

Anaerobic capacity of upper extremity muscles of male and female swimmers

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Summary

Study aim: To assess the anaerobic capacity of upper extremity muscles of male and female swimmers by applying two exercise tests.

Material and methods: Male and female swimmers (n = 9 and 6, respectively), aged 19 – 23 years and having training experience of over 10 years, were subjected to two tests: 30-s Wingate for upper extremities and semi-tethered swimming test. The following variables were determined: body fat content (from 4 skinfolds), maximum power output, heart rate (HR) and lactate (LA) concentration in blood.

Results: Relative power outputs in the Wingate test and swimming force in semi-tethered swimming test (maximum and mean) were significantly ($p < 0.001$) higher in male than in the female swimmers. Maximum LA concentrations were higher in male than in female swimmers, but maximum LA values related to relative power output were in both genders alike. Maximum force produced in the semi-tethered swimming test was strongly ($r = 0.765$; $p < 0.001$) correlated with maximum relative power output in the Wingate test.

Conclusions: Both tests may be interchangeably applied to determine the anaerobic capacity of upper extremity muscles in swimmers.

Key words: Anaerobic capacity – Wingate test – Semi-tethered swimming test – Swimmers

Introduction

Swimming markedly engages anaerobic glucose metabolism [3], especially in upper extremity muscles [19]. The velocity at 50-m distance (freestyle) depends on the power output of upper extremities but that dependence declines at longer distances [10]. Anaerobic capacity, associated with short exertions of maximum intensities, utilises energy from intramuscular ATP and phosphocreatine (CrP), as well as from anaerobic glucose metabolism inducing lactate generation in muscles [6,8]. The elimination rate of lactate depends, to a high degree, on training-induced fitness, especially the endurance training, thus reducing exercise-induced homeostatic disorders and improving the recovery processes [9].

The 30-s Wingate test has been most widely used in assessing anaerobic capacity [12] but many sport-specific tests become increasingly popular. Among them is 30-s semi-tethered swimming test used also in establishing threshold values [20]. The aim of this study was to determine anaerobic capacity of upper extremity muscles

in experienced male and female swimmers by applying that latter test and the Wingate one for upper extremities in order to assess the interchangeability of those tests.

Material and Methods

A group of 9 male and 6 female experienced swimmers aged 19 – 23 years, members of Academic Sport Association, volunteered to participate in the study and submitted their written consents after having been informed about study objective and protocol. Their characteristics are presented in Table 1.

Body fat content was determined from 4 skinfolds (biceps, triceps, subscapular and hip) [5] by using caliper (Holtain, U.K.). The measurements were performed on the left side of the body in upright position. Lactate in blood was assayed using commercial kits and photometer (Dr Lange, Germany).

The swimmers were subjected to two tests a day apart: 30-s Wingate test on hand cycle ergometer (Lode, Netherlands) and 30-s semi-tethered swimming test (STS).

The loads in the Wingate test amounted to 5.5 and 4.5% of body mass for male and female swimmers, respectively; maximum and mean power outputs were re-corded and related to body mass. The STS consisted of maximum intensity swimming with a fast elastic line fixed to a special belt. Swimming force was recorded with the use of a tensometric dynamometer coupled to MAX-5 device (JBA Staniak, Poland) via WTP 003 amplifier and computer software Max_5.1. Immediately after every test had been terminated, as well as 3, 5, 7 and 9 min post-test, blood was sampled from earlobes and heart rate (HR) was recorded using sport-tester (Polar, Finland).

Statistica® 7.0 software was used in data analysis. Student's *t*-test was used to assess between-gender differences and regression analysis to assess the relationships; the level of $p \leq 0.05$ was considered significant.

Results

Somatic characteristics and training experience of male and female swimmers are presented in Table 1 and the results of measurements in Tables 2 - 4. Male swimmers were taller, heavier and had lower body fat content than the female ones.

Table 1. Mean values ($\pm$ SD) of somatic variables and training experience of swimmers

Variable	Swimmers Male (n = 9)	Female (n = 6)
Age (years)	21.7 $\pm$ 1.8	20.3 $\pm$ 1.6
Body height (cm)	185.7 $\pm$ 4.0	174.2 $\pm$ 8.6 **
Body mass (kg)	79.8 $\pm$ 2.8	63.8 $\pm$ 7.5 **
BMI	23.1 $\pm$ 1.9	21.0 $\pm$ 1.1
Body fat content (%)	11.4 $\pm$ 2.0	22.3 $\pm$ 1.5 ***
Training exp. (years)	10.0 $\pm$ 1.4	11.5 $\pm$ 2.1

Significantly different from the respective value in male swimmers: ** $p < 0.01$; *** $p < 0.001$

Relative mean and maximum power outputs were significantly ($p < 0.001$) lower in women than in men but the peak lactate concentration relative to mean power output was in both genders alike. All indices of swimming force were also significantly ($p < 0.001$) lower in women than in men (Table 2).

The post-test peak heart rate was significantly ($p < 0.05 - 0.01$) higher following Wingate than following STS in both genders alike. On the other hand, peak lactate concentration was in both genders alike following STS, but following the Wingate test significantly ($p < 0.05$) higher values were noted in men than in women. Lactate con-

centrations increased in all but few cases up to 9 min post-test, so the recorded values were unsuitable to compute the lactate elimination rates.

Table 2. Mean values ($\pm$ SD) of variables recorded in the 30-s Wingate and semi-tethered swimming tests

Swimmers Variable	Male (n = 9)	Female (n = 6)
Wingate test		
$P_{\max}$ (W/kg)	7.96 $\pm$ 1.1	5.14 $\pm$ 0.4 ***
P_{mean} (W/kg)	5.97 $\pm$ 0.8	4.22 $\pm$ 0.3 ***
LA_{peak}	10.1 $\pm$ 3.2	6.7 $\pm$ 2.0 #
$LA_{\text{peak}}/P_{\text{mean}}$	1.71 $\pm$ 0.48	1.62 $\pm$ 0.36
HR_{peak}	164.7 $\pm$ 7.3	171.7 $\pm$ 9.7
Semi-tethered swimming test (STS)		
$F_{\max}$ (N)	230.4 $\pm$ 22.4	131.9 $\pm$ 18.6 ***
$F_{\min}$ (N)	102.8 $\pm$ 9.0	80.7 $\pm$ 13.3 ***
F_{mean} (N)	146.5 $\pm$ 16.0	99.8 $\pm$ 15.0 ***
LA_{peak}	9.3 $\pm$ 2.6	8.0 $\pm$ 2.1
HR_{peak}	152.9 $\pm$ 12.5 °	149.2 $\pm$ 5.2 °°

Significantly lower than in men: ** $p < 0.01$; *** $p < 0.001$;
Nearly significantly ($p = 0.07$) lower than in men;
Significantly lower from the respective STS value: ° $p < 0.05$;
°° $p < 0.01$

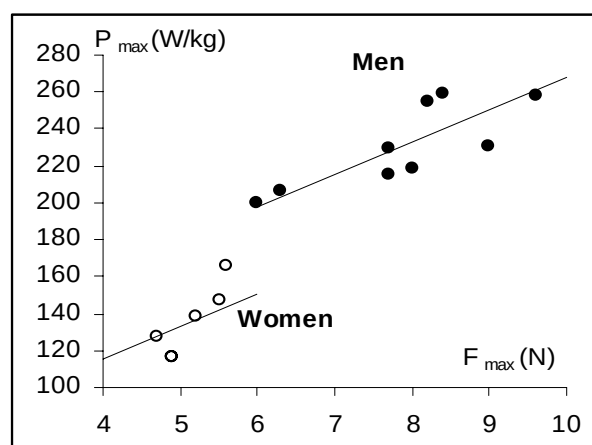


Fig. 1. Relationship between maximum swimming force recorded in the semi-tethered swimming test and maximum power output recorded in the Wingate test

Maximum swimming strength produced in STS and maximum relative power output in the Wingate test were significantly correlated in both genders. It was shown by regression analysis that regression slopes did not differ significantly, therefore Pearson's correlation coefficient was computed from residual variances and covariances for both groups combined: $r = 0.765$, $p < 0.001$ (see Fig. 1). No such within-gender correlation was found for

found for mean values of strength and power output, but when the data from both groups were combined, correlation coefficient amounted to 0.754 ($p < 0.001$).

Discussion

Maximum and mean relative power outputs in 30-s Wingate test were reported to be significantly lower in the female than in male swimmers [17], muscle cross-section, size and number of muscle fibres, and mechanical properties of muscles being considered responsible for gender-related differences in power output [15]. Also, training-induced fitness and sex hormones may indirectly affect the anaerobic capacity [17]. As reported by Okhuwa *et al.* [18], the training of female athletes, even the elite ones, is of lower volume and intensity compared with male athletes.

Among the few reports on gender-related differences in the anaerobic capacity of upper or lower extremities are those of Little [14], who found higher relative power output in the 30-s Wingate test in male than in female judoists of various ages; similar results were reported for wrestlers [11], whose female-to-male ratio for mean power output amounted to 67%, for various sports including swimming [22], where that ratio for swimming time amounted to 55%, and for physically active subjects. In that latter report [23], the female-to-male ratio for mean power output for upper extremities amounted to 69%. Similar ratios were found in this study for the 30-s Wingate test for upper extremities (mean relative power output; 71%) and for the semi-tethered swimming test (mean swimming force; 68%). All those data suggest that the gender-related differences in power output do not depend on the kind of exercise test.

It has been claimed that the Wingate test does not reflect the specificity of swimming; therefore, the semi-tethered swimming test (STS), enabling the use of various swimming styles, has been often employed [24]. Mourouco *et al.* [16] applied the 30-s STS and found that the swimming force (minimum, maximum or mean) was highly correlated with velocity at 50 and 200 m distances; they recommended that test to predict swimming velocity at those distances. However, reports on comparing the Wingate and STS tests are lacking. The here presented data showed a high within-gender correlation between the maximum results of both tests. No such correlation was found for mean values, like in another study of that kind [13], but this could have been due to small numbers of subjects in both groups and much smaller ranges of mean vs. maximum power outputs. Nevertheless, combining both groups resulted in a high correlation, practically identical with that found for

maximum power out-put ($r = 0.754$ and 0.765 , respectively).

Physiological response to on-land exercise is known differ from that in water [21]; at comparable intensities, that latter exercise may induce heart rate by about 10 bpm lower and the oxygen uptake – higher compared with that on-land [4]. In this study, mean differences between the Wingate and STS tests amounted to 12 and 23 bpm in male and female swimmers, respectively, although LA_{peak} values, which reflect the work intensity, were in both tests alike.

Peak lactate concentrations tended to be lower in the female than in male swimmers (10.1 ± 3.2 and 6.7 ± 2.0 respectively; $p = 0.07$); these values were similar to those noted in male and female wrestlers [11]. Bonifazi *et al.* [2] reported gender-related differences in LA_{peak} in swimmers at distances 50 – 400 m and suggested that this was due to greater swimming velocity of male swimmers. However, no such gender-related differences were found in swimmers at diverse distances by Avlonitou [1]. By and large, the 30-s Wingate test for upper extremities does not seem to reflect maximal capacity of muscles to engage anaerobic energy sources; lower extremities markedly contribute to swimming exertion which affects the post-exercise lactate concentration.

Mean power output, the measure of work output in the Wingate test, is known to reflect the contribution of anaerobic energy sources in that exertion and this indicated a smaller work output of female than male swimmers in this study. Yet, when relating LA_{peak} to P_{mean} , the values obtained for men and women were alike and similar results were reported also for wrestlers [11] and sprinters [7]. This is indicative of the contribution of anaerobic energy sources to the work of upper extremities being gender-independent.

Summing up, male swimmers attained higher values of mean and maximum relative power output in the 30-s Wingate test for upper extremities, as well as of mean and maximum swimming force in swimming test, compared with female swimmers. Thus, gender-related differences were shown to be independent of the kind of applied exercise test. Post-exercise peak lactate concentration was also higher in male than female swimmers in both tests, but the peak lactate-to-power output was in both genders alike, which indicated that the amount of energy generated from anaerobic glucose metabolism was gender-independent. Yet, the post-exercise lactate elimination rate was higher in male than female swimmers.

In conclusion, a high correlation between swimming strength produced in the semi-tethered swimming test and relative power output in the Wingate test for upper

extremities is indicative of interchangeability of those tests in the assessment of anaerobic capacity of upper extremities in male and female swimmers.

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