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THE IMPACT OF ENDURANCE TRAINING ON FUNCTIONAL PARAMETERS DURING THE PREPARATION PHASE AMONG CROSS-COUNTRY SKIERS

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Summary: In the study, we have tried to demonstrate the effect of endurance training on changes in functional parameters during the preparation phase (12-week mesocycle) among cross-country skiers. The group consisted of 10 male cross-country skiers (age: 21.4 ±5 year) who completed control (1^{st} 6 week mesocycle) and experimental period (2^{nd} 6 week mesocycle).We focused on the following time-varying parameters: changes in maximal oxygen uptake (VO_2max), the level of aerobic (AeT) and anaerobic thresholds (AT), maximum heart rate (HRmax) and performance on the running treadmill. The intra-individual monitoring of each athlete revealed statistical significance of VO_2max (mid_ VO_2max = 69.48 ± 5.72 l.kg^{-1}.min^{-1}, post_ VO_2max = 70.96 ± 5.67 ml.kg^{-1}.min^{-1}; $p \leq 0.05$) and the level of AT (mid_AT = 86.2 ± 5.43 %, post_AT = 87.8 ± 5.59 %; $p \leq 0.01$) the performance on the running treadmill (mid_t = 14:54 ± 1:43 min., post_t = 15:30 ± 1:50 min.; $p \leq 0.05$).The significant changes were recorded in the AeT(pre_AeT = 70.3 ± 7.56 %, mid_AeT = 72.5 ± 7.59 %; $p \leq 0.05$) in theHRmax(pre_HRmax = 190 ± 8.04 bpm, mid_HRmax = 189 bpm, post_HRmax = 188 ± 7.34 bpm; p = n.s.) during control period. We assume that the significant differences occurred as a result of adaptation changes due to training stimuli, which were induced by changes in functional parameters. Increased training volume in zone lower level of oxygen regime (A1), upper level of oxygen regime (A2) and upper level of lactate tolerance(T2) during experimental period elicited changes which reflected the increase functional parameters and performance on the running treadmill compared to that of control period.

Key words: cross-country skiing, maximal oxygen uptake, aerobic and anaerobic threshold level, the endurance training

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Introduction

Every sport has its own kinematic structure. Therefore, it is difficult to determine objectively maximum functional parameters, which correspond to performance parameters during the competition and/or in a selected sport discipline. To determine and evaluate the training volume properly, it is important to recognize specific parameters corresponding to sport specialization and internal loading (physiological responses) of the organism during the performance. The most common methodto obtain these parameters isspiroergometric examination based on a gradually increased load on the bicycle spiroergometer, the running treadmill or any other specialized ergometers. In the scientific community, there are different opinions about VO_2max development throughout training. Maximal oxygen uptake is an important variable that sets the upper limit of endurance performance (David, R. et al. 1999). Authors Komadel et al. (1997) report that genetic predisposition of VO_2max is approximately 80 %. Meško et al. (2005) suggest that the development of VO_2max is in the range of 5 to 30 %. In contrast to that, Dívald (2009) states that the rate of VO_2max increases are only 2 - 3 % on condition that the training program is chosen properly. Rusko (2003) describes that development of VO_2max increases with age and quality of the actual and previous training background. Hickson et al. (1977) claim that a 40 % VO_2max increase is possible in a10-week training period with appropriate training intensity and frequency. Despite the increase of VO2max being larger than 10 %, there is significant individual physical variation in response to training stimuli (Hautala et al. 2003). Heart volume begins to equilibrate after the age of 18 to 20 years, and VO2 max after the age of 20 to 22 years among less successful skiers. Skiers who reached the excellent level were able to increase their VO_2max as well as heart volume after the age of 18 to 20 years provided that there was an increased training volume and intensity. Anaerobic threshold of an elite 800 m runner is 83 % VO_2max. 400-metre runners and marathoners reach the threshold of 84 % and 88 % VO_2max. Top marathoner is able to run the whole race at the level of 86 % VO_2max, whereas an average runner at 70 % of VO_2max (Valiska 2005). The best cross-country skiers reach the anaerobic threshold at 90 % of VO_2max. The development of VO_2max, to a lesser extent, may be affected by the training program, but to a large extent, it can shift the upper limit of AT towards the VO_2max. The intensity of exercise is considered key determinant of the training response (Rusko 2003).

Several studies, examining this issue found significant changes in VO_2max after endurance training consisting of 3 x 40 min. within a week (a 4-week mesocycle), where the intensity of exercise exceeded 75 % of HRmax (Nummela et al. 2015).

Aim

The aim of this study is to highlight the impact of endurance training on functional parameters among cross-country skiers in the preparatory phase.

Methods

Subjects

Ten cross-country skiers volunteered to take part in this study. The subjects' characteristics are shown in Table 1. This is a one-group time parallel quasi-experiment. The subjects represent the currently best cross-country skiers in Slovakia, who regularly participate in the Slovak Cup competition and international events. Prior to the study, they were fully informed about the study design and possible risks were explained. All the athletes signed an informed consent. A local ethic committee at the Faculty of Physical Education and Sport in Bratislava approved the study.

Table 1 *The characteristics of the each athlete*

Character	Age	Sporty (age)	Height [cm]	Weight [kg]
Me	21	10	180	74
x	21.4	10.7	181	74
Vr	10	14	18	20

Note. Me – median, x – average, Vr – variation range

Experimental design

At the beginning of the preparatory phase (27 May -28 May 2015) pre-training measurements were performed. Mid-training measurements were obtained after 6 weeks of the training period (on 15July – 17July 2015). Post-training measurements were obtained after 12 weeks of the training period (on 9 Sept. – 10 Sept. 2015) (Tab. 2). We have obtained the data from the spiroergometric examination on the running treadmill operating at the National Sport Centre. The running test was done on a treadmill with a gradually increasing slope and speed. We have monitored the following parameters: maximal oxygen uptake (VO2max), maximal heart rate (HRmax), aerobic (AeT) and anaerobic (AT) thresholds and running time until exhaustion, which was considered the end of the performance test.

Table 2
Experiment illustration

Pre-training measurement	6 week	Post-training measurement Pre-training measurement	6 week	Post-training measurement
	CONTROL PERIOD		EXPERIMENTAL PERIOD	

In the period between the first pre-training and post-training measurement we have recorded overall training content which was subsequently analyzed. We have monitored general and specific training indicators.

Exercise protocol

The exercise protocol consisted of running at 8km/h for 4 minutes at a 0° slope of the treadmill. The following 4 minutes were at 10 km/h at a 5° slope of the treadmill. After the initial warm-up with consistent treadmill, inclination at 6° the speed of the treadmill was increased every minute up to 15 km/h. At the moment when each athlete reached this speed, the inclination of the treadmill increased in 1° after each minute had elapsed. For evaluation of functional parameters, the running treadmill (Power Cube) was used. All the measurements were performed in National Sport Center. We have monitored following parameters: ANP, VO_2max, VO_2 ANP, % ANP of VO_2max, % AEP of VO_2max, HRmax, HR AEP, % AEP of HRmax, HR ANP, % ANP of HRmax and time of testing.

12 weeks training protocol

During the two 6 week training period (control and experimental) all the athletes trained under the supervision of their own personal coaches. The purpose of this period was to develop aerobic capacity using general and/or non-specific training methods (running, cycling).Participants have used specific training methods as well (roller skis).The exercise intensity was monitored and recorded via sport testers in four different loading zones, based on individually adjusted HRmax values (Tab. 3).

Table 3
Descriptions of individual zones

A1	lower level of oxygen regime	(50 – 70 % of HRmax)
A2	upper level of oxygen regime	(70 – 80 % of HRmax)
T1	lower level of lactate tolerance	(80 – 95 % of HRmax)
T2	upper level of lactate tolerance	(95 – 100 % of HRmax)

Jansen (1994) and Dívald (2009) describe these loading zones, which are included in our experiment. The first zone is characterized as the lower level of oxygen regime (A1) with lactate values up to 2.5 $mmol.l^{-1}$ (aerobic activity). This zone is located below aerobic threshold. Physical activity, which is performed in this aerobic zone, does not have any developing impact, but it is intended to maintain the level of aerobic endurance. The second zone (A2) is characterized by aerobic nature as well, but lactate values are around 2.5 – 3.5 $mmol.l^{-1}$. This zone is also called “stabilization zone” which is located between aerobic and anaerobic threshold. In the third zone is 10 – 30 % of energy coverage provided by anaerobic manner and the rest by aerobic way. Lactate in the blood is about 4.5 $mmol.l^{-1}$ to 9 $mmol.l^{-1}$. Therefore, this zone is called “developing”. The last training zone, which we have applied in our study, is T2. Lactate values in the blood are above 9 $mmol.l^{-1}$. Training at this level elicits the greatest changes in VO_2max. We have recorded specific training indicator (overall training volume in each zones) which as an independent variable affected functional parameters. During the experimental period subjects completed total training volume which was higher about 7 % (12:09 h) compared to the control period. From this total volume they performed higher training volume in zone A1 and A2 (11:27 h) and in zone T1 and T2 (0:42 h) during the experimental period.

Statistical analysis

To evaluate significant differences between pre- and post-training in the study, the Wilcoxon T-test has been used. To compare significant differences between experimental and control protocol Mann-Whitney U-test has been used. Alpha was set at 1 % ($p<0.01$) and 5 % ($p<0.05$). Effect sizes according to Cohen's *d,* whereby<0.2 is a small 0.2-0.4 is a moderate, and >0.4 is a large effect were calculated.

Results and discussion

The first part of the experiment (control period) was realized from 1.6. to 15.7.2015 and the second (experimental period) was from 16.7. to 31.8.2015. We have recorded overall training volume in each training zone (Fig. 1). We use the average values achieved by all the athletes. During the experimental period, participants performed about 12.4 % higher volume compared to the control. In the experimental part of the study all the group performed about 7

% higher volume in zone A1 compared to the control. In zone A2, they performed about 23 % higher volume compared to the control. In zone T1, they completed about 14 % lower volume compared to the control and about 55 % higher volume in zone T2 compared to control period.

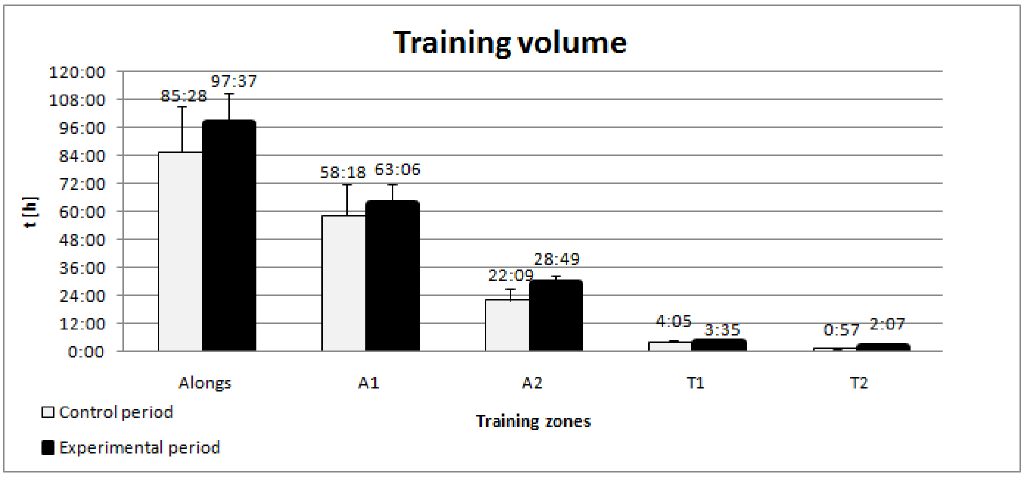

Figure 1

Specific training indicator – overall training volume (in minutes)

In VO2max during the control period, we recorded pre-training average value 68.68 $ml.kg^{-1}.min^{-1}$ and mid-training 69.48 ± 5.72 $ml.kg^{-1}.min^{-1}$. There were no significant differences between pre- and mid-training (0.8 $ml.kg^{-1}.min^{-1}$, 1.15 %, p = n.s., d = 0.18). In the experimental period, we observed 69.48 ± 5.72 $ml.kg^{-1}.min^{-1}$ (mid-training) and 70.96 ± 5.67 $ml.kg^{-1}.min^{-1}$ (post-training). In this case significant differences were recorded (1.48 $ml.kg^{-1}.min^{-1}$, 2.1 %, $p \leq 0.05$, d = 0.40) (Fig. 2).

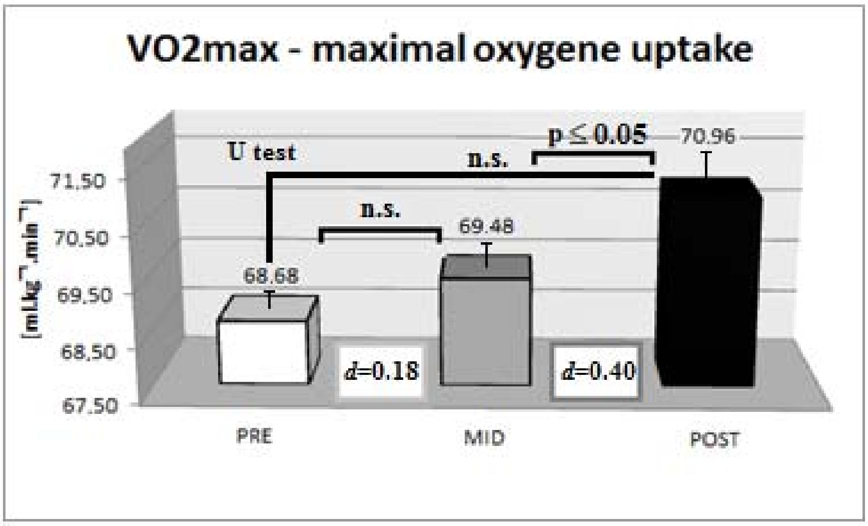

Figure 2

Pre-, mid-, and post-training maximal oxygen uptake

Percentage changes obtained in the anaerobic threshold toward the VO_2max before the control period were 86.5 ± 5.43 % VO_2max. At the end of the control period, we recorded the value of 86.2 ± 5.43 %. These changes were non-significant (0.3 %, *d* = 0.22). Over the next 6 week period (experimental) we observed mid-training values 86.2 ± 5.43 % VO_2max and post-training value 87.8 ± 5.59 % VO_2max. These changes were significant at the alpha level of 1 % (1.8 %, *d* = 0.20) (Fig. 3).

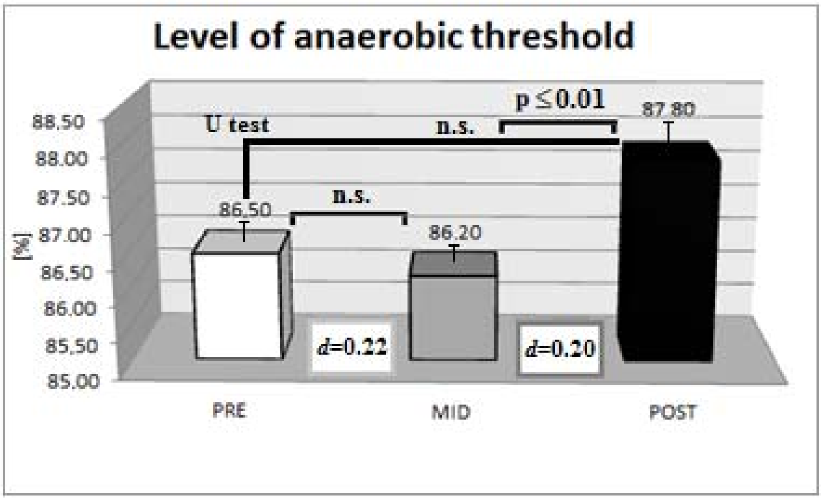

Figure 3

Pre-, mid-, and post-training percentage changes of the anaerobic threshold

Percentage changes obtained in the aerobic threshold toward the VO2max after the experimental and control period were increased, but there were no significant differences after the end of the experimental period (from 72.5 ± 7.59 % to 73.7 ± 7.82 %, diff = 1.2 %, p = n.s., *d*= 0.28) (Fig. 4). However, there were significant differences between pre-, and mid-training (control period) in the AeT (from 70.3 ± 7.56 % to 72.5 ± 7.59 %, diff = 2.2 %, p ≤0.05, *d* = 0.14).

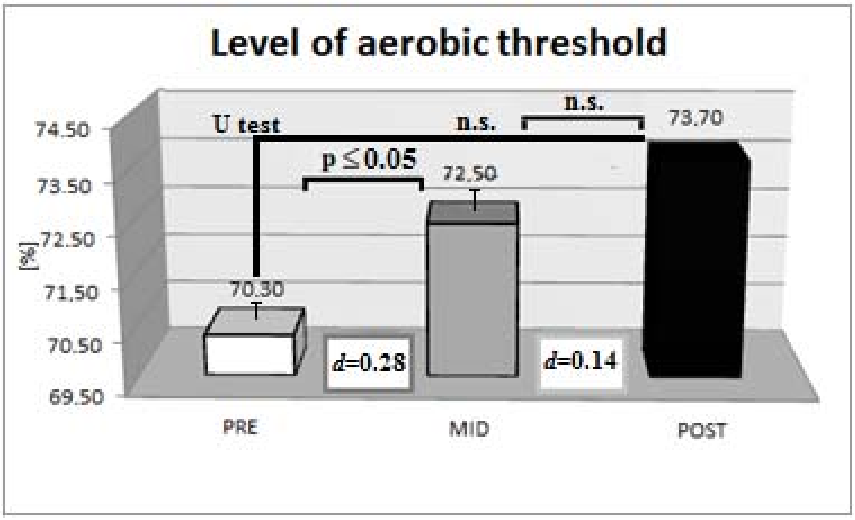

Figure 4

Pre-, mid-, and post-training percentage changes of the aerobic threshold

We think that increased level of the AeT is related to the training program that participants completed in zone A1 and A2. In the performance test (time of testing until exhaustion) we observed significant changes only after the experimental period (+ 36 seconds, 3.87 %, p≤0.05, *d* = 1.00). There were no significant changes after the control period (Fig. 5).

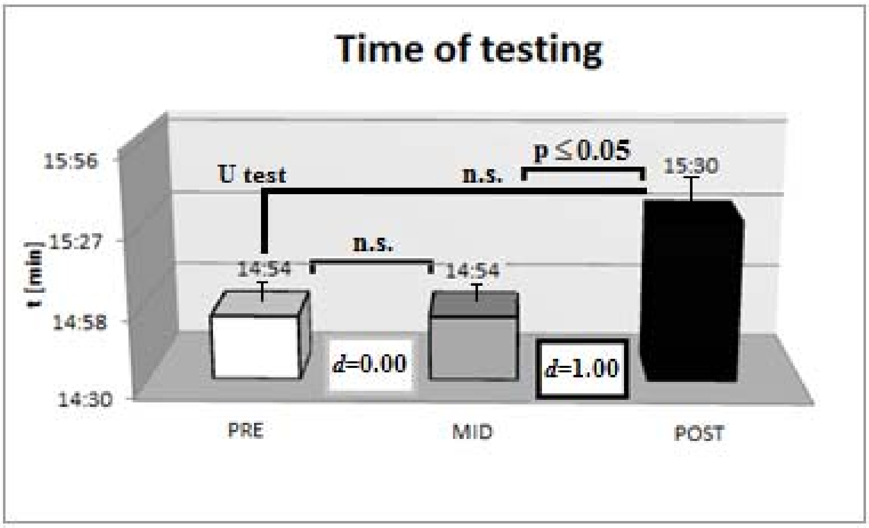

Figure 5

Pre-, mid-, and post-training changes in the performance test (time of testing until exhaustion)

Non-significant changes have occurred in the parameter of maximal heart rate frequency, where the average post-training values decreased from pre-training to mid-training and from mid-training to post-training as shown in Figure 6.

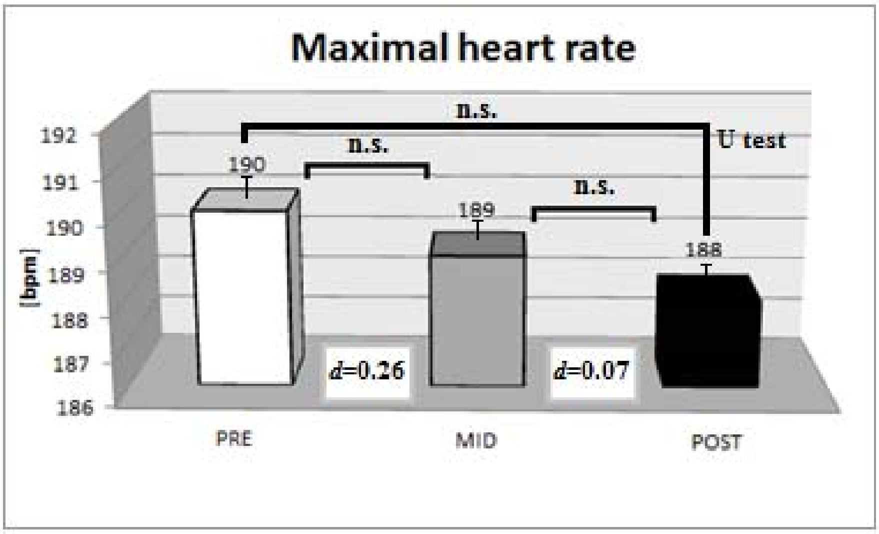

Figure 6

Pre-, mid-, and post-training differences in the parameter of the maximal heart rate frequency

Mann-Whitney U-test revealed no significant changes in all the above-mentioned parameters between experimental and control group.

From the results of the impact of a 3-month training intervention (2x6 week training period), which involved changes in functional parameters in cross-country skiers, we can draw following conclusions. Endurance training may cause increased activities of mitochondrial enzymes, which improves the performance through increased fat oxidation and decreased lactic acid content (David et al. 1999), resulting in increased VO_2max. In the study by McArdle et al. (1978), in a 10-week training period the researchers focused on the development of aerobic endurance through an interval training method. They concluded that this led to a significant decrease of HRmax as well as to submaximal HRmax during the training. Porges (1992) and Hynynen et al. (2008) state that the changes in HRmax can be caused by stress and the impact of the parasympathetic nervous system, which can be seen in the autonomous response to stress situation (e.g. the training load). Some studies focusing on this topic confirm the increments of AT and VO_2max, but only in the case when AT is expressed as a percentage ratio of VO_2max. In this case there are no changes in AT in the age group over 16 years. At the international level, 20-year-old cross-country skiers have been able to improve the level of VO_2max. Intensive interval training appears to be the most effective method for increasing VO_2max. Prolonged low-intensity endurance training was more effective for improvements in anaerobic threshold (Rusko 1987).

Intra-individual monitoring has shown statistical significance in the parameter of VO_2max after the experimental period (mid_VO_2max = 69.48 ± 5.72 $l.kg^{-1}.min^{-1}$, post_VO_2max = 70.96 ± 5.67 $ml.kg^{-1}.min^{-1}$; $p \leq 0.05$), AT (mid_AT = 86.2 ± 5.43 %, post_AT = 87.8 ± 5.59 %; $p \leq 0, 01$) and performance on the running treadmill (time) (mid_t = 14:54 ± 1:43 min., post_t = 15:30 ± 1:50 min.; $p \leq 0,05$). Significant changes are seen in (pre_AeT = 70.3 ± 7.56 %, mid_AeT = 72.5 ± 7.59 %; $p \leq 0.05$) after the control period. There were no significant differences in HRmax (pre_HRmax = 190 ± 8.04 bpm, mid_HRmax = 189 bpm, post_HRmax = 188 ± 7.34 bpm; p = n.s.). We attribute these significant changes to applied training intervention, which has evoked changes in functional parameters. Studies by Gaskill et al. (1999) and Laursen and Jenkins (2002) show that high intensity endurance trainings beyond the anaerobic threshold are the most efficient approaches to improve performance and increase VO_2max.Eversen et al. (2001) have not shown significant changes in VO_2max after 5 month endurance training whereas the control group (cross-country skiers) performed 86 % of overall training volume at 60 - 70 % of VO_2max. However, they have shown significant improvement in running test lasting 20 minutes (experimental group: + 160.23 m, + 3.8 %; control group: + 77.32 m, + 1.9 %; $p \leq 0.05$). In the experimental group, we recorded an increase in running speed at anaerobic threshold (+3.2 $m.s^{-1}$, 0.9%, $p \leq 0.03$). The results of the studies by Steinacker et al. (1993), Steinacker et al. (1998) and Eversen et al. (2001) recommend increasing training volume in zone T1 and T2 whereupon the adaptive changes relate to the intensity of training stimuli might occur. In our study, participants performed low volume (6 %) in zone T1 and T2. Billat et al. (2001) report that improvement in endurance performance depends on the training volume in zone T1 and T2 which should exceed 15 % of total training volume.

For increasing AeT, we recommend boost training volume in zone A1 and T1, whereas in the control period we observed significant changes in AeT. In zone, T1 during the control period was training volume higher about 12 % compared to experimental period. Development of aerobic power should be implemented in zone T1 and in zone A1; we should turn out our attention for developing aerobic capacity. In zone A2, athletes should develop aerobic capacity as a basis for the development of VO_2max. According to Everson et al. (2001), the greatest impact for increasing AT is in zone T1 and T2 similarly as we demonstrated in our study. For required adaptation, process influenced by training stimuli it is necessary to spend more than 1.1 % of total training volume in zone T2 because in the control period there were no significant changes caused by this training volume. Studies realized by Gaskill et al. (1988) and Seiler et al. (2004) demonstrated polarized training model with high volume in zone A1 and medium volume in zone T1 and T2.

During the preparation phase, we recommend to split the training program as follows: A1 – 64 %, A2 – 30 %, T1 – 4 %, T2 – 2 %. It was also reported that gold medallist from Olympic Games (cycling) (Schumacker & and Muller 2002), marathoners (international level) (Billat et al. 2001) and rowers (Steinacker 1993; Steinacker et al. 1998) split the training zones into 3 parts: "75 % - 5 % - 20 %". From the total annual training volume (75 %) is intensity where the lactate values are below 2 $mmol.l^{-1}$ – zone 1.5 % of total training volume consists of intensity where the lactate values are between 2 – 4 $mmol.l^{-1}$ – zone 2. However, 20 % of total volume consists of intensity where the lactate values are higher than 4 $mmol.l^{-1}$ – zone 3. Also, the authors Seiler and Kjerland (2004) report similar distribution of each zone (75 ± 3 % - zone 1; 8 ± 3 % - zone 2; 17 ± 4 % - zone 3). They consider that this distribution is one of the most optimal for top endurance athletes.

Intraindividual comparison showed us that some athletes achieved higher time ratio spent in zone T1 and T2 of total volume than the average of all group. Therefore, we recommend decreasing volume in zone T1 and T2 in favour of A1 and A2 causing an increase in the level of AeT and AT during preparation phase. Preparation phase is an important part of the annual training cycle, which is the basis for the further increasing performance. The athlete P.M. we recorded the highest total training volume the similar composition of the training zones as the diameter of all group, except that overall volume was higher about 27 % compared to the average of all group. Thus, we think that this significant difference contributes to higher values of functional parameters during the spiroergometric examination compared to the average of the group. Further research should focus to find the relationship between total training volume and functional parameters, as well as examine the relationship between different training methods and the results of functional parameters. This might help to solve the problem of stagnation of our cross-country skiers.

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