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Spirographic study of functional reserves of masters' athletes in track-and field

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Abstract

Background and Study Aim — The progressive aging of the global population presents significant challenges, particularly in maintaining the functional reserves of vital systems. The respiratory system is crucial for sustaining physical performance. However, it is especially vulnerable to age-related decline. This study aims to assess the impact of structured physical activity on the respiratory function of sports-active veteran track-and-field athletes aged 50–59 and 60–75 years.

Material and Methods — A total of 93 men were examined, including 54 in the reference group (30 men with an average age of 53.67±0.25 years and 24 with an average age of 67.08±0.35 years). These men were involved in athletics in the past but did not participate in veteran sports. The study group included 29 athletics veterans. Among them, 18 individuals had an average age of 52.27±0.18 years, and 11 had an average age of 65.64±0.16 years. These athletes engage in specifically organized physical activity 2–4 times a week and have participated in athletics competitions over the last five years. Anthropometric measurements included the assessment of chest circumference at rest, maximal inspiration, maximal exhalation, and diaphragmatic excursion (DE). The functional state of the respiratory system was assessed using the SpiroCom diagnostic complex (HAI). The data were processed using the SPSS Statistics 17.0 software.

Results — Sports veterans aged 50–59 years and those over 60 years exhibit statistically significant differences compared to their peers in several indicators. These include diaphragmatic excursion, tidal volume, minute volume, respiratory rate, tidal volume maximal, respiratory rate maximal, and maximal voluntary ventilation. The respiratory reserve indicator showed a lower degree of respiratory function tension during physical exertion. Statistically significantly higher values of external respiration indicators were found in veteran athletes compared to men with no regular activity (NRA). These indicators include expiratory time, forced expiratory volume in 1 second, and forced expiratory volume maximal. Additionally, veteran athletes showed higher values in the modified Tiffeneau-Pinelli index, peak expiratory flow, and forced expiratory flow at 25%, 50%, 75%, and forced mid-expiratory flow. As a result, sports veterans with high regular activity (RA) exhibited the lowest rates of regressive-destructive changes in the respiratory system indicators overall, with the exception of HOD and BH. In contrast, men with low RA are characterized by an accelerated rate of aging in the respiratory system.

Conclusions — The results of the study identified indicators that can serve as spirographic criteria for selecting functional types. These types include individuals with low, medium, and high regular activity (RA). It has been proven that systematic exercises involving specially organized cyclic motor activity form a rational, physiologically optimal type of breathing. Additionally, these exercises inhibit age-related degenerative-dystrophic processes in the human respiratory system.

Keywords: sports veterans, spirography, athletics, respiratory system

Introduction

The global aging of the population increasingly raises the issue of maintaining the functional reserves of vital systems in the body. The respiratory system, in particular, is especially vulnerable to age-related changes and plays a crucial role in sustaining physical activity and overall health. This creates a need to find new solutions aimed at supporting and improving respiratory function in

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sports-active veterans involved in track and field. Such a need requires detailed study and analysis of their functional indicators.

According to the Population Reference Bureau, the aging of the population at the current stage is of great importance in the socio-economic life of countries worldwide [1]. The number of people over 65 years old in Europe accounts for 19% of the total population [2], while in Ukraine, this figure is 21.6% [3]. It has been established that the respiratory system undergoes significant morphological and functional changes during aging, affecting the chest, airways, lung parenchyma, and the pulmonary vascular system [4, 5]. Therefore, the study of age-related features of the respiratory system holds a prominent place within gerontological research. This is primarily due to the importance of the external breathing apparatus in supplying the body with oxygen. Hypoxic conditions are characteristic of older age and significantly impact the progression of age-related changes in various organs and systems. Additionally, there is a need to identify the causes and mechanisms that will help maintain respiratory system function in older age. Establishing age-related respiratory system criteria at later stages allows for distinguishing actual age-related changes from those caused by pathological processes [6].

Morphological changes in the respiratory apparatus during aging significantly affect the functional features of external breathing. As a result, with aging, the tidal volume decreases slightly, while the inspiratory reserve volume and expiratory reserve volume decrease more significantly. These changes in tidal volume, inspiratory reserve volume, and expiratory reserve volume lead to a decrease in lung vital capacity. The negative correlation of this indicator with age is reflected in vital capacity formulas [7, 8]. Additionally, with aging, the lung diffusion capacity decreases [9]. This decline is especially pronounced during physical exertion; the surface area of functioning alveolar epithelium, characterized by the number of alveoli and capillaries that are functionally connected, also decreases. By the age of 70, the total number of alveoli decreases by 40% compared to at 40 years old [10]. All these negative processes eventually lead to various diseases of the respiratory system and other body systems. According to research [11], mortality from respiratory system diseases ranks third worldwide.

One of the reasons for the sharp negative changes in the respiratory system is a decrease in the level of motor activity with aging [12]. As research by various authors shows, mental and physical abilities (such as maximum strength, endurance, and flexibility) can be effectively maintained at a high level, regardless of age, under regular training conditions [13, 14, 15, 16]. This is also evidenced by the results of sports veterans who continue to train and compete in older age, and even in very old age. As noted by the authors [17, 18, 19, 20, 21], the decrease in physiological functions in these sports veterans is less significant compared to their peers who lead a sedentary lifestyle. It should be noted that scientific research on the influence of specially organized motor activity on the state of functional systems, particularly the respiratory system, in veteran athletes is rarely conducted.

The aim of the work: To investigate the impact of specially organized motor activity on the respiratory system of veteran athletes aged 50–59 and 60–75 years who participate in competitive activities.

Materials and Methods

Participants

A total of 93 men were examined, 54 of whom were in the reference group (30 men with an average age of 53.67±0.25 years, and 24 with an average age of 67.08±0.35 years). These men were involved in athletics in the past. The study group consisted of 29 experienced athletes: 18 men in the age group 50–59 years (average age 52.27±0.18 years) and 11 men in the age group 60–75 years (average age 65.64±0.16 years). These participants are consistently engaged in specially organized physical activity (2–4 times a week) aimed at achieving sports results and have participated in competitions at various levels over the past five years. All participants were healthy and reported no physical problems or illnesses.

Research Design

To assess motor activity, participants were asked to keep a physical activity diary over a two-month cycle. Among the sports veterans, subgroups were identified based on their average number of training days per year. There were 12 people (66.67%) in the age category of 50–59 years and 6 people (54.55%) in the age category of 60–75 years with an average of 80–140 training days per year. Additionally, a high level of physical activity (more than 140 training days per year) was observed in 6 people (33.33%) in the 50–59 years category and 5 people (45.45%) in the 60–75 years category. Anthropometric studies included the measurement of thorax circumference at rest (ThCp), on maximal inspiration (ThCi), on maximal expiration (ThCe), and diaphragmatic excursion (DE).

The analysis of the functional state of the external breathing apparatus was carried out using the SpiroCom diagnostic complex (HAI, Ukraine). As part of the mandatory set of functional tests in spirography, a test of calm breathing and three special breathing maneuvers were performed to determine vital capacity (VC), forced vital capacity (FVC), and maximal voluntary ventilation (MVV). The registration and processing of spirograms were divided into six stages: changes in tidal volume (TV), changes in inspiration and expiration vital capacity, recording of forced inspiration and expiration, and determination of maximal voluntary ventilation. When recording rest breathing and tidal volume, the subjects breathed with their natural frequency and depth of breathing (for 40–50 seconds). Based on the sample data, the following average values were calculated:

- TV – tidal volume (l);
- VE – minute volume (l);
- RR – respiratory rate (min^{-1});
- Ti – inspiratory time (sec);
- Te – expiratory time (sec);
- Ti/Te – inspiratory/expiratory ratio;
- RRmax – respiratory rate maximal (min^{-1});
- TVmax – tidal volume maximal (l);
- VC – vital capacity (l);
- IRV – inspiratory reserve volume (l);
- ERV – expiratory reserve volume (l);
- FVC – inspiratory (expiratory) forced vital capacity (l);
- FEV1 – forced expiratory volume in 1 second (l);
- FEVPEF – forced expiratory volume maximal (l);
- FEV1/FVC – modified Tiffeneau-Pinelli index (%);
- PEF – peak expiratory flow ($l \cdot sec^{-1}$);
- FEF25 – forced expiratory flow at 25% FVC ($l \cdot sec^{-1}$);
- FEF50 – forced expiratory flow at 50% FVC ($l \cdot sec^{-1}$);
- FEF75 – forced expiratory flow at 75% FVC ($l \cdot sec^{-1}$);
- FEF25-75 – forced mid-expiratory flow ($l \cdot sec^{-1}$);
- FEF75-85 – forced expiratory flow 75–85% ($l \cdot sec^{-1}$);
- TPEF – time of peak expiratory flow (sec);
- MVV – maximal voluntary ventilation ($l \cdot min^{-1}$).

Statistical analysis

Statistical processing of the results was carried out using SPSS Statistics 17.0. The data were tested for normality distribution using the Shapiro-Wilk test. Since the studied samples were small ($7 \leqslant n \leqslant 30$), the Mann-Whitney test was used to determine the significance of differences in the indicators. The significance of differences was accepted at a level of $p \leqslant 0.05$. All research results are expressed in the standard form as $\bar{X}$±SE.

Results

We studied the spirographic indicators of respiratory volume changes in veteran athletes aged 50–59 and 60–75 years who are consistently engaged in training aimed at achieving sports results and compared them with the corresponding indicators of people of the same age with a low habitual motor activity level (Table 1). As the data analysis showed, sports veterans aged 50–59 with moderate regular activity (MRA) and high regular activity (HRA) have statistically significant differences compared to their peers in indicators such as DE (UCPA=27; UBPA=1; $p < 0.01$), TV (UCPA=144.5; UBPA=27.5; $p < 0.01$), VE (UCPA=53.5; UBPA=36.5; $p < 0.01$), RR (UCPA=179.5; $p < 0.05$; UBPA=56.5; $p < 0.01$), TVmax (UCPA=43.5, $p < 0.01$; UCPA=102, $p < 0.05$), RRmax (UCPA=143.5; UCPA=102, $p < 0.05$), and MVV (UCPA=46; UBPA=57; $p < 0.01$).

When analyzing the obtained values for this age category, we can state that indicators such as DE (U=179.5; $p < 0.05$) and RRmax (U=62; $p < 0.05$) are statistically significantly better in veteran athletes with high RA compared to those with moderate RA.

Under the influence of systematic sports training, veteran athletes who train regularly at least three times a week show clear benefits. Compared to their peers who train less than three times a week, they exhibit a significant decrease in breathing frequency at rest. Additionally, these athletes demonstrate relatively greater pulmonary ventilation values both at rest and under standard loads.

A similar pattern is observed in veteran athletes aged 60–75. Statistically significant differences compared to peers with low RA were found in indicators such as DE (UCPA=24; UBPA=23; $p < 0.01$), TV (UCPA=9.5; $p < 0.01$; UBPA=11; $p < 0.01$), and RR (UCPA=191.5; $p < 0.05$; UBPA=60; $p < 0.01$). The differences also extend to RRmax (UCPA=191.5; $p < 0.05$; UBPA=60; $p > 0.01$), TVmax (UCPA=5.5; UBPA=0.5; $p < 0.01$), and MVV (UCPA=79; UBPA=38.5; $p < 0.01$).

Also, in this age category, indicators such as DE (U=0; $p < 0.01$), RRmax (U=46; $p < 0.01$), and MVV (U=44; $p < 0.01$) were significantly better in veteran athletes with high RA compared to those with moderate RA.

It should be noted that the majority of the studied participants had a normal inhalation to exhalation ratio, which ranged from 1.11 to 1.53.

Based on the obtained indicators, we calculated the breathing reserve (BR) during the pulmonary stress test. This value provides information about the degree of respiratory function tension and the load on the respiratory system. For example, in men aged 50–75 years with low RA, respiratory reserves ranged from 7.22% to 13.64%. In sports veterans with moderate RA, BR was within the lower limit of the norm (23.22%–23.35%). In contrast, sports veterans with high RA had BR within the upper limit range (38.18%–41.12%).

The characteristics of external breathing functional tests in men aged 50–59 and 60–75 years with different levels of RA are presented in Table 2. Compared with men with low RA, the average value of VC in sports veterans with moderate RA and high RA aged 60–75 years is statistically significantly higher by 35.78% (UCPA=67.5; $p < 0.01$) and 56.55% (UBPA=22; $p < 0.01$), respectively. Among sports veterans aged 50–59, VC is higher by 37.43%

Table 1. Characteristics of functional tests of respiratory volume changes of sports veterans and men aged 50–75 who are not engaged in sports, X̄±SE.

Indicators	Age group	Contingent categories		
		Men with low PA	Ssports veterans with moderate PA	Sports veterans with high PA
DE, cm	50–59	4.40 ± 0.23	7.74 ± 0.11*	8.25 ± 0.12*†
	60–75	3.11 ± 0.19	7.23 ± 0.14*	7.86 ± 0.12*†
TV, l	50–59	0.53 ± 0.04	0.71 ± 0.06*	0.77 ± 0.09*
	60–75	0.49 ± 0.02	0.58 ± 0.02*	0.66 ± 0.05*
VE, $l \cdot min^{-1}$	50–59	6.99 ± 0.52	9.05 ± 0.49*	7.75 ± 0.65
	60–75	6.54 ± 0.46	9.70 ± 0.61*	9.15 ± 0.65*
RR, min^{-1}	50–59	22.21 ±0.74	14.85 ± 0.88*	11.58± 0.32*†
	60–75	24.82 ± 0.76	16.74 ± 0.91*	15.18 ± 0.76*
$T_{i.}$, sec	50–59	1.44 ± 0.07	1.41 ± 0.09	1.27 ± 0.08
	60–75	1.23 ± 0.05	1.17 ± 0.07	1.11 ± 0.06
Te, sec	50–59	1.61 ± 0.05	1.63 ± 0.07	1.65 ± 0.13
	60–75	1.68 ± 0.18	1.69 ± 0.08	1.75 ± 0.15
T_i/T_e	50–59	0.91 ± 0.03	0.87 ± 0.04	0.78 ± 0.03*
	60–75	0.77 ± 0.03	0.76 ± 0.04	0.75 ± 0.04
RR_{max}, min^{-1}	50–59	76.50 ± 3.73	66.31 ± 3.36*	61.12 ± 1.67*
	60–75	79.43 ± 3.15	65.80 ± 3.32	67.05 ± 2.15
TV_{max}, l	50–59	1.50 ± 0.05	1.87 ± 0.06*	1.93 ± 0.09*
	60–75	1.07 ± 0.04	1.81 ± 0.05*	1.99 ± 0.08*
MVV, $l \cdot min^{-1}$	50–59	106.30 ± 2.70	161.50 ± 3.31*	167.50 ± 3.32*
	60–75	96.60 ± 2.30	155.40 ± 2.49*	165.20 ± 3.78*†

Note. * – statistically significant difference in parameters in relation to men with low RA; † – statistically significant difference in parameters between sports veterans with moderate RA and high RA; DE: diaphragmatic excursion; TV: tidal volume; VE: minute volume; RR: respiratory rate; Ti: inspiratory time; Te: expiratory time; Ti/Te: inspiratory/expiratory time ratio; RRmax: maximal respiratory rate; TVmax: maximal tidal volume; MVV: maximal voluntary ventilation.

(UCPA=64.5; $p < 0.01$) and 52.86% (UBPA=94.5; $p < 0.01$) (Fig. 1a, 1b).

A similar pattern was observed for the FVC indicator, where the average values were higher by 56.51% (UCPA=48; $p < 0.01$) and 69.18% (UBPA=55; $p < 0.01$) in sports veterans with moderate RA and high RA aged 50–59, and by more than 43.37% (UCPA=45; $p < 0.01$) and 63.08% (UBPA=55.5; $p < 0.01$), respectively, among sports veterans aged 60–79. As we can observe, with the increase in physical training, FVC increases above 90% of VC: 95.01% and 93.08% in sports veterans aged 50–59 years with moderate RA and high RA, respectively; and 94.12% and 92.86%, respectively, in sports veterans over 60 years old. In untrained men, FVC was 77.71% at the age of 50–59 and 76.36% at the age of over 60.

In addition, the difference in VC between men in this age range with low RA and high RA is outside the normal range (200–300 ml), indicating a negative effect from both the absence of physical activity and very intense sports on the airway resistance of small bronchi. This difference is within the normal limits for men with moderate RA. The negative impact of training four times a week is also evidenced by a longer period of exhalation at rest compared to the reference group and sports veterans with moderate RA.

It should be noted that in veteran athletes aged 50–59 years who are regularly engaged in sports, there are statistically significant higher values of external breathing parameters compared to men with low RA. Specifically, the ERV is higher by 78.57% (UCPA=15; $p < 0.01$) and 97.96% (UBPA=30; $p < 0.01$). The FEV1 is higher by 80.85% (UCPA=1; $p < 0.01$) and 85.11% (UBPA=0; $p < 0.01$). The FEVPEF is higher by 25.76% (UCPA=113.5; $p < 0.01$) and 43.94% (UBPA=49; $p < 0.01$). The FEV1/FVC is higher by 36.81% (UCPA=3; $p < 0.01$) and 30.78% (UBPA=4.5; $p < 0.01$). The PEF is higher by 53.27% (UCPA=0; $p < 0.01$) and 70.33% (UBPA=0; $p < 0.01$). The FEF25 is higher by 32.47% (UCPA=3; $p < 0.01$) and 52.84% (UBPA=0; $p < 0.01$). The FEF50 is higher

Table 2. Characteristics of functional tests of external breathing of sports veterans and men aged 50–75 who do not do sports, X̄±SE.

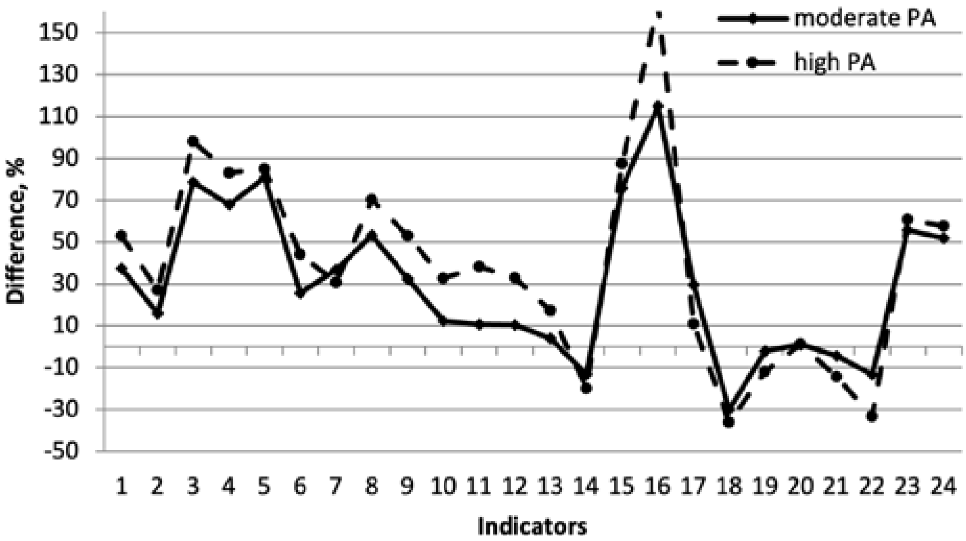
Indicators	Age group	Contingent categories		
		Men with low PA	Sports veterans with moderate PA	Sports veterans with high PA
VC, l	50–59	3.50 ± 0.11	4.81 ± 0.10*	5.35 ± 0.07*†
	60–75	3.13 ± 0.05	4.25 ± 0.07*	4.90 ± 0.09*†
IRV, l	50–59	2.00 ± 0.05	2.32 ± 0.08*	2.54 ± 0.06*†
	60–75	1.76 ± 0.05	2.25 ± 0.07*	2.40 ± 0.03*
ERV, l	50–59	0.98 ± 0.04	1.75 ± 0.06*	1.94 ± 0.11*
	60–75	0.88 ± 0.03	1.45 ± 0.05*	1.90 ± 0.09*†
FVC, l	50–59	2.92 ± 0.05	4.57 ± 0.07*	4.94 ± 0.10*
	60–75	2.79 ± 0.05	4.00 ± 0.07*	4.45 ± 0.09*
FEV1, l	50–59	2.35 ± 0.05	4.25 ± 0.09*	4.35 ± 0.08*
	60–75	2.22 ± 0.05	3.75 ± 0.10*	3.9 ± 0.07*
FEV_{PEF}, l	50–59	0.66 ± 0.03	0.83 ± 0.04*	0.95 ± 0.08*
	60–75	0.56 ± 0.02	0.68 ± 0.03*	0.94 ± 0.08*†
FEV_1/FVC, %	50–59	69.18 ± 0.81	96.00 ± 1.18*	91.77 ± 1.52*†
	60–75	71.66 ± 0.80	85.42 ± 1.06*	87.64 ± 1.54*
PEF, $l \cdot sec^{-1}$	50–59	4.28 ± 0.10	6.56 ± 0.11*	7.29 ± 0.10*†
	60–75	4.20 ± 0.10	5.73 ± 0.15*	6.79 ± 0.15*†
FEF_{25}, $l \cdot sec^{-1}$	50–59	3.88 ± 0.06	5.14 ± 0.10*	5.93 ± 0.06*†
	60–75	3.76 ± 0.06	4.69 ± 0.11*	5.51 ± 0.08*†
FEF_{50}, $l \cdot sec^{-1}$	50–59	3.67 ± 0.10	4.12 ± 0.14	4.87 ± 0.16*†
	60–75	3.27 ± 0.10	3.92 ± 0.15*	4.67 ± 0.13*†
FEF_{75}, $l \cdot sec^{-1}$	50–59	2.88 ± 0.06	3.19 ± 0.10*	3.98 ±0.05*†
	60–75	2.25 ± 0.07	3.09 ± 0.18*	3.79 ± 0.19*†
FEF_{25-75}, $l \cdot sec^{-1}$	50–59	3.95 ± 0.22	4.36 ± 0.37	5.25 ± 0.27*
	60–75	2.68 ± 0.18	3.17 ± 0.34	4.56 ± 0.24*†
FEF_{75-85}, $l \cdot sec^{-1}$	50–59	2.32 ± 0.12	2.41 ± 0.19	2.72 ± 0.31
	60–75	1.86 ± 0.19	2.31 ± 0.18	2.70 ± 0.24*
T_{PEF}, sec	50–59	0.15 ± 0.01	0.13 ± 0.01	0.12 ± 0.02
	60–75	0.24 ± 0.02	0.21 ± 0.02	0.13 ± 0.01*†

Note: * – statistically significant difference in parameters compared to the reference group; † – statistically significant difference in parameters between sports veterans with moderate RA and high RA; VC: vital capacity; IRV: inspiratory reserve volume; ERV: expiratory reserve volume; FVC: forced vital capacity; FEV1: forced expiratory volume in one second; FEVPEF: forced expiratory volume maximal; FEV1/FVC: Tiffeneau-Pinelli index; PEF: peak expiratory flow; FEF25, FEF50, FEF75: forced expiratory flow at 25%, 50%, 75% FVC; FEF25-75: forced mid-expiratory flow; FEF75-85: forced expiratory flow at 75–85% FVC; TPEF: time of peak expiratory flow.

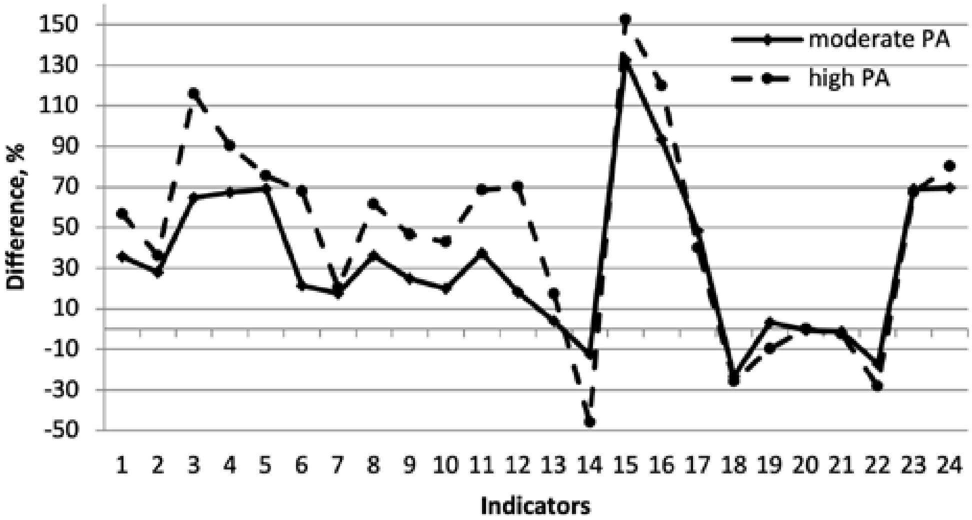
by 32.70% (UBPA=10.5; $p < 0.01$). The FEF75 is higher by 10.76% (UCPA=137.5; $p < 0.01$) and 68.44% (UBPA=0; $p < 0.01$). Finally, the FEF25-75 is higher by 32.91% (UBPA=87.5; $p < 0.01$).

In sports veterans over 60 years old, similar differences were observed, along with additional differences in the TPEF (UBPA=45.5; $p < 0.01$) for sports veterans with high RA (Fig. 1b). We also determined the rates of destructive (regressive) changes in the respiratory system indicators of men with a 10-year age difference (Fig. 2).

As can be seen from Figure 2, the lowest rates of regressive-destructive changes in the respiratory system indicators, in general, except for VE and RR, are typical for sports veterans with high RA. Men with low RA are characterized by an accelerated rate of respiratory system aging.



a)



b)

Figure 1. Spirographic profile of sports veterans aged a) 50–59 years and b) 60–75 years with different motor activity levels (in % relative to persons with low RA): 1 – vital capacity; 2 – inspiratory reserve volume; 3 – expiratory reserve volume; 4 – forced vital capacity; 5 – forced expiratory volume in one second; 6 – forced expiratory volume maximal; 7 – Tiffeneau-Pinelli index; 8 – peak expiratory flow; 9 – forced expiratory flow at 25% FVC; 10 – forced expiratory flow at 50% FVC; 11 – forced expiratory flow at 75% FVC; 12 – forced mid-expiratory flow; 13 – forced expiratory flow 75–85%; 14 – time of peak expiratory flow; 15 – diaphragmatic excursion; 16 – tidal volume; 17 – minute volume; 18 – respiratory rate; 19 – inspiratory time; 20 – expiratory time; 21 – inspiratory/expiratory ratio; 22 – maximal respiratory rate; 23 – maximal tidal volume; 24 – maximal voluntary ventilation.

Discussion

The aim of this study was to investigate the impact of regular, organized physical activity on the respiratory system of veteran athletes aged 50–59 and 60–75 years. The results demonstrated that sports veterans with high levels of physical activity exhibited significantly lower rates of regressive-destructive changes in respiratory system indicators compared to their peers with low physical activity. This was particularly evident in parameters such as vital capacity (VC) and forced vital capacity (FVC), where veterans with higher activity levels showed markedly better performance.

Over the last 50 years, physiologists have

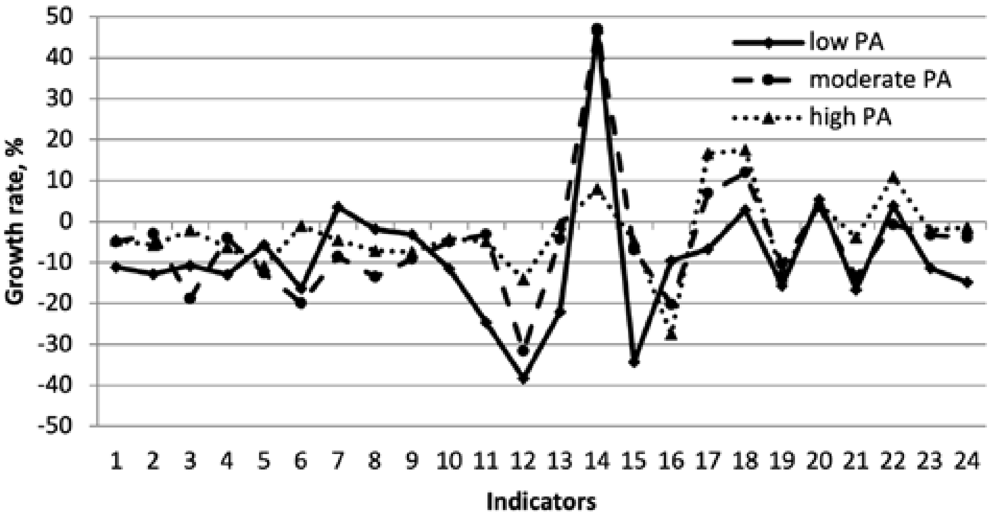


Figure 2. Rates of regressive changes in the respiratory system indicators of sports veterans and men with low RA: 1 – vital capacity; 2 – inspiratory reserve volume; 3 – expiratory reserve volume; 4 – forced vital capacity; 5 – forced expiratory volume in one second; 6 – forced expiratory volume maximal; 7 – Tiffeneau-Pinelli index; 8 – peak expiratory flow; 9 – forced expiratory flow at 25% FVC; 10 – forced expiratory flow at 50% FVC; 11 – forced expiratory flow at 75% FVC; 12 – forced mid-expiratory flow; 13 – forced expiratory flow at 75–85% FVC; 14 – time of peak expiratory flow; 15 – diaphragmatic excursion; 16 – tidal volume; 17 – minute volume; 18 – respiratory rate; 19 – inspiratory time; 20 – expiratory time; 21 – inspiratory/expiratory ratio; 22 – maximal respiratory rate; 23 – maximal tidal volume; 24 – maximal voluntary ventilation.

conducted a significant number of studies on the functional state of the external respiratory system, both at rest and under conditions of increasing standard physical exertion, in an ontogenetic context [22, 23, 24, 25, 26]. We established a decrease in the functional capabilities of the respiratory system with aging in both men who are not engaged in specially organized physical activity and in veteran athletes, as emphasized in work [27]. However, this decrease in the functional reserves of the respiratory system occurs at a significantly higher rate in non-athletes.

Under the influence of systematic sports training, compared to non-athletes of the same age, sports veterans experience a distinct decrease in breathing frequency, and relatively smaller values of pulmonary ventilation are observed both at rest and during standard loads, as confirmed in works [28, 29].

Many authors have noted that the intensification of external breathing during physical exertion occurs to a greater extent due to an increase in breathing depth and to a lesser extent due to an increase in respiratory rate [30]. This finding was confirmed by our study, where TVmax in sports veterans aged 50–59 and over 60 years was 26.67% and 77.57% higher, respectively, while the average values of RRmax were lower by 6.03% and 2.10%, respectively. Therefore, during exercise, lung ventilation can be enhanced both by an increase in tidal volume and by respiratory rate, with a significant reduction in respiratory cycle duration, leading to an overall increase in the productivity of the respiratory process.

Among sports veterans, quite high values of lung excursion were noted, with the difference being approximately 82% in those aged 50–59 years, and 1.5 times greater in those over 60 years old, which coincides with the results of previous studies [31, 32]. This is due to the fact that intensive training can lead to improvements in respiratory muscle strength, reaching the maximum upper limit of the respiratory muscle functional reserve and corresponding diaphragmatic excursion. Additionally, targeted training of respiratory muscle strength can be an effective strategy to increase ventilatory function in less physically prepared individuals [33].

As for the ratio of inhalation to exhalation duration, which characterizes the balance between ventilation and oxygenation, it is known that under normal conditions with calm breathing, it is equal to 1:1.2 (maximum 1:1.5). During obstructive processes, this ratio changes to 1:2 and sometimes even 1:3. The obtained values of this ratio indicate an increase in average pressure in the respiratory tract, which contributes to better oxygenation due to CO_2 removal. However, the disadvantage is greater hemodynamic instability and the possibility of gas retention, especially in volume-depleted men, such as those with low RA [34, 35].

The studies [36, 37] emphasize a significant increase in vital capacity (more than 70%) in sports veterans compared to untrained men, which is confirmed by our results. An important fact is that the higher the VC, the lower the external breathing apparatus consumption.

A crucial functional indicator of external breathing is the forced vital capacity (FVC) of the lungs. In healthy men, FVC typically ranges between 70–80% of the actual VC. With increased physical training, FVC rises above 80% [38], as confirmed by our results.

As our studies have shown, the difference between VC and FVC in sports veterans with high RA and non-athletes exceeds the normal range (200–300 ml), while it remains within this range in veteran athletes with moderate RA. This suggests that endurance physical training can cause narrowing of the small bronchi, leading to reduced bronchial patency during forced exhalation. The negative impact of training four times a week for sports veterans over 60 years old is also indicated by a longer exhalation period at rest compared to athletes with low and moderate RA, as mentioned in works [39, 40].

It is known that during exercise, the TVmax of athletes can increase up to 4 liters. However, an increase in respiratory volume above 40–60% of VC leads to uneconomical respiratory system function. In our study, this ratio was in the range of 34.19–42.86%, indicating a physiologically rational type of breathing.

One of the main and valuable functional indicators of external breathing is the maximum lung ventilation in 1 minute (MVV). Normally, MVV reaches 80–100 $l \cdot min^{-1}$. In athletes who primarily train for endurance, MVV can reach 130–150 $l \cdot min^{-1}$ or more [41, 42], which we observed in sports veterans aged 50–59 years and over 60 years.

It is believed that an MVV level of 120 l is a critical limit, beyond which the energy consumption of the external breathing apparatus becomes particularly high. Achieving the limit values of pulmonary ventilation, characteristic of highly skilled athletes, results from the high coordination of respiratory acts with the contraction of respiratory muscles [43, 44].

According to data [45, 46], most of the absolute and relative indicators of external respiration (VC, MVV, etc.) in athletes of various ages (especially men) who primarily train for endurance are significantly higher than in those who train in other sports. This, in some way, reflects the degree of long-term extensive load influence on the external respiratory system.

As our studies have shown, the average value of breathing reserve in men aged 50–75 years with low RA indicates a decrease in their ability to perform physical exercises, while in sports veterans it remains within the physiological norm [47].

On the other hand, as our data showed, intensive training four or more times a week, while having positive effects, also has a negative impact on the respiratory system [48, 49], as observed in our research.

Veteran athletes, compared to men with low RA aged over 60 years, exhibit a more pronounced difference in the average values of external breathing indicators, which is evidenced by lower rates of regressive changes in sports veterans. Additionally, for men in this age group, even a slight increase in motor activity leads to a significant improvement in overall respiratory system functioning.

The results of our study confirmed the significant impact of regular physical activity on the functional indicators of the respiratory system in veteran athletes. However, it is important to note that intensive training can have both positive and negative effects on the respiratory system, particularly in men over 60 years old. The limitations of this study include a relatively small sample size and the lack of data on the long-term effects of training. Future research could focus on exploring the mechanisms of respiratory system adaptation to different levels of physical activity and identifying optimal training regimens for maintaining and improving respiratory health in older adults.

Conclusions

The analysis of the results from the conducted research made it possible to identify indicators that can serve as spirographic criteria for selecting functional types, specifically those with low, medium, and high PA. It has been proven that systematic exercises involving specially organized cyclical motor activity help form a rational, physiologically optimal type of breathing and inhibit age-related degenerative-dystrophic processes in the human respiratory system. Further work is required to determine the peculiarities of the functional reserves of the respiratory system in masters athletes, depending on the specific track and field events.

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