atins la testul intermitent Yo-Yo (Yo-Yo), timpul (s) de menţinere al contracţiei izometrice la testul scaunului roman în izometrie (SR), distanţa (m) parcursă în înălţime la testul săriturii în înălţime (SI), distanţa (m) parcursă în lungime la testul săriturii în lungime (SL). Datele au fost prelucrate în Excel (v2205) iar prelucrarea statistică s-a efectuat cu ajutorul testului Student t. S-a considerat faptul că rezultatele sunt semnificative statistic pentru valori ale lui $p< 0.05$.
Rezultate: În analiza datelor obţinute din cele două momente de evaluare, se observă o tendinţă de îmbunătăţire a performanţei sportive pentru tot grupul analizat exprimată prin rezultatele superioare obţinute după perioada de antrenament desfăşurată la altitudine. Progresul înregistrat a fost cuantificat prin normalizarea valorilor absolute şi a fost exprimat procentual astfel: Yo-Yo= -1% ±0.08 STD; SR= +168% ±1.26STD; SI-genuflexiune= -4% ±0.16STD; SI- mâinile la nivelul şoldurilor= -2% ±0.14STD; SI- mâinile libere= +2% ±0.14STD; SL= +6% ±0.04STD; SL SLJ R= +9% ±0.08STD; SL SLJ L= +10% ±0.08STD.
Concluzii: Din evaluările efectuate la nivelul mării, înainte şi după perioada de antrenament, a rezultat o îmbunătăţire notabilă a forţei musculare a membrelor inferioare prin următoarele teste: scaunul roman în izometrie, săritura în lungime cu sprijin bilateral, săritura în lungime cu sprijin unilateral. fie pe partea stângă, fie pe partea dreaptă; înregistrând un (p) statistic semnificativ. Cu toate acestea, nu s-a observat nicio îmbunătăţire semnificativă la restul testelor.

Cuvinte cheie*: antrenament la altitudine, schi, performanţă sportivă*

Introduction

The interest in high-altitude training in the world of sports increased beginning with the Summer Olympics in Mexico City in 1968, an edition in which several athletes recorded remarkable results for long-distance events or even jumping. Moreover, athletes from high altitude countries such as Kenya or Ethiopia won a higher percentage of medals in medium-long distance races (Wilber, 2004).

These results have led various athletes, coaches and researchers to deepen the influence of high altitude training on sports performance, approaches that can be seen in the emergence of concepts such as: living high-training low (HiLo), living high-training high (HiHi), etc., but also through the results of the Olympic Games in 1988 and 1992, when most of the medals in the long-distance running events were won by athletes who approached a style of training at altitude (Rusko, 1996).

Various studies have shown that exposure to hypoxia leads to a number of adaptations in the body, such as a transient increase in hemoglobin and hematocrit, explained by a rapid decrease in plasma volume, immediately followed by an increase in erythropoiesis; VO2 max enhancement, etc.

Both high-performance athletes and non-athletes reach a maximum reticulocytosis threshold after about 8-10 days at a moderate altitude.

A training period of 3 weeks at moderate altitude results in an individual increase in hemoglobin concentration of about 1 to 4%. (Berglund, 1992).

Aim and purpose of the study

The present paper is based on the hypothesis according to which the trainings carried out at medium altitude, in a mountain environment, of short-medium duration, influence the manifestation of the muscular force at the level of the lower limbs, as well as the aerobic resistance.

Thus, the objective of the paper is to collect and analyze the results obtained by using a battery of evaluation tests performed before and after a 4 weeks long training period on a group of students from the Physical Education and Sports Faculty in Timisoara, who participated in the in-depth course in a branch of sports- skiing.

Material and method

Material and participants

The group of participants to the study consisted of 9 students from the Physical Education and Sports Faculty in Timisoara. All participants are students that took part in the in-depth course in a branch of sports- skiing. The characteristics of the analyzed group are as follows: age: average = 25.12 years± 7.39; gender: 1 woman / 8 men; each participant having a sports background. All the participants were involved both in the specific activities of this course, as well as in the altitude training. Only one subject was excluded from this batch due to failing to appear in all assessments performed.

Methods

This study is an experimental type of research that aimed at assessing the impact of altitude training on the manifestation of muscle strength in the lower limbs and aerobic endurance. The selection of participants was made from the students of the Physical Education and Sports Faculty (PESF) in Timisoara, with the following inclusion criteria: a) are students in PESF Timisoara; b) participated in the ski specialization course; c) participated in the ski specialization course for one month. The exclusion criteria were: a) they are not students within PESF Timisoara; b) did not participate in the ski specialization course; c) participated in the short-term ski specialization course (two weeks); d) they did not appear at all the evaluations performed. Following the selection, a number of 9 students (1 female / 8 males) were included in the experimental study for whose results were analyzed further as pool data. The setting in which the experiment took place is represented by the mountain resort Straja, with a pronounced specificity for winter sports, being at an altitude of 1445 meters. The specialized intervention in this study refers to the running and strength training carried out in the morning, but also to the skiing course that took place on the slope, where the students spent an average of 4 hours a day.

Table I. Training microcycles where value 1= km achieved, value 2= altitute, value 3= level difference

Microcycle 1: 21- 26 January	2,96 km 1343- 1440 m 119m	2,18 km 1342- 1432m 88m	2,57 km 1334- 1431m 87m	2 km 1343- 1430m 84m	2,25 km 1342- 1382m 75m	REST
Microcycle 2: 27 January- 1 February	2,33 km 1334- 1431 m 86m	2,25 km 1343- 1439m 83m	2,13 km 1340- 1431m 87m	2,37 km 1349- 1439m 82m	2,40 km 1334- 1431m 87m	REST
Microcycle 3: 2- 7 February	3,53 km 1346- 1448 m 151m	3,76 km 1337- 1440m 141m	2,26 km 1330- 1361m 79m	3,86 km 1343- 1440 m 118m	2,52 km 1342- 1432 m 97m	REST
Microcycle 4: 8- 11 February	2,5 km 1342- 1387 m 63m	2,25 km 1342- 1439m 83m	2,33 km 1255- 1364m 111m	REST	-	-
Microcycle 5: 12- 17 February	3 km 1334- 1431 m 109m	2,03 km 1341- 1376m 58m	1,96 km 1333- 1375m 35m	2 km 1342- 1352m 25m	1,33 km 1329- 1353m 22m	REST

The evaluation methods used in this study were the following: Yo-Yo Intermittent Recovery Test Level Level 1 (YYIRT1) to assess the individual's ability to perform high intensity intervals with a short recovery time- evaluated through the level of difficulty (level) reached; isometry test holding the genuflexion position (Roman seat) on the wall evaluated through the maintenance time (s) of the given position; the long jump with bilateral support (3 runs/test) and the long jump with unilateral support (2 runs on each side/test) evaluated in the distance (m) covered by the jump; high jump with: countermovement jump (1 run/test), countermovement jump- free arms (1 run/test) and squat jump (1 run/test) evaluated through the OPTOJUMP device where the distance (m) covered by the jump was assessed. The evaluation of the subjects was performed in two moments: the first moment represents the collection of data from the above mentioned tests 9 days before the training period, while the second moment refers to the collection of data from the tests 11 days after the training period. In both stages, similar evaluation conditions were ensured, such as: the tests were performed in the same gym, the same time frame for evaluation was maintained, the same individual equipment was maintained, the same evaluation devices and equipment were utilized, a collective warm up was performed in which the same exercises and elements were maintained, etc. In order to carry out an objective evaluation, a number of 4 supervisors participated in both stages. Under these conditions, the data of 8 subjects were collected in two moments for 8 tests.

Results

After each of the subjects were tested, the data was centralized from all the utilized forms and software and then sorted into an Excel file (v2205). For each test, the average of the values obtained at pre-test in T0, at post-test in T1, respectively the standard deviation for T0 and T1 was calculated. Finally, the results obtained in the two moments were compared using the T-test, thus obtaining the statistical significance (p) for each test. The results were considered statistically significant for values of $p < 0.05$. The progress recorded by the group was quantified by normalizing the absolute values and was expressed as a percentage.

Table II- a) The results of the subjects in the Yo-Yo test at T0 and T1; b) The results of the subjects in the Roman seat test at T0 and T1

Yo-Yo	T0	T1	RS ISO	T0	T1
SUB1	14.9	12.3	SUB1	1:32	4:26
SUB2	14.6	15.3	SUB2	3:44	11:00
SUB3	14.4	13.4	SUB3	1:55	7:42
SUB4	16.4	16.7	SUB4	1:22	2:14
SUB5	13.1	14.2	SUB5	2:04	10:02
SUB6	16.4	15.1	SUB6	4:34	5:48
SUB7	14.2	14.4	SUB7	1:24	3:14
SUB8	14.2	15.1	SUB8	1:40	2:32

In table II, in section a) we can see the results of the subjects obtained in the Yo-Yo test, having at T0 the group average of 14.77 and a standard deviation of 1.12, while at T1 the group average was 14.56 and the standard deviation of 1.32. Thus, the T-test obtained an insignificant $p = 0.32$. The recorded regression of the group was -1% ±0.08STD. In section b) of the table we can see the results of the subjects obtained in the test of the Roman seat in

isometry, having at T0 the group average of 2:16 and a standard deviation of 0.04, while at T1 the group average was 5:52 and standard deviation of 0.14. Thus, via the T-test a significant p = 0.005 was obtained. The recorded progression of the group was +168% ±1.26STD.

Table III- a) The results obtained by the subjects in the long-jump jump test at T0 and T1; b) The results obtained by the subjects in the long-unilateral-right jump test at T0 and T1; c) The results obtained by the subjects in the long-unilateral-left jump test at T0 and T1.

LJ	T0	T1	LJ SLJ R	T0	T1	LJ SLJ L	T0	T1
SUB1	218.3	229.6	SUB1	172.5	173.5	SUB1	173.5	173.5
SUB2	204.3	209.3	SUB2	161.5	171.5	SUB2	169.5	168.5
SUB3	206.3	216.6	SUB3	173	180.5	SUB3	172	185.5
SUB4	207.6	217.3	SUB4	164	180	SUB4	165	194.5
SUB5	152	174	SUB5	114.5	137.5	SUB5	144	156.5
SUB6	208.3	208.3	SUB6	185	189	SUB6	165	195.5
SUB7	196	208	SUB7	151.5	184.5	SUB7	148.5	177.5
SUB8	194.3	211	SUB8	145.5	150.5	SUB8	148	155

In table III, in section a) we can see the results obtained by the subjects in the long jump test with bilateral support, having a T0 group average of 198.38 with a standard deviation of 20.18, whilst the T1 group average was 209.26 with a standard deviation of 15.95. Therefore, a significant p = 0.001 has been obtained via the T-test. The recorded progression of the group was +6% ±0.04STD. In section b) of the table, results obtained by the subjects in the long jump test with unilateral support on the right side can be observed. The T0 group had an average of 158.53 with a standard deviation of 21.71, while the T1 group average has been 170.87 with a standard deviation of 17.83. As a result, a significant p= 0.007 has been obtained from the T-test. The recorded progression of the group was +9% ±0.08STD. Furthermore, in section c) we can see the results of the subjects obtained in the long jump test with unilateral support on the left side, having the T0 the group average of 160.68 and the standard deviation of 11.92, while the T1 group average was 175.81 with a standard deviation of 15.57. Consequently, via the T-test a significant p = 0.006 was obtained. The recorded progression of the group was +10% ±0.08STD.

In table IV, at section a) we can see the results of the subjects obtained at the squat-high jump test, having the T0 group average of 31.26 and a standard deviation of 7.30, while the T1 group average was 29.07 and the deviation standard of 4.50. Therefore, via the T-test, an insignificant p=0.07 has been obtained. The recorded regression of the group was -4% ±0.16STD. In section b) of the table we can see the results obtained in the countermovement jump, recoding a T0 average of 32.46 and a standard deviation of 6.12, whilst the T1 average was 31.36 with a standard deviation of 4.57. As a result of the T-test, an insignificant p = 0.23 was obtained. The recorded regression of the group was -2% ±0.14STD. Furthermore, in section c) the results of the subjects performing the countermovement jump- free arms can be noted, recording the T0 average of 39.36 and a standard deviation of 7.01, while the T1 group average was 39.51 with a standard deviation of 5.25. Consequently, the T-test obtained an insignificant p = 0.46. The recorded progression of the group was +2% ±0.14STD.

Table IV- a) The results obtained by the subjects in the squat jump test at T0 and T1; b) The results obtained by the subjects in the countermovement jump at T0 and T1; c) The results obtained by the subjects in the countermovement jump- free arms at T0 and T1.

SQUAT JUMP	T0	T1	CMJ	T0	T1	CMJ FA	T0	T1
SUB1	37.4	32.4	SUB1	37.1	34.3	SUB1	45.3	45.9
SUB2	33.9	29.4	SUB2	36.7	31.4	SUB2	47	45
SUB3	28.8	24.3	SUB3	30.5	23.9	SUB3	37.8	31.4
SUB4	41.1	35.9	SUB4	38.3	37.4	SUB4	44.1	42
SUB5	17.4	23.2	SUB5	20.6	25.9	SUB5	25.3	33.1
SUB6	34.2	33.4	SUB6	36.7	35.3	SUB6	42.2	42
SUB7	31.1	27	SUB7	32.5	31.9	SUB7	38.2	37.8
SUB8	26.2	27	SUB8	27.3	30.8	SUB8	35	38.9

Discussions

A multitude of studies conducted in the recent decades on the significance of altitude trainings as a mean to improve performance in competitions, held both at altitude and at sea level, demonstrate that this method of training can be a key element in the training process of an athlete. (Dill,1971; Gore, 2008; Pugh, 1964).

Numerous studies in the literature show an improvement in sea-level performance after a period of sustained trainings at high-altitude. (Bailey, 1998; Burtscher, 1996; Daniels, 1970; Dill, 1971).

Considering the preferred use of high-altitude training by both athletes and coaches in most endurance sports to the detriment of other hypoxia methods, suggests the effectiveness and importance of this type of training. (Friedmann-Bette, 2008; Dick, 1992).

There are several factors which characterize altitude trainings such as: the altitude (where different opinions have been expressed concerning the optimal interval for training or even living), the time spent at altitude (where it has been suggested that at least 2 weeks are recommended to achieve an improvement in altitude performance, whilst 3-4 weeks are recommended in achieving an improvement at sea-level performance) etc. (Pottgiesser, 2008; Rusko, 2004; Schuler, 2007).

According to the latest studies, classical trainings carried out at moderate altitude, correlated with a period in which the athlete also lives at that respective altitude, is the most popular training method to improve sea-level performance. (Bonetti, 2009).

The authors recognise the limitations of the experiment expressed by a small batch of participants and the unequal distribution by gender, having one female and 8 males selected at the beginning of the study. Taking these aspects into consideration the data recorded in the evaluations performed was centralized as pool data.

Conclusions

The present study included a group of 8 students from the Physical Education and Sports Faculty in Timisoara. These subjects have attended the in-depth training course in a branch of sports-skiing, performing daily training at moderate altitude throughout the experiment, based on the "living high-training high (HiHi)" training model.

From the evaluations performed at sea level, before and after the training period, a noticeable improvement in the muscular strength of the lower limbs has resulted via the following tests: the Roman seat in isometry, long jump with bilateral support, long jump with unilateral support on either the left or right side; registering a significant statistical (p). However, there was no significant improvement noticed on the rest of the tests.

References

1. Bailey, D. M., Davies, B., Romer, L., Castell, L., Newsholme, E., & Gandy, G. (1998). Implications of moderate altitude training for sea-level endurance in elite distance runners. *European Journal of Applied Physiology and Occupational Physiology*, *78*(4), 360-368.
2. Berglund, B. (1992). High-altitude training. *Sports Medicine*, *14*(5), 289-303.
3. Bonetti, D. L., & Hopkins, W. G. (2009). Sea-level exercise performance following adaptation to hypoxia. *Sports Medicine*, *39*(2), 107-127.
4. Burtscher, M., Nachbauer, W., Baumgartl, P., & Philadelphy, M. (1996). Benefits of training at moderate altitude versus sea level training in amateur runners. *European journal of applied physiology and occupational physiology*, *74*(6), 558-563.
5. Daniels, J. T. (1970). The effects of alternate exposure to altitude and sea level on world-class middle-distance runners. *Med Sci Sports*, *2*, 107-112.
6. Dill, D. B., & Adams, W. C. (1971). Maximal oxygen uptake at sea level and at 3,090-m altitude in high school champion runners. *Journal of Applied Physiology*, *30*(6), 854-859.
7. Dick, F. W. (1992). Training at altitude in practice. *International journal of sports medicine*, *13*(S 1), S203-S205.
8. Friedmann-Bette, B. (2008). Classical altitude training. *Scandinavian journal of medicine & science in sports*, *18*, 11-20.
9. Gore, C. J., McSharry, P. E., Hewitt, A. J., & Saunders, P. U. (2008). Preparation for football competition at moderate to high altitude. *Scandinavian journal of medicine & science in sports*, *18*, 85-95.
10. Pottgiesser, T., Ahlgrim, C., Ruthardt, S., Dickhuth, H. H., & Schumacher, Y. O. (2009). Hemoglobin mass after 21 days of conventional altitude training at 1816 m. *Journal of science and medicine in sport*, *12*(6), 673-675.
11. Pugh, L. G. C. E., Gill, M. B., Lahiri, S., Milledge, J. S., Ward, M. P., & West, J. B. (1964). Muscular exercise at great altitudes. *Journal of Applied Physiology*, *19*(3), 431-440.
12. Rusko, H., Tikkanen, H., & Peltonen, J. (2004). Altitude and endurance training. *Journal of sports sciences*, *22*(10), 928-945.
13. Rusko, H. R. (1996). New aspects of altitude training. *The American journal of sports medicine*, *24*(6_suppl), S48-S52.
14. Schuler, B., Thomsen, J. J., Gassmann, M., & Lundby, C. (2007). Timing the arrival at 2340 m altitude for aerobic performance. *Scandinavian journal of medicine & science in sports*, *17*(5), 588-594.
15. Wilber, R. L. (2004). *Altitude training and athletic performance*. Human Kinetics