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AGE-RELATED CHANGES AND GENDER DIFFERENCES OF UPPER BODY ANAEROBIC PERFORMANCE IN MALE AND FEMALE SPRINT KAYAKERS

D. Sitkowski[1], R. Grucza[2]
[1]Dept. of Physiology, Institute of Sport, Warsaw, Poland; [2]Dept. of Physiology of Exercise, Collegium Medicum, Nicolaus Copernicus University, Bydgoszcz, Poland

Abstract. The aim of the study was to examine whether young female kayakers performing intense training of the upper extremities could significantly increase upper body anaerobic performance with age and training, diminishing in that way gender differences. Totally, 264 male and 195 female athletes participated in the survey. All subjects were sprint kayakers representing elite athletes for their specific age groups and undergo long lasting training, supervised by Polish Canoe Federation. They were grouped by sex and age. The subjects performed 40-s all-out exercise in upright position, by upper extremities, on modified Monark cycloergometer. Total work performed (W_{tot}), peak power (PP) and rate of decrease in relative peak power (PD) was measured. Lactate (LA) concentration in capillary blood was measured after 4 min of cessation of the exercise. W_{tot}, PP, and PD showed significant differences between men and women. In women, indices of anaerobic performance did not increased significantly beginning from the age of 19 years. In men, the development of anaerobic performance with age and training was more diverse. Rate of decrease in PD significantly increased in male and female kayakers for the groups of 13, 14 and 15 years old. PD correlated well with PP ($W \cdot kgBM^{-1}$) in male ($r=0.806$, $p<0.001$) as well as in female kayakers ($r=0.722$, $p<0.001$). Post-exercise LA concentration was significantly higher in male than in female (13.9 ± 2.2 $mmol \cdot l^{-1}$ and 11.0 ± 2.0, $p<0.001$). It was concluded that upper body anaerobic performance increased with age and training in both male and female kayakers at least up to the end of second decade of life. There are significant gender differences in relative indices of anaerobic performance despite of age and training. ***(Biol.Sport 26:325-338, 2009)***

Key words: Kayakers – Anaerobic performance - Arms - Age - Gender differences

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Reprint request to: Dariusz Sitkowski Ph.D., Dept. of Physiology, Institute of Sport, Trylogii 2/16, 01-982 Warsaw, Poland; E-mail: dariusz.sitkowski@insp.waw.pl

Introduction

Performance capacities of short time all-out anaerobic exercises significantly increase in males during second decade of their lives [16,22]. In females, for this same period of life, the anaerobic abilities are less pronounced and rather limited to lower extremities [2,31]. It was observed, however, that trained females are able to improve results of 10-, 30-, and 90- seconds tests on bicycle ergometer to greater extent than males [7,28]. It has been also reported that resistance training of the same relative intensity and volume causes in women a greater relative increase in strength of flexor elbow joint muscle than in men [24]. This observation may suggest that anaerobic performance of the upper extremities in trained women could similarly increase with age as in men. Such possibility would be of some importance in kayaking when efficiency of muscle work of the upper extremities depends significantly upon anaerobic re-synthesis of adenosine triphosphate (ATP) [18,34].

The aim of the study was to examine whether young female kayakers performing intense training of the upper extremities could significantly increase upper body anaerobic performance with age and training, and whether they are able to diminish gender differences.

Materials and Methods

Subjects: Totally, 264 males (aged 13-26 years) and 195 females (aged 13-23 years), participated in the study. All subjects were sprint kayakers representing elite athletes for their specific age groups. They were grouped by sex and age. Characteristics of the male and female age groups are presented in Table 1 and Table 2, respectively.

Research program: The study was performed as a part of systemic control of training supervised by Polish Canoe Federation. Local Committee for Ethics in Scientific Research approved the research program. Over the whole study period some of the athletes performed exercise test several times, but only one per year, so this mixed study included cross-sectional and longitudinal observations. The overall number of the tests was 983.

The subjects were informed about the aim and procedures of the study in details. They were obliged to present current medical permission indicating no contradictions for competitive sport performance. Medical examination of the athletes was additionally performed before exercise test. Subjects showed any health abnormalities were excluded from the study.

Table 1
Characteristics of male kayakers participating in the study

Age group (years)	Training experience (years)	Body height (cm)	Body mass (kg)	Body fat content (%)	Fat free mass (kg)	Body mass index ($kg \cdot m^{-2}$)
13	2.6	173.9	64.6	10.4	57.8	21.3
n=11	±0.8	±5.5	±5.5	±2.3	±4.6	±1.1
14	3.6	176.3	68.8	11.0	61.2	22.1
n=47	±1.3	±5.5	±7.5	±2.0	±6.6	±1.8
15	4.4	178.0	71.8	10.1	64.5	22.6
n=101	±1.5	±5.0	±6.4	±1.6	±5.9	±1.5
16	5.3	180.0	76.2	9.9	68.7	23.5
n=104	±1.3	±5.6	±6.6	±1.7	±5.9	±1.8
17	5.9	181.1	78.2	9.8	70.5	23.8
n=97	±1.5	±5.9	±6.7	±1.8	±6.0	±1.5
18	6.9	181.6	79.7	9.2	72.4	24.1
n=75	±1.5	±5.7	±7.4	±1.5	±6.9	±1.5
19	8.1	184.1	83.0	9.4	75.2	24.5
n=30	±1.4	±4.8	±6.4	±1.7	±6.0	±1.4
20	9.0	184.9	84.5	9.1	76.9	24.8
n=18	±1.4	±3.0	±4.9	±1.2	±4.6	±1.2
21	9.6	184.5	86.4	9.8	77.9	25.4
n=20	±1.6	±3.8	±7.2	±1.5	±5.8	±1.6
22	10.6	185.7	86.4	9.1	78.5	25.0
n=16	±1.4	±5.0	±6.0	±1.4	±5.5	±1.1
23	11.4	184.9	86.2	10.0	77.6	25.2
n=16	±1.8	±5.1	±6.5	±1.1	±5.6	±1.1
24	12.5	183.8	84.2	9.2	76.5	24.9
n=13	±1.4	±4.1	±6.7	±1.4	±5.8	±1.3
25	12.6	186.4	85.4	8.9	77.8	24.5
n=13	±1.8	±5.3	±6.5	±0.9	±5.7	±1.1
26	16.3	184.6	87.2	9.3	79.5	25.6
n=7	±2.0	±4.1	±4.2	±1.2	±4.2	±0.8

Table 2
Characteristics of female kayakers participating in the study

Age group (years)	Training experience (years)	Body height (cm)	Body mass (kg)	Body fat content (%)	Fat free mass (kg)	Body mass index ($kg \cdot m^{-2}$)
13	3.1	165.5	57.2	18.5	46.6	20.9
n=22	±1.0	±4.1	±4.8	±3.2	±4.1	±1.5
14	3.3	166.0	59.5	17.5	49.0	21.6
n=66	±1.2	±5.0	±4.8	±3.2	±4.1	±1.2
15	4.1	166.5	61.7	18.1	50.5	22.2
n=97	±1.3	±5.1	±6.2	±3.2	±5.1	±1.8
16	4.6	167.8	62.6	18.0	51.3	22.2
n=79	±1.4	±3.9	±4.8	±3.7	±4.4	±1.5
17	5.3	168.1	64.2	16.7	53.4	22.7
n=61	±1.5	±4.7	±5.4	±3.9	±4.9	±1.5
18	5.9	168.4	65.7	16.5	54.8	23.2
n=39	±1.8	±5.6	±6.1	±4.3	±5.7	±1.7
19	7.5	167.9	66.7	18.6	54.4	23.7
n=18	±1.7	±4.7	±4.3	±4.8	±5.3	±0.9
20	9.1	167.7	65.6	17.1	54.3	23.3
n=9	±1.5	±6.3	±6.3	±3.9	±5.6	±1.6
21	9.6	166.1	63.1	15.7	53.2	22.9
n=9	±1.3	±5.3	±3.4	±3.5	±3.8	±0.9
22	10.4	165.0	63.3	15.0	53.8	23.3
n=7	±0.8	±5.1	±3.1	±4.2	±4.0	±1.2
23	12.2	165.6	62.7	14.5	53.6	22.8
n=8	±1.5	±6.3	±7.2	±4.2	±4.4	±1.2

Training: An example of one-year training cycle in junior male kayakers showed in fig. 1. The men, on average, covered on kayak 3000 km, run 700 km and lifted a weight of about 2 500 t. In women, the total volume of training was about 20% less than in men.

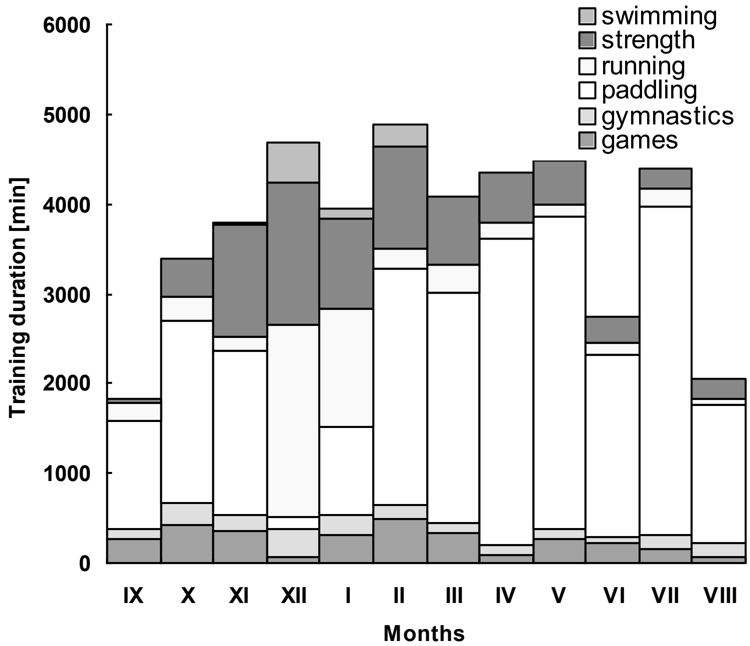

Fig. 1
Characteristics of one year training cycle in junior male kayakers

Anthropometric measurements: Body weight, height and three point measurements of fat-skin folds (Harpenden Caliper) were performed in the subjects. Body fat content and fat free mass (FFM) was then calculated [27].

Exercise test: The exercise test consisted of 40-s all-out exercise performed on modified Monark cycloergometer, calibrated before each test. Pedals of the ergometer were changed for cranks (23 cm long) enabling work with upper extremities. The subjects performed exercise test in up-right position with the ergometer individually regulated to the height of the subject.

The test was preceded by 5-min warm-up with intensity of 0.85 $W \cdot kg^{-1}$ in men and 0.75 $W \cdot kg^{-1}$ in women. Within 150 and 240 s of the warming-up the subjects accelerated to attain possibly maximal cranking velocity with resistance increased to 75-80% value predicted for test. Warm-up and test was separated by 2-min period during which the subjects continued warm-up individually. The period was necessary to adjust of ergometer resistance to the level of 0.065 $kg \cdot kg^{-1}$ for men, and 0.055 $kg \cdot kg^{1}$ for women. For minimizing the muscle activity of the lower part of the body the subject's hips were fixed by two belts. The exercise started with first impulse of an electromagnetic sensor. Total volume of work performed (W_{tot}), peak power (PP) and rate of decrease of relative peak power (PD) was measured by a special system (MCE, JBA, Poland). Additionally, in 72 men and in 48 women, lactate (LA) concentration in capillary blood was measured after 4 min of cessation of the exercise, by an enzymatic method (Boehringer Mannheim, Germany).

Statistics: Significance of differences for data obtained within the individual age group (separately for men and for women) was estimated by one-way analysis of variance (ANOVA). Significance of differences for data obtained for respective age group for men and women was estimated with Student's t-test for independent variables. The data were considered to be statistically significant for $p<0.05$.

Results

Total work W_{tot} (Fig.2 A-C) and peak power PP (Fig. 3 A-C) showed significant differences between men and women in specific age group. In women, indices of anaerobic performance did not increased significantly beginning from the age of 19 years except PP which reached plateau at the age of 18.

In males, the development of upper body anaerobic performance with age was more diverse than in females. No further increase in PP (expressed in $W \cdot kgFFM^{-1}$) was observed beginning from 16 years, in W_{tot} ($J \cdot kgFFM^{-1}$) beginning from 17 years, in PP ($W \cdot kg^{-1}$) and in W_{tot} ($J \cdot kg^{-1}$) beginning from 18 years, and in PP (W) and W_{tot} (kJ) beginning from 19 years old.

In the all age groups females performed significantly lower volume of work and achieved lower value of peak power comparing to males.

Rate of decrease in peak power (PD) significantly increased in male and female kayakers for the groups of 13, 14 and 15 years old. In both men and women the rate of decrease in relative peak power PD ($W \cdot kg^{-1} \cdot s^{-1}$) stabilized at an elevated level beginning from 16 years old (Fig. 4). However, the values of PD were significantly greater for men than for women. PD correlated well with PP ($W \cdot kgBM^{-1}$) attaining correlation coefficient equal to $r=0.806$ ($p<0.001$) in male kayakers and $r=0.722$ ($p<0.001$) in female kayakers.

Lactate concentration after exercise test was significantly higher in male than in female kayakers attaining respective values of 13.9 ± 2.2 and 11.0 ± 2.0 $mmol \cdot l^{-1}$, ($p<0.001$). LA concentration correlated with PD only in men ($r=0.406$, $p<0.001$).

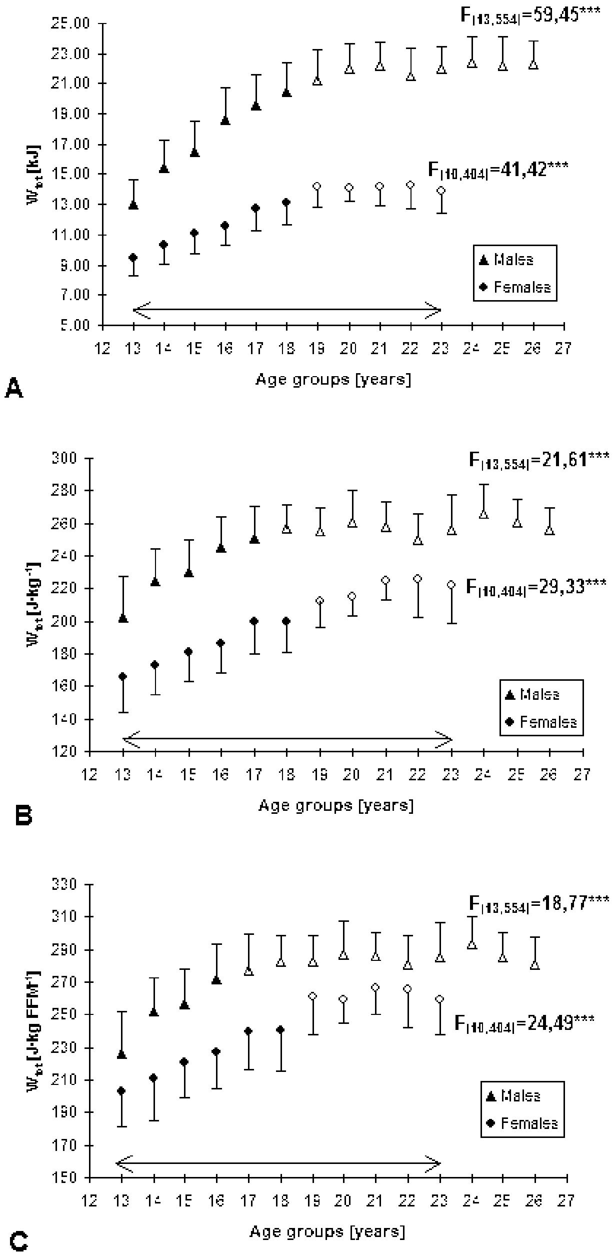

Fig. 2
Total work (W_{tot}) in 40-s all-out exercise test performed by upper extremities in male and female kayakers of different age group. A- absolute values; B- calculated for body mass; C- calculated for fat free mass. Values are means ± SD. Arrows indicate significant differences between males and females for this same age group. Black symbols indicate significant change related to age and training (ANOVA); ***p<0.001

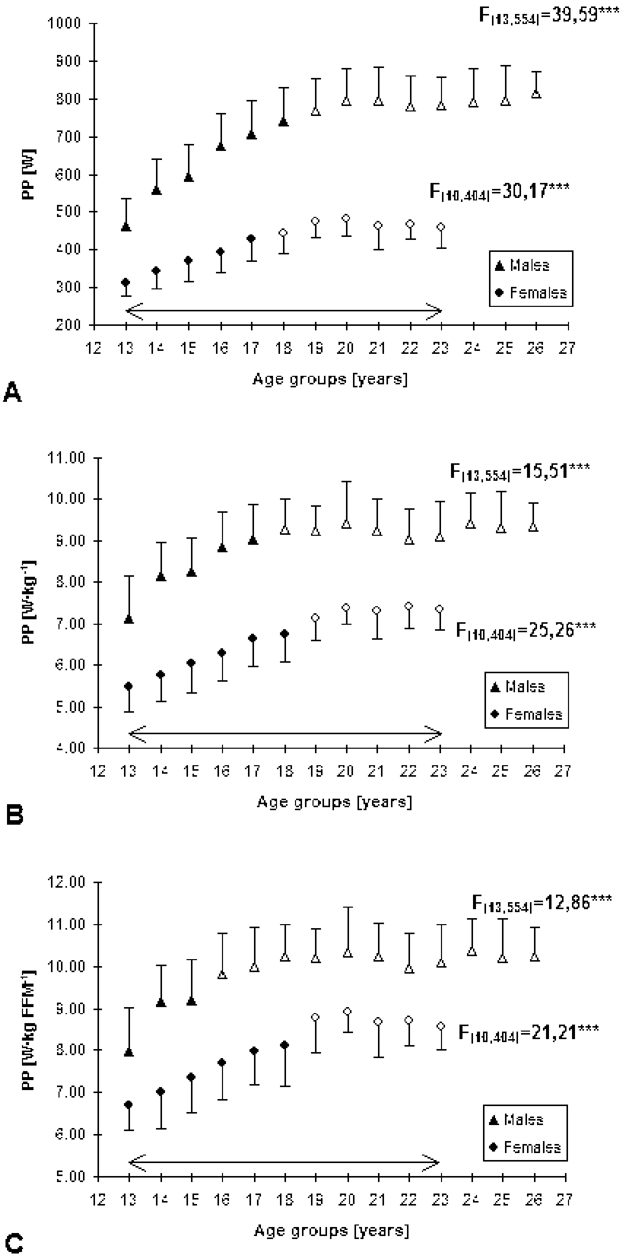

Fig. 3
Peak power (PP) in 40-s all-out exercise test performed by upper extremities in male and female kayakers of different age group. A- absolute values; B- calculated for body mass; C- calculated for fat free mass. Values are means ± SD. Arrows indicate significant differences between males and females for this same age group. Black symbols indicate significant change related to age and training (ANOVA); ***$p<0.001$

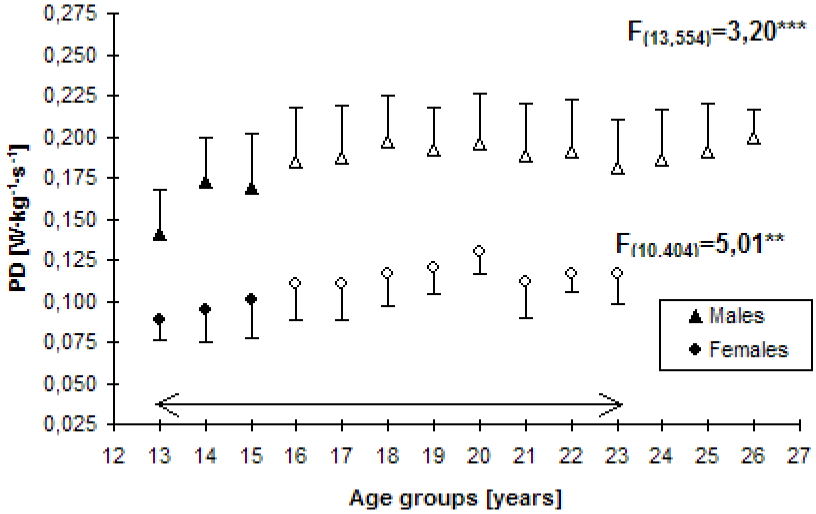

Fig. 4
Rate of decrease in peak power (PD) in 40-s all-out exercise test performed by upper extremities in male and female kayakers of different age group. Values are means ± SD. Arrow indicates significant differences between males and females for the same age group. Black symbols indicate significant change related to age and training (ANOVA); ***p<0.001

Discussion

Wingate test is one of the generally accepted method for estimation of anaerobic performance in humans. In the present study a modified Wingate test was used in which the duration of exercise was prolonged to 40 s in order to mimic the effort time necessary to cover the shortest kayaking distance of 200 m. The 40 s period of exercise is also regarded as an optimum time for development of anaerobic processes in an organism [9,17].

Despite of criticism concerning adjustment of ergometer resistance in relation to body mass [2,26,32] this kind of adjustment was chosen because of its simplicity and easy application in large group of subjects characterized by a relative uniformity of fat free body content.

Results obtained in the present study indicated that, with development of age, both male and female young kayakers were able to increase their capacity for better performance of 40-s all out upper body exercise test. Such biological tendency has been already reported in untrained men [2,16]. However, in girls and young women performing Wingate test by upper extremities no increase of mean and maximum power was observed in relation to age [2,15]. Similarly, Parker *et al.* (1990) reported that in girls, from 5 to 17 years old, the strength of flexor elbow joint muscles related to height and body mass did not increase significantly with age, or even slightly decreased [25].

The observed changes in anaerobic performance of kayakers in upper body exercise were not only an effect of development of their physical maturity with age but also depended on the training process. There are numerous studies concerning the influence of training on anaerobic performance in trained and untrained subjects exercising by lower extremities. In most of them [20,29,33], but not in all [1], reported that intense training can cause an increase in the anaerobic performance. In contrast, only limited data are available on anaerobic performance in exercise of upper extremities. Kraemer *et al.* (1995) showed that in men, under 2 years of military service, strength training led to significant increase in mean and maximum power of lower and upper extremities during Wingate test [19]. Similar effect was observed in boys undergoing swimming training when the anaerobic power was estimated by a force-velocity test [32]. On the other hand, Delgado *et al.* (1993) found only weak relationship between the age of boys training horse riding and maximum power developed during the force-velocity test performed by upper extremities [5]. For judo, total work and peak power of upper extremities were reported to be greater in older than in younger male competitors, but not such effect was observed for female judo competitors [21].

In the present study the female kayakers were able to improve their upper body anaerobic performance with age and training in similar manner as the male kayakers. It was also found that with progress of age and the time of training the differences in indices of anaerobic performance, calculated for fat free mass, diminished between male and female kayakers. For the group of 14 years old W_{tot} $J{\cdot}kg^{-1}$ in females was 77% of value observed for males whereas for the group of 22 years it was 90%. The other anaerobic performance indices showed similar pattern: PP $W{\cdot}kg^{-1}$ 71% and 82%; W_{tot} $J{\cdot}kgFFM^{-1}$ 84% and 94%; PP $W{\cdot}kgFFM^{-1}$ 77% and 88%, expressed as a percentage of increase in respective group of 14 and 22 years old females kayakers compared to males. The diminishing differences in anaerobic performance between men and women for lower extremities exercise were previously reported by Esbjörnsson Liljedahl *et al.* [7]. Also Serresse *et al.*

(1989) concluded that the gender differences in anaerobic performance could be diminished by physical training, but not eliminated [28]. The results obtained in the present work present some evidence that the diminishing effects of age and training on gender differences in anaerobic performance would also be observed in subjects exercising by upper extremities.

Nindl *et al.* (1995), examining upper body anaerobic performance in trained boys and girls aged 16 years old found, that gender differentiation was expressed by peak power (PP) as well as mean power (MP) [23]. In their study the girls attained following relative increases in PP and MP comparing to boys: 62.7 and 63.5% (expressed in absolute value), 82.7 and 83.6% (in kgBM), and 93.4 and 94.7% (in kgFFM). The same age group of kayakers tested in the present work showed greater gender differentiation for PP and W_{tot} : 60 and 62% (absolute value), 71 and 76% (kgBM), and 79 and 84% (kgFFM). The discrepancy in the discussed results would be caused by different duration of exercise tests (30s vs 40 s) and equal resistance load for boys and girls (0.050 $kg \cdot kgBM^{-1}$) applied in the Nidl *et al.* study. The equal load resistance could limit the boys in development of maximum power during exercise tests [6].

Rate of decrease of peak power (PD) significantly increased in male and female kayakers for the 13, 14 and 15 years groups. Similar results were obtained by Gaul *et al.* (1995) who compared anaerobic performance of young boys and men [11]. The lower PD would be an effect of limited engagement of anaerobic processes during maximum exercise in the young subjects [14]. The greater PD in male than in female kayakers observed for all age groups are also in agreement with results of other experiments when exercise was performed by lower extremities [10].

Rate of decrease in peak power (PD) significantly correlated with the maximum value of peak power PP ($W \cdot kgBM^{-1}$) in both male and female kayakers. Other studies showed, that in men exercising by lower extremities the rate of decrease in peak power was in some proportionality to the content of FT fibers in working muscles [3,30]. Also the values of PP, PD and W_{tot}, as well as post-exercise lactate concentration, were found to be related to the number of FT fibers in men performing Wingate test by lower extremities [10]. Results of the present study suggest that such mechanism would be responsible for changes in the rate of peak power decrease.

Lactate concentration after the exercise test was lower in female than in male kayakers. Such regularities has already been observed in other studies [8,13]. The greater PD and LA concentration in males would be a result of greater reliance on anaerobic metabolism of their muscles. On the other hand, it should be noticed that lactate concentration in blood depends not only on the rate of its production [4], and that PD can be related to the value of resistance load during exercise [24].

Results of the present work lead to conclusion that upper body anaerobic performance increases with age and training in both male and female kayakers at least up to end of second decade of life. There are significant gender differences in relative indices of anaerobic performance despite of its diminishing tendency observed with progress of age.

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