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Evaluation of respiratory function indicators of elite athletes in academic rowing using the method of computer spirography

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Abstract

Background and Study Aim In modern sports, the research and study of the functional capabilities of athletes' breathing is relevant. The analysis of individual results made it possible to form an idea about the respiratory functions of athletes. Among elite athletes, parameters of respiratory functions are significantly higher than the norm, so their interpretation relative to the general healthy population is inadequate. The purpose of the study is to determine lung volumes and dynamic parameters of the respiratory act and their difference in height and weight categories, respectively.

Material and Methods The study involved 22 elite athletes aged 19-24 took part in the study. Testing of all athletes was carried out during the period of preparation for the competition The following research methods were used: method of anthropometry; method of computer Spirometry (was used to assess the functional state of reserve possibilities of the external breathing of athletes by absolute indicators). The studied material was processed by the methods of mathematical statistics using the "Statistica 6.0" software and MS Excel. Athletes were divided into three groups of height categories: group-A (190 cm and above), group-B (180-189 cm), group-C (170-179 cm) and three weight categories: group-D (90 kg and above), group-E (80-89 kg), group-F (70-79 kg).

Results Studies have shown that the absolute values of respiratory functions in athletes with significant hight and significant body weight are higher than in athletes with short height and insignificant weight. Real indicators of respiratory functions in most athletes are within the normal range. The highest actual indicators of respiratory functions are observed in the group of athletes with average height and average body weight. Also, in elite athletes with average height and average body weight, individual actual indicators are practically the same.

Conclusions Planning and construction of the training process requires knowledge of absolute and actual indicators of respiratory functions. The conducted research made it possible to establish the level of functional reserves of power and mobilization functions of breathing in elite-level rowers. The results allow effective planning of physical activity during training.

Keywords: lung volumes, respiratory system, elite athletes

Introduction

Modern sports science research is impossible without training planning knowledge. Bubka et al. [1], Naglak [2], Platonov [3] stated that training planning is related to physical, technical-tactical and psychological training. According to other scientists [4, 5, 6] when planning physical activity, it is necessary to take into account the current state and functional capabilities of the athlete's body systems. In the scientific literature [7, 8, 9, 10, 11, 12] it is proposed many methodological approaches and a list of parameters that largely reflect the functional fitness of athletes who specialize in various sports.

Malikov et al. [6] emphasized that today it is extremely necessary to expand and practically implement new innovative methods of functional research that would satisfy the demands of modern requirements. Bazzucchi et al. [13] note that information about the functional state of an athlete's body is necessary for timely obtaining data on determining the level of training, and is one of the necessary conditions for achieving high results in sports. As Bourgois [14] notes, it is no less important to study quantitative indicators of the functional capabilities of the respiratory system of the athletes' body, which allow establishing the most promising approach to improving physical fitness. This problem arises when training athletes who specialize in cycle sports, including academic rowing [15]. Pengcheng et al. [16] emphasize the parameters of functional indicators, namely the respiratory functions of elite athletes, as they are important in the process of planning the training load. Okun et al. [17] established that the construction and planning of the training process of rowers depends on the assessment of the functional capabilities and dynamics of the performance of the

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athlete's body.

Omelchenko [18] indicated the need to use modern innovative research methods, primarily cardiointervalography. The received data and the analysis of the athlete's functional capabilities allow from a scientific point of view to make adjustments to the physical load in the training process of training athletes. Also, the results of functional capabilities provide an opportunity to increase the specialized focus of physical activity. In addition, these data make it possible to form a complete structure of the functional support of athletes according to their individual capabilities.

According to the research of other [4, 15, 19], in sports with a predominant manifestation of endurance, the functional state of the external respiratory system plays an important role. Determining the level of the functional state of the respiratory system is extremely important for rational planning and control of functional capabilities.

In the practice of sports, such methods include computer Spirometry, which allows you to explore the functions of external respiration, including the measurement of volumetric and speed indicators of respiration. Evaluation of the results of a computer spirographic study allows you to compare the actual values of respiratory parameters with the normative («ideal»), to assess the level of functionality of the respiratory system or its disorders. Recently, in sports, the study of respiratory functions by the computer Spirometry method has been of great importance in cyclic endurance sports (rowing, cycling, swimming, cross-country skiing, triathlon, etc.). Analyzing the data obtained in the process of the computer Spirometry method, sports physicians and coaches can obtain information not only on the absolute indicators of the respiratory system, but also on the reserve respiratory capabilities of athletes, taking into account various factors (age, gender, weight, height, specifics of the sport, psychological the physical state of the organism, natural climatic conditions, etc.). Thus, the study of the parameters of the respiratory system of rowers using the computer Spirometry method is relevant.

It is assumed that obtaining data on the reserve capabilities of external breathing of rowers athletes will allow to establish identity or differences according to the absolute indicators of the dynamic parameters of the respiratory act.

Material and Methods

Participants

22 elite athletes aged 19-24 took part in the study. The average sports experience was 7.2 years. This study was conducted by the Declaration of Helsinki and was approved by the Ethics Committee of University. All participants had provided written informed consent.

Research Design

The method of computer Spirometry was used to assess the functional state of reserve possibilities of the external breathing of athletes by absolute indicators:

- tidal volume (VT) – the volume of air inhaled or exhaled during each respiratory cycle;
- inspiratory vital capacity ($VC_{inspiratory}$) – the largest volume measured on complete exhalation after full inspiration;
- inspiratory reserve volume (IRV) – the maximal volume of air inhaled from end-inspiration;
- expiratory reserve volume (ERV) – the maximal volume of air exhaled from end-expiration;
- breathing rate (BR) – the number of breaths in a minute;
- minute ventilation (MV) – breathing rate × tidal volume – the total volume of air entering the lungs in a minute;
- forced vital capacity (FVC) – the total volume of air that can be exhaled during a maximal forced expiration effort;
- forced expiratory volume in one second (FEV1) – the volume of air exhaled in the first second under force after a maximal inhalation;
- maximal voluntary ventilation (MVV) - a pulmonary function test that measures the maximum amount of air a person can inhale and then exhale with voluntary effort.

In the process of calm breathing, the spirogram (the graph of changes in the volume of inhaled and exhaled air) and the pneumotachogram (the graph of changes in the speed of the air flow over time) of the athlete's breathing are recorded in real time.

An idea about the functions of external breathing during Spirometry is formed on the basis of the analysis of lung volumes and dynamic characteristics of the respiratory act. Each of the spirographic indicators is compared with its proper value, which is calculated according depending on gender, age, and height and body weight. The actual indicators are taken as 100%, and the actual values obtained in the research process are displayed as a percentage of the proper ones.

Statistical Analysis

Statistical analysis of the obtained data was performed using licensed MS Excel and "Statistica 6.0". The main indicators of mathematical statistics were: $\bar{X}$– mean, SD – standard deviation, CV – coefficient of variation. A calculation was used to compare indicators between groups t_{score} – student's, the level of significance was taken as $p<0.05$-0.001.

Results

The parameters of the main lung volumes and dynamic parameters of the respiratory act of rowers are given in table 1. The results of the study were

Table 1. Indicators of the main lung volumes and dynamic parameters of the respiratory act

Indicators / Group	Mathematical statistics	Basic lung volumes							Dynamic parameters of the respiratory act							
		VT (L)	$VC_{inspiratory}$ (L)	$VC_{inspiratory}$%	IRV (L)	IRV%	ERV (L)	ERV%	BR, (mov/min)	MV, (L/min)	FVC (L)	FVC%	FEV1 (L)	FEV1%	MVV (L)	MVV%
Growth categories (sm)																
Group-A (n=10, 195.4±4.2)	X̄	1.1	5.6	91.8	2.6	89.7	2.6	89.7	17.9	18.2	5.4	89.6	4.6	91.0	170.5	83.9
	±*SD*	0.3	0.3	6.4	0.5	15.9	0.5	15.9	4.2	5.1	0.4	7.6	0.4	6.8	19.7	11.1
	V	26.2	6.2	7.0	17.2	17.7	17.2	17.7	23.4	2.2	7.1	8.5	7.6	7.5	11.5	13.2
Group-B (n=7, 184.7±2.2)	X̄	0.9	5.7	102.7	2.6	98.6	1.6	98.0	12.7	13.8	5.4	99.3	4.3	92.6	156.0	85.9
	±SD	0.2	0.6	7.67	0.4	13.1	0.2	12.9	5.1	3.4	0.4	4.9	0.3	5.2	12.0	5.3
	V	22.4	10.0	7.5	14.2	13.3	12.5	13.1	39.9	24.5	7.5	4.9	6.9	5.6	7.7	6.2
Group-C (n=5, 176.0±2.0)	X̄	0.7	4.6	89.6	2.8	129.0	1.5	83.8	17.3	12.8	4.1	79.6	3.4	80.6	120.8	81.0
	±SD	0.1	0.5	7.3	0.6	28.0	0.2	27.8	1.3	2.5	0.8	11.3	0.6	15.5	19.7	24.0
	V	19.5	10.0	8.1	21.1	21.7	15.1	33.2	7.6	19.6	18.5	14.2	18.6	19.3	16.4	29.6
$p_{A,B}$		0.76	0.25	3.09	0.05	1.26	0.66	1.04	2.19	2.09	0.02	3.19	2.10	0.54	1.89	0.48
$p_{B,C}$		2.09	3.75	3.01	0.77	2.26	0.13	1.06	2.28	0.62	3.48	3.66	2.97	1.66	3.55	0.44
$p_{A,C}$		2.84	4.54	0.57	0.73	2.91	0.69	0.42	0.38	2.73	3.60	1.79	4.07	1.43	4.60	0.26
Weight categories (kg)																
Group-D (n= 8, 94.8±4.2)	X̄	1.2	5.8	95.0	2.7	93.6	1.5	83.3	16.9	18.9	5.5	91.5	4.6	90.1	167.4	82.6
	±SD	0.3	0.5	9.5	0.5	16.8	0.3	18.5	4.8	5.8	0.4	8.4	0.4	5.9	22.6	10.6
	V	23.1	8.8	10.0	16.7	18.0	20.4	22.2	28.6	30.6	7.7	9.2	8.6	6.5	13.5	12.9
Group-E (n=7, 84.9±3.3)	X̄	0.9	5.3	97.3	2.6	100.0	1.6	103	17.5	14.9	5.1	93.9	4.2	91.3	137.4	79.0
	±SD	0.1	0.5	8.6	0.3	13.1	0.3	17.7	2.6	2.2	0.4	7.6	0.4	10.5	28.5	12.3
	V	14.9	9.5	8.9	11.4	13.1	16.4	17.2	14.8	14.8	8.5	8.0	10.1	11.5	20.7	15.6
Group-F (n=7, 76.7±1.8)	X̄	0.8	4.9	92.0	2.6	111.9	1.4	76.9	13.8	12.4	4.6	85.7	3.9	85.9	142.7	90.1
	±SD	0.2	0.5	7.4	0.5	29.8	0.5	32.7	4.9	3.1	0.8	11.8	0.7	11.9	19.7	17.6
	V	21.7	11.0	8.1	18.7	26.6	35.8	42.6	35.1	24.7	18.4	13.7	17.1	13.9	13.8	19.6
$p_{D,E}$		2.80	1.79	0.49	0.55	0.82	0.70	2.11	0.30	1.85	1.90	0.57	1.78	0.26	2.24	0.61
$p_{E,F}$		3.39	3.22	0.69	0.47	1.43	1.09	0.75	1.22	2.77	2.43	1.08	2.54	0.86	2.27	0.98
$p_{D,F}$		1.11	1.46	1.23	0.03	0.96	1.52	1.96	1.76	1.71	1.23	1.54	1.17	0.90	0.40	1.37

Note: VT - tidal volume, $VC_{inspiratory}$ - inspiratory vital capacity, $VC_{inspiratory}$ % - actual indicators inspiratory vital capacity, IRV - inspiratory reserve volume, IRV% - actual indicators inspiratory reserve volume, ERV - expiratory reserve volume, ERV% - actual indicators expiratory reserve volume, BR – breathing rate, MV - minute ventilation, FVC - forced vital capacity, FVC % - actual indicators forced vital capacity, FEV1 - forced expiratory volume in one second, FEV% - actual indicators forced expiratory volume in one second, MVV - maximal voluntary ventilation, MVV%- actual indicators maximal voluntary ventilation; X̄ – mean, SD – standard deviation, CV – coefficient of variation; - significant differences t score – Student's as p<0.05-0.001

analyzed by groups of growth categories (group-A, group-B, group-C) and weight categories (group-D, group-E, and group-F).

The VT indicators of rowing athletes of two categories are directly dependent - the higher the height and weight of the athlete, the higher the VT indicator. Note that VT indicators in each group are heterogeneous, as evidenced by the coefficient of variation. According to score - Student's t-test, the reliability of differences (p<0.05) in height category between group-A and group-C, in weight categories between group-D and group-E, between group-E and group-F is monitored.

In the $VC_{inspiratory}$ indicators, there is no dependence with height and weight categories, it is practically the same in all groups of rowing athletes. However, there are significant differences according to score - Student's in growth indicators. It is important to note that this indicator characterizes the functional capabilities of the external breathing apparatus. The value of FVC depends on both the size of the lungs and the strength of the respiratory muscles. The $VC_{inspiratory}$ structure consists of IRV and ERV, which characterize the potential capabilities of the external respiratory system and can indicate the strength of the respiratory muscles.

In rowers of all groups, the actual indicators of FVC%, IRV% and ERV% are normal and correspond to the average level of functional reserves. At the same time, in groups by growth categories, the lowest level of functional reserves of $VC_{inspiratory}$% y according to this indicator is observed in group-C and the highest in group-B. In groups by weight categories, the lowest level of functional reserves is observed in group-F, and the highest in group-E. So, the best level of functional reserves according to the actual indicators of $VC_{inspiratory}$% of the appropriate indicators was demonstrated by rowers with average height and body weight, and the worst by rowers with short height and insignificant body weight. In group-C and group-F athletes, a significant percentage of actual IRV% indicators were determined. The obtained indicators testify to the high potential of the external respiratory system of our subjects in groups with low height and low body weight. Rowers of group-A and group-D had the lowest actual IRV% (89.7% and 93.6%, respectively), namely rowers with high height and overweight. We conclude that inspiratory muscles are the most trained in rowers with short height and low body weight, and the least trained are in rowers with the highest height and the largest body weight. The actual ERV% is within the normal range in all groups. The highest actual ERV% indicators among height categories were determined in group-B, the lowest in group-C, among weight categories the highest in group-E, the lowest in group-F. This indicates the most powerful and trained exhalation in rowers of average height and average body weight. The least powerful exhalation was observed in rowers of short stature and the lowest body weight. We note that significant differences according to t_{score} - students were determined in the actual IRV% indicator between group-A and group-C ($p<0.05$). The coefficient of variation in $VC_{inspiratory}$ indicators has no differences, in were determined in the IRV and ERV indicators differences. With the most significant differences in athletes with short height (group-C) and low body weight (group-F).

Analyzing the dynamic parameters of the respiratory act (table 1), BR in groups of rowing athletes is within the normal range and ranges 12.7-17.9 mov/min. The lowest indicators were determined in group-B and group-F. Such indicators testify to the efficiency of breathing of rowers. We note that there are intragroup differences in BR indicators, as evidenced by the coefficient of variation, which ranged 14.8-39.9%, with the exception of group-C, the smallest growth category.

The value of MV in rowers varies within fairly wide limits 12.4-18.9 L/min. The results presented in table 1 indicate a proportional increase in these indicators relative to the height and body weight of the rower athlete. The largest MV is observed in group-A from the height category and in group-D from the weight category, and the smallest in group C from the height category and group-F from the weight category. Significant intragroup discrepancies of MV indicators were established, as the coefficient of variation ranged – 14.8-30.6%.

The FVC indicators in groups of rowing athletes are practically the same and are within 4.1-5.4 L, and her actual FVC% indicators were determined at the level of 79.6-99.3%, which correspond to age norms. We note that the actual indicators of FVC% are the best in group-B and group-E, that is, with average indicators of body height and body weight of rowers. The lowest actual indicators of FVC% in rowers were determined in group-C and group-F with the smallest height and insignificant body weight. We point out the fact that significant differences according to t_{score} – Student's at $p<0.01$ were determined in growth categories: FVC – between group-B and group-C, between group-A and group-C; actual indicators of FVC% – between group-A and group-B, between group-B and group-C.

The FEV1 indicators in groups of rowing athletes are practically the same and are within 3.4-4.6 L, the actual FEV1% indicators were determined at the level 80.6-92.6%. We note that FEV1 indicators decrease in each height and weight category, the higher the height and weight category, the higher the indicators. Discrepancies between the results of FEV1 and their actual FEV1% in group-C and group-F were established, which indicates a significant range with low height and insignificant weight of rowers. There were no significant differences between the groups. It was established that the best bronchial patency according to the actual FEV1% is observed in rowers with average height and average body weight, and the worst - with short height, and insignificant body weight.

MVV characterizes not only the potential capabilities of the external breathing apparatus, but also the degree of mobilization of these capabilities. In rowers, MVV and its actual values MVV% is within the normal range. There is a decrease in MVV in groups of height categories, namely, the smaller the height, the lower the indicators. In group-C, they are the lowest. In group-A and group-C growth categories, in group-D, group-E, group-F there are intra-group differences in the coefficient of variation. There was a significant difference between group-A and group-B, between group-A and group-C according to t_{score} - Student's at $p<0.01$.

Figure 1 shows the individual indicators of

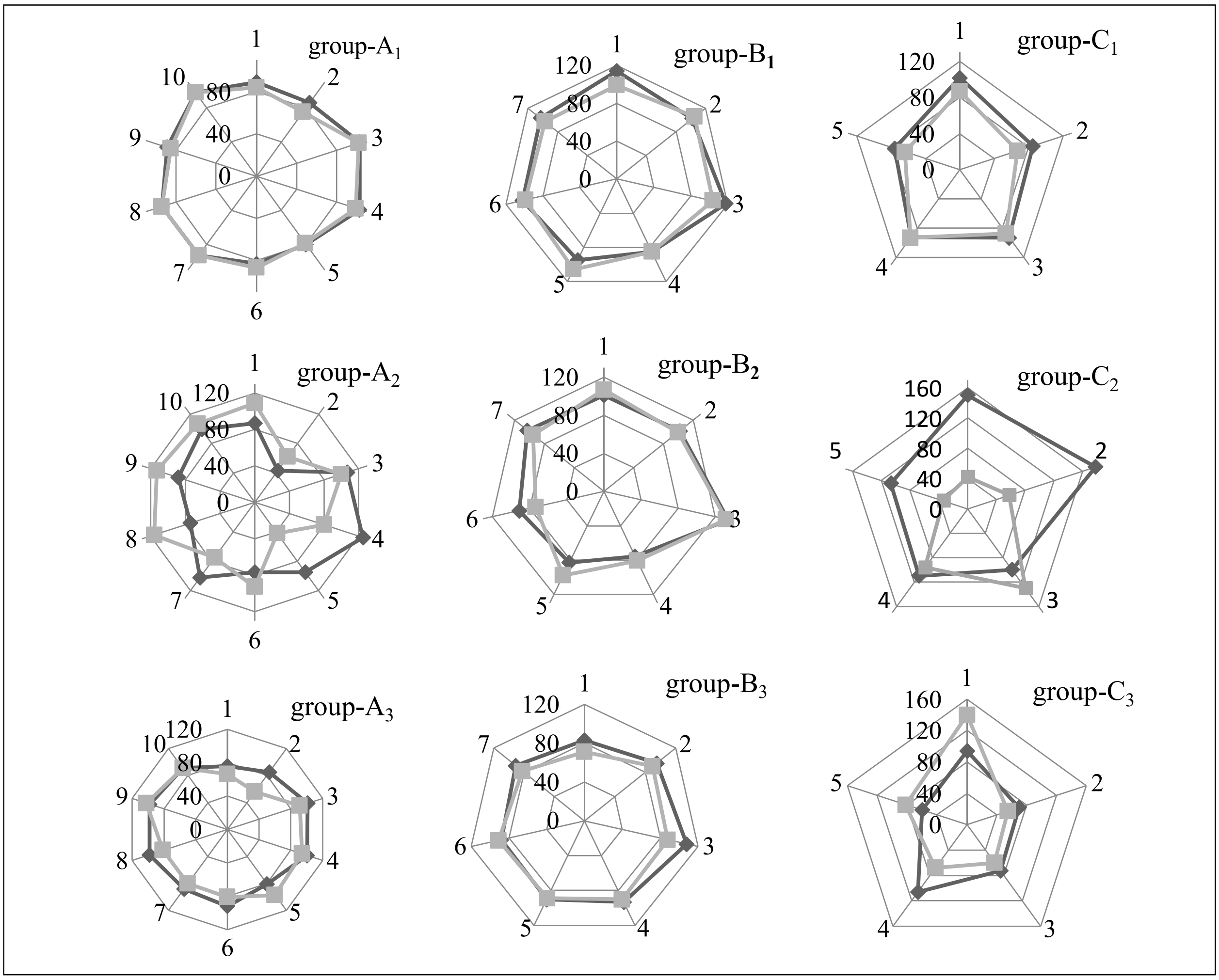

Figure 1. Individual actual indicators of reserve breathing capabilities of rowers athletes of growth categories: group-A_1, group-B_1, group-C_1 ——— individual actual indicator VCinspiratory %, ——— individual actual indicator FVC%; group-A_2, group-B_2, group-C_2 ——— individual actual indicators of IRV%, ——— individual actual indicators of ERV%; group-A_3, group-B_3, group-C_3 ——— individual actual indicators of FEV1%, ——— individual actual indicators of MVV%; 1-10 athlete.

the reserve capabilities of the respiratory system of athletes, taking into account growth data. In group-A_1, group-B_1 and group-C_1, the actual indicators of $VC_{inspiratory}$% and FVC% of rowing athletes are presented, which indicate the following: individual data of athletes of group-A_1, group-B_1 and group-C_1 are within 75%-102% and have no significant differences. Almost the same indicators of $VC_{inspiratory}$% and FVC% in all group-B_1 rowers.

The actual indicators of IRV% and ERV% of rowers are shown in figure 2 (group-A_2, group-B_2 and group-C_2). It should be noted that the greatest differences are observed in group-A_2 rowers in ERV% indicators and in IRV% indicators. In group-B_2 rowers, slight differences in these indicators are observed, in group-C_2 the difference in indicators is significant in ERV%.

In Figure 2, group-A_3, group-B_3 and group-C_3 show the actual indicators of FEV1% and MVV%. In the athletes of group-A_3 and group-B_3, there are no large differences between the indicators of athletes, which are within 60-100%, and in group-C_3, and vice versa, there are quite significant differences – 50-100% in FEV1% and even greater in indicators of MVV% – 44-140%.

Figure 2 presents individual indicators of the reserve capabilities of the respiratory system of athletes, taking into account weight categories. In group-D_1, group-E_1 and group-F_1, we do not observe significant differences in the indicators of $VC_{inspiratory}$% and FVC%, they are within 80-100%.

There are differences in rowing athletes in IRV% and ERV% indicators (figure 2; group-D_2, group-E_2, and group-F_2). In group-D_2, the IRV% range 42-107%, the ERV% range 62-107%. In group-E_2, the IRV% indicators are 80-130%, and the ERV% indicators are 70-130%. IRV% indicators in group-F_2 have the largest differences 75-178%, and ERV% indicators 34-116%.

Figure 2 shows individual actual FEV1% and

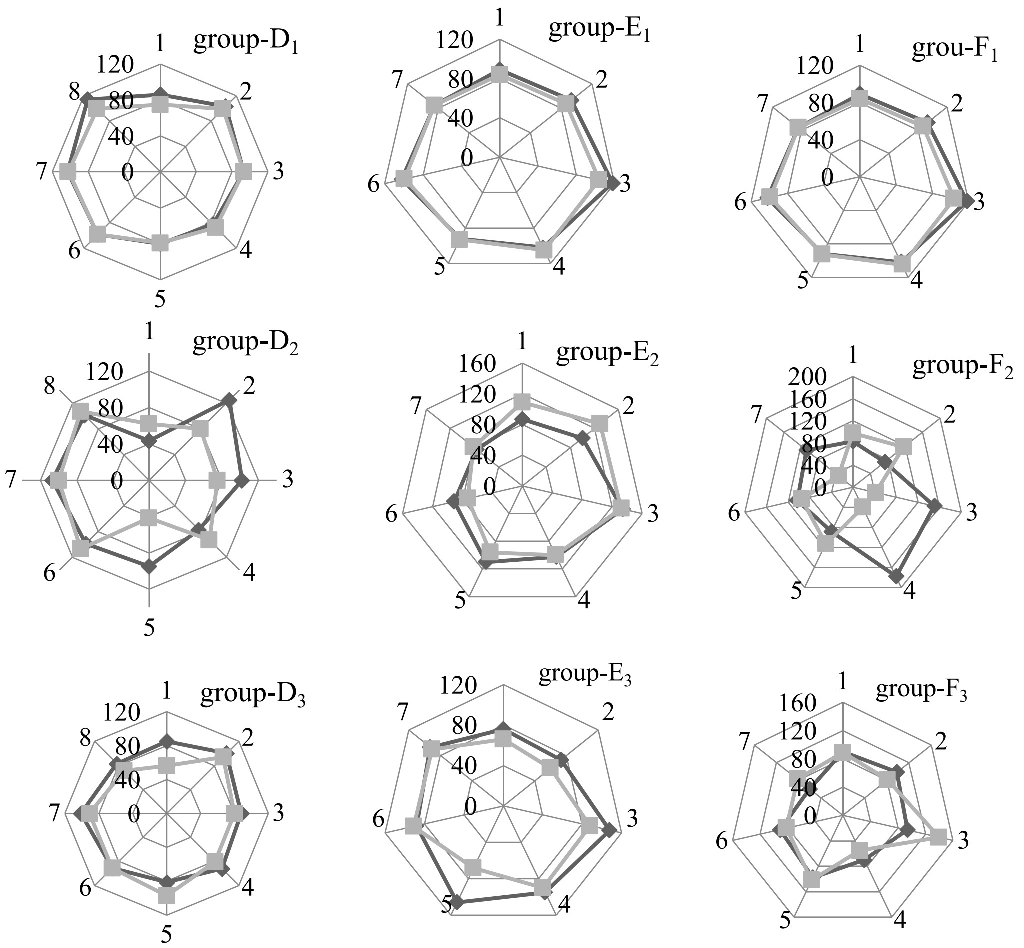

Figure 2. Individual actual indicators of the reserve capabilities of the respiratory system of athletes, taking into account weight data in %: group-D_1, group-E_1, group-F_1 - ——— individual actual indicator VCinspiratory%, ——— individual actual FVCindicator%; group-D_2, group-E_2, group-F_2 – ——— individual actual IRV%, ——— individual actual ERV%; group-D_3, group-E_3, group-F_3 – ——— individual actual indicators FEV1%, ——— individual actual indicators MVV%; 1-8 – an athlete.

MVV% indicators in group-D_3, group-E_3 and group-F_3. The results indicate slight differences in these indicators of group-D_1 and group-E_1. In the FEV1% indicator, group-D_3 ranged 81-94%, group-E_3 ranged 60-106%; in the MVV% indicator group-D_3, the discrepancy was 56-97%, group-E_3 – 60-90%. A significant discrepancy was determined in group-F_3 in FEV1% –55-102%, in MVV% – 55-140%.

Discussion

Assessment of the state of external breathing functions is an important study that allows observing the proper and actual performance of athletes. The results of studies of the functional state of external breathing, namely the main lung volumes and dynamic parameters of the breathing act of rowers, were not previously the subject of detailed scientific studies taking into account height and weight categories. This fact makes it impossible to compare the obtained data with other categories of athletes.

Numerous studies have proven that there is a relationship between respiratory functions and an athlete's anthropometric indicators, namely athlete's weight and athlete's height [20, 21, 22]. It is also natural that athletes who are mainly engaged in endurance show changes in indicators of the functional state of the respiratory system, namely adaptive changes in spirometric indicators - FVC, $VC_{inspiratory}$, FEV1 [15] In the studies of Durmic et al. [23] noted the presence of a high correlation dependence of body weight indicators with respiratory function indicators of elite athletes, and the highest was observed between body weight indicators and MVV.

Our studies confirm this dependence in VT (1.1±0.3 and 1.2±0.3), $VC_{inspiratory}$ (5.6±0.3 and 5.8±0.5), ERV (1.5±0.5 and 1.6±0.5), MV (18.2±5.1 and 18.9±5.8), FVC (5.4±0.4 and 5.5±0.4), FEV1 (4.6±0.4 in two cases), MVV (170.5±19.7 and 167.4±22.6). The IRV indicator was the largest in group-C rowing athletes with the smallest height (2.8±0.6), almost the same indicators in group-D, group-E and Group-F weight categories of rowing athletes. Indicators of the efficiency of breathing of athletes, namely BR, indicate the most economical processes in group-B rowing athletes with average height and group-F with the smallest body weight (12.7±5.1 and 13.8±4.8).

It was established that most of the indicators of the dynamic parameters of the respiratory act (BR, FVC, FEV1, MVL) are within the normal range, while the indicators of the main lung volumes exceed the normal indicators (VT, $VC_{inspiratory}$, IRV) and naturally increase with increasing anthropometric indicators. The actual indicators of respiratory functions of the main lung volumes according to the results of our research, the best level of functional capabilities according to the actual $VCi_{nspiratory}$% have group-B rowers with average body height (97.3±8.6) and group-E with average body weight indicators (102.7±7.7). The most trained muscles during inhalation according to the IRV indicator, in group-C rowers with the smallest body height (129.0±28.0) and group-F rowers with the smallest body weight (111.9±29.8). The most trained muscles during exhalation according to the ERV index in group-B rowers with average body height (98.0±12.9) and group-E rowers with average body weight (103.0±17.7). The actual parameters of bronchial patency during maximal rapid exhalation after deep inspiration (FVC%) and total bronchial patency and lung elastic properties (FEV1) are the best in group-C rowers and group-E rowers of average height and weight categories (99.3±4.9 and 93.9±7.6; 92.6±5.2 and 91.3±10.5). The actual dynamic indicator of MVV% is the highest in group-C of the medium height category (85.9±5.3) and in group-F of the insignificant weight category (90.1±17.6).

Individual scientific results are subject to scientific discussion. This is due to the fact that sufficient differences in the coefficient of variation were determined. Significant differences in the indicators of the main lung volumes of rowers athletes of the highest and group-C of the lowest growth category were determined in group-A and group-C (VT, IRV, IRV%, ERV, ERV%; V=15.1-33.2%). Identical results were obtained in weight categories, group-D and group-F (VT, IRV, IRV%, ERV, ERV%; V=16.4-42.6%). In the indicators of the dynamic parameters of the respiratory act, such a pattern was determined in rowers group-C and group-F with the smallest height and insignificant body weight (V=4.2-29.6% and V=17.1-35.1%).

It has been established that rowing athletes have one of the high indicators of the main lung volumes and dynamic parameters of the respiratory act, which are higher, the higher the athlete's weight, height and qualifications. The data of our study of individual lung volumes and dynamic parameters of the respiratory act (FEV1/VC, MVV) are consistent with the study of Lazovic et al. [22] and Pezelj et al. [24], and in some indicators they are lower (VC, FVC, FEV1). This can be explained by the fact that the level of sports professionalism of Ukrainian rowers is inferior to the level of Finnish rowers, who belong to the sub-elite senior and elite senior group of rowers. Also, the results obtained in our study can be compared with the data of Omelchenko [18], Lazovic et al. [22] and Pezelj et al. [24], in which it is shown that rowers with lower indicators of height and body length also have lower indicators of respiratory functions (VT, IRV, ERV, MV, BR, FVC, FEV, MVV). Note that the data of our study are slightly lower than the data of Vovkanych et al. [25] and Ahsan and Mohammed Feroz [26] in the indicators of the main lung volumes by an average of 16%. An exception is the IRV indicator – the volume of air that a person can inhale additionally after a calm inhalation. This indicator is the same in both studies and is 2.6 liters. The research data of Ichiba et al. [27], on the contrary, are lower than the indicators of our study in the main lung volumes by 28-50%. In the indicators of the dynamic parameters of the breathing act of athletes, the data of our study coincide with the data of Çelik et al. [28] in the FVC indicator and are 4.6 liters. In other indicators of dynamic parameters (FVC, FEV1, MVV), our data coincide with the data of Ozmen et al. [29], Çelik et al. [28] and are slightly lower than the indicators of studies by Pezelj et al. [24], Vovkanych et al. [25], Ahsan and Mohammed Feroz [26], Ozmen et al. [29], Lazovic-Popovic et al. [30]. In the MVV indicator, these data are lower than the data of other authors by an average of 25%. Indicators of FVC, FEV1 from our study exceed the data of Komici et al. [31] by 21%.

Comparing the results with athletes involved in speed-power and strength sports with the studies of Lazovic et al. [24] confirmed that groups of athletes training for endurance had higher VC, FVC, MVV indicators compared to others. The results of our research are confirmed by the research of Vovkanych et al. [25], where the indicators of the main lung volumes (VT, VC, IRV, ERV) are within the same limits. These indicators are almost identical, except for the VT indicator, in which it is slightly higher in biathletes than in other studies. Other indicators of lung volumes are within the same limits. VT indicators are within 0.7-1.6 l, VC – 4.9-6.2 l, IRV – 2.6-3.1 l, ERV – 0.9-1.6 l. Indicators of the dynamic parameters of the respiratory act (BR, MV, FVC, FEV1, MVV) in the studies of Omelchenko [18], Lazovic et al. [22], Pezelj et al. [24], Vovkanych et al. [25], Ozmen et al. [29] are in the same ranges. They are: FVC - 4.3-5.9 l; FEV1 – 3.8-4.9 l; MVV - 142-180 liters. The exceptions are the indicators from the study [26], where the FVC indicator is 25% higher than the average indicators of other studies. FEV1 is also highest in groups of athletes who train for endurance [24] and in rugby players and football players. The MVV indicator is the largest in rugby players and football players [26] and is 207 L, which is 24.6% more than these indicators in groups of other athletes.

We supplemented the data on indicators of the main lung volumes and dynamic parameters of the respiratory act of rowers of height and weight categories. Presented individual indicators of the reserve capabilities of the respiratory system of athletes taking into account height and weight categories. Made an analysis, determined the differences in height and weight categories, respectively. These indicators are extremely important for timely obtaining data on the determination of the training level of athletes and are a necessary condition for achieving a high sports result.

Conclusions

The study of the absolute parameters of lung volumes and dynamic parameters of the respiratory act using computer Spirography made it possible to establish a high level of functional reserves of power and mobilization of respiratory functions of elite rowers.

The absolute values of the respiratory functions of athletes who have significant height and significant body weight are higher than those of athletes with short height and insignificant weight (VT, $VC_{inspiratory}$, ERV, BR, MV, FEV1, MVV). The actual indicators of respiratory functions in most athletes are within the normal range. The highest actual indicators of respiratory functions are observed in the group with average height and average body weight of athletes ($VC_{inspiratory}$%, ERV%, FVC%, FEV1%). In elite athletes with average height and average body weight of athletes, individual actual indicators of $VC_{inspiratory}$% are practically homogeneous, significant discrepancies are observed in other indicators.

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Conflict of interest

The authors state no conflict of interest.

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