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ORIGINAL ARTICLE

Effect of interval training in the competitive period on anaerobic capacity in judo athletes

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Summary

Background. The aim of the study was to evaluate the effect of interval training on cycle ergometer on relative values of mechanical work (J/kg), peak power (W/kg) and time of work (s) at the level of 97.5% of peak power during 6 repetitions of exercise on cycle ergometer.

Material and methods. Ten judo athletes randomly divided into two groups performed 5-week training programs. Before each judo training session, the experimental group (n=5) performed an additional training session on cycle ergometer in the form of six 10-second maximum efforts divided with periods of passive rest (45s each). The control group (n=5) performed a standard judo training typical of the competitive period.

Results. Comparison of the results obtained for the experimental and control groups at the end of the competitive period demonstrated that mean mechanical work (J/kg), peak power (W/kg) and time of work (s) at the level of 97.5% of peak power in each of six test efforts in the group that performed additional exercise on cycle ergometer were significantly higher than in the control group that participated in a standard judo training program.

Conclusions. Regular interval training sessions on cycle ergometer during the competitive period in judo is effective in maintaining high level of anaerobic capacity over a longer period of time.

Introduction

Competitive load in many sports requires comprehensive engagement of all energy systems that help human body work under conditions of long-term and intensive physical exercise. These requirements also concern judo athletes since a judo bout involves repeated exercise at high intensity and with variable duration, with energy costs covered mainly from anaerobic energy systems used during contraction of skeletal muscles [1,2,3]. The specific nature of competitive exercise performed during a 5-minute judo bout causes that muscle glycogen is the major energy substrate while contribution of anaerobic processes is similar to 70% of the entire energy demand in a human body [4]. Judo athletes at the highest level of sports skill are characterized by high level of anaerobic capacity [5], ability to work effectively under conditions of decompensated metabolic acidosis and ability of fast removal of acid metabolites during short periods of rest typical of a judo bout. According to Sikorski et al. [7,8], mean post-exercise blood levels of lactic acid measured after judo bouts during international and national-level tournaments were 13.7 mmol/l, ranging from 8 to 20 mol/l. Maintaining a high level of anaerobic capacity is essential in judo training in the competitive period since it determines the effectiveness of a series of actions that are taken during a bout. Few reports in the literature have attempted to analyse interval training performed under real conditions of training by athletes at high sports skill level.

Study aim: to determine the effect of interval training on cycle ergometer on relative values of mechanical work (J/kg), peak power (W/kg) and time of work (s) at the level of 97% of peak power during 6 repetitions of test exercise on cycle ergometer.

Material and methods

Participants: Ten judo athletes at high sports skill level (7 class I athletes, 3 champion class athletes). The participants were randomly divided into two groups, 5 athletes in each group. Before each judo training session, the first group (experimental) performed an additional interval training program at maximum intensity on a cycle ergometer. The second group (controls) performed only a standard judo training.

The experimental group: mean age 23.4±0.7 years, mean body height 182.2±2.4 cm, mean body mass 84.20±4.1 kg. The control group: mean age 22.7±1.1 years, mean body height

180.8±4.0 cm, mean body mass 86.2±3.9 kg. The groups did not differ statistically in terms of age and anthropometric characteristics.

Twenty five standard judo training sessions were performed during 5 weeks of the competitive period. For several hours before each judo training session, the experimental group repeated six 10-second maximum exercise bouts on cycle ergometer with periods of passive rests (45 seconds each). During the period of the study, all the athletes from the experimental and control group performed 2 exercise tests on cycle ergometer that consisted in performing six 10-second repetitions of exercise at maximum intensity with periods of passive rest with duration of 45s. The first test was performed at the beginning of the competitive period while the second after 5 weeks of training.

All the tests were conducted using cycle ergometer Monark 824E with on-line connection with a personal computer with MCE v.5.0 software [9]. Sensors were fixed to a flywheel which, during a single rotation with the pedals, covered the distance of 6 m. The load was each time equal 7.5% of body mass. A 5-minute warm-up procedure on cycle ergometer was used before each test, with a 5-minute rest. Relative values of mechanical work (J/kg), peak power (W/kg) and time of work (s) at the level of 97.5% of peak power were recorded during each repetition.

The significance of differences in mean values of the indices that describe anaerobic capacity between groups was evaluated for two periods of the study based on the analysis of variance ANOVA with repeated measurements and the post-hoc LSD test, with level of significance set at $p<0.05$. All the computations were carried out using STATISTICA software (v.5.5.Stat Soft. USA).

Results

The data contained in Table 1 demonstrate that the relative value of mechanical work performed in both periods of the experiment with consecutive repetitions was gradually decreasing, with the lowest values recorded for the last test exercise. No statistically significant differences were found between the experimental and control groups in the first period of study. Analysis of the results obtained in the control group revealed no statistically significant differences between the characteristic analysed in both periods of study. Evaluation of the degree of variation between the results obtained in the experimental group in the periods of the study showed that, after a 5-week training program on cycle ergometer, mean values of mechanical work in each repetition of the test exercise were significantly higher compared to the initial level and statistically significantly higher than the results obtained in the control group.

The data contained in Table 1 show that mean value of peak power developed in consecutive repetitions was declining compared to the first test effort. Analysis of the results

Table 1. Mechanical work (J/kg) for repetitions of test exercise in groups performing different training programs (mean±SD)

Periods of measurements	Group	1st effort	2nd effort	3rd effort	4th effort	5th effort	6th effort
Before training program (1)	A	96.83 ±4.70	93.48 ±3.16	85.90 ±3.42	78.80 ±3.01	70.33 ±3.88	61.17 ±3.93
	B	90.20 ±3.43	89.02 ±4.47	79.84 ±5.25	71.27 ±5.11	67.65 ±4.90	58.84 ±5.15
After 5 weeks of training program (2)	A	106.32 ±5.05*#	104.33 ±3.68*#	99.87 ±2.40*#	92.66 ±1.98*#	90.29 ±2.63*#	82.84 ±3.46*#
	B	93.44 ±4.56	91.46 ±6.02	85.49 ±5.30	79.94 ±7.10	74.18 ±6.82	67.78 ±5.60

Notes: 1,2 - periods of measurement, A - experimental group, B - control group, * - statistically significant difference during a period of measurement ($p<0.01$), # - statistically significant difference between periods of measurement ($p<0.01$).

Table 2 Peak power (W/kg) for repetitions of test exercise in groups performing different training programs (mean±SD)

Periods of measurements	Group	1st effort	2nd effort	3rd effort	4th effort	5th effort	6th effort
Before training program (1)	A	11.26 ±0.41	10.87 ±0.34	10.51 ±0.44	10.06 ±0.69	9.69 ±0.35#	9.35 ±0.37
	B	11.02 ±1.07	10.91 ±0.53	10.40 ±0.50	9.74 ±1.60	9.33 ±0.55	8.57 ±1.31
After 5 weeks of training program (2)	A	12.54 ±0.72*#	12.24 ±0.49*#	11.73 ±0.83*#	11.37 ±0.94*#	10.83 ±5.82*#	10.62 ±0.88*#
	B	11.21 ±0.68	11.22 ±1.41	10.58 ±0.81	10.05 ±0.75	9.48 ±1.22	9.35 ±0.88

Notes: 1,2 - periods of measurement, A - experimental group, B - control group, * - statistically significant difference during a period of measurement ($p<0.01$), # - statistically significant difference between periods of measurement ($p<0.01$).

Table 3. Time of work (s) at the level of 97.5% of peak power for repetitions of test exercise in groups performing different training programs (mean±SD)

Periods of measurements	Group	1st effort	2nd effort	3rd effort	4th effort	5th effort	6th effort
Before training program (1)	A	1.83 ±0.69	1.35 ±0.38	1.25 ±0.55	1.16 ±0.82	1.09 ±0.48	1.04 ±0.45
	B	1.68 ±0.78	1.48 ±0.47	1.43 ±0.34	1.24 ±0.37	1.15 ±0.54	1.05 ±0.60
After 5 weeks of training program (2)	A	2.68 ±0.88*#	2.55 ±0.67*#	2.51 ±1.02*#	2.24 ±0.66*#	2.11 ±0.57*#	1.95 ±0.46*#
	B	1.71 ±0.67	1.43 ±0.54	1.35 ±0.23	1.26 ±0.34	1.30 ±0.62	1.14 ±0.56

Notes: 1,2 - periods of measurement, A - experimental group, B - control group, * - statistically significant difference during a period of measurement ($p<0.01$), # - statistically significant difference between periods of measurement ($p<0.01$).

obtained in the control group revealed no statistically significant differences in the levels of peak power generated in the respective repetitions of test effort. Further, no statistically significant differences were found between the experimental and control groups in the first period of study.

Analysis of the results obtained in the experimental groups revealed that, after 5 weeks of additional training on cycle ergometer, mean values of peak power generated in each repetition of test effort were statistically higher compared to the period of initial measurement.

The data contained in Table 3 show that mean time of work at the level of 97.5% peak power was gradually shortening for consecutive test efforts. Analysis of the results obtained in the control group revealed no statistically significant differences in this index over the whole period of the study. No significant differences were found between the experimental and control groups in the first period of study.

Analysis of the results obtained in the experimental group revealed that, after 5 weeks of additional training, mean values of time of work at the level of 97.5% of peak power were significantly higher compared to the previous period. During the second period of the study, mean values of time of work at the level of 97.5% of peak power in the experimental group were statistically significantly higher in each consecutive test than in the control group.

Discussion

Temporal structure of a judo bout is characterized by short efforts at high intensity with duration of about 25s, divided with short periods of rest, most of which (80%) take about 10s [10]. Studies [11,12] have demonstrated a regular increase in the number of actions and shortening of duration of individual actions for judo bouts recorded during tournaments at the highest level. The repeated sequences of efforts at high power, divided with periods of reduced intensity and sometimes passive rest, cause accumulation of acid metabolites in human body, base excess (BE), reduced blood pH and elevated lactic acid (LA) levels. Short periods of rest during a bout do not allow human body to fully remove acid metabolites and require good adaptation from the athlete in order to maintain high exercise ability over the whole 5-minute bout [4,13]. According to Sikorski [12], the most of judo-specific training measures used for coaching athletes at champion level (with exception of kakarigeiko, sute-geiko and simulated judo bouts) do not cause such profound metabolic response as a judo bout during real competition. The Wingate test is commonly employed to evaluate the level of anaerobic capacity of judo athletes [5,13,14,5,15]. Individual, 30-second supramaximal test exercise on cycle ergometer, however, does not reflect the specific structure of load in a judo bout, which, in our opinion, limits its diagnostic value, particularly with respect to the athletes at the highest sports skill level.

With regard to these observations, the study employed an empirically verified method of development of anaerobic capacity [1,16,17,18] which consists in a sequence of 10-second supramaximal anaerobic exercise bouts divided with 45-second periods of passive rest.

After five weeks of training period, the value of mechanical work in the experimental group that performed, on daily basis, a single interval exercise session, increased by ca. 20% for six repetitions of the effort. In each consecutive 10s of the exercise, the value of work was statistically significantly higher compared to the initial state, with the scope of changes ranging from 9.8% in the first effort to 35.43% in the sixth. Comparison of the results obtained in the control group in the beginning and at the end of the competitive period revealed no significant differences in the value of mechanical work for the repetitions. Evaluation of the degree of variation of peak power in two periods of measurement demonstrated no statistically significant values in the case of athletes performing only a standard judo training program and significant (ca. 11-14%) increases in mean power developed in consecutive efforts by the athletes from the experimental group.

In the context of cognitive value, an essential aspect of the study was analysis of the range of changes in time of work at the level of 97.5% of peak power. The results obtained after 5 weeks of interval training in the experimental group showed significant elongation of time of work at this level of intensity for each repetition of the effort, both with respect to the control group and compared to the initial level. Mean time of maintaining the mechanical work at the level of 97.5% of peak

power during six efforts was by around 45% longer, whereas mean values for next repetitions increased from 31% to 51%.

Comparison of the results obtained in the study with the data presented in a study by Norkowski [18], who employed a 4-week interval training with similar structure of exercise revealed that mean values of mechanical work and peak power in untrained students were by ca. 10% higher than in judo athletes.

It is essential when evaluating the effects of the exercise load used in the study that anaerobic capacity is strongly determined genetically and that the data were collected in a group of judo athletes at very high sports skill level. The substantial increase in the indices analysed in the study suggest maximum motivation of the participants during training but it can also be expected that they could have been caused by a judo non-specific exercise on cycle ergometer.

Conclusions

1. regular repetition of judo non-specific exercise stimuli on cycle ergometer in the competitive period causes a positive response in the form of increased anaerobic capacity and allows athletes to maintain its high level over a longer period of time;
2. the concept of interval training used in the study turned out to be an effective method in development of a high level of ability to perform repeated intensive anaerobic exercise, with both alactic and lactic character;
3. evaluation of anaerobic capacity in judo athletes should be based on a sport-specific competitive load and the exercise using the phosphagen energy system in the form of interval training.

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