

## THE ASSESSMENT OF AEROBIC PHYSICAL CAPACITY IN YOUNG SWIMMERS

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**Abstract.** The purpose of this paper was to confront some selected physiological parameters that describe aerobic capacity with young swimmers' sports achievements. For the study, some athletes with the average age of 14.67, who train swimming at the SMS Szczecin Club, were selected. A progressive test of their oxygen power was performed in order to determine their aerobic capacity, with the means of the *European Ranking* (LEN). Each swimmer's sports level was presented in points [pts.]. The swimmers' characteristics were presented as divided into three groups: (S) – short-distance specialization, (M) – medium-distance specialization and (L) – long-distance specialization. In group (S), maximum oxygen consumption –  $\dot{V}O_2\text{max}$  [l/min] achieved the levels of 3.95 [l/min] (male swimmers) and 2.77 [l/min] (female swimmers); in group (M) – 4.12 [l/min] and 2.97 [l/min], respectively; and in group (L) – 4.14 [l/min] and 3.338 [l/min]. Among male swimmers, level of  $\dot{V}O_2\text{max}$  [ml/kg/min] equaled 58.96 – group (S), 59.72 – group (M) and 62.10 – group (L); while among female swimmers it reached 48.67 (S), 49.36 (M) and 54.60 (L), respectively. The recorded values of  $\dot{V}O_2\text{max}$  [ml/kg/min] qualify the young swimmers to the group of people with a very high physical capacity. Our selection of Szczecin's athletes to individual groups proved to be correct. The considerations presented in the paper bring one's attention to the substantive quality of the intake and selection of swimmers. In the selection, it is necessary to take such physiologic rates as  $\dot{V}O_2\text{max}$  or  $\dot{V}O_2/\text{HR}$  into consideration.

**Key words:** swimming, aerobic capacity, young swimmers

### Introduction

Swimming belongs to such sport disciplines where the range of events is quite broad. Therefore, swimmers competing in different events feature various levels of the training work intensity. Training orientation is related to the problem of the swimmer's effort energy balance: aerobic, anaerobic and mixed (aerobic-anaerobic) work and sprints (Montgomery and Chambers 2009). In the short swimming distances (50 and 100 m), the share of oxygen-based and non-oxygen-based sources of energy in maximum speed efforts are compared to athletic sprints (100 m). For the muscular work, the main source of energy is ATP, in 90% sourced from non-oxygen transformations and in 10% drawn from oxygen transformations. During medium distances (200 and 400 m), like in runs for 400 m, 70% ATP is

gained from non-oxygen transformations and 30% of it – from oxygen transformations. The longer the muscle work becomes, as it happens during covering the distances of 800 or 1500 m, the larger gets the share of oxygen-based processes in satisfying the metabolic demand from the working muscles. At the distance of 800 m, oxygen-sourced ATP makes for 60%, while for 1500 m the share of oxygen-sourced energy rises to 80% (Maughan et al. 1997).

Aerobic capacity of the organism depends on various physiologic, bio-chemical, constitutive and, ultimately, social factors. Physiologic parameters effecting aerobic capacity include:

- consumption of ( $VO_2$ ) per a unit of work,
- maximum consumption of oxygen ( $VO_{2max}$ ),
- oxygen-dependent heart rate ( $VO_2/HR$ ), and
- minute lung ventilation (VE) (Jastrzębska 2010).

The most frequently used criterion for assessment of aerobic capacity or, in general, an organism's physical capacity, is maximum oxygen consumption ( $VO_{2max}$ ). It is strongly gen-dependent, unstable and stabilizes in boys around their early 20s (Jastrzębska 2010). A review of both the world and national literature on the subject indicates that in many sports the results are basically related to minute lung ventilation (VE), total oxygen consumed during the effort, concentration of hydrogen ions in one's blood and total resting heart rate (EPS) (Zatoń 2010). The results of the studies performed by the team of Gastinger et al. (2010) indicate that lung ventilation (VE) is more closely correlated with oxygen consumption ( $VO_2$ ) than with the heart contraction rate (HR). Within the wide range of problems discussed, there are not many works which would present dependences between swimmers' achievements and their physiological parameters, or so called oxygen capacity rates.

The purpose of this paper was to discover which of the physiological parameters defining aerobic capacity, as e.g. oxygen consumption ( $VO_2$ ) per a work unit, maximum oxygen consumption ( $VO_{2max}$ ) or oxygen-related heart rate ( $VO_2/HR$ ), is most significant for the assessment of sport capabilities of young swimmers at the Sports Mastership School in Szczecin.

## Methods

The studies presented herein covered young male and female competitors, practicing swimming in the Sports Mastership School in Szczecin. The tested group consisted of 30 people, including 17 swimming boys (between 14 and 16) and 13 girls (between 13 and 16), with the average age being 14.94 and 14.87 respectively. It was a selected group, which included competitors who had been training swimming for 2–10 years (for all the people tested, the average training experience was 7.61 years), achieving continuous progress at the level of the national juniors' avant-garde, gaining medals in the Poland's Swimming Championships for Juniors and Seniors.

According to Siewierski (2005), the best sports mastership schools in our country, where the level of selection is the highest for both the number and the selection criteria, include: the SMS's in Szczecin, Oświęcim and Cracow. Those schools yielded contestants qualified for the National Team of swimmers and also the Polish Team for the Olympic Games.

Analysis of the scale and structure of the training load was performed based on some prepared coach spreadsheets. During the tests the contestants trained twice a day. Each time they swam distances between 5 and 7 km, depending on the training period. Additionally, the afternoon training was preceded by some land-based exercises. The effort applied during the training was based on as much as 60% on oxygen transformations (within the ranges of oxygen intensity zones up to 2–3 mmol/l).

In order to determine the body height and mass, anthropometric measurements were conducted. To assess aerobic capacity, the oxygen power progressive test was applied, consisting in the performance of physical effort under a growing load till the moment of refusal to carry on or till the moment when the growth of the external resistance brought about a reduction of consumption of O<sub>2</sub>, despite the growth of lung minute ventilation (VE). The test was performed, using a Jaeger ER900 cycle Ergometer. Aerobic capacity was assessed by the direct method, using a Jaeger Oxycon Pro exhaust gas analyzer (Viasys) and a software called Breath by Breath. The measurements were conducted as per the protocol proposed by Wasserman et al. (1987), Bentley (2007) and Bishop and Edge (2005).

During the test, the following parameters were monitored and recorded continuously:

- (VO<sub>2</sub> – oxygen consumption) – consumption of oxygen in relative units – milliliters per kilogram per minute [mL × kg<sup>-1</sup> × min<sup>-1</sup>] and absolute units – litres per minute [L × min<sup>-1</sup>],
- (VCO<sub>2</sub> – carbon dioxide production) – discharge of carbon dioxide in relative units [mL × kg<sup>-1</sup> × min<sup>-1</sup>] and in absolute units [L × min<sup>-1</sup>],
- (RER – respiratory exchange ratio) – a coefficient of respiratory exchange,
- (VE) – minute ventilation of lungs in litres per minute [L × min<sup>-1</sup>],
- (BF – breath frequency) – number of breaths per minute [odd × min<sup>-1</sup>],
- (HR – heart rate) – frequency of heart contractions in a minute in [sk × min<sup>-1</sup>],

This test permitted the determination of the parameters characterizing aerobic capacity of the organisms with such aerobic capacity indicators as:

- oxygen heart rate – VO<sub>2</sub>/HR [ml/contraction], and
- maximum oxygen consumption – VO<sub>2</sub>max [l/min] and VO<sub>2</sub>max [ml/kg/min].

The data collected in the measurements underwent statistical calculations. In the analysis of differences and relations among the variables, a test referred to as t – a Student, based on the Microsoft Excel 2007.

## Results

The measurement results of selected anthropomorphic parameters, which evaluate aerobic capacity, were analyzed, having divided the swimmers into three groups: S – specialized in short distances, M – specialized in medium distances, and L – specialized in long distances. This division was grounded on the distance-related specialization of individual swimmers (Table 1).

**Table 1.** Criteria for identification of groups, based on distance-related specialization (S), (M) and (L)

Distance-based specialization	Group	
50, 100 m	Specialization in short distances	S
200, 400 m	Specialization in medium distances	M
800, 1500 m	Specialization in long distances	L

From all sport achievements recorded in each swimmer's career, their best results achieved in formal competitions were identified (the shortest time achieved), referring to the main distance and style the person swims. The authors used the *European Ranking* and so called *Swimming Score Tables* of the European Swimming

Association (LEN 2013). This way, each swimmer's sport level was identified and presented in the paper in points [pts.] (Table 2). If the highest level results were achieved for distances of 50 and 100 m, the swimmer was allotted to the short-distance group (S). If the best scores were achieved at distances of 200 and 400 m, they were identified as short-distance (M). Similarly, where the results were best for distances of 800 and 1500 m, the swimmer was qualified as a long-distance swimmer (L).

**Table 2.** Numeric characteristics of Szczecin's male and female swimmers from group S (short-distance specialty), M (medium-distance specialty) and L (long-distance specialty)

Group (Distance-based specialization)	n	Arithmetic mean/standard deviation	Training seniority [years]	Age [years]	Height of the body [cm]	Mass of the body [kg]	Sports level [pts.]
Boys							
S	8	$\bar{x}$	7.12	14.62	179.25	67.50	541.37
		S	2.42	0.52	7.69	11.11	109.19
M	5	$\bar{x}$	7.60	15.20	178.80	68.80	589.4
		S	2.07	1.09	3.77	7.59	124.87
L	4	$\bar{x}$	8.25	15.00	177.00	67.50	645.25
		S	1.26	1.15	5.29	9.85	137.45
Girls							
S	4	$\bar{x}$	6.75	14.25	170.25	56.75	565.75
		S	3.20	0.96	5.79	5.19	194.42
M	8	$\bar{x}$	7.00	14.37	170.25	60.50	564.25
		S	2.27	0.92	2.96	6.16	121.58
L	1	$\bar{x}$	9.00	16.00	170.00	62.00	799.00
		S	-	-	-	-	-

Table 2 provides a detailed characteristics of the subjects, divided into the three groups: (S) – short-distance specialty, (M) – medium-distance specialty, and (L) – long-distance specialty. As far as the height-related parameters are concerned, on average the tallest were the boys from group (S) – 179.25 cm, then came the boys of group (M) – 178.80 cm. In group (L) the average height of the body was the lowest, being 177.00 cm. In all specialty groups of the young female swimmers, the height-related parameters were quite similar and ranged around 170.00 cm. The differences between the boys and girls were not statistically significant.

As far as the weight is concerned, all the male swimmers groups (S, M and L) were basically similar (avg. 67.50 kg – groups S and L, and 68.80 kg – group M). Among the female swimmers the lowest average mass of the body was recorded for the (S) group girls – 56.75 kg, followed by the girls from (M) – 60.50 kg. In group (L) the body mass was the highest and amounted to 62.00 kg. Anthropometric parameters – the body mass, analyzed in examination of the individual swimmers' groups, does not differentiate the groups in question either.

According to Table 2, the highest sport level [pts.] was demonstrated by the male swimmers of the long-distance predisposition (L) – 645.25 [pts.], followed by the medium-distance male group (M) with 589.40 [pts.] and the male swimmers from the short-distance group (S) – 541.37 [pts.] respectively. Among the girls, the highest sport level was presented by a swimmer from the long-distance group (L) – 799.00 [pts.]. Swimmers from the medium-distance (M) and short-distance (S) groups demonstrated a similar sport level, scoring approximately 575.00 [pts.].

Figure 1 shows the results of physiologic parameter measurements, reflecting potential capacities of the organism in relation to maximum physical effort, circulation or respiration values.

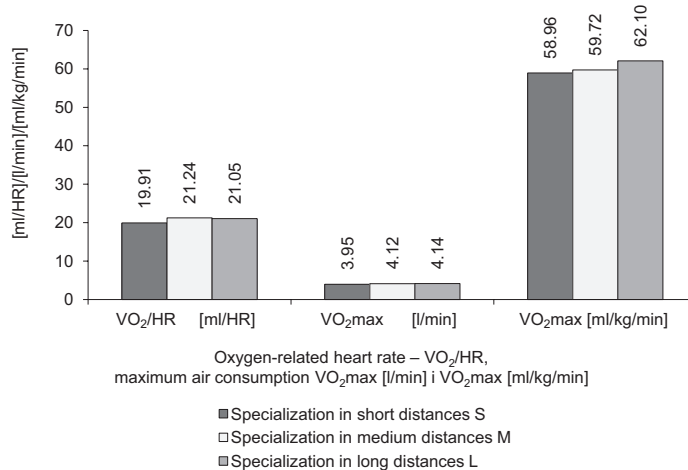


Figure 1. Aerobic capacity in the young male swimmers

The first analyzed parameter was the oxygen heart rate value – VO<sub>2</sub>/HR [ml/contraction]. In the short-distance male swimmers (S), the average value of this parameter was the lowest (of the tested S, M and L groups) – 19.91 [ml/contraction], for the medium-distance swimmers (S) – 21.24 [ml/contraction], and – 21.05 [ml/contraction] for the long-distance ones (D).

Maximum oxygen consumption – VO<sub>2</sub>max, expressed in absolute values – litres per minute [l/min], maintained the level of 3.95 [l/min] in the short-distance male swimmers’ group (S), 4.12 [l/min] in the group of the medium-distance male swimmers, and 4.14 [l/min] for the long-distance ones.

Maximum oxygen consumption VO<sub>2</sub>max, expressed in relative values [ml/kg/min], reached the following values: 58.96 in group (S), 59.72 in group (M) and 62.10 in group (L), respectively.

A similar tendency was observed in the female swimmers as in the male swimmers. Namely, the value of the oxygen-related heart rate – VO<sub>2</sub>/HR [ml/contraction] was the lowest in the group of the short-distance female swimmers (S) – 14.19 [ml/contraction], then, for the medium-distance ones (M) it amounted to 14.93 [ml/contraction], while the female swimmers from the long-distance group (L) featured the highest value of this parameter – 19.34 [ml/contraction].

In female swimmers, maximum oxygen consumption – VO<sub>2</sub>max, measured in absolute values – litres per minute [l/min], displayed the same tendency as the oxygen-related heart rate. It reached 2.77 [l/min] in the group of female swimmers specialized in short distances (S), 2.97 [l/min] in the medium-distance ones and 3.38 [l/min] in the long-distance female swimmers’ group (L).

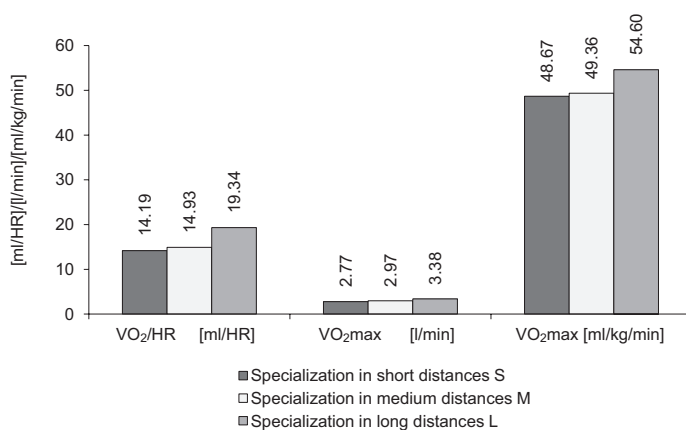
The level of the maximum oxygen consumption VO<sub>2</sub>max, expressed in relative values [ml/kg/min], amounted to 48.67 in the group (S), 49.36 in the group (M) and 54.60 in the group (L).

## Discussion

Within the scope of this study, the assessment of the young male and female swimmers' physical capacities was performed. Maximum oxygen consumption  $VO_2max$  served as the criterion for the aerobic capacity assessment. In Szczecin's young male and female swimmers, the aerobic capacity level was high. The values of the maximum oxygen consumption  $VO_2max$  [l/min], that were recorded in all the subjects, allow us to qualify the swimmers to the group of people with a very good physical capacity. Interpreting the maximum oxygen consumption values recorded during the test, following the path of Jastrzębska (2010), using the distance-based division, the group of male and female swimmers specialized in short-distances (S) presented a high  $VO_2max$  (for men: 3.70–3.99; for women 2.50–2.79), whereas the group of male and female medium (M) and long (L) distance specialties demonstrated particularly high values of  $VO_2max$  (for men: >4.00; for women: >2.80), denominated in absolute values.

The test results may suggest that the short-distance male and female swimmers (S) – the sprinters – should also perform some training exercise on the oxygen transformations. They may also serve as evidence that the height and mass of the body are much more important for sprinters than oxygen-related heart beat or maximum oxygen consumption.

Interpreting the determined maximum oxygen consumption values in the test, presented in relative figures –  $VO_2max$  [ml/kg/min], all three groups of the swimming boys and girls (S, M and L) presented very high values of  $VO_2max$  (for men: >57.00; for women: >49), while the highest  $VO_2max$  expressed in [ml/kg/min] was recorded in the long-distance male swimmers, with the score of 73.30. Practice tells us that in those sports where the contestant relocates his or her body, a relative force is needed. One's fitness is expressed by  $VO_2max$  [ml/kg/min]. A  $VO_2max$  [ml/kg/min] result that remains within the limits of 70.00 is a sign of the person's organism's sufficient capacities for achieving a result of international recognition.



**Figure 2.** Aerobic capacity in the young female swimmers

The team of Wojciechowska-Maszkowska et al. (2005) conducted some research on the assessment of physical capacities of Opole's boys practicing canoeing and swimming (average age of the subjects: 15 ± 1.16), on

the basis of measuring maximum oxygen consumption ( $VO_{2max}$ ). The obtained values ( $3.66 \pm 0.55$ ) of  $VO_{2max}$  [l/min] parameter were lower in Opole's competitors, comparing to those recorded for the group of young Szczecin's swimmers (average age of the subjects:  $14.94 \pm 0.92$ ), where the mean value of  $VO_{2max}$  [l/min] recorded was  $4.07 \pm 0.5$ . In the group of Opole's competitors, mean values of the maximum oxygen consumption  $VO_{2max}$  [ml/kg/min] were also lower than the average results in Szczecin. The parameter of  $VO_{2max}$  [ml/kg/min] amounted to  $59 \pm 6.37$  in Opole's group, and  $60.26 \pm 6.10$  in Szczecin's group respectively. The differences in the  $VO_{2max}$  levels among Opole's and Szczecin's competitors might be attributed to the longer training seniority of Szczecin's swimmers, where the average training seniority of all Szczecin's swimmers in question was 7.61 years. In Opole, on the other hand, that seniority lasted 3 years only. This may indicate earlier adaptive changes in the circulatory-respiratory system, which will be sustained during the years to follow, proving the influence of a regular physical training on the young person's organism. Training effectiveness depends on both the exercise scheme and its frequency, intensity and duration (EU Physical Activity Guidelines 2008).

According to Rowland (2007), during one's puberty this characteristic develops most dynamically. The drop of the maximum oxygen consumption that is related to the mass of the body ( $VO_{2max} \times kg^{-1}$ ) may be probable not because of a temporary deterioration of the circulatory system, but because of an increase in the fat tissue in one's youth.

In order to compare what values are taken by the maximum oxygen consumption in boys who do not take physical exercise regularly, we may refer to the studies performed by Zatoń et al. (2009). The team of Zatoń et al. (2009) focused on the effect of recreational snowboarding on effort capacities in 16/17-year-old boys. The mean values of  $VO_{2max}$  [ml/kg/min] were much lower than those of the young Szczecin's swimmers, being respectively  $45.06 \pm 4.33$  (before commencement of the tests) and  $48.32 \pm 5.16$  (after a period of snowboarding).

Another physiologic parameter, belonging to the so-called oxygen indicators, is the oxygen-related heart rate  $VO_{2}/HR$  [ml/contraction]. It reflects one's predispositions to absorb larger amounts of oxygen, i.e. his or her ability to cover longer distances with a lower heart rate. The value of this parameter determines the person's capacity to swim longer distances. Such predispositions refer to the circulatory system, and genetic factors play an important role here. Among the swimmers in the study, the lowest value of this parameter was recorded for those specialized in short-distances (S), followed by the long (L) and medium (M) distance swimmers, where that value took similar rates. This parameter helps identify swimmers without the predisposition to swim medium or long distances, and assign them to swim short distances.

Some significant correlations between the results in the sport and  $VO_{2max}$  in people swimming 200 and 400 m freestyle were observed by the team of Obert et al. (1992).

The qualification of the swimmers to the long-distance team (L) proved to be correct. In the long-distance swimming, apart from the oxygen-related parameters, the body height is also particularly important due to the significance of swimmer's step length resulting from a larger reach of the arms. In this group, the swimmer's body should be slender-built.

Selection of Szczecin's male and female swimmers to individual groups: short-distance (S), medium-distance (M) and long-distance (L), proved to be correct. This notion is confirmed by the recorded values of their aerobic capacity.

The considerations presented herein bring one's attention to the specific importance of intake and selection in swimming sports. Siewierski (2005) stated that in the selection processes, boys or girls, whose puberty pace

is not that quick, should not be eliminated and that such physiologic parameters as  $\text{VO}_2\text{max}$ ,  $\text{VO}_2/\text{HR}$  or time of regeneration HR after strain should be taken into account. In the sport of children and youth, this approach will guarantee the long-term effects, as referred to by Sozański et al. (2008). Training effectiveness, estimated through the assessment of the swimmer's career progress, shows that the course of the training process and appropriate selection and qualification on all individual stages of the training had the critical impact on the results in swimming disciplines. Observation of the swimmers' careers disclosed a different pace of development of their results in swimmers tested by the team of Sozański et al. (2008), which indicated a differentiated sports level of the swimmers in different years of training. Enhanced effectiveness of individual swimming technique might constitute a boost for progress in sports results (Makar et al. 2010).

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