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ORIGINAL RESEARCH PAPER

RELATIONSHIP BETWEEN RESPIRATORY SYSTEMS' PARAMETERS AND RESULT IN SWIMMING

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Abstract

The efficiency of swimming time could have a close relationship with swimming technique as well, as respiratory system parameters. This research aimed to evaluate the relationship between respiratory system parameters and result in a 100m distance in 44 competitive swimmers (males n=28, females n=16). Swimmers were divided in two groups: young swimmers (males n=14, ages 16.5±0.3 years, body mass 74.3±7.5kg, height 183.9±3.5cm; females n=11, ages 16.5±0.3 years, body mass 60.2±7.2kg, height 170.3±7.1cm) and adults athletes (males n=14, ages 21.2±3.3 years, body mass 83.2±10.0kg, height 187.8±7.2cm; females n=5, ages 21.8±4.5 years, body mass 65.7±7.5kg, height 174.20±7.29cm). Outcome measures were 100m distance time and respiratory parameters. Results. The average competition results in the men's group were 628 FINA points, in the women's group 592 FINA points, in the group of 16-17-year-old athletes men's group is 588 FINA points, in the women's group 574 FINA points. Respiratory system indicators: men`s group FVC – 6.47±0.53l., PIF – 8.55±1.34l/s, PEF – 9.95±0.40l/s, in the women's group FVC – 4.86±0.67l., PIF – 6.15±0.67 l/s, PEF 7.57±0.43 l/s. Conclusions. A strong relationship was found between 100m competitive swimming time and peak inspiratory flow in the adult male swimmer group (r=.75). As well as a relationship between the volume of fortified inhale per second and a competitive result in a group of 16-17 years old was found during the research (r= .55).

Key words: *swimming time, respiratory system characteristics, competitive swimmers.*

Introduction

Swimming, although a cyclic sport, has a unique set of characteristics that set it apart from other sports, including the horizontal position of the body, increased humidity, limited ventilation underwater, and higher external pressure. Because of the higher specific heat and conductivity of water, body heat loss is also rapid. The pressure on the diaphragm is also higher during swimming than running (Mehrotra, Varma, Tiwari & Kumar, 1998). Of course, all of these elements should be considered, while preparing the strategy for the training process and looking for the right method to develop precisely those skills and abilities, that will influence the outcome in these specific circumstances. There is an increase in the number of mitochondria in muscle fibers as a result of low-intensity, long-duration swimming training. All of these modifications result in greater endurance with less weariness (Widmaier, Raff & Strang, 2004).

Swimming performance is highly dependent on the underwater phase, which begins with the start and turn, consisting of gliding and dolphin kicking during the first 15 m of the distance. The efficiency of swimming time could have a close relationship with swimming technique as well, as with respiratory system parameters (Wells, Plyley, Goodman & Duffin, 2005). The condition of the respiratory system can affect the performance of high-level athletes, especially at a high intensity (Harms, Wetter, Croix, Pegelow & Dempsey, 2000).

The aim of this research was to evaluate the relationship between respiratory systems parameters and results in 100m distance in young and adult competitive swimmers. Respiratory system parameters and swimming time relationship determination and analysis could help identify the most important respiratory parameters that affect swimming performance and sports result. This knowledge could help to improve the training process in competitive swimming.

Respiration in the body is responsible for gas exchange within the body. Respiration can be categorized as either external respiration or internal respiration. External respiration describes the exchange of gas at the alveolar-capillary membrane and the pulmonary capillaries. Internal respiration is the exchange of gas between the pulmonary capillaries and the cells of the surrounding tissues. The respiratory system performs ventilation functions, air mass exchange to and from the body during inhalation and exhalation. The respiration process requires coordinated ventilatory muscles activity, rib cage movements, appropriate structure and function of the upper and lower respiratory tracts (Kisner & Colby, 2007).

Usually, during normal daily life activities oxygen intake by inhaling is viewed as an active process, which is provided by a diaphragm, external intercostals, and interchondral part of internal intercostal (part which elevates ribs up) muscles. The neck, chest, and shoulder muscles such as sternocleidomastoid, scalenes group, and pectoralis major also help during deep breathing inhale. But the transfer of carbon dioxide with exhaled air during quiet breathing appears to be a passive process due to the elastic recoil of the lungs, chest, and diaphragm. It is known that the following helps while exhaling during some active work,: internal intercostals muscles part, which pulls ribs down, abdominals – pull ribs down and compress abdominal contents thus pushing diaphragm up and quadratus lumborum and also pulling ribs down. We can observe the same process in swimming. When a swimmer is underwater, the compression effect of water reduces bronchial patency, vital capacity, and maximum ventilation of the lungs, the inspiratory reserve volume increases by 6 – 8%, and the expiratory reserve volume decreases by 10 – 12%, which naturally needs to be compensated. Resistance to airflow in the pulmonary system during active swimming increases by more than 50%, which requires the increased activity of the respiratory muscles (Солопов, 1988).

However, factors such as additional work of the inspiratory muscles to overcome water resistance, active work of the expiratory muscles, periodic disturbances in the rhythm of breathing, holding the breath while inhaling and lengthening the exhalation when performing turns and sliding, unexpected breath holdings in case of accidental ingress of water into the trachea create an additional load on the swimmer's pulmonary system. In turn, the condition of the respiratory system will undoubtedly affect the result in swimming.

The following parameters have been used for the respiratory system evaluation in the study, such as:

1. Forced expiratory volume (FEV) – the amount of air a swimmer can exhale during a forced breath. The amount of air exhaled was measured 1s (FEV1) of the forced breath.
2. Forced vital capacity (FVC) – the total amount of air exhaled during a deep breath. during exhale.
3. Forced inspiratory volume during 1s (FIV1) - the amount of air that can be inhaled during the first 1s.
4. Peak expiratory flow (PEF) – a person's maximum speed of expiration.
5. Peak inspiratory flow (PIF) – a person's maximal speed of inspiration.

In the scientific literature, there are several publications about swimmers' pulmonary system condition (Солопов, 1988; Rumaka, 2008). In the Bougault et al. (2009) research, it was shown that chemicals formed from the interaction of chlorine with organic substances can irritate the respiratory tract, cause upper, and lower respiratory symptoms, and affect respiration system parameters and swimming time, especially in children, lifeguards, and high-level swimmers. The study of about 14 years old Polish swimmers' respiratory system parameters and result in 100m distance showed the correlation analysis between the sports result and the selected breathing parameters in the study group. Significant correlation took place only in one case – between the swimming fitness test and the volume of forced exhalation in 1s (FEV1). In all other cases, no statistically significant correlation was observed (Dybinska & Kucia–Czyszczon, 2007).

It has been recognized that endurance training for respiratory muscles, in addition to regular swimming training, is more effective than just regular swimming training for 50m and 200m distance time results (Lemaitre, Coquart, Mucci & Costalat, 2013). It was shown that after 8 weeks of the training period, including respiratory muscle endurance training, swimming results improved by 3 – 4%. Similar conclusions were made in research with club-level competitive swimmers – additional respiratory muscle training had a positive effect on 100m and 200m distance swimming time (Kilding, Brown, McConnell, 2009). Endurance training of respiratory muscles for 4 weeks (30min per day, 5 days per week) significantly increased the endurance of swimmers.

However, this study shows the relationship between some respiratory systems' parameters and 100m results in young and adult competitive swimmers.

The hypothesis of the study is that the respiratory system parameters of the swimmers have a close relationship with 100m distance time in competitive young and adult swimmers. To define that, a correlation analysis of 100m distance time and individual respiratory system parameter indicators in young and adult competitive swimmers has been performed.

The identification of the relationship level between respiratory system parameters and result in swimming could help in young swimmers' selection process as well as improve the efficiency of the training process in competitive swimming.

Material and Methods

The primary technique of measurement was direct observation of the following variables:

1. A spirometry test is used to measure the level of the physical condition of different characteristics of the respiratory system.
2. The level of readiness for swimming is determined by the result at a distance of 100m.

Forty four competitive swimmers (28 males, 16 females) from Latvia, Lithuania, Estonia, and Russia participated in the study. Participants' characteristics are presented in Table 1.

Table 1.

Participant's characteristics

	Number of participants	Age (years) (mean±sd)	Height (cm) (mean±sd)	Body mass (kg)(mean±sd)	Qualification FINA points*	Age group (years)
men	14	21.23±3.32	187.84±7.17	83.17±10.01	≥ 640	18+
	14	16.5±0.33	183.85±3.46	74.26±7.53	640 - 540	16-17
women	5	21.8±4.54	174.20±7.29	65.7±7.47	≥640	18+
	11	16.5±0.33	170.27±7.08	60.24±7,17	± 540	16-17

* The qualification of swimmers represents FINA points -an objective swimming performance evaluation tool. The points are calculated using a cubic curve: with the swim time of the current athlete (T) and the base time (The base times are defined every year, based on the latest World Record that was approved by thee international swimming federation FINA. For short course (25m SCM) the base times are defined with the cut of date of August 31st. For long courses (50m LCM) the base times are defined at the end of the year (December 31st). of the distance (B) in seconds: P=1000* (B / T)*3.

Spirometer Schiller SP – 250 (Switzerland) S. Forced vital capacity (FVC) was used for swimmers respiratory system parameter evaluation, forced expiratory volume during first second (FEV1), forced inspiratory volume during first second (FIV1), peak expiratory flow (PEF) and peak inspiratory flow (PIF) were tested. Data was preceded by Shiller SDS-10 software (Switzerland) according to ATS/ERS criteria.

Testing procedure. Before performing spirometry, the equipment used must be calibrated, or at least the calibration checked at the beginning of the session. Environmental data (temperature (measured at 22 – 25 degrees Celsius), atmospheric pressure (1005hPa), and relative humidity (36 – 40%).

Prior to doing spirometry, the swimmer's identity should be verified, their height and weight measured without shoes or boots, and their age and sex documented, from which the individual norm is determined.

The observed subject was in a sitting position. The participant was requested to take a nose clip and then it was placed on the subject's nose, and he was instructed to take the deepest breath possible, followed by a maximum of rapid and deep breathing, and a maximum of rapid and deep breathing into the spirometer. Three trials were registered, with the best measurement utilized for data processing.

Data analysis. The data obtained were entered and mathematically processed with Microsoft Office Excel data processing program, proceeding with:

1. Descriptive statistics – arithmetic mean, standard errors, confidence interval (α<0,05);

2. Calculation of the Kolmogorov-Smirnov test criterion (to determine whether the data is parametric or non-parametric); in this test, the deviation of the empirical distribution from the normal distribution is considered significant if the significance is $p<0.05$;
3. The correlation between the selected parameters of the respiratory system and the result of the competition at a distance of 100m was sought using Pearson linear correlation by calculating the correlation coefficient (r) data processing is performed with the Microsoft Office Excel program. To determine the correspondence of the measurement data to the normal distribution (confidence interval $\alpha<0.05$), on the basis of which mathematical-statistical methods for further processing of data were selected.

The value α is determined on the basis of the "Scientific Convention" agreements received in the scientific community, based on practical experience in various fields of research. Such a value α is recommended for small samples.

Results

The athletes' sports results (FINA points) are listed in Table 2.

Table 2.

Average race results at Fina Points

Gender	Age	FINA points
men	16 – 17 (mean±sd)	588±59.1
	Adults (mean±sd)	674±52.6
	Average (mean±sd)	628±70.6
women	16 – 17 (mean±sd)	574±56.3
	Adults (mean±sd)	649±54.4
	Average (mean±sd)	592±61.9

The average results in the men's group is 628 FINA points, in the women's group 592 FINA points, the percentage difference is 5.73%. In the group of 16 – 17 year-old athletes, the average result in the men's group is 588 FINA points, in the women's group 574 FINA points, the percentage difference is 2.3%. In the adult men's group is 674 FINA points, women are 649 FINA points, the percentage difference is 3.7%.

The table (Tab. 3) shows the average values of the measured indicators of the respiratory system.

Table 3.

Statistical values of measured respiratory parameters

gender	age	FVC	FEV1	FIV1	PEF	PIF
men	16 – 17(mean±sd)	6.17±0.55	5.49±0.47	4.81±1.47	9.67±1.36	7.6±1.50
	18+ (mean±sd)	6.78±0.62	5.67±0.53	5.37±1.63	10.24±1.02	9.5±1.67
	Average(mean±sd)	6.47±0.53	5.58±0.12	5.09±0.39	9.95±0.40	8.55±1.34
units of measurement		l	l	l	l/s	l/s
women	16 – 17 (mean±sd)	4.38±0.63	3.91±0.57	3.08±1.03	7.26±1.26	5.64±1.53
	18+ (mean±sd)	5.34±0.89	4.67±0.55	4.55±0.94	7.88±0.55	6.59±0.73
	Average (mean±sd	4.86±0.67	4.29±0.53	3.81±1.03	7.57±0.43	6.15±0.67

(FVC - forced vital capacity, FEV1 - forced expiratory volume during first second
FIV1 - forced inspiratory volume during 1 s, PEF - peak expiratory flow
PIF - peak inspiratory flow)

In contrast to the data obtained from the scientific literature, in the surveyed objects, peak respiratory flow indicators prevail over peak inspiratory flow indicators, in all age and gender groups.

To test the promoted hypothesis, the obtained data were processed using Pearson's linear correlation by calculating the linear correlation coefficient (r).

A correlation analysis was carried out to identify the relationship between the respiratory rates of adults and young swimmers and the results of the competition (Tab. 4).

Table 4.

Correlation indicator (k) between sports results and selected parameters of the respiratory system

0.39	0.09	0.48*	0.05	0.63*	Men
0.19	0.02	0.55*	-0.25	0.22	M16-17
0.08	-0.1	0.38	0.12	0.75*	18 +
FVC	FEV1	FIV1	PEF	PIF	
0.22	0.12	0.33	-0.15	0.12	Woman
-0.28	-0.38	-0.019	-0.58*	-0.007	W16-17
0.17	0.048	0.09	0.41	-0.21	18 +
0.34	0.11	0.33	0.14	0.48	average

In the male group, the most closely matched result correlates with the closest result correlated with the peak inspiratory flow (r= .63), the fortified inhalation volume per second (r= .480), and the fortified vital capacity (r= .39). A weak correlation is determined by the volume of the forced expiratory volume during the first second (r= .09) and the peak expiratory flow (r= .05).

In the female group, statistically reliable correlation factors were obtained between the result of the race (FINA Points) and the forced inspiratory volume per second (r = .33), the fortified vital capacity (r = .22). A weak correlation factor is detected between the result of the race and the volume of the fortified exhalation per second (r = .12) and the maximum rate of the exhalation flow, as well as the (r = -.15).

The first (Fig. 1) and second (Fig. 2) figures show a graphical representation of the highest indicators of correlation analysis.

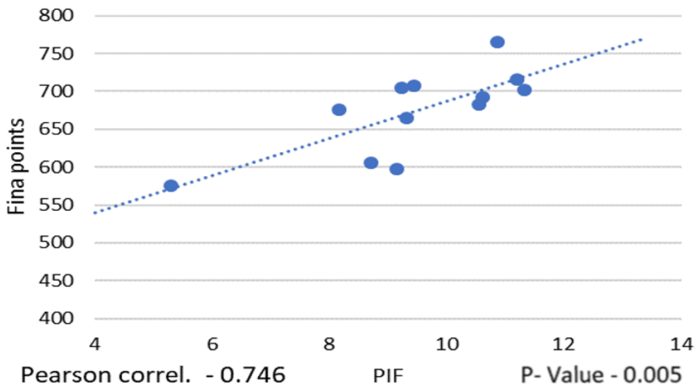

Figure 1. Dispersion chart: Fina points vs. PIF – peak inspiratory flow l/s – adult men swimmers

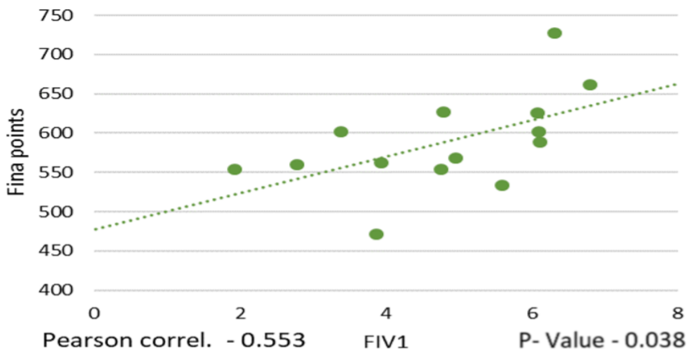

Fig. 2 Dispersion chart: Fina points vs. PIF - forced inspiratory volume during 1/s, – 16-17 men swimmers

Based on the detailed analysis of the chosen respiratory parameter levels male and female swimmers and relation to their sports result in 100m distance, the following general statements have been formulated:

Strong relationships were found between 100 m competitive swimming time and peak inspiratory flow in the adult male swimmer group (r= .75). In addition, a link was discovered between the volume of fortified inhale per second and a competitive result in a group of 16 – 17 year olds (r= .55).

Discussion

The results of studies have shown that the volume of the swimmer's breathing rate is mainly determined compared to the breathing rate volume. According to scientific literature, swimmers, due to the peculiar nature of breathing during swimming, have a pre-fertilization of the peak inspiratory flow over the peak expiratory flow (Абрамов, 1964).

The obtained data show that both the male group (PEF=9.97l/m) and the female group (PEF=7.46l/m), have a low peak inspiratory flow (male group (PIF=8.45, female group PIF=5.94/m). The provided findings contradict data from the specialized literature (Солопов, 1988), as well as the complete determination of Latvian pelting groups with effective underwater swimming.

The aquatic environment that swimming competitions take place it limits breathing freedom and alters breathing patterns. As a result, it demonstrates how important the respiratory system is in swimming.

It is worth evaluating whether or not it's possible to improve the air ventilation system, and if so, how far these improvements may be applied. In competitive swimming, a well-functioning respiratory system can be a critical aspect in deciding the final athletic result. According to scientific literature, swimmers have a pre-fertilization of the volumetric rate of exhalation due to the distinctive character of swimming breathing.

The purpose of this article was to determine whether there is a relationship between specific parameters of swimmers' breathing and the final competition results.

The hypothesized thesis has been confirmed, (as the correlations between chosen respiratory system parameters and the competitive results of the tested swimmers were statistically significant in several circumstances ($p<0.05$).

Conclusions

It seems that the results of this examination, apart from having a theoretical function, can be used in practice, as they can help coaches and instructors diagnose, forecast, analyze or plan the training process for young swimmers, especially in relation to the shaping of the functional abilities of the respiratory system.

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