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Effects of anaerobic fatigue on postural control in taekwondo practitioners

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Summary

Introduction. Sport training forms and develops specific abilities and motor skills (strategies). It involves an alternating application of training loads and rest intervals. Static postural control determines the effectiveness of human motor function in upright stance. Fatigue, on the other hand, resulting from physical activity, is manifested by a lower performance level and affects an athlete's movement accuracy and speed as well as endurance. The aim of the study was to examine the effects of physical exercise (fatigue) on athletes' static postural control by measuring the mean velocity of body sway.

Material and methods. Twelve taekwondo practitioners took part in measurements of their body balance control. The stabilographic measurements were carried out with the use of a force platform. Postural control was measured in four tests: with the eyes open and with the eyes closed, pre- and post-exercise (Wingate test).

Results. Mean values, mean velocity of body sway taekwondo competitors in traffic levels, in control anterior-posterior plane before the Wingate test: eyes open 12,31 ± 6,1 [mm/s], eyes closed: 13,61 ± 2,9 [mms]. Mean velocity after the Wingate test eyes open 15,39 ± 8,5 [mm/s], eyes closed 18,22 ± 6,2 [mm/s]. The mean values mean velocity in control medial-lateral plane before the Wingate test: eyes open 7,22 ± 2,3 [mm/s] eyes closed 8,74 ± 2,4 [mm/s], and after the Wingate test eyes open 8,91 ± 2,1 [mm/s], eyes closed 10,14 ± 2,9 [mm/s].

Conclusions. Results of the study show that intensive physical exercise has an adverse effect on dynamics of body control. The impairment of erect body position is more pronounced in sagittal plane. In state of fatigue eye sight is an important factor of stable body posture control.

Introduction

Biomechanical research in combat sports usually focuses on the improvement of technique effectiveness [1,2,3]. Training loads are to produce specific fatigue-induced changes. Fatigue results from performance and is desired in sports training, provided it reaches a specific level. An external measurable symptom of fatigue is a reduction of speed, strength and precision of movements. Such a state may also lead to sports injuries. Postural control is of crucial significance in physical activity as it constitutes a basis for development of other motor abilities in upright body stance.

The quality of body balance control is determined by the proper function of the vestibular system and involves a vast array of issues related to motor control, spatial orientation and effects of different forces on the human body. Many researchers agree that physical exercise and sight do affect postural control in upright stance [4,5,6,7].

There has been a number of studies concerned with the impact of anaerobic and aerobic exercise as well as peripheral and central fatigue on body balance control [8,9,10,11,12, 13,14,15,16]. Some researchers claim that exercise has a negative influence on the quality of postural control in upper stance [5,12,17], while others stipulate that the impact of exercise depends on applied training loads [15,18]. This divergence of researchers' opinions may certainly be related to the application of different methods in research experiments. It was noted by Paillard T. [14], who advocates some standardization of test protocols examining the impact of exercises in sport and rehabilitation. He also concludes that the fatigue of leg muscles, proximal muscles and extensors decreases the quality of postural control to a greater degree than the fatigue of arm muscles, distal muscles, and flexors. Different authors also claim that specific forms of movement may improve parameters of postural control, e.g. Tai-chi training [19]. It can be assumed that a similar positive impact can be observed in the case of taekwondo, karate and other combat sports. The fighting stance in taekwondo is more natural than in traditional karate. It is taller and its stability determines the effectiveness of attack and defense [20,21].

The aim of the present study was to examine the effects of anaerobic exercise on athletes' postural control in upright stance by measuring the mean velocity of body sway.

Material and methods

The research sample consisted of twelve ITF taekwondo practitioners aged between 14 and 23 years. Their average training experience amounted to 3 years of regular training, 1.5 hours four times a week. The subjects participated in the experiment voluntarily and were informed about its aims. The tests were approved by the Bioethics Board of the Regional Physicians' Chamber in Opole, Poland. Subjects' characteristics and age are presented in Table 1.

The experiment was carried out in the Institute of Physical Education of the Faculty of Physical Education and Physiotherapy at the Opole University of Technology in Poland. For the purpose of the study two testing stations were assembled at which three tests were carried out: two on a Kistler force platform for stabilographic measurements, and one on a cycloergometer (Wingate test). The stabilographic tests measured the distribution and changes of the pressure of the feet on the platform support surface in relation to the center of pressure. Each subject was standing on the platform for 20 seconds during each test (before and after exercise, with eyes open and eyes closed). The changes of the center of pressure of subjects' feet on the platform were registered with the sampling frequency of 100 Hz. Then mean values of body sway velocity in the anterior-posterior and medial-lateral planes were calculated. The cycloergometer exercise test was carried out in accordance with measurement standards and procedures of anaerobic Wingate test.

The obtained data was used to calculate mean values and standard deviations. The differences between the mean values of body sway velocity pre- and post-exercise were determined with a t-test at $p < 0.02$. The significance of differences between the planes of movement was estimated with a repeated measures analysis of variance (ANOVA). All statistical calculations were made with the use of STATISTICA software package (ver. 9).

Table 1. Subjects' (n = 12) mean (± OS) age and physical characteristics

Subjects' age and characteristics	**Mean** (± OS)
Age [years]	18.68 ± 3.93
Body mass [kg]	68.75 ± 11.01
Body height [cm]	174 ± 7.56

Table 2. Arithmetic means of subjects' Wingate test parameters (N = 12).

Parameter	**Value** (± SD)
Total work of the force - W_{tot} [J/kg]	164.93 ± 54.65
Maximal power - P_{max} [W/kg]	7.07 ± 2.08
Time of maximal power attainment - T_{at} [s]	8.84 ± 3.12

Table 3. Mean values (± OS) of body sway velocity in the anterior/posterior and medial/lateral plane. Values in boldface indicate statistically significant differences at *p < 0.01, **p < 0.02 (N = 12)

Plane	**Measurement***	**Mean sway velocity [mm/s]**	
		Eyes open	**Eyes closed**
Anterior/posterior	1	**7.22 ± 2.34**	**8.74 ± 2.35***
	2	**8.91 ± 2.09**	**10.14 ± 2.29****
Medial/lateral	1	12.31 ± 6.14	13.61 ± 2.82
	2	**15.39 ± 8.48**	**18.22 ± 6.72****

* Stabilographic measurement: (1) before Wingate test, (2) after Wingate test

Results

Table 2 presents subjects' arithmetic means of the Wingate test parameters. Tab. 3 and Figures 1 and 2 present mean values of body sway velocity in the anterior-posterior and medial-lateral planes.

Discussion

The analysis of data in the medial-lateral plane (Tab. 3, Fig. 1) revealed significant differences in the dynamics of postural control in upright stance in terms of mean values of body sway velocity. The difference between test results with the eyes open and closed, before the Wingate test, was 1.52 mm/s, i.e. about a 21% increase in the test with the eyes closed (p = 0.01). However, the difference in the increase of mean body sway velocity post-exercise in the medial-lateral plane was 1.23 mm/s, i.e. only 14% (p = 0.02). A significant increase in the post-exercise mean body sway velocity as compared with pre-exercise quiet standing was also noted at 23% with the eyes open (p = 0.004) and at 16 % (p = 0.03) with the eyes closed.

The highest value of mean body sway velocity was found in the anterior-posterior plane (Figs 2), in the post-exercise test with the eyes closed (18.22 mm/s). This was about 18% higher than in the post-exercise test with the eyes open, and about 34% higher than in the pre-exercise test with the eyes closed. Significant differences were also observed in the test with the eyes open between mean pre- and post-exercise results, with the latter higher for about 25% (p = 0.01). In the medial-lateral plane, in both pre-exercise tests (eyes open/

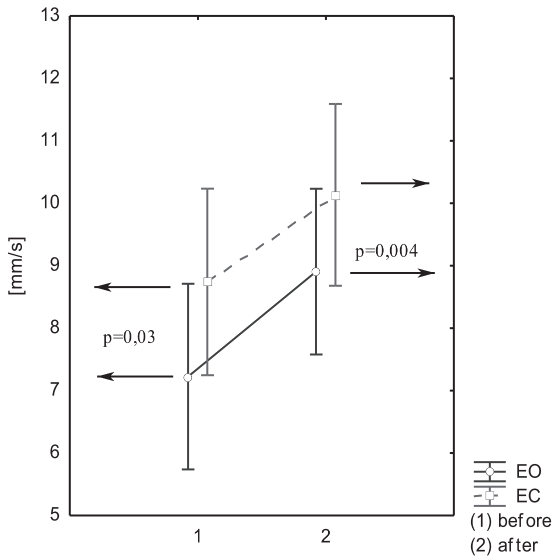

Figure 1. Mean body sway velocity in medial-lateral plane. EO – eyes open; EC – eyes closed; (1) Before exercise, (2) After exercise

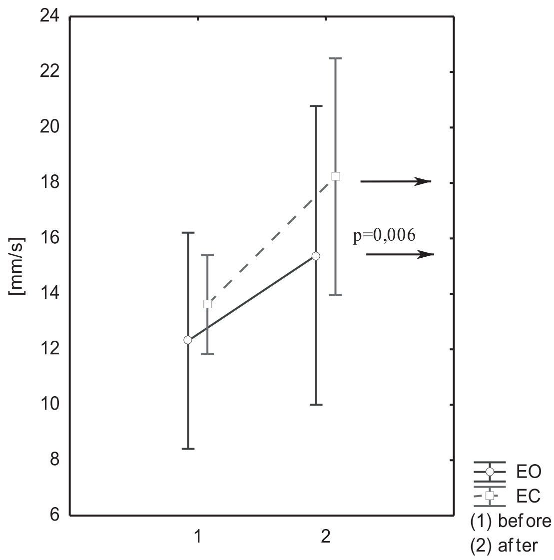

Figure 2. Mean body sway velocity in anterior-posterior plane. EO – eyes open; EC – eyes closed; (1) Before exercise, (2) After exercise

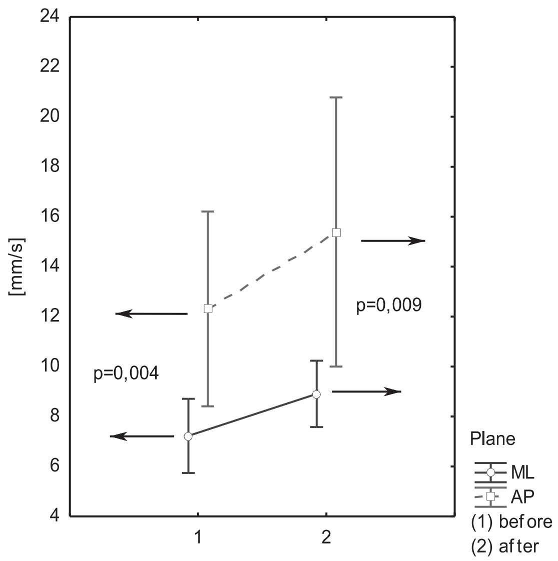

Figure 3. Mean velocity (test with eyes open). ML – medial/lateral plane, AP – anterior/posterior plane; (1) before exercise, (2) after exercise

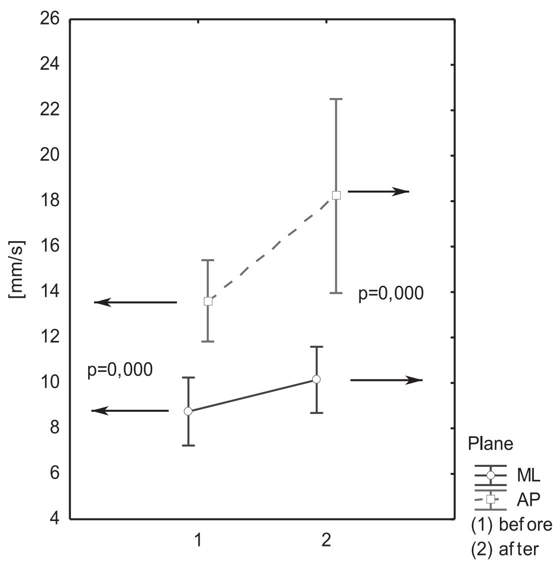

Figure 4. Mean velocity (test with eyes closed). ML – medial/lateral plane, AP – anterior/posterior plane; (1) before exercise, (2) after exercise

eyes closed), the difference between the values of mean body sway velocity was non-significant (1.3 mm/s).

The analysis of mean body sway velocity between the planes of movement revealed higher mean values in the anterior-posterior plane than in the frontal plane. The differences in the mean velocity values (Figs 3 and 4) between the two planes of movement were highly significant. The differences that more negatively affect body balance control in the anterior-posterior plane than in the medial-lateral plane can be observed in post-exercise tests. In the test with the eyes open the increase in the mean velocity amounted to 6.48 mm/s (73%), while in the test with the closed eyes the difference was 8.08 mm/s (nearly 80%). This analysis also showed an increase in the dynamics of body balance control under fatigue with the eyes closed. Pre-exercise differences in mean body sway velocity between the planes of movement are slightly smaller and follow a reverse pattern. The difference between test results with the closed eyes and the open eyes was significantly smaller: 4.87 mm/s and 5.09 mm/s, respectively.

Taekwondo practitioners' postural control in the anterior-posterior plane is more diversified as indicated by a greater scattering of their test results. The exception are results of pre-exercise tests with the eyes closed in both planes of movement. It seems also interesting that in the medial-lateral plane fatigue reduced the level of scattering of subjects' results of both tests with the open and closed eyes. Also, in the anterior-posterior plane, the results were less diversified in tests with the closed eyes (pre- and post-exercise) than in tests with the open eyes, while in the frontal plane the diversification of results increased minimally.

In stabilographic analysis, an increase in amplitudinal parameters, including mean velocity, is indicative of poorer postural control. According to many authors, low stabilographic parameters can indicate more effective upright stance control [4]. Low mean velocity, for example, is assumed to indicate low dynamics of body balance control, i.e. a subject standing still. High mean velocity value, on the other hand, can be indicative of sudden and "rapid" body sways [4,5]. However, a stabilographic study of judo practitioners revealed a greater shift in the stabilographic curve than in subjects with a lower physical fitness level [22]. Higher values of amplitudinal stabilographic parameters in groups of different athletes seem to result from their specialist sport training.

In consideration of the above results, significant differences were revealed between pre- and post-exercise body balance control tests as well as between upright stance control tests with the eyes open and closed. A lower mean body sway velocity was noted in subjects in the frontal plane than in the anerior-posterior plane. It can be concluded that in the medial-lateral plane the subjects were characterized by smoother body balance control. It is much more difficult for them to control their body balance in the anterior-posteriorl plane, especially after exercise and with their eyes closed, when the dynamics of postural control increases. This can be explained by the characteristic lateral fighting stance in taekwondo. While performing kicks taekwondo practitioners tend to sway more often in the frontal plane than in the anterior-posterior plane. These observations correspond to those by Zemkova (2009).

The area of this study requires further analysis with a possible application of surface electromyography [23]. More detailed research procedures would explain the impact of physical exercise on postural control in a much more comprehensive manner.

Conclusions

1. The results of the study show that the body balance during dynamic changes of the organism's energetic processes relies on increased effort of the muscles responsible for body balance in anterior-posterior plane compared to the muscles ensuring balance in the lateral plane.
2. Monitoring changes in the mean velocity of body sway in the anterior-posterior plane in situation of physical fatigue, may be important in sport training and help protect the athletes against the risk of falling and injury.

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