Original Article

Upper body anaerobic power and freestyle swimming performance

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Abstract

Most of the official swimming events involve a significant use of anaerobic energy systems. Therefore, the evaluation of these systems plays an important role in monitoring in swimming. Various laboratory anaerobic tests have been described in the literature, but one of the most commonly used in swimming is the upper body Wingate anaerobic test (WAnT). Some of the studies conducted so far have observed high correlations between the different indicators of WAnT and swimming speed or swimming achievements, and others have observed a lower or no significant correlations. The participants in this study are 52 swimmers from the Bulgarian Youth National Swimming Team - 15 girls at an average age of 15.5 ± 1.46 years and 37 boys at an average age of 15.9 ± 1.29 years. They performed the upper body WAnT with a resistance of 5% of body weight. As a result, the WAnT test parameters correlate significantly with the swimming achievements, with the highest correlation being observed between the average power and 50 m freestyle for both sexes- $r = -0.788$ ($p < 0.001$) for girls and $r = -0.811$ ($p < 0.001$) for boys. The observed high correlations allow us to recommend the test for anaerobic power monitoring in swimmers.

Key Words: anaerobic power, swimming, upper body, Wingate anaerobic test.

Introduction

Most of the official swimming events last from 22-24 s to 3-4 min and are running with a significant involvement of anaerobic energy systems (Gullstrand, 2000; Izov, 2017). Therefore, the evaluation of these systems plays an important role in monitoring in swimming. Assessment of anaerobic performance can be done with the use of field or laboratory tests. Testing swimmers in a laboratory environment is a reliable non-invasive procedure which has the advantage of being an easy way to evaluate training-induced changes in competitive swimmers (Dalamitros, Vassiliki, & Pelargio, 2014).

Various anaerobic laboratory tests have been described in the literature, but the most commonly used in sports practice is the Wingate anaerobic test (WAnT) in both upper and lower body modifications (Inbar et al., 1996). Swimming, with the exception of breaststroke, involves mainly the muscles in the upper body (Maglischo, 2003). For example, in front crawl about 90% of the velocity is due to the movement of the hands, while the work of the legs is restricted mainly in maintaining the correct position of the body in the water (Deschodt, Arsac, & Rouard, 1999; Gourgoulis et al., 2014). For that reason, the upper body modification of WAnT is widely used to determine the anaerobic power of swimmers (Guglielmo & Denadai, 2000; J. Hawley & Williams, 1991; J. Hawley, Williams, Vickovic, & Handcock, 1992; Rohrs, Joel, & Stager, 1991).

The basic parameters of WAnT which characterize anaerobic performance are: peak power (PP), average power (AP), and power drop (PD). It is considered that the peak power developed in the first seconds of the test is the result of the energy generated by adenosine triphosphate and creatine phosphate (ATP-CP) and serves to estimate the power of the ATP-CP system. On the other hand, the average power developed during the whole test is predominantly a result of the glycolysis-generated energy supply and serves to estimate the power of the anaerobic glycolytic system (Dotan & Bar-Or, 1983; Forbes, Kennedy, Boule, & Bell, 2014; Inbar, Bar-Or, & Skinner, 1996; Lovell et al., 2013). The power drop index represents the ratio between the values of the peak power and the minimum power at the end of the test.

The setting of mechanical resistance for WAnT is an important factor in obtaining an accurate assessment of the anaerobic performance of the upper body. According to Forbes et al. (2014) in the arm crank modification, the maximum peak power is reached at a load of 7.5% of body weight in men and 6.5% in women. According to the same authors, maximum average power values are reached at a resistance of 6.5% of body weight in men and 5.0% in women. Another study recorded the highest values of average power at a resistance of 6.1% of body weight in men, and of 4.8% in women (Dotan & Bar-Or, 1983). Other authors recommend an optimal resistance of about 5.0% of body weight in both sexes (Inbar et al., 1996; Nindl et al., 1995). There have been various studies on the contribution of the three energy systems during the upper body WAnT and swimming in sprint disciplines. For the upper body WAnT, Lovell et al. (2013) determine the relative

share of the anaerobic-alactate system in the total energy consumption on $28.3\% \pm 4.9\%$, of the anaerobic-lactate system on $60.3\% \pm 5.6\%$ and $11.4\% \pm 1.4\%$ of the aerobic system. In another study the contribution of the three energy systems to 50 m freestyle swimming is set at 38% for the anaerobic-alactate system, 58% for the anaerobic-lactate system, and 4% for the aerobic system (Rodriguez & Mader, 2011). The relative contribution of the three systems for the anaerobic test and the 50 m competitive swim is very close, making the WAnT very suitable for assessing swimmers in sprint disciplines.

In a study of 16 women and 14 men, J. Hawley & Williams, (1991) found very high correlations between the upper body WAnT test parameters (peak power, the average power, and the power drop index), and the swimming speed of 50 m front crawl ($r = 0.82$; $r = 0.83$; $r = 0.41$, respectively). In another study of 10 girls (13.2 years) and 12 boys (13.6 years), J. A. Hawley et al., (1992) found a significant correlation between the average power and the swimming speed of 50 m front crawl ($r = 0.63$). In a study of 39 adolescents with an average age of 15.9 years, Rohrs et al., (1991) found a moderate correlation of the peak and the average power with the swimming speeds on 25 yards ($r = 0.50$ and $r = 0.41$, respectively), on 50 yards ($r = 0.53$ and $r = 0.47$ respectively) and on 100 yards ($r = 0.41$ and $r = 0.44$ respectively).

Contrary to these results, in the study of 9 men (18.1 years) Guilherme and Denadai (Guglielmo & Denadai, 2000) did not find high correlations between WAnT test parameters (maximum power, average power, and power drop index) and the swimming speed for 25 m front crawl ($r = 0.28$; $r = 0.39$; $r = -0.17$ respectively), for 50 m ($r = 0.03$; $r = 0.09$; $r = -0.31$), and for 400 m ($r = -0.52$; $r = -0.37$; $r = -0.65$). A similar study of 10 men, university swimmers, found unreliable correlations between swimming time per 100 m front crawl and maximum power ($r = 0.59$), average power ($r = -0.47$) and power drop index ($r = -0.31$) (Ellis, 2010).

The discrepancy in the results of the authors cited above may be due to the heterogeneity in terms of sports qualification and the relatively small number of studied subjects. Clarifying the relationship between upper body, Wingate anaerobic test performance, and swimming achievements is important in assessing the place of the test in swimming monitoring.

The aim of the study was to evaluate the correlation between the anaerobic upper body performance and the swimming achievements in short disciplines of high-level swimmers.

Materials and Methods

Participants

The participants were 52 high swimmers from the Bulgarian Youth National Swimming Team: 15 girls with an average age of 15.5 ± 1.46 years and 37 boys with an average age of 15.9 ± 1.29 years.

Swimming achievements

We recorded the official results of the swimmers in 50, 100 and 200 m freestyle events during their main competitions, which were held no later than 2 weeks after the WAnT test date. Swimming results were also calculated in FINA (Fédération Internationale de Natation) points except in seconds. The calculation formula is based on a world record in a particular discipline that is considered to be 1000 points. We used point estimates to compare results across the different distances and between the two sexes.

Upper Body Wingate Anaerobic Test

The upper body WAnT was performed on a specialized Monark 894E mechanical ergometer, modified for arm ergometry. The cycle ergometer was mounted on a specially designed stand. A comfortable swivel chair for the tested person was attached to it. Specially designed handles were installed in place of the pedals. Power calculation and analysis of the results were performed using the *Monark Anaerobic Test Software* for Monark 894E. To perform the upper body WAnT, we used the standard protocol for the lower body WAnT (Inbar et al., 1996), modified for the upper body, and chose a resistance of 5.0% of body weight for both sexes (Nindl, Mahar, Harman, & Patton, 1995). The test was performed in two parts: preparation and main part. The preparation part (warm up) was 3 min low-intensity pedaling without resistance at 60 rpm. At the end of the 1st and 2nd minutes the subjects performed sprints with maximum revolutions with a duration of 5 seconds. Then there was a recovery period of 3 minutes of passive rest. The main part started with no resistance pedaling for 10 seconds followed by an acceleration to maximum rpm without resistance and the start of the test at maximum velocity with 5% of body mass resistance for a duration of 30 seconds.

The specialized software automatically calculated many basic and derivative parameters, in our study we used the following: Peak Power (PP) [W]; Relative Peak Power (RPP) [W/kg]; Average Power (AP) [W]; Relative Average Power (RAP) [W/kg]; Minimum Power (MP) [W]; Relative Minimum Power (RMP) [W/kg]; Power Drop (PD) [W]; Relative Power Drop (RPD) [W/kg]; Power Drop (PD%) [%]; Total work (TW) [J]

Statistics

Statistical analysis was conducted using Statistical Package for Social Sciences (SPSS) version 19, IBM, USA. Descriptive statistics, correlation analysis, regression, and multiple regression step analyses were also conducted. Mean values in the text and tables are represented by their standard deviation (mean $\pm$ SD). The test for the normality of the distribution was done using the Shapiro-Wilk test. The validity test for differences between the mean values of the studied variables with normal distribution in girls and adolescents was performed with Student's t-test for independent samples and the difference between those with distribution other than normal, with the nonparametric U-test of Mann-Whitney.

Results and analysis

Descriptive statistics of anthropometric data, upper body WAnT parameters, and swimming achievements of the studied girls and boys are shown in

Table 1. The average age of the girls was 15.0 ± 1.46 years, the mean height was 167.2 ± 7.10 cm and the mean weight was 57.8 ± 6.27 kg. The average age of the boys was 15.6 ± 1.37 years, the mean height was 177.8 ± 7.46 cm and the mean weight was 68.2 ± 7.63 kg. All three parameters for both sexes have a low coefficient of variation (from 4.2% to 11.2%).

The mean values of the Wingate absolute parameters for girls were: peak power (PP) - 512.84 ± 111.96 W, average power (AP) - 398.50 ± 79.57 W, minimum power (MP) - 274.82 ± 61.97 W and power drop (PD) - 238.02 ± 63.97 W, and for the relative parameters were: peak power (RPP) - 8.83 ± 1.39 W / kg, average power (RAP) - 6.87 ± 0.95 W / kg, minimum power (RMP) 4.79 ± 0.85 W / kg and power drop (RPD) - 4.08 ± 0.87 W / kg. The mean values of the Wingate absolute parameters for boys were: maximum power (PP) - 770.77 ± 146.32 W, average power (AP) - 573.53 ± 95.69 W, minimum power (MP) - 374.29 ± 72.92 W and power drop (PD) - 376.49 ± 106.19 W, and for relative parameters were: peak power (RPP) - 11.27 ± 1.58 W / kg, average power (RAP) - 8.38 ± 0.90 W / kg, minimum power (RMP) 5.76 ± 0.73 W / kg and power drop (RPD) - 5.52 ± 1.42 W / kg. The coefficients of variation in absolute and relative parameters in both sexes ranged between 10.7% and 28.2%, with the lowest being that for the average power and the highest being for the power drop.

The average swimming achievements for girls were: 50 m freestyle - 28.75 ± 0.89 s, which corresponds to 507 points on the FINA table, 100 m freestyle - 63.12 ± 3.34 s (504 points) and 200 m freestyle - 136.17 ± 6.31 s (533 points). The average swimming achievements for boys were: 50 m freestyle - 25.59 ± 1.56 s, which corresponds to 496 points on the FINA table, 100 m freestyle - 56.12 ± 3.74 s (513 points), and 200 m freestyle - 120.55 ± 5.70 s (560 points). The coefficient of variation in sports performance was in the range of 3.1 to 6.7%, indicating a strong uniformity of the samples in terms of sports qualification.

Most of the values have a normal distribution except those for height, relative average power (RAP) and swimming performance in both sexes. All mean values except the age differ significantly between the two sexes.

Table 1. Descriptive statistics of anthropometric data, upper body WAnT parameters, and swimming achievements of the studied girls and boys.

Variables	Women ♀				Men ♂			
	n	min	max	mean $\pm$ SD	n	min	max	mean $\pm$ SD
Age	15	13.0	18.0	15.5 ± 1.46	37	13.0	18.0	15.9 ± 1.29
Height [cm]!	15	162.0	178.0	171.2 ± 4.89 &	37	163.0	192.0	178.9 ± 6.81 &
Weight [kg]	15	52.3	66.7	59.6 ± 4.29 &	37	49.2	81.7	69.8 ± 6.77 &
PP [W]	15	176.6	413.3	282.5 ± 75.31 &	37	255.7	915.2	538.1 ± 137.60 &
RPP [W/kg]	15	3.20	6.30	4.71 ± 1.07 &	37	4.20	12.40	7.68 ± 1.68 &
AP [W]	15	138.8	296.8	209.5 ± 47.82 &	37	200.0	517.5	378.1 ± 69.06 &
RAP [W/kg]!	15	2.60	4.50	3.49 ± 0.65 &	37	3.40	6.90	5.39 ± 0.77 &
MP [W]	15	99.3	203.4	147.9 ± 33.34 &	36	136.8	354.1	244.6 ± 47.32 &
RMP [W/kg]	15	1.60	3.10	2.47 ± 0.47 &	36	2.10	4.50	3.50 ± 0.50 &
PD [W]	15	65.5	209.9	134.6 ± 44.75 &	36	118.9	620.9	287.4 ± 111.63 &
RPD [W/kg]	15	1.10	3.20	2.25 ± 0.67 &	36	1.60	8.40	4.10 ± 1.46 &
PD [%]	15	31.00	52.20	46.88 ± 5.62 *	36	37.50	69.20	52.48 ± 8.87 *
TW [J]	15	4171	8789	6205 ± 1409 &	37	5897	15311	11161 ± 1992.3 &
50 m [s]!	15	26.01	31.05	28.81 ± 1.38 &	37	23.56	28.28	25.39 ± 1.34 &
100 m [s]!	7	56.81	66.31	63.46 ± 3.75 &	18	52.18	62.96	54.99 ± 2.97 &
200 m [s]!	7	124.83	142.13	136.21 ± 6.35 &	17	112.69	133.46	119.28 ± 4.99 &

* - $p < 0.01$, & - $p < 0.001$ women vs. men; ! – Non-normal distribution

Correlation analysis of anthropometric data, upper body Wingate anaerobic test parameters, and swimming achievements of the studied girls are presented in Table 2. There was a significant correlation between height and weight ($r = 0.692$; $p < 0.004$). Significant positive correlations were reported between the absolute anaerobic test parameters and age and anthropometric data, with the highest being between weight and average power (AP) ($r = 0.680$; $p < 0.005$).

We found significant correlations between age and relative peak power (RPP) ($r = 0.538$; $p < 0.038$) and between age and relative average power (RAP) ($r = 0.594$; $p < 0.020$). Age, height, and weight correlate with 50 m freestyle swimming achievement, with the highest correlation between weight and 50 m ($r = 0.730$; $p < 0.002$). Significant correlations were observed between the absolute and relative test parameters and swimming achievements, with the highest reported between the average power (AP) and 50 m freestyle ($r = -0.788$; $p < 0.001$). Very high internal correlations were observed both inside the WAnT test parameters and inside the swimming achievements at different distances.

Table 2 Correlation matrix of the main variables obtained for girls

♀	Wingate upper body	Age	Height	Weight	PP	RPP	AP	RAP	50 m	100m
Height	corr. sig.	0.377 0.166	1.000							
Weight	corr. sig.	0.370 0.174	0.692 0.004	1.000						
PP	corr. sig.	0.564 0.029	0.574 0.025	0.628 0.012	1.000					
RPP	corr. sig.	0.538 0.038	0.450 0.092	0.414 0.125	0.967 0.000	1.000				
AP	corr. sig.	0.606 0.017	0.615 0.015	0.680 0.005	0.989 0.000	0.934 0.000	1.000			
RAP	corr. sig.	0.594 0.020	0.468 0.079	0.438 0.102	0.963 0.000	0.983 0.000	0.956 0.000	1.000		
50 m	corr. sig.	-0.517 0.049	-0.730 0.002	-0.620 0.014	-0.785 0.001	-0.717 0.003	-0.788 0.000	-0.711 0.003	1.000	
100 m	corr. sig.	-0.789 0.035	-0.720 0.068	-0.293 0.524	-0.569 0.182	-0.551 0.200	-0.626 0.133	-0.624 0.134	0.939 0.002	1.000
200 m	corr. sig.	-0.656 0.110	-0.623 0.135	-0.129 0.783	-0.359 0.429	-0.356 0.433	-0.419 0.349	-0.437 0.327	0.854 0.014	0.965 0.000

The correlation analysis of anthropometric data, upper body Wingate anaerobic test parameters, and swimming achievements of the studied boys are presented in **Error! Not a valid bookmark self-reference..** Significant correlations were observed between age and anthropometric data, with the highest correlation between weight and height ($r = 0.642$; $p < 0.001$). Significant positive correlations were observed between the absolute test parameters and age, weight, and height, with the highest being between weight and average power (AP) ($r = 0.645$; $p < 0.001$).

There are no statistically significant correlations between relative parameters (RPP and RAP) on the one hand, and age and anthropometric data on the other. Negative correlations were observed between age and swimming performance as well as between anthropometric data and swimming performance, with the highest being between height and 100 m freestyle ($r = 0.826$; $p < 0.001$).

The test results correlate significantly with sports performance, with the highest correlation being between average power (AP) and 50m freestyle ($r = 0.811$; $p < 0.001$). As with the girls, very high internal correlations are observed both within the WAnT test parameters and within the swimming achievements at different distances.

Table 3 Correlation matrix of the main variables obtained for boys

♂	Wingate upper body	Age	Height	Weight	PP	RPP	AP	RAP	50 m	100m
Height	corr. sig.	0.506 0.001	1.000							
Weight	corr. sig.	0.624 0.000	0.642 0.000	1.000						
PP	corr. sig.	0.431 0.008	0.363 0.027	0.511 0.001	1.000					
RPP	corr. sig.	0.282 0.091	0.178 0.292	0.203 0.228	0.942 0.000	1.000				
AP	corr. sig.	0.524 0.001	0.376 0.022	0.645 0.000	0.935 0.000	0.822 0.000	1.000			
RAP	corr. sig.	0.294 0.077	0.084 0.620	0.188 0.264	0.868 0.000	0.926 0.000	0.868 0.000	1.000		
50 m	corr. sig.	-0.487 0.002	-0.356 0.031	-0.627 0.000	-0.762 0.000	-0.642 0.000	-0.811 0.000	-0.648 0.000	1.000	
100 m	corr. sig.	-0.588 0.010	-0.826 0.000	-0.625 0.006	-0.736 0.000	-0.671 0.002	-0.800 0.000	-0.735 0.001	0.951 0.000	1.000
200 m	corr. sig.	-0.483 0.050	-0.662 0.004	-0.394 0.118	-0.553 0.021	-0.507 0.038	-0.584 0.014	-0.525 0.031	0.785 0.000	0.864 0.000

Regression analysis

A linear multiple regression step analysis was performed to evaluate the impact of the anaerobic performance test on the swimming achievement of 50 m for both sexes individually. In the stepwise regression, for independent variables were taken the most informative parameters obtained from the upper body Wingate anaerobic test (PP, RPP, AP, and RAP) and the age, height, and weight of the competitors.

From the stepwise regression analysis of the girls, the parameter absolute average power (AP) remained the only parameter in the regression equation. The regression equation is as follows:

$$50 \text{ m time [s]} = -0,0227 * AP \text{ [W]} + 33,58 \quad (r = -0,788; p < 0,001)$$

The linear regression equation is graphically represented in Fig.1.

From the stepwise regression analysis of the boys, the parameter absolute average power (AP) remained the only parameter in the regression equation. The regression equation is as follows:

$$50 \text{ m time [s]} = -0,0158 * AP \text{ [W]} + 31,36 \quad (r = -0,811; p < 0,001)$$

The linear regression equation is graphically represented in Fig.2.

Fig.1 Graphical representation of the linear regression equation for the dependence of athletic achievement on average power (AP) developed in the upper body WAnT ($r = 0.788$; $p < 0.001$) for girls. Dotted lines indicate the 90% prediction interval and points that extend beyond it are encircled.

Fig.2 Graphical representation of the linear regression equation for the dependence of swimming achievement on average power (AP) developed in the upper body WAnT ($r = 0.811$; $p < 0.001$) for boys. Dotted lines indicate the 90% prediction interval and points that extend beyond it are encircled.

Discussion

The descriptive statistics (

Table 1) found that, the mean values of all tested parameters except age differ significantly between both sexes. Despite the wide age range (13-18 years), the studied groups of girls and boys were strongly homogeneous in weight and height. In both sexes, the relative anaerobic performance parameters have a lower coefficient of variation than the corresponding absolute parameters. This lower coefficient can be explained with the removed variation due to the difference in weight in absolute parameters. The coefficient of variation is lowest for relative average power (RAP) and highest for absolute power drop (PD).

The 50, 100 and 200m freestyle swimming achievements of girls and boys vary between 496 and 560 FINA points and have a very low coefficient of variation (from 3.10% to 6.67%). This shows a strong uniformity in the sample in terms of swimming performance. The girls' achievements in 50, 100 and 200 m freestyle were slower by 1.14, 1.15 and 1.14 times respectively than the boys. This difference corresponds to 1.90 times higher peak power (PP) and 1.80 times higher average power (AP) for the boys compared to the girls. Given that the required power in swimming increases with the third degree of the speed (Toussaint & Hollander, 1994), at 1.80 times higher average power of girls compared to boys, it can be expected that speed and swimming achievement should be $\sqrt[3]{1.80} = 1.22$ times lower. The correlation analysis of both sexes (Table 2 and

Table 3), shows that the highest significant correlation between age and anthropometric data was that between weight and height for both girls ($r = 0.692$; $p < 0.004$), and boys ($r = 0.642$; $p < 0.001$). Reliable correlations between age and anthropometric data were only observed in boys. Both girls and boys have a strong correlation between the main anaerobic test parameters - PP, AP and MP. The higher peak power is associated with a greater power drop (correlations with PD not shown in the tables). Also, the higher peak power corresponds to higher average power. In both sexes, the relative test parameters do not have a significant correlation with weight, since its influence is eliminated in their calculation. Of the anaerobic test parameters in both sexes, the highest correlated with the swimming achievement of 50 m freestyle, was the absolute average power. The correlation coefficient for girls was $r = -0.788$ ($p < 0.001$) and for boys was $r = -0.811$ ($p < 0.001$). The two correlation coefficients did not differ significantly ($p = 0.849$). The correlation of relative average power (RAP) with the swimming achievement of 50 m was lower than that of the absolute power - for girls $r = -0.711$ ($p < 0.003$), and for boys $r = -0.648$ ($p < 0.001$). This lower correlation of relative to absolute average power is consistent with the observations of other authors according to which, when swimming, the body is balanced by the hydrostatic lift force and therefore relative power does not give a higher correlation with achievement than absolute power (Morouço, Keskinen, Vilas-Boas, & Fernandes, 2011; Yeater, Martin, White, & Gilson, 1981).

Other authors have also identified the average power (AP) of the upper body WAnT as the most highly correlated parameter with swimming speed in sprint disciplines (J. A. Hawley et al., 1992; J. Hawley & Williams, 1991). On the other hand, Rohrs et al., (1991) reported slightly higher correlations between swimming speeds of 25 and 50 yards and peak power, while at a distance of 100 yards they reported slightly higher correlations with average power. Other studies have found either low correlations between major parameters of upper body anaerobic test and swimming performance (Guglielmo & Denadai, 2000) or non-significant ones (Ellis, 2010). Achievements in distances of 100 and 200 m correlated with average power only in boys. Anaerobic average power is positively correlated with the age of the competitors. It is possible that the improvement of the technical skills in older swimmers determines the more efficient use of anaerobic power in swimming. For this reason, the partial correlation coefficients between the swimming achievements of 50 m freestyle and average power, controlled for age, were calculated. The following correlation coefficients were obtained: $r = -0.698$ ($p < 0.006$) for girls and $r = -0.747$ ($p < 0.001$) in boys. This shows some influence of swimming experience on the swimming achievements in both sexes. The correlation between anaerobic test results and swimming achievement decreases with the increasing of the race distance. This tendency is also reported in the results obtained by other authors (Guglielmo & Denadai, 2000; Rohrs et al., 1991). The probable cause is the decline in the contribution of the anaerobic systems and the increasing proportion of the aerobic system with the increasing race distance. The duration of the 50 m freestyle competitive swimming is commensurate with the time for performing the anaerobic upper body test, and accordingly, we have a close distribution of the shares of the energy supply mechanisms in terms of the total energy consumption.

To analyze the effect of major WAnT parameters on swimming achievements of 50 m freestyle, a linear stepwise regression was performed. The only parameter that remained in the regression equation for both sexes was the absolute average power (AP). Competitors whose 50 m freestyle achievements correspond to points well above the regression lines (which are outside the 90% predictive interval in Fig.1 and Fig.2) show a discrepancy between the measured average power and their swimming achievement, which at its highest degree may be due to their less efficient than the average freestyle swimming technique. Competitors whose 50m freestyle achievements correspond to points that lie significantly below the respective regression lines in Fig.1 and Fig.2 show better swimming achievements than expected on the basis of their measured anaerobic power. In these cases, the most probable reason can be a much more effective than the average freestyle swimming technique. Thus, of the studied competitors, in Fig.1 highlighted are the results of 1 swimmer whose results are above the 90% predictive interval (encircled), and in Fig.2 are highlighted the results of 3 swimmers whose results are outside the 90% predictive interval (encircled). Two of them are above the predictive interval (the two

upper encircled points) and one is below the predictive interval (the two lower encircled points). This analysis can provide guidance for the future preparation of the athletes described above. For example, increasing the work in order to develop anaerobic power in some, or improving the swimming technique in others.

Conclusions

The mean values of all tested parameters except age differ significantly between both sexes. The WAnT test parameters correlate significantly with the swimming achievements, with the highest correlation observed between the average power and 50 m freestyle for both sexes. The observed high correlations allow us to recommend the test for monitoring of anaerobic power in swimmers.

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