Computer Spirometry: Research of Respiratory System Functionality and Its Enhancement in Young Swimmers

Anna Zakharova[a], Alexey Gorelov[b] and Tatiana Miasnikova[c]
Institute of Physical Education, Sport and Youth Policy, Ural Federal University named after the first President of Russia B.N. Yeltsin, Mira Street, Ekaterinburg, Russia

Keywords: Respiratory System, Spirometry, Vital Capacity, Forced Vital Capacity, Swimmers, Respiratory Muscle Training.

Abstract: The control of the swimmers' fitness should include an assessment the respiratory system. The aim of the study to evaluate the age features of respiratory system in young swimmers and suggest the methods for respiratory system improvement. Methods: young athletes underwent two tests with MicroLab spirometry; relaxed and forced vital capacity measurement. Findings: (i) young swimmers 10-11 years old with at least 5 years of experience in swimming showed low spirometry indicators (85% of predicted value); (ii) the more experienced and successful swimmers the better their respiratory system developed. High-performance sport swimmers have high level (120 % of predicted value) of all spirometry indicators; (iii) breathing exercises selected for solving the respiratory problems in swimmers improve the respiratory muscles functionality.

1 INTRODUCTION

Respiratory system is one of the essential factor providing general endurance in sport (Sheel, 2010). Competitive swimming is challenging to human pulmonary system as (i) whole body muscles are required for propulsion through water thus O_2 intake should be high; (ii) swimmer's face is submerged in water; (iii) breathing is constrained by swimming technique, that is stroke cycles, etc. Moreover, in normal (dry land) breathing, only inhalation is active, and exhalation occurs passively, due to the relaxation of the muscles that provide inhalation. In water, exhalation should be forced, with the participation of the muscles that produce exhalation.

Breathing in swimmers was under consideration in a number of articles (Vašíčková, 2017, Bovard, 2018, Rosser-Stanford, 2019). It was reported that functional readiness of athletes-swimmers was largely determined by functional mobilization of physiological systems, namely of respiratory and circulatory systems' functionality.

Respiratory muscles dysfunction manifests itself in a decrease in their functional properties - strength (the ability to develop maximum effort) and/or endurance (the ability to continuously maintain submaximal efforts). is expressed in the development of their fatigue or weakness (Segizbaeva, 2019). An important result of numerous studies in recent years is the physiological substantiation of the possibility of training the respiratory muscles in order to increase their strength and endurance, as well as increase the overall physical performance of healthy subjects (Segizbaeva, 2019) and athletes (Vašíčková, 2017).

The purpose of the study was twofold – to evaluate the age features of respiratory system in young swimmers and suggest the methods for respiratory system improvement in young swimmers.

2 METHODS

The study was conducted in the laboratory "Functional Testing and Complex Control in Sports" of the Institute of Physical Education, Sports and Youth Policy, Ural Federal University (Yekaterinburg, Russia).

[a] https://orcid.org/0000-0002-8170-2316
[b] https://orcid.org/0000-0002-9550-1793
[c] https://orcid.org/0000-0002-0894-1337

Zakharova, A., Gorelov, A. and Miasnikova, T.
Computer Spirometry: Research of Respiratory System Functionality and Its Enhancement in Young Swimmers.
DOI: 10.5220/0010147302280233
In *Proceedings of the 8th International Conference on Sport Sciences Research and Technology Support (icSPORTS 2020)*, pages 228-233
ISBN: 978-989-758-481-7

The investigation conforms to the principles of the Declaration of Helsinki of the World Medical Association. Subjects involved in the study and their parents had been provided with comprehensive information on the procedures, methods, benefits and possible risks before their written consent was obtained. The study protocol was approved by the Ural Federal University Ethics Committee (#05-2020).

To evaluate respiratory system correctly it is obligatory to determine the anthropometric measurements as the lungs volume and their functionality depend upon the patient physical development (that is height and weight).

2.1 Anthropometry

The height was measured with height meter in vertical position without shoes. Weighting was done with Mi Body Composition Scale (Xiaomi, China).

2.2 MICROLAB™ Spirometry

The portable spirometer MicroLab (Care Fusion, USA) was used to measure respiratory volumes and functions. The device is an essential spirometer in today's healthcare professional. Vyaire's Gold Standard Turbine measurement technology is certified by the American Thoracic Society (ATS), the internationally recognized body for spirometry performance. MicroLab spirometer is provided with Spirometry PC Software program to calculate the expiratory and inspiratory indices, taking into account age, gender, weight and height. There is a built-in strip printer which prints out the individual report after spirometry testing.

A nose-clip was used for accuracy of measured spirometry data (Figure 1) and the disposable mouthpieces Ø28 mm were used for the patients' safety.

Figure 1: Spirometry test procedure.

Before running the spirometry tests it was necessary to enter a patient's details (identity, sex, date of birth, height, weight).

Two tests were conducted: relaxed vital capacity measurement prior to performing a forced vital capacity manoeuvre.

2.2.1 Relaxed Vital Capacity Measurement

For relaxed vital capacity (VC) testing the patient was instructed to breathe in until their lungs are completely full, to seal the lips around the mouthpiece and to blow out at a comfortable rate until he (she) cannot push out any more air.

Three attempts were allowed.

2.2.2 Forced Vital Capacity Measurement

A Forced vital capacity test was conducted three minutes later after completion of a Relaxed VC test. The patient was instructed to breathe in as in the previous test—until the lungs were completely full, seal their lips around the mouthpiece and blow out as hard and as fast as possible until he (she) cannot push any more air out, then breathe in immediately after the expiratory manoeuvre and repeat this cycle (inspiration-expiration) three times without stop.

As the patient details had been entered before the first test the spirometry screen displayed the predicted Flow/Volume curve as a dashed line. During the test the patient is looking after his Flow/Volume curve and predicted one (dashed line) and try to enhance the breathing performance to achieve the breathing pattern (Figure 2).

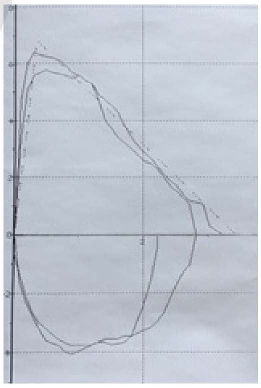


Figure 2: The Flow/Volume loop.

2.2.3 Spirometry Test Results

After the completion of both tests Spirometry PC Software fulfills manoeuvre quality check to allow a decision to be made to accept or reject these blows. There are four quality checks performed on each spirometry manoeuvre to determine its acceptability. If the patient performs an acceptable manoeuvre ‘Good blow’ is displayed at the top of the screen. Automatically or manually the ‘best’ blows for the report are selected (MicroLab Operating Manual, 2004).

The MicroLab Spirometer report includes (i) respiratory performance and (ii) a graphic depiction of the breathing loop and (iii) the contours of the proper breathing loop based on the patient's height, weight and age.

Following indicators were under consideration: vital capacity (VC, l), forced vital capacity (FVC, l) and forced expiratory volume in the first second (FEV1) as well as the percentage of the predicted values along with the Flow/Volume loop.

The testing procedures were explained to each participant and informed consent was obtained in accordance with the Declaration of Helsinki of the World Medical Association.

2.3 Statistics

Statistical analysis was performed with the use of statistic software package “SPSS Statistics 17.0” (IBM). The descriptive analysis of the obtained data was applied. Normality of distribution was assessed by the Shapiro-Wilk test. Mean value (M) and standard deviation (SD) of the measured parameters were calculated. The level of significance was set at $P < 0.05$.

2.4 Subjects

In October 2019 in the sport scientific laboratory of the Ural Federal University stage control including spirometry was carried out for the group of swimmers (6 boys and 5 girls) 10-11 years old (height 148.9 ± 9.12 cm, weight 38.8 ± 7.87 kg). These athletes have been engaged in sports swimming for at least 5 years and had I youth and III sport category in swimming In Russia there is a system of sport categories according to competition results: to achieve I youth category and III sport category in swimming one must cover the distance of 200 m for boys 3:08.0 and 2:42.5 and for girls 3:29.0 and 2:58.0 in crawl swimming respectively.

To reveal the level of respiratory system development in other athletes spirometry tests were carried out with a group of 12 young professional hockey players of 9 years old (height 135.75 ± 4.69 cm, weight 34.3 ± 2.22 kg) and 10 amateur hockey players 10–11 years old (height 143.33 ± 4.46 cm, weight 35.7 ± 5.92kg), engaged in the outdoors training all year round.

For comparison “young athletes vs a group of classmates” 28 pupils of one form (18 boys and 10 girls) aged 9-10 years (height 138.9 ± 7cm, weight 32 ± 6.32kg) were studied with spirometry (Zakharova, 2020).

3 RESULTS

Analysing the spirometry indicators of the respiratory system in a group of swimmers aged 10-11 (Table 1), we found that only 2 swimmers or 18% of the studied subjects showed a normal VC with a proper individual indicator above 100%, 2 swimmers (18%) were within the norm of 95-100%, 27% (3 swimmers) had the result below normal (80–95% of VC) and 36% or 4 swimmers had extremely low VC.

Table 1: Pulmonary system function indicators of swimmers’ group 10-11 years old (M±m (min-max)).

Indicator	Vital capacity	Forced Vital Capacity	FEV1
Absolute measure, l	2.50±0.58 (1.51-2.9)	2.41±0.58 (1.37-3.3)	2.03±0.40 (1.36-2.7)
Percentage of proper value, %	86.2±15.3 (60-111)	85.2±16.7 (55-108)	85.6±12.9 (65-109)

One swimmer coped with the FVC test as he had only excellent indicators (above 100%) of the FVC test (VC, FVC and FEV1) and 27% (3 swimmers) were within normal FVC.

7 swimmers showed an FVC indicator below normal: 4 swimmers demonstrated 80-95% of predicted FVC and 3 swimmers had poor FVC, that is, below 80% of predicted FVC).

Taking into account that, first, predicted by Spirometry PC Software values of respiratory system intend for healthy children but not for athletes specially and, second, larger lungs are necessary for competitive swimming, we conclude that young swimmers with more than 5 years of sport swimming experience showed poor results in spirometry tests. So we came to the idea to check the spirometry in other young athletes and non-athletes of the same age.

Ice hockey players (n=12) training in modern indoor ice palaces demonstrated satisfactory spirometry data (table 2).

Table 2: Spirometry indicators of different groups of children 9-11 years old (M±m (min-max)).

Indicators	Ice hockey	Outdoor amateur ice hockey	Swimming	Pupils of one class
	9 years old	10-11 years old	10-11 years old	9-10 years old
VC, l	2.35±0.3 (1.88-2.51)	2.53±0.15 (2.36-2.75)	2.50±0.58 (1.51-2.92)	2.11±0.36 (1.45-3.12)
FVC, l	2.32±0.26 (1.98-2.55)	2.57±0.24 (2.28-2.95)	2.41±0.58 (1.37-3.33)	2.10±0.36 (1.38-3.16)
FEV1, l	2.13±0.19 (1.93-2.40)	2.24±0.28 (1.82-2.59)	2.03±0.40 (1.36-2.77)	1.87±0.26 (1.35-2.56)
Percentage of predicted value				
VC, %	97.3±16.8 (72-106)	98±4.65 (93-105)	86.2±15.3 (60-111)	89.7±11.2 (64-112)
FVC, %	98.5±17.1 (78-110)	101.8±6.27 (94-112)	85.2±16.7 (55-108)	89.9±10.4 (74-110)
FEV1, %	108±17.06 (91-128)	105.5±6.69 (99-117)	85.6±12.9 (65-109)	97.3±7.9 (85-114)

VC- vital capacity, FVC- forced vital capacity and FEV1 - forced expiratory volume in the first second

Amateur hockey players (n=10), training outdoors all year round had even better results in relative values than young professional hockey players.

Group of 11 athletes-swimmers and ordinary pupils from one class both have the spirometry data statistically not distinguished.

So all average spirometry indicators (VC, FVC and FEV1) in swimmers (Table 2) were lower than necessary for healthy children. We found that swimmers 10-11 years old with at least 5 years of experience have an insufficiently developed respiratory system, that is, they cannot breathe correctly and use the respiratory muscles effectively.

These spirometry results were unexpected both for us and for the coach. What is the reason of such a backlog in the respiratory muscles functionality?

In conversation with the swimming coach it was revealed that the motor tasks for breathing were used in training of studied swimmers: under water swimming without breath, swimming with one intake of breath for three- four strokes, etc. These exercises adapt the swimmers for swimming in lack of breathing but do not improve the breathing pattern. So we can't consider these exercises as respiratory muscle training. Moreover, speed swimming with high frequency of strokes suppress the normal breathing.

It was reported that swimming training did not enlarge the lungs in children (Bovard, 2018). To reveal the level of the respiratory system development in swimmers of different sport categories we carried out the spirometry research with young swimmers (n=10) aged 11-12 years old (height 149.2±8.78 cm, weight 37.9±7.59kg), more experienced swimmers (n=5) 15-18 years old (height 184.4±4.4 cm, weight 77± 4.2 kg) and high performance sport swimmers (n=4) 20-23 years old (height 187.5±3.5cm, weight 84.5±2.1kg) and used the earlier obtained data of studied swimmers aged 10-11 (Table 3).

The spirometry results of swimmers (Table 3) prove that the more experienced and successful swimmers the better their respiratory system developed. High-performance sport swimmers have high level (120 % predicted value) of all spirometry indicators.

It is not clear: the large lungs of swimmers is the result of intensive training or swimmers with low respiratory functions give up competitive sport. But our next task was to help the young swimmers with low respiratory functions to improve them.

From the above mentioned spirometry results and swimmers' Flow/Volume loops with insufficient strength of expiration muscles and short breathing cycle (Figure 3) we stated following respiratory problems in swimmers:

- Low vital capacity;
- Low FEV1 id est power of expiratory muscles;
- Insufficient (short) expiration;
- Weak inhale.

FEV1 is associated with the power of expiratory muscles as the power is defined as the ability to produce large force in a limited period of time with high rates of force development. So the value of Forced Expired Volume in the first second may be high only in case of good strength and what is more important of good ability to produce high expiration in short time.

Table 3: Spirometry indicators of swimmers of different sport qualification (M±m (min-max)).

Spirometry indicators	Age			
	10-11 years old	11-12 years old	15-18 years old	20-23 years old
VC, l	2.50±0.50 (1.51-3.28)	2.74±0.47 (2.09-3.28)	5.99 ± 1.7 (4.18-7.59)	7.42±0.1 (7.35-7.49)
FVC, l	2.41±0.58 (1.37-3.337)	2.72±0.51 2.07-3.33	5.63±1.5 (3.96-6.82)	7.12±0.06 (7.07-7.16)
FEV1, l	2.03±0.40 (1.36-2.77)	2.51±0.46 (1.84-3.32)	4.85±1.1 (3.75-5.96)	5.62±0.19 (5.48-5.75)
Percentage of predicted value				
VC, %	86.2±15.3 (60-111)	96.1±13.16 (70-115)	117.3±9.7 (109-135)	120±4.24 (117-123)
FVC, %	85.2±16.7 (55-108)	97.7±12.18 (80-120)	117.3±9.7 (109-128)	120±4.24 (117-123)
FEV1, %	85.6±12.9 (65-109)	107.2±9.70 (93-120)	114±5.6 109-120	120.5±7.78 (115-126)

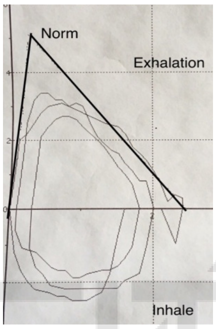


Figure 3: The Flow/Volume loop of the swimmer#1.

Short expiration may have place in two cases: low strength or endurance of expiratory muscles.

For each respiratory problem the exercises were selected:

1) to increase VC, it is necessary to ensure correct posture, chest mobility with stretching and bending, and elasticity of the muscles responsible for the function of breathing, especially the diaphragm;

2) for the development of the expiratory muscles power - blowing out the candles, blowing off the ball rolled from A4 paper sheet and explosive exhalations through a swimming tube dipped in water. or the development of the duration of exhalation;

3) for longer expiration–blowing off a paper ball folded from a napkin; play "tennis" blowing a paper ball in pairs, blowing out 5–10 candles placed in a row at a distance of 5–10 cm from each other, etc;

4) for developing the strength of inspiration – swimming with a tube with a clamp restricting the flow of air.

We considered these exercises would help young swimmers to learn how to breathe correctly.

The experiment for respiratory system improvement via exercises was organized. Initial spirometry testing were held in October 2019 with the group of swimmers 10-11 years old. The coaching part of the experiment included:

• Conversation with the trainer based on the test results;

• Conducting theoretical and practical classes on respiratory system exercises with the swimmers;

• Informing parents about the importance of breathing exercises for encouraging the swimmers to fulfil the exercises at home;

• Performing breathing exercises during the period from December 1, 2019 to February 16, 2020, at home (daily) and in training (5 times a week).

Due to the outbreak of acute respiratory none in January-February 2020 only 4 swimmers were able to take part in post-experiment spirometry. Comparing the results of spirometry indicators before and after experiment in four swimmers, we found improvements in the functioning of the respiratory system for each indicator (Table 4). In swimmer # 1 after the experiment we found an increase in the FVC, FEV1 and his Flow/Volume loop was normalized (Figure 4) in comparison with his primary spirometry (Figure 3).

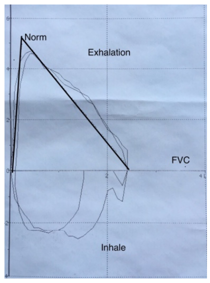
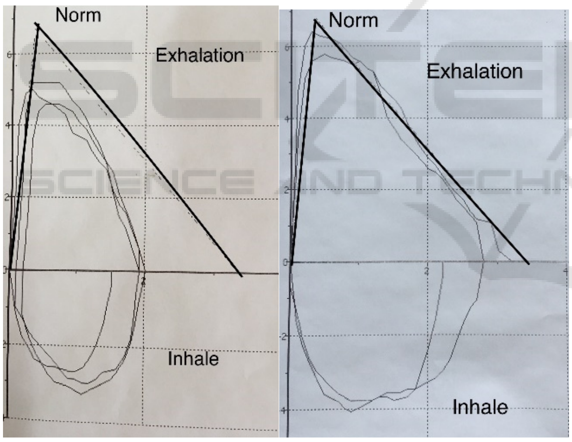


Figure 4: Post- experiment Flow/Volume loops of swimmer #1.

Table 4: Spirometry indicators of young swimmers before and after experiment (M±m (min-max)).

Indicators	Pre-	Post-
VC, l	2.15± 0.58 (1.51-2.92)	2.59 ±0.39 (2.32-3.16)
FVC, l	2.05±0.24 (1.81-2.38)	2.46 ±0.48 (2.1-3.14)
FEV1, l	1.91±0.18 (1.64-2.05)	2.21 ±0.6 (1.7-2.93)
VC, %	80.7±15.6 (60-97)	97.2 ±4.79 (92-103)
FVC, %	81.5±18.8 (59-98)	94.2 ±5.3 (88-100)
FEV1, %	89.7±17.7 (71-109)	99.5 ±11.7 (89-114)

In swimmer #2 at the first testing the following problems were identified: weak inhalation, weak exhalation and its duration (Figure 5a). After the experiment there was an improvement in the depth of inhalation, the peak of exhalation and the duration of exhalation as well as in FVC (Figure 5b). Thus we can conclude that breathing exercises helped the swimmer#2 to improve his respiratory muscles functionality: enhance their strength and workability.



a b

Figure 5: Pre- and post- experiment Flow/Volume loops of swimmer #2.

Although the results of the experiment reveal no statistically significant differences (Table 4) but qualitative information from the Flow/Volume Loops (Figures 4 and 5) proves that experiment was successful.

Thus breathing exercises selected according to respiratory system problems revealed with the help of MicroLab spirometry are effective for young swimmers.

4 CONCLUSIONS

1. Competitive swimming does not develop respiratory system in young swimmers.
2. The level of respiratory functionality of swimmers must be under supervision with the help of computer spirometry.
3. Swimmers' breathing requires special training including exercises for lungs enlargement, development of power and endurance of expiratory muscles as well as strength of inspiratory muscles.

ACKNOWLEDGEMENTS

The work was supported by Act 211 Government of the Russian Federation, contract № 02.A03.21.0006.

REFERENCES

Bovard, J. M., Welch, J. F., Houghton, K. M., McKenzie, D. C., Potts, J. E., & Sheel, A. W., 2018. Does competitive swimming affect lung growth?. In *Physiological reports*, *6*(15), e13816. https://doi.org/10.14814/phy2.13816

MicroLab Operating Manual 069-12 Revision 1.4 August 2004. Micro Medical Limited, 2004. Micro Medical Ltd., PO Box 6, Rochester, Kent ME1 2AZ ENGLAND www.micromedical.co.uk

Rosser-Stanford, B., Backx, K., Lord, R., & Williams, E. M., 2019. Static and Dynamic Lung Volumes in Swimmers and Their Ventilatory Response to Maximal Exercise. In *Lung*, 197(1), 15–19.

Segizbaeva M. O., & Aleksandrova N. P., 2019. Assessment of the Functional state of Respiratory Muscles: Methodical Aspects and Data Interpretation. In *Human Physiology*, 45(2), 213–224.

Sheel, A. W., MacNutt, M. J., & Querido, J. S., 2010. The pulmonary system during exercise in hypoxia and the cold. In *Experimental physiology*, *95*(3), 422–430. https://doi.org/10.1113/expphysiol.2009.047571

Vašíčková, J., Neumannová, K., & Svozil, Z., 2017. The Effect of Respiratory Muscle Training on Fin-Swimmers' Performance. In *Journal of sports science & medicine*, 16(4), 521–526.

Zakharova, A. V., Gorelov, A. N., Makarov D., Nikitina J. G., 2020. Role of physical culture and sports in the development of the respiratory system at children aged 9-10 years old (on the example of one class). In J *Uchenye zapiski universiteta imeni P.F. Lesgafta,* 5(183), 169-174.