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INTERVAL TRAINING WITH ACTIVE RECOVERY AND THE PHYSICAL CAPACITY OF RECREATIONAL MALE RUNNERS

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Abstract
Introduction. So far there have been few studies on the effect of interval training with active recovery aimed at increasing aerobic power on the physical capacity of long-distance runners. Unlike standard interval training, this particular type of interval training does not include passive rest periods but combines high-intensity training with low-intensity recovery periods. The aims of the study were to determine the effect of aerobic power training implemented in the form of interval training with active recovery on the physical capacity of amateur long-distance runners as well as to compare their results against those of a group of runners who trained in a traditional manner and only performed continuous training. ***Material and methods.*** The study involved 12 recreational male long-distance runners, who were randomly divided into two groups, consisting of 6 persons each. Control group C performed continuous training 3 times a week (for 90 minutes, with approximately 65-85% VO_2max). Experimental group E participated in one training session similar to the one implemented in group C and additionally performed interval training with active recovery twice a week. The interval training included a 20-minute warm-up and repeated running sprints of maximum intensity lasting 3 minutes (800-1,000 m). Between sprints, there was a 12-minute bout of running with an intensity of approximately 60-70% VO_2max. The time of each repetition was measured, and the first one was treated as a benchmark in a given training unit. If the duration of a subsequent repetition was 5% shorter than that of the initial repetition, the subjects underwent a 15-minute cool-down period. A progressive treadmill test was carried out before and after the 7-week training period. The results were analysed using non-parametric statistical tests. ***Results.*** VO_2max increased significantly both in group E ($p < 0.05$; $d = 0.86$) and C ($p < 0.05$; $d = 0.71$), and there was an improvement in effort economy at submaximal intensity. Although the differences were not significant, a much greater change in the post-exercise concentrations of lactate and H^+ ions was found in group E. ***Conclusions.*** The study showed that interval training with active recovery increased VO_2max in amateur runners with higher initial physical capacity and stimulated adaptation to metabolic acidosis more than continuous training.

Key words: amateur runners, training, continuous method, interval training with active recovery, physical capacity

Introduction

Amateur running is becoming increasingly popular year by year. More and more running events are being organised, and the largest marathons in the world are seeing increasing numbers of participants [1]. Running is a sport discipline that is accessible to persons of all ages and genders. It is only those who are professionally active that may not have enough time for regular and time-consuming training [2].

The most important physiological factors influencing performance in endurance disciplines such as long-distance running include maximum oxygen uptake (VO_2max), work intensity (at anaerobic threshold), and work economy or efficiency [3]. Although the duration of effort during the most popular long-distance races makes it impossible to achieve VO_2max and maintain it during the entire race, this feature still plays a key role in such events. Marathons are run with an average intensity of 75-85% VO_2max; 10,000-m distances are covered at approximately 90% VO_2max; while in 5,000-m races, competitors reach near-maximum values of VO_2max [4, 5]. Work economy (or work efficiency) is associated with lower values of oxygen uptake or heart rate during the performance of effort of a certain intensity (expressed in absolute values of power or velocity) [6, 7]; this means that the energy and physiological costs of the work are lower. Better work efficiency or economy is reflected in a lower percentage of VO_2max required to perform the same work, which can be beneficial in improving endurance [8].

In recent years, many studies have confirmed the effectiveness of HIIT (high-intensity interval training) in long-distance running training [9, 10, 11]. Although previous authors have used many different training protocols, in which the ratio of effort to interval duration was, for instance, 1:1 or 2:1, and work intensity was close to 100% VO_2max, more research is required in the field [12, 13]. It is assumed that in order to improve maximum oxygen uptake, efforts with an intensity (velocity or power) of at least 90% VO_2max achieved in the progressive test should be used [14]. The duration of work in this zone (of a minimum of 90% VO_2max) during a training unit should be as long as possible. Considering the findings of Denadai et al. [15], it is worth noting that in aerobic power training, it is not necessary to use maximum intensity to achieve VO_2max improvement [16, 17]. The time since the beginning of the exercise in which VO_2max is reached is a frequent subject of research, and the results range from 97 s to 299 s [18, 119].

So far there have been few studies on the effect of interval training with active recovery aimed at increasing aerobic power on the physical capacity of long-distance runners. The feature which distinguishes this type of training from the standard interval method is the lack of passive rest intervals; instead, high-intensity efforts are interspersed, either in a planned or spontaneous manner, with moderate-intensity efforts [20]. Performing moderate-intensity efforts (at approximately 70% VO_2max) between maximal repetitions (90-100% VO_2max) makes it possible to achieve VO_2max faster and to maintain it longer than when recovery periods that allow for reaching near-resting values are used [21]. Repetitions performed at an intensity of 90-100% of the velocity achieved at maximum oxygen uptake (VO_2max) lasting for 1-8 minutes have been found to be the most effective in raising VO_2max levels in runners [9, 17]. Interval training with active recovery can therefore be effective in developing the aerobic capacity of long-distance runners, as the absence of passive rest intervals makes it necessary to "repay" the oxygen debt incurred when high-intensity work was being performed during moderate-intensity efforts. It has also been suggested such types of training could be as effective as prolonged and moderately intense exercise [22].

The aims of the study were to determine the effect of aerobic power training carried out in the form of interval training with active recovery on the physical capacity of recreational long-distance runners and to compare their results against those of a group of runners who trained in a traditional way, using only the continuous method.

Material and methods

The study involved 12 male long-distance runners who were all amateurs. All subjects gave written consent to participating in the study and were acquainted with its procedure. The subjects were randomly divided into two groups: experimental group E (n = 6) and control group C (n = 6). The characteristics of the groups are presented in Table 1. The mean values for age, body weight and height, training experience, and life records in the 10-km run and marathon did not differ significantly between the groups.

Exercise testing

Each participant underwent a progressive exercise test twice, before and after the training programme. The tests took place at the Laboratory for Cardiac Stress Testing at the University School of Physical Education in Wroclaw (PN-EN ISO 9001:2001 Certificate).

Progressive test

The progressive exercise test was carried out on a SEGTA7720 treadmill (InSportLine, Czech Republic). The test started with a velocity of 6 km h^{-1}, which was increased by 2 km h^{-1} every 3 minutes. It was carried out to exhaustion or until VO_2max was reached and stabilised despite increases in running speed. The recording of respiratory parameters started 3 minutes before the test and ended 5 minutes after its completion. The subjects breathed through a mask, and expired air was analysed using a Quark b2 device (Cosmed, Italy). The equipment was calibrated using atmospheric air and a gas of the following composition: CO_2 – 5%, O_2 – 16%, and N_2 – 79%. Respiratory parameters were registered breath by breath. Heart rate (HR) was measured using a S810 heart rate monitor (Polar Electro, Finland) compatible with Quark software. Arterialised blood was taken from the fingertip (before the exercise test, that is at rest, and 3 minutes after its completion) in order to determine the following: (a) acid-base balance, using a RapidLab 348 analyser (Bayer, Germany), and (b) lactate concentration (La^-), with LactateScout+ (EKF, Germany).

Training programme

Both groups participated in a 7-week training programme. Group C performed standard continuous training three times a week. The duration of a single training unit was 90 minutes, and work intensity was approximately 65-85% VO_2max. Group E took part in one training session which was the same as that of group C's and additionally performed aerobic power training in the form of interval training with active recovery twice a week. The intervals between training sessions lasted 48 hours. Each training unit was preceded by a 20-minute warm-up. Aerobic power training included a 3-minute maximal exercise bout (the distance covered being 800-1,000 m), followed by a 12-minute period of moderate exercise of an intensity of approximately 60-70% VO_2max. Thus, the ratio of maximal effort duration to moderate effort duration was 1:4. These efforts of different intensities were repeated alternately until the subject was unable to perform work of the highest intensity, that is one whose power (distance covered in 3 minutes) was similar to that of the first 3-minute bout of effort. The initial maximal effort in the training unit was used as a benchmark. During one unit of aerobic power training, participants made 2-4 maximal efforts. All training sessions were carried out on a running track. We meas-

Table 1. Arithmetic means ($\overline{x}$) and standard deviations (SD) for selected physique and performance characteristics before the training programme in the experimental (E) and control (C) groups

Group	Age (years) ± SD	Height (cm) ± SD	Weight (kg) ± SD	Training experience (years) ± SD	10-km life record (min:sec) ± SD	Marathon life record (min:sec) ± SD
E	29.60 ± 5.08	179.40 ± 5.85	70.66 ± 7.04	2.80 ± 1.30	41:05 ± 1:30	217:05 ± 14:38
C	34.14 ± 7.64	179.71 ± 4.06	78.50 ± 8.46	3.20 ± 1.60	44:52 ± 07:19	231:42 ± 40:23

ured the distance covered during each repetition. If the distance travelled during a given bout of maximal exercise was 5% shorter than the distance recorded for the initial bout, the training was finished, and the participant proceeded to a 15-minute cool-down period. The total duration of a training unit was 65-95 minutes. In addition, each of the participants performed aerobic capacity training using the continuous method lasting 90 minutes (continuous running). The runners from both groups participated in all training units.

Statisitics and calculations

Maximum velocity (Vmax) was defined as the highest velocity at the completion of the progressive test. Respiratory parameters recorded during the test were averaged to 30-second segments (per minute). The following parameters were measured: oxygen uptake (VO_2), minute ventilation (VE), tidal volume (VT), and respiratory frequency (Rf). Maximum oxygen uptake (VO_2max) and maximum minute ventilation (VEmax) were identified as the highest values of VO_2 and VE, respectively, obtained for averaged 30-second segments of the test. The time from reaching VO_2max to volitional exhaustion was measured. The relative values of VO_2 and HR were also calculated, and the values of these parameters obtained at the speeds of 6, 10, and 14 km h^{-1} were compared against the maximum values achieved during the progressive test. Hydrogen ion (H^+) concentration was measured by means of a pH scale.

The data were analysed statistically using Statistica 13 (StatSoft, USA). The arithmetic mean ($\bar{x}$) and the standard deviation (SD) were calculated for each variable. We used the Shapiro-Wilk test to assess normality of distribution for the parameters examined. The non-parametric Wilcoxon signed-rank test was applied in evaluating the significance of differences caused by the training, while the differences between groups were assessed using the Mann-Whitney U test. Statistical significance was set at $p < 0.05$. Effect size (ES), that is Cohen's *d*, was calculated in order to explore the practical effect, using the following criteria: 0.1 – trivial, 0.2 – small, 0.5 – medium, and 0.8 – large.

Results

When the results of the progressive tests before and after the experiment were compared, higher values of the following parameters were observed in both groups: Vmax, Tmax, VEmax, VTmax, HRmax, and tVO_2max. The changes in VEmax in group C (d = 1.59) and VTmax in group E (d = 0.53) were nearly statistically significant. VO_2max increased statistically significantly both in group E ($p < 0.05$; d = 0.86) and C ($p < 0.05$; d = 0.71) (Tab. 2).

There was a statistically insignificant increase in the post-exercise values of La^- and H^+ in the blood in both groups. A significantly greater change in post-exercise lactate concentration was found in group E (close to statistical significance, d = 1.11) (Tab. 2).

Table 2. Arithmetic means ($\bar{x}$) and standard deviations (SD) for selected variables in the progressive test before and after the training programme in the experimental (E) and control (C) groups

Variable		Group E				Group C			
		Pre-training	Post-training	Δ(%)	ES	Pre-training	Post-training	Δ(%)	ES
Vmax (km h^{-1})	$\bar{x}$ SD	18.67 ± 1.03	19.00 ± 1.10	1.77	0.31	17.00 ± 2.10	17.33 ± 2.07	1.94	0.16
Tmax (min:sec)	$\bar{x}$ SD	19:36 ± 1:19	20:12 ± 1:04	3.06	0.50	18:25 ± 2:34	18:47 ± 2:29	1.99	0.14
VEmax (L min^{-1})	$\bar{x}$ SD	141.08 ± 5.34	147.40 ± 10.12	4.48	0.82	142.63 ± 8.52	156.19 ± 8.52	9.51	1.59
VTmax (L)	$\bar{x}$ SD	2.79 ± 0.34	2.94 ± 0.23	5.38	0.53	2.70 ± 0.37	2.80 ± 0.40	3.70	0.26
Rfmax (breaths min^{-1})	$\bar{x}$ SD	55.68 ± 4.70	54.32 ± 5.04	2.40	0.28	59.99 ± 11.98	63.83 ± 12.27	6.40	0.32
VO_2max (mL $kg^{-1} \cdot min^{-1}$)	$\bar{x}$ SD	52.69 ± 5.29	56.38* ± 3.33	7.00	0.86	46.57 ± 4.68	50.86* ± 4.62	9.21	0.71
tVO_2max (s)	$\bar{x}$ SD	66.01 ± 49.30	72.13 ± 58.48	9.27	0.11	25.71 ± 26.99	34.29 ± 36.45	33.37	0.23
HRmax (bpm)	$\bar{x}$ SD	185.00 ± 12.41	187.00 ± 12.88	1.08	0.16	182.43 ± 7.61	183.30 ± 4.83	0.48	0.14
La^- (mmol L^{-1})	$\bar{x}$ SD	11.32 ± 0.80	14.24 ± 4.47	25.79	1.11	11.03 ± 3.80	12.06 ± 2.62	9.34	0.32
H^+ (mmol L^{-1})	$\bar{x}$ SD	59.31 ± 10.45	63.40 ± 3.92	6.90	0.57	54.93 ± 14.21	55.84 ± 7.56	1.66	0.08

Vmax – maximum velocity; Tmax – test time; VEmax – maximum minute ventilation; Rfmax – maximum respiratory frequency; VTmax – maximum respiratory volume; VO_2max – maximum oxygen uptake; tVO_2max – VO_2max plateau time; HRmax – maximum heart rate; La^- – post-exercise lactate concentration; H^+ – post-exercise hydrogen ion concentration; Δ(%) – average percentage change in variable caused by training; ES – effect size (Cohen's *d*); * – statistically significant change ($p < 0.05$).

Table 3. Changes in relative values of HR (%HRmax) and VO_2 (%VO_2max) in relation to the maximum values recorded before and after the training programme for selected velocities in the experimental (E) and control (C) groups

Variable	V (km h^{-1})	Group E				Group C			
		Pre-training	Post-training	Δ(%)	ES	Pre-training	Post-training	Δ(%)	ES
%HRmax (%)	6	59.10 ± 6.82	60.10 ± 7.50	1.69	0.14	61.79 ± 6.75	61.53 ± 5.19	0.42	0.04
	10	79.69 ± 3.05	79.78 ± 3.97	0.11	0.03	78.04 ± 8.93	76.20 ± 6.24	2.36	0.24
	14	92.02 ± 1.95	91.53 ± 0.74	0.53	0.36	92.10 ± 6.75	91.39 ± 5.29	0.77	0.12
%VO_2max (%)	6	38.12 ± 6.89	35.48* ± 5.70	6.92	0.42	47.14 ± 10.53	43.01 ± 7.24	8.76	0.46
	10	69.77 ± 4.89	63.40 ± 3.74	9.13	1.48	70.17 ± 7.65	66.75* ± 7.77	4.87	0.44
	14	86.16 ± 4.35	82.25 ± 3.88	4.54	0.95	89.95 ± 6.33	82.65 ± 10.05	8.12	0.89

ES – effect size (Cohen's *d*); * – statistically significant change ($p < 0.05$).

We observed a change in the relative values of individual parameters at submaximal velocities in the progressive test before and after the experiment as a result of training (Tab. 3). The values of %VO_2max decreased in both groups at each of the velocities analysed. The changes were statistically significant in group E for 6 km h^{-1} (d = 0.42) and in group C for 10 km h^{-1} (d = 0.44). Lower %VO_2max in group E compared to group C occurred during exercise at the velocity of 6 km·h^{-1} (pre- and post-training) as well as 10 km h^{-1} (post-training) and 14 km h^{-1} (pre-training). The %HRmax changes caused by the training were not statistically significant in any of the groups.

Post-exercise changes in selected variables expressed in the values of these variables and as percentage differences, that is Δ(%), did not differ significantly between groups (Tab. 2., Tab. 3).

Discussion

The results of the current study suggest that aerobic power training in the form of interval training with active recovery leads to an increase in maximum oxygen uptake in amateur runners, which is consistent with the findings of other studies [23, 24]. VEmax was found to have increased significantly in both groups examined in the current study, but it was in the experimental group that we observed an increase in respiratory volume (close to statistical significance) with no increase in respiratory frequency. This may be related to improved respiratory muscle fitness and may affect VO_2max changes due to redistribution of blood (oxygen) to the lower limb muscles performing the work [25]. Helgerud et al. [23] studied moderately trained amateur runners who were randomly assigned to three groups and performed the following types of training for 8 weeks: (1) long-term continuous training (70% HRmax), (2) continuous training at the anaerobic threshold (85% HRmax), and (3) aerobic power training in the form of interval training with active recovery (4 x 4 minutes of running at an intensity of 90-95% HRmax followed by 3-minute lower intensity exercise at 70% HRmax). Only the latter training programme caused a statistically significant increase in VO_2max compared to the programme where participants trained solely with a lower-intensity continuous training method. Long-term aerobic capacity training does not cause further improvement in VO_2max [26]. It has been suggested that physical capacity can be developed with the use of intense interval training [11, 13]. This is confirmed by the results of our research, which found an increase in this parameter in both groups (E and C), although group E was characterised by a much higher (initial) level of VO_2max before the experiment in comparison with group C as well as by better results for the time of the progressive test and the maximum velocity achieved. Thus, our study evidenced the effectiveness of aerobic power training in better trained runners (large effect size value, d = 0.86).

In many studies, HIIT training was based on 3- to 5-minute bouts of exercise; however, the interval between repetitions was only 3-4 minutes long [12, 23, 27]. The time and intensity of lower-intensity work periods are of great importance when planning aerobic power interval training with active recovery [27, 28]. Both variables must be selected in such a way as to maximise work volume during consecutive higher-intensity repetitions by increasing blood flow; this makes it possible to accelerate phosphocreatine (PCr) resynthesis, lactate (La^-) transport and oxidation, hydrogen ion (H^+) buffering, as well as potassium ion (K^+) transport. In addition, this training requires maintaining an adequate level of VO_2 so that the time needed to reach VO_2max in subsequent repetitions is shortened [12, 22, 29]. According to Mavrommataki et al. [27], in aerobic power training, the rest interval should be at least twice as long as the high-intensity repetition time. In the current study, a 12-minute active recovery period was used with a view to meeting these requirements. One of the main reasons why moderate-intensity effort was performed between exercise repetitions was to accelerate the process of gluconeogenesis [30]. Research shows that passive rest intervals can be used in aerobic power training with repetitions of up to 2-3 minutes [22, 30]. In repetitions lasting 3-5 minutes, it is suggested that moderate exercise should be performed during recovery periods so as to make it possible to maintain high intensity during subsequent repetitions [28, 31].

In a study by Seiler and Hetlelid [32], after aerobic power exercise lasting 4 minutes, lactate concentration was approximately 5-10 mmol L^{-1}. However, the study was carried out in a group of runners with high aerobic capacity (VO_2max ~ 72 mL kg^{-1} min^{-1}). Buchheit and Laursen [12] report that after HIIT exercise, significantly higher lactate concentrations (>12 mmol L^{-1}), which stimulated the enhancement of glycolytic capacity, were recorded. In the current experimental group, as a result of the training, lactate concentration after the progressive test reached a much higher value, by almost 26% ($d = 1.11$; $p = 0.06$); a likely reason why the differences were not statistically significant is the size of the group. Higher values of maximum concentrations of lactate and hydrogen ions after the progressive test indicate an improvement in adaptation to metabolic acidosis in the group that performed interval training with active recovery. This is confirmed by the results of Kohn et al.'s study [33], in which the activity of lactate dehydrogenase (LDH) in type IIa muscle fibres increased after the implementation of HIIT in well-trained runners. This was due to the high velocities achieved during training units, which was confirmed by the significant correlation found in their study ($r = 0.65$, $p < 0.05$). In addition, group E in the current study had more than double the VO_2max plateau time. According to Gordon et al. [34], a longer duration of this phase indicates a higher level of anaerobic capacity. This is extremely important in the context of competitive running with regard to the need to increase running intensity during uphill sections, escapes, or the finish.

Another interesting aspect related to the results of this study is the statistically significant decrease in relative oxygen uptake in group E at a velocity of 6 km h^{-1} (it was close to statistical significance for 10 and 14 km h^{-1}). Such a change indicates an increase in running economy and a greater functional reserve of the body. Improved work economy can be observed for the intensity of work which is used most often during training. Hence, it can be assumed that interval training with active recovery creates additional opportunities for the improvement of work economy, both with moderate and near-maximal work intensity. Using only aerobic capacity training does not have a positive effect on work economy [35]. This suggests the need to include high-intensity efforts in the training process. Moreover, in the control group, %VO_2max changed significantly only for the velocity of 10 km h^{-1}. The results of the current study are consistent with the findings of the research by Helgerud et al. [23] cited above, where running economy improved in all groups, though no significant differences were found between groups. Further research is needed regarding this issue.

The current study has several limitations due to, among others, the low number of participants in the groups and different (although statistically insignificant) baseline levels of the physical capacity parameters of the groups. This was due to the random division into groups which was applied. It may be necessary to use a different division, for example, considering VO_2max or Vmax values, in order to make the groups that are compared more homogeneous in future research. Nevertheless, the study has yielded interesting findings, and such research is worth continuing. For example, it seems necessary to compare HIIT training in which 3- to 4-minute intervals are used with the current method with longer intervals between repetitions of high intensity.

Conclusions

The study showed that interval training with active recovery increased VO_2max in amateur runners with higher initial physical capacity and better fostered adaptation to metabolic acidosis than continuous training. This training can be an effective alternative and way of diversifying the often monotonous long-lasting work performed using the continuous method.

Literature

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