THE ASSESSMENT OF AEROBIC AND ANAEROBIC POWER ON A BICYCLE ERGOMETER AND ARM CRANK ERGOMETER IN RELATION TO SWIMMING PERFORMANCE

Ivan **MATÚŠ**

Faculty of Sports University of Prešov, Prešov, Slovakia

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- Aerobic power,
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Abstract:
When controling the training process, we need to have enough information about swimmers' states of training. To determine levels of training, we may use various tests for the assessment of aerobic and anaerobic power on a bicycle ergoemeter or arm ergometer in relation to swimming performance in the crawl. Ergometer tests are one of the most administered tests, especially thanks to their availability and non-invasiveness. Our review study has shown that the tests concerned are reliable tests for the assessment of aerobic and anaerobic power. We also found that the correlation between aerobic power and long-distance swimming performance was stronger than that between anaerobic power and swimming performance. On the other hand, this performance did not correspond with both anaerobic and aerobic performance in water because swimming performance requires the recruitment of all muscle groups. The swimming performance is significantly affected by swimming technique, which the tests did not assess.

INTRODUCTION

If we wish to control the training process effectively, we need to have enough information about changes in athlete's fitness and sports performance levels. The information about these changes is obtained by monitoring the fitness levels, which makes coaches consider whether to continue in the training planned or to make certain corrections [Feč, Matúš 2015]. To test functional capacity, coaches administer laboratory tests of aerobic and anaerobic abilities, for instance, using ergometers. The assessment of aerobic and anaerobic power of swimmers in relation to their performance should be considered the basis of the training process. With regard to time, the results of testing indicate operative, common or relatively permanent changes in the states of swimmers, which are the result of the combination of immediate and delayed training effects during a specific time púeriod, for instance, during a mesocycle or macrocycle. To conduct an effective assessment, swimmers have to be tested several times throughout a macrocycle. The most frequent period in the macrocycle include the preseason period and the beginning of the competition period. Some authors [Feč, Matúš 2015; Maglischo 2003] propose a more regular assessment, especially at the beginning and the end of every mesocycle. The assessment of aerobic and anaerobic power should be beneficial for talent identification in swimming. The fact that is to be considered as well is that swimming is a physical activity different from other physical activities. The difference is that swimming takes place in water, which shows specific principles, including the swimmer's body position, which is horizontal rather than vertical, and the way of breathing [Ružbarský, Matúš 2017]. The purpose of the study was to provide information about the assessment of aerobic and anaerobic power in relation to the swimming performance in the crawl.

MATERIAL AND METHODOLOGY

Literary searches were conducted in the following databases: Web of Science, PubMed, proceedings of international congresses and swimming databases. When looking for articles, the most frequently searched key words included aerobic power, anaerobic power, performance, Wingate test, swimming and ergometer. We also used Google scholar to find in particular articles in English language. Studies on other swimming strokes and water polo have not been included in the systematic review.

AEROBIC POWER TESTING ON A BICYCLE ERGOMETER AND ARM CRANK ERGOMETER

Conditioning abilities and body constitution are primarily responsible for the quality of yielding energy physiologically and biomechanical transfer of energy during sports performance [Hohmann, Lames, Letzelter 2010]. According to [Grasgruber, Cacek 2008], swimming performance is primarily determined by anatomical factors, trunk and arm strength, explosiveness, and endurance. These factors also include level of technique acquisition of particular swimming strokes and movement coordination in water. Another important factor is flexibility that affects the effectiveness of mastering the technique of swimming strokes and movement efficiency or stroke cycle. According to [Olbrecht 2000], aerobic power is considered to be the key component determining sports performance in swimming, either in endurance or sprint events. Aerobic power refers to maximum uptake of oxygen (VO_{2max}) that particular physiological systems of human organism are able to supply to the human organism per unit of time. VO_{2max} is an important indicator of the functioning of the transport system and the activity of oxidative enzymes in skeletal muscles. Therefore, VO_{2max} is one of the important parameters for the assessment of aerobic power. Laboratory testing of VO_{2max} in swimming has been based on the administration of lower-body tests (cycle ergometry) and arms (arm crank ergometer). Higher VO_{2max} values were reported for cycle ergometry particularly because large muscle groups are involved during the cycle ergometer test (mm. coxae, partis liberae membri inferioris, femoris, cruris, pedis) than during testing on an arm crank ergometer [Swaine, Winter 1999].

There is currently a variety of protocols to assess maximum oxygen consumption on a cycle ergometer. The protocols differ in the length of both exercise and rest, intensity (submaximal, maximal) and also in changes of body position (various body or arm angles) during testing. Currently used ergometers use the principle of electromagnetic braking. The performance is determined by the number of revolutions and frictional resistance. To assess aerobic power, the mode between 0 to 600, or even 900 W, is used [Cooper, Storer 2001]. Strzala, Tyka, Krezalek [2007] and Strzala, Tyka [2009] determined correlation between cycle and arm crank ergometer testing and front-crawl swimming. In the VO_{2max} arms test the intensity was gradually increased every three minutes, for 12 or 18 W. The incremental exercises were performed at 70 rpm^{-1} in VO_{2max} for legs and at 60 rpm^{-1} for arms. Smith, Norris, Hogg [2002] and Smith et al. [2004], specifically for arm-cracking, recommend the cycling cadence between 70 to 80 arm rpm^{-1} and greater elbow extension of 0 and 15 º during testing to elicit greater $VO_{2peak/max}$ values. In the study by Kitamura, Yeater, Martin [1990], authors recommend beginning to pedal at a work load of 100 watts on the bicycle ergometer and to increase the bicycle ergometer work load progressively by 50 W for each three-minute exercise bout until the VO_{2max} levels off. The cranking frequency was set at 50 rpm^{-1} and was regulated by a metronome. In their study, subjects began to crank at a work load of 25 W. The arm ergometer work load increased progressively by 25 W for each three-minute exercise bout. Each subject was required to crank until he could no longer continue and/or he could not keep cadence with the metronome. The peak VO_{2max} was considered the highest value of VO_{2max} obtained during the arm crank test. A similar bicycle ergometer protocol was applied by Roels et al. [2005] who increased worklaod every two minutes.

The correlations found between VO_{2max} values measured on a bicycle ergometer and arm crank ergometer and the distance swum show that the correlations tend to be higher as testing distance increases. This finding indicates that the ratio of aerobic and anaerobic energy contribution increases with longer distances favoring the aerobic energy contribution. For instance, Strzala, Tyka [2007] found a correlation of r= 0.37 between arm crank ergometer performance and 25 m swimming speed. On the other hand, according to Obert et al. [1992], correlation coefficients tend to increase with longer swimming distances (100 m r= -0.61; 200 m r= -0.71; 400 m r= -0.76). Also, Duche et al. [1993] and Strzala, Tyka, Kreyalek [2007] found low correlations between leg cycling on a bicycle ergometer and swimming distance (25 m: 0.53 and 50 m: 0.37). On the contrary, to assess aerobic power, Roels et al. [2005] administered a bicycle ergometer test and a 5x200 m swimming test. The authors found a significant correlation between VO_{2max} in cycling and swimming (r= 0.77). When assessing VO_{2max} the swimming distance should be 400 m long because [28] found no significant correlation between performance over a 2000 m distance and VO_{2max} values assessed during arm-cracking and leg cycling in young swimmers. The correlations between bicycle ergometer testing and arm cracking and performance over a specific distance may be misleading because, in the studies above, the participants were heterogeneous groups of swimmers. The samples differed in age, gender, and, most probably, in maturation status. The differences in the values of VO_{2max} during swimming and ergometer test performance may be caused also by the fact that water environment is specific compared with the performance on dry land. When swimming in water, trunk muscles are recruited as well, whereas these muscles are not recruited during bicycle ergometer and arm crank ergometry testing, or their recruitment is minimal. Another factor that has effect on the crawl swimming performance is the fact that the lower-body movement does not generate primary propulsion as compared with bicycle ergometer testing. Hollander et al. [1988] and Deschodt, Arsac, Rouard [1999] found that the legs propulsion contributes to the speed and performance by 10 to 15 %. Arm crank ergometer performance indicates a certain degree of arm propulsion, which resulted in a closer relationship with 400 m distance compared with shorter distances. On the other hand, arm crank ergometer does not provide valid VO_{2max} values because, in swimming, the stroke trajectory is longer, and the arms' angles are different during the pull phase from those on the arm crank ergometer. Also, this movement fo arms is a movement isolated from the movement of other body parts (trunk, lower body), which are recruited during swimming as well and need some supply of oxygen.

There is a paucity of studies dealing with aerobic power in swimming. To make the tests valid, the tests of aerobic power in swimming have to be administered multiple times because test results are affected by a variety of factors that need to be eliminated.

ANAEROBIC POWER TESTED ON BICYCLE ERGOMETER AND ARM CRANK ERGOMETER

The values of anaerobic power are used to estimate peak performance in order to predict maximum speed during swimming, especially in short distances [Stager, Tanner 2005] because the performance in short distances takes 20 to 30 s [Feč, Matúš 2015]. For instance, in the crawl swimming over short distances, 85 to 90 % of propulsive force is generated by the arm stroke, and the role of the legs is to maintain body in the proper posture [Gourgoulis et al. 2012; Ružbarský, Matúš 2017]. The most frequently used devices to test anaerobic power are the bicycle ergometer and arm crank ergometer, the testing on which provides data about peak anaerobic power and anaerobic capacity [Vandewalle, Gilbert, Monod 1987; Feč, Matúš 2015]. *The testing of anaerobic power requires maximum effort (by pedalling or arm cranking) for 30 s against a certain resistance, which is either mechanical or electrical* [Bar-Or 1987]. *To determine testing procedure validity, one must test the protocol against a "gold standard" trusted to elicit "true" values. In instances where there is such a standard, such as hydrostatic weighing to determine body composition, this is easy* [McArdle, Katch F., Katch V. 2007]. *There is, however, no such standard protocol for the determination of either anaerobic capacity or power. Due to this problem, the Wingate test (WAnT) has instead been compared with sport performance, sport specialty, and laboratory findings. These comparisons have determined that the Wingate test (WAnT) is measuring what it claims to measure, and is a good indicator of these measurements* [Bar-Or 1987]. *Other references question the validity because the usual method of calculating the resistance of a brake band loaded with weights does not take into account all aspects of rope-brake theory and overestimates the actual force by 12-15 %* [Franklin 2007]. The standard setting of resistance for the Wingate anaerobic test is 0.075 $g.kg^{-1}$ [Ayalon, Inbar, Bar-Or 1974]. Some studies emphasize the fact that resistance should depend on age because adults should work against greater resistance. For instance, Katch et al. [1977] used resistances of 0.053, 0.067, and 0.080 $g.kg^{-1}$, weheras Evans, Quinney [1981] used greater resistance (0.098 $g.kg^{-1}$). The advantage of increasing resistance of worklaod may be the achievement of maximum performance, for instance, in team games. The workload resistance may be changed, but the standard resistance for the WAnT is 0.075 $g.kg^{-1}$. The workload resistance for arm crank ergometer. For arm testing, the set resistance varies from 0.029 to 0.065 $g.kg^{-1}$. Peak and mean power values are determined from the 1, 3 or 5 s averages of power. In one of the first studies by Reilly, Bayley [1988], who carried out WAnT testing on a bicycle ergometer, female adolescent swimmers exhibited correlations between peak and mean power values and 30 m swimming performance (peak power: r= 0.59, mean power: r= 0.54). Hawley, Williams [1991] found a correlation between 50 m sprinting and mean power values of the legs (r= 0.76). Also, Duche et al. [1993] found a correlation between peak and mean WAnT power and 50 m swimming performance (peak power: r= 0.57, mean power: r= 0.35). The correlations between peak and mean anaerobic power and 400 m swimming performance were lower (peak power: r= 0.51, mean power: r= 0.15).

The correlations between WAnT bicycle ergometer testing and swimming distances show that peak and mean values for WAnT decrease with increasing distance, which may be caused by the swimming velocity because the longer the distance the lower the swimming velocity.

Reilly, Bayley [1988] found a correlation between peak and mean power for WAnT arms and 30 m swimming performance (peak power: r= 0.86, mean power r= 0.83). Lower degree of correlation was found between WAnt arms and 90-meter swimming distance (peak power: r= 0.57, mean power r= 0.63). There was a non-significant correlation between WAnT arms and 360 m distance. Hawley, Williams [1991] administered a WAnT arm ergometry and found correlations between peak and mean power outputs and 50 m distance (peak power: r=

0.82, mean power r= 0.83). Rohrs, Stager [1991] found that the correlation between peak and mean WAnT power outputs was higher for 50 y distance (peak power: r= 0.53, mean power r= 0.47) than for 25 y distance (peak power: r= 0.50, mean power r= 0.41) and 100 y distance (peak power: r= 0.41, mean power r= 0.44). Guglielmo L., Guglielmo A., Denadai [2000] found stronger orrelations between WAnT arms and performance over a distance shorter than 25 m (14 m, peak power r= 0.40, mean power r= 0.64) than longer distances (25 m, peak power r= 0.28, mean power r= 0.39).

The assessment of peak and mean power outputs using WAnT on an arm ergometer showed lower degrees of correlation with increasing distance than on bicycle ergometer.

As mentioned before, when assessing aerobic power, we have to take into account the fact that WAnT on a bicycle ergometer does not take into consideratiohn the body rotations and the coordination of leg and arms movements.

CONCLUSIONS

Testing swimmers by administering bicycle ergometer tests and arm crank ergometer tests is reliable because the tests that may be administered to assess both aerobic and anaerobic power. These ergometers are available in most testing facilities, and the testing is non-invasive. Information from such testing may be used as feedback for the assessment of fitness levels during various stages of swimming preparation, either during macrocycle or mesocycle. This information may be used to make some corrections in training. On the other hand, these tests are not entirely objectively because swimmers perform movements in a specific water environment, which shows certain principles. Moreover, swimmer's arms and legs are located in space and time. Comparing results with other studies may be difficult because the authors of studies apply different protocols that are not sufficiently standardized.

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