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Changes in power output under the influence of high-intensity training

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The purpose of this research was to study the effect of high-intensity training programme carried out with a cycle ergometer and in the form of run intervals on physical fitness as measured in a running test and on power output measured in Wingate test. The study was carried out on 24 subjects divided into two groups: group GC (12 persons) did the high-intensity training on a cycle ergometer; group GR (12 persons) did the training in the form of running. The training lasted 8 weeks, 5 times a week in both groups. Running test consisted of a series of four 50 m sprints (25 m + 25 m back) at 15-second intervals. The training improved alactic anaerobic output (the phase of power increase and maintenance phase (IMP) in the Wingate test) by 20.3% W_{IMP} and 9.1% P_{aIMP} in the GC group and by 15.2% W_{IMP} and 11.5% P_{aIMP} in the GR group, and lactic anaerobic output (the phase of power decrease (DP)) by 9.1% W_{DP} and 12.4% P_{aDP} for group GC and by 12.8% W_{DP} and 10.8% P_{aDP} for group GR. In both groups, a significant improvement in time required to cover the distance in the series of four runs was noted (significantly larger in the group GR than in the group GC). The changes in running times, in terms of percentages, differed significantly between the groups. However, the groups did not differ in terms of their Wingate test results.

Key words: cycle ergometer, high-intensity training, power output, run, the Wingate test

1. Introduction

Changes in muscles under the influence of training depend on the type of training and its structure (ABERNETHY et al. [1]). Speed training causes an increase in the activity of anaerobic enzymes (COSTILL et al. [8], LINOSSIER et al. [14], ROBERTS et al. [20]) and an increase in energy-bearing substrates in muscles (CADEFAU et al. [6], ROBERTS et al. [20], THORSTENSSON et al. [26]). The metabolic mechanism explaining the increase in maximal power during short, maximal exercise is not fully understood (LINOSSIER et al. [14]). According to HIRVONEN et al. [11], intense exercises lasting several seconds mainly depend on anaerobic metabolic processes. In studies by REHUNEN et al. [19], THORSTENSSON et al. [26], sprint training did not cause any changes in the resting levels of high-energy phosphates (adenosine triphosphate (ATP) and phosphocreatine (PCr)) in muscles. Several studies found that maximal power can increase, while the amount of anaerobic energy used remained the same (THORSTENSSON et al. [26]). BOGDANIS et al. [5], [6], TRUMP et al. [28] demonstrated that in high-intensity intermittent exercise, advantage is taken of aerobic metabolism during the rest cycle to resynthesize depleted stores of PCr and to remove lactic acid accumulated during the exercise (TOMLIN and WENGER [27]). According to LINOSSIER et al. [14], exercises lasting less than 10 s are better for developing anaerobic capacity than longer exercises lasting e.g. 30 s, during which power diminishes significantly in the final phase of the exercise. In the studies by LINOSSIER et al. [14], SIMONEAU et al. [23], [24], STATHIS et al. [25], sprint training on a cycle ergometer caused an increase in maximal power and amount of work performed in the Wingate test and in 10-second and 90-second maximal exercises. Opposite data presented JACOBS et al. [13], ESBJÖRNSSON et al. [9], ESBJÖRNSSON LILJEDAHL et al. [10], and RODAS et al. [21]. They did not find significant changes in maximal power and amount of work performed in the Wingate test and in the 10-second and 90-second maximal exercises following sprint training on a cycle ergometer. In the literature, there is a lack of studies describing the effect of balanced sprinter training conducted in running form and with a cycle ergometer on the changes in anaerobic power.

The purpose of this investigation was to study the effect of an eight-week high-intensity training programme performed on a cycle ergometer and in the form of interval running on physical fitness as measured in a running test and on power output measured in the Wingate test.

2. Materials and methods

The study was conducted on 24 non-training third-year intramural students (major: physical education) of the Physical Education Academy of Warsaw. The subjects were divided into two groups of 12 persons, each realizing training programmes with identical load structures but different forms of exercise: group GC – training on a cycle ergometer and group GR – run training in a gym. The subjects had the following physical characteristics (mean ± standard deviation): group GC – age, 22.5 ± 1.4 years; height, 180.0 ± 4.9 cm; body mass, 73.8 ± 6.9 kg; group GR – age, 22.3 ± 1.2 years; height, 178.1 ± 8.1 cm; body mass, 78.6 ± 8.3 kg. In terms of anthropometric characteristics, the groups did not differ significantly.

The study was approved by the Senate Commission on Scientific Research of the Physical Education Academy of Warsaw. The participants were informed of the purpose of the research and its methodology, and given the option to withdraw from the experiment at any phase. The subjects expressed their written consent to participate in the experiment.

2.1. Methods for measuring the power output (the Wingate test)

The Wingate test was used after a standard 5-minute warm-up on a cycle ergometer and 5 minutes of rest. The test consisted in performing a maximal 30-second exercise using an individually selected weight resistance amounting to 7.5% of body weight (BAR-Or [3]). For the study, a Monark 824 E (Sweden) cycle ergometer was used. It was hooked up to an IBM class PC Pentium computer running on the program MCE v. 4.0 (JBA, Zb. Staniak, Poland). Sensors were affixed to a flywheel. The flywheel's external surface covered a distance of 6 m about an axis. The subjects, after selecting an appropriate height for the seat and handlebars, performed the test in a sitting position without standing on the pedals, commencing pedalling from a motionless position. Their feet were strapped to the pedals. The subjects were energetically encouraged to attain the highest possible pedalling velocity and to maintain it to the end of the test. The following measurements and calculations were made: average power (P_a), maximal power (P_{max}) and amount of work performed (W). The progression of power as a function of time was divided into three phases:

1. The phase of power increase (IP), where: $0 \leq IP \leq 0.997\ P_{peak}$.
2. The phase of maximal power maintenance (MP), where: $P_{peak} - 0.023\ P_{peak} \leq MP \leq P_{peak}$.
3. The phase of power decline (DP) – from the instant maximal power falls below P_{max} to the power reading at the instant of the completion of the test.

2.2. Run test

The run test was performed after a standard 5-minute warm-up (running and gymnastics) and a 5-minute rest. The test consisted of a series of 4 maximal sprints covering a distance of 50 m (25 m + 25 m back) in 15-second intervals. The subjects started from a standing position. The subjects were told to attain the fastest possible time in every run. During the interval breaks they rested passively. The run times were measured with a stopwatch. The average times of successive sprints in the series were analysed.

2.3. Protocol of the experiment

Prior to the start of the experiment, the subjects were familiarised with all the measurements.

The subjects in both groups realized a high-intensity 8-week training programme consisted of 5 training sessions per week (from Monday to Friday). The structure of the training was as follows: group GR – run training consisting of running a distance of 50 m (25 m + 25 m back) as quickly as possible. Monday, Wednesday and Friday – series of 3 sprints of 50 m (25 m + 25 m back) at 45-second intervals; Tuesday and Thursday – series of 6 sprints at 45-second intervals. The sprint training was conducted on a standard team handball court covered with painted wooden boards. The subjects in group GC did training that consisted of maximal sprints on a cycle ergometer (17 pedal revolutions, which was the equivalent of 76.28 J/kg of an average work done; the time required to do 17 pedal revolutions was comparable to the time required to sprint a distance of 50 m). Monday, Wednesday and Friday – a series of 3 maximal efforts of 17 pedal revolutions each at 45-second intervals; Tuesday and Thursday – a series 6 maximal efforts at 45-second intervals. The equipment used in this training was a MONARK 824E (Sweden) cycle ergometer connected to a computer running the program MCE v. 4.0 (JBA, Zb. Staniak, Poland), which made it possible to set, control and register the weight resistance variants used. Weight resistance on the cycle ergometer was selected individually (7.5% of body weight).

The subjects in both groups started each training session after warming up for 5 minutes. All the training sessions were supervised by personnel. The following parameters were continually registered: the amount of work done (number of pedal revolutions), power developed, time of work and intervals (breaks) in the GC group as well as the distance covered and time of intervals (breaks) in the GR group.

On every Saturday at the end of each week (1–8), starting prior to the beginning of the experiment (0), control measurements were taken: the Wingate test and a run test based on performing a series of four 50-m sprints (25 m + 25 m back) at 15-second intervals. The tests were staggered 3 hours and conducted in the order cited above.

ANOVA variance analysis in a system with repeating measures was used to compare the research results. The significance of differences between averages was estimated post hoc using the Tukey test, assuming the level of significance $p < 0.05$ as significant. All calculations were done using the STATISTICA™ program (v. 5.5, Stat Soft, USA).

3. Results

3.1. Wingate test

The duration of the power increase and maintenance phases and the power decline phase did not change significantly under the influence of training in either group.

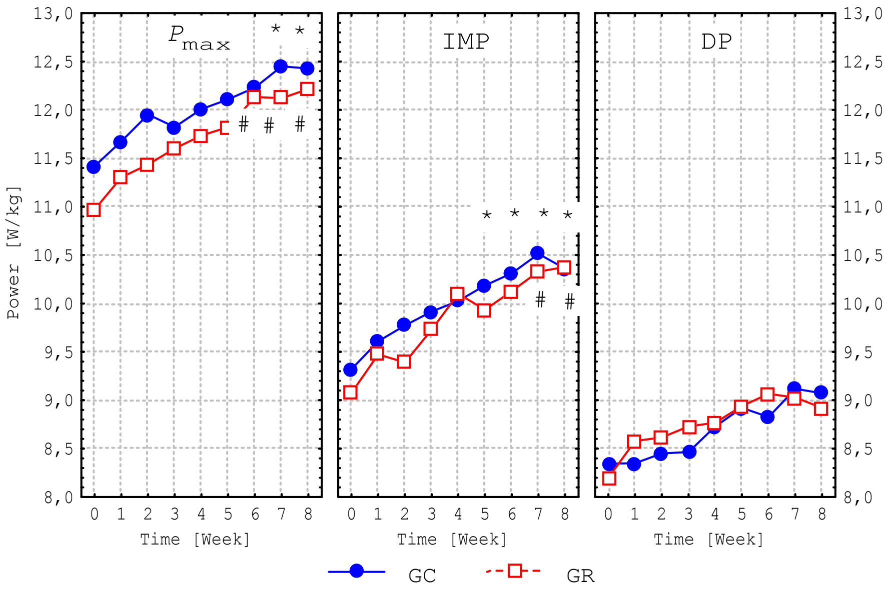

Fig. 1. Average values of maximal power (P_{max}) and power developed during the increase and maintenance phases (IMP) and decline phase (DP) in the Wingate test. The significance of average differences in relation to the values recorded prior to the start of the training programme (0) and successive measurements during 8-week training programme (1–8) for the group GC (training on a cycle ergometer, *) and for the group GR (run training, #) was also given

Maximal power increased significantly, from 11.42 ± 0.68 to 12.43 ± 0.90 W/kg (9.1%) in group GC and from 10.97 ± 0.99 to 12.25 ± 0.72 W/kg (12.1%) in group GR, after 8 weeks of training (figure 1). The subjects in both groups done significantly more work (group GC – increase from 256.77 ± 20.21 to 281.8 ± 19.78 J/kg; and group GR – from 252.35 ± 20.31 to 278.74 ± 19.43 J/kg) after 8 weeks of training (figure 2).

Power developed by the subjects in the power increase + maintenance phases (IMP) and in the power decline phase (DP) increased significantly – respectively, from 9.32 ± 0.69 to 10.36 ± 0.72 W/kg and from 8.35 ± 0.71 to 9.07 ± 0.72 W/kg in the group GC, and from 9.08 ± 0.82 to10.38 ± 0.75 W/kg and from 8.20 ± 0.66 to 8.92 ± 0.62 W/kg in the group GR – after 8 weeks of training.

The greatest amount of work was done by the subjects on the cycle ergometer after 6 weeks of training in the IMP (a significant increase from 65.16 ± 13.93 to 77.29 ± 13.93 J/kg), and after 7 weeks of training in the DP (from 191.61 ± 16.95 to 208.26 ± 11.54 J/kg). The subjects who did the run training did the greatest amount of work in the IMP after 8 weeks of training (a significant increase from 68.63 ± 11.57 to 77.97 ± 11.74 J/kg), and in the DP after 6 weeks of training (a significant increase from 183.71 ± 14.36 to 206.57 ± 14.72 J/kg).

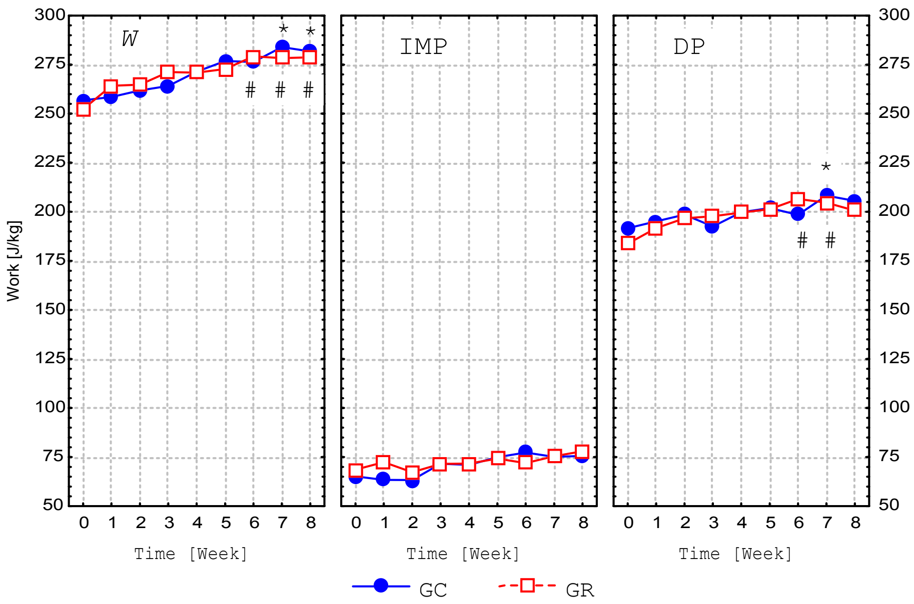

Fig. 2. Average values of total work (*W*) and work done in the power increase and maintenance phases (IMP) and decline phase (DP) in the Wingate test. The significance of average differences in relation to the values recorded prior to the start of the training programme (0) and successive measurements during 8-week training programme (1–8) for the group GC (training on a cycle ergometer, *) and for the group GR (run training, #) was also given

No significant differences between groups were observed in the case of any of the values being analysed.

3.2. Run test

The time it took to run 50 m, the first (25 m + 25 m back) in the series of 4 sprints, was significantly shortened (from 8.47 ± 0.26 to 8.25 ± 0.25 s after 8 weeks of training on the cycle ergometer and from 8.49 ± 0.19 to 8.33 ± 0.21 s after 6 weeks of run training). Significant differences between groups were observed after 8 weeks of training in terms of running time expressed in percentages (figure 3).

The time of the second run was significantly limited in group GC (from 8.92 ± 0.23 to 8.56 ± 0.23 s after 8 weeks of training) and in group GR (from 9.33 ± 0.40 to 8.64 ± 0.18 s after 5 weeks of training). Significant differences between groups were observed with respect to the run time before and after one week. In both groups, the changes in run time expressed in percentages were significantly different in every week of training.

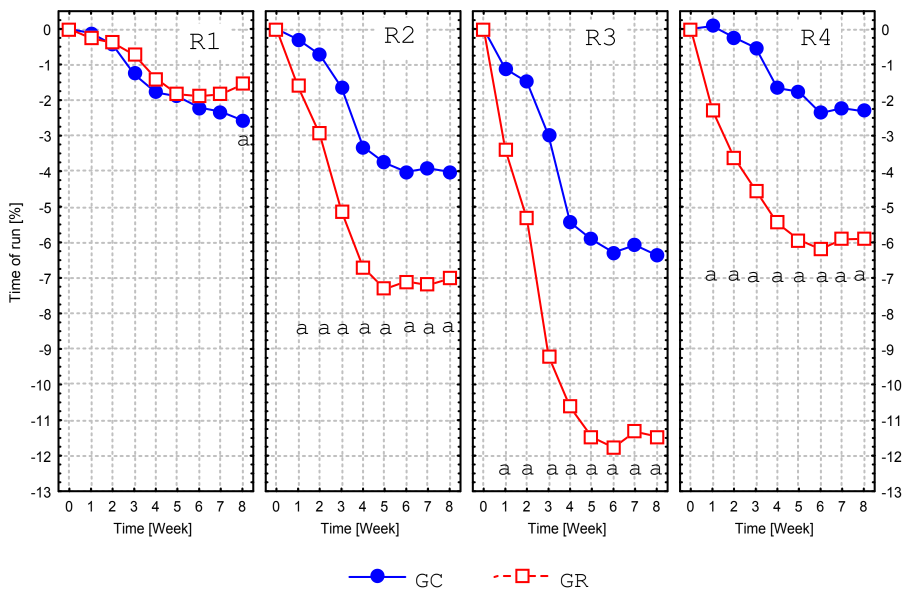

Fig. 3. Average values of changes [%] in time of the 4 consecutive runs (R1–R4) in the series covering a distance of 50 m (25 m + 25 m back) in relation to the values recorded prior to the start of the training programme (0) and successive measurements during 8-week training programme (1–8). The significance of average differences between group GC (training on a cycle ergometer) and group GR (run training) was given by "a"

The time of the 3rd run was significantly shortened (from 9.84 ± 0.30 to 9.22 ± 0.30 s after 6 weeks of training on the cycle ergometer and from 10.44 ± 0.32 to 9.22 ± 0.33 s after 6 weeks of run training). Significant differences between groups were observed with respect to run time before and after one week of training. In both groups, the changes in run time expressed in percentages were significantly different in every week of training.

The time of the 4th run was entirely shortened (from 10.51 ± 0.26 to 10.26 ± 0.30 s in group GC and from 10.86 ± 0.32 to 10.18 ± 0.45 s in group GR, after 6 weeks of training). Significant differences between groups were observed with respect to the run time before the start of the training programme. In both groups, the changes in run time expressed in percentages were significantly different in every week of training.

Generally, both types of training caused a decrease in run time up to the 6th week of the training programme; thereafter, a stabilisation in results was observed. The first run in the series was considered to be an exception, because in such a case an improvement in results was observed in group GC throughout 8 weeks of training.

6. Discussion

In professional literature on the topic, one encounters divergent results describing the changes in power after various types of sprint training or training using shortly repeated high-intensity exercise. In a study by NEVILL et al. [17], 8-week run sprint training caused a power increase by 12% and an average power increase by 6% in a 30-second run on a motorless treadmill. THORSTENSSON et al. [26] reported significant improvements in isometric strength of the lower limbs, anaerobic power measured by the Margaria test, high jump height and 25-metre run time after an 8-week sprint training programme consisting of 5-second runs on a treadmill. In our study, due to run training, the following significant increases were obtained: 12.1% in maximal power, 10.9% in amount of the work done (measured by the Wingate test). Time in the specific run test (4 × 50 m) declined by –1.9%, –7.3%, –11.8% and –6.1%, respectively. These findings were consistent with those yielded by ROTSTEIN et al. [22], who reported that a 9-week run training programme caused a significant improvement in work and power – 10% and 14%, respectively, as measured by the Wingate test.

ALLEMEIER et al. [2], ESBJÖRNSSON et al. [9], ESBJÖRNSSON, LILJEDAHL et al. [10], JACOBS et al. [13], RODAS et al. [21] found that sprint training conducted on cycle ergometer did not cause any changes in power. In a study by PARRA et al. [18], the subjects gathered in two groups did similar training consisting of 14 training sessions. The first group trained without breaks, day after day for two weeks; the second group had two days' rest after each training session. Each group trained for a total of 6 weeks. Peak power and average power in the 30-s test increased by 20% and 14%, respectively, in the group training every third day; these two values did not change significantly in the group that trained every day. Participants of an experiment conducted by LINOSSIER et al. [14], after performing sprint training on a cycle ergometer for 7 weeks, increased their maximal power in the Wingate test by 26% and the work done by 16%. Analysing the changes in power in 2-second intervals, they found a significant change in power up to 18 seconds compared to test results prior to the start of sprint training. In a study by STATHIS et al. [25], a 16.8% improvement in maximal power and an 11.8% increase in an average power were observed in the Wingate test after 7 weeks of training. The progression in power calculated at 5-second intervals changed significantly in the first 25 seconds of the test compared to the power generated by the subjects prior to the training, with the largest changes occurring in the first 10 seconds of the test.

In our study, high-intensity training on a cycle ergometer caused significant increases, i.e. by 9.1% for maximal power and by 10.8% for amount of work done in the Wingate test. Time in the series of sprints (1–4) decreased by –2.6%, –4.0%, –5.9% and –2.4%, respectively. These changes in power and work (expressed in percentages) are similar to the results obtained by the authors cited above.

In the Wingate test, the energy expended comes from anaerobic and aerobic sources (BAR-OR [3]). In the opinions of BAR-OR [3], CALBET et al. [7] and MEDBØ

and TABATA [16], from 13% to 40% of total energy produced during the Wingate test comes from aerobic sources. JACOBS et al. [12] found that the greatest power developed in the Wingate test in the course of 5 seconds is generated from intramuscular sources of phosphates (alactic component), and the average power represents anaerobic output which primarily depends on glycolysis (lactic component). In a study carried out by SIMONEAU et al. [23], anaerobic alactic capacity was defined as the amount of work done in a 10-second test, and anaerobic lactic capacity as the amount of work done in a 90-second test on a Monark ergometer. The sprint training on
a cycle ergometer used in the study of SIMONEAU et al. [23] caused a significant increase in the work done (26%) in the 10-second test and in the 90-second test (33%). BOGDANIS et al. [4] reported that an average power observed in the Wingate test in the first 10 seconds of the exercise was $P_{a10} = 920$ W, and in the last 20 seconds, $P_{a20} = 600$ W. The average power generated in the test reached the value of 707 ± 25 W. The ratio of P_{a10} to P_{a20} was 1.53.

In our study, the sum of the work done in the power increase and maintenance stages ranged from 25.4% to 28.8% in group GC, and from 27.2% to 28.0% in group GR. In a study carried out by BOGDANIS et al. [4], the subjects developed 45% of work during the first 10 seconds of exercise in the Wingate test. In our research, the ratio of power developed in the increase + maintenance phases to the power developed in the decline phase in the Wingate test approached 1.1 in both groups. The division into phases applied in this study does not closely resemble the division used by SIMONEAU et al. [23], [24] and BOGDANIS et al. [4], who assumed a 10-second period for alactic anaerobic output and 30-second or longer (90 second) period for lactic anaerobic output. In our study, the duration of the power increase + maintenance phases ranged from 7.0 seconds to 7.48 seconds in group GC, and from 7.16 seconds to 7.67 seconds in group GR, thus, this phase is shorter than 10 seconds. We can therefore assume that the amount of work done in the power increase and maintenance phases (IMP) corresponds to anaerobic alactic capacity, and in the power decline phase, to lactic anaerobic capacity. Hence, both the training régimes tested improved alactic anaerobic output (power increase + maintenance phases) by 20.3% of W_{IMP} and 9.1% of P_{aIMP} in group GC, and by 15.2% of W_{IMP} and 11.5% of P_{aIMP} in group GR; and lactic anaerobic output (power decline phase) by 9.1% of W_{DP} and 12.4% of P_{aDP} in group GC, and by 12.8 % W_{DP} and 10.8 % P_{aDP} in group GR. The results of the run test also testify to an improvement in anaerobic output with larger changes generated by run training than by cycle ergometer training. These findings are consistent with the opinion of LINOSSIER et al. [15], who report that sprint training on a cycle ergometer causes a large increase in maximal power, mainly due to an increase in strength. However, the ability to develop speed in sprint training appears to be difficult to interpret in a clear-cut manner and could be connected with the transformation of ST and FTb fibres into FTa fibres.

To sum up, the run training caused a greater improvement in the power measured in the Wingate test and a greater improvement in time in the series of 4 runs compared to the training done on a cycle ergometer. In the case of the Wingate test, the differences between both groups were not statistically significant. The greatest changes in the Wingate test were noted after 7–8 weeks of training, and in the run test, after 5–6 weeks of training. The training done on the cycle ergometer contributed more to improved alactic anaerobic output; the run done contributed to both alactic and lactic anaerobic outputs. Significant differences between the groups were observed only with respect to changes in times (expressed in percentages) for particular runs.

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