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Original Article

Cardiorespiratory and anthropometric parameters in athletes across various sports

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Abstract:
Current scientific literature does not adequately address the relationship between cardiorespiratory characteristics and strength capabilities in athletes from different sports disciplines, limiting the full potential of physical activity. ***Purpose***: This study aims to evaluate the cardiorespiratory system parameters and strength capabilities of students involved in both team and cyclic sports. ***Material and methods***: The study involved 31 students in their 1st to 3rd years at a medical university in Russia. Anthropometric indicators were assessed using floor scales with a height meter and body mass index calculations. The vegetative balance was studied by recording a cardiointervalogram lasting at least 5 minutes, for which the hardware and software complex "NS-Polyspectrum-Neurosoft" was used. Measurement of lung volumes was carried out using a hardware and software complex with a pneumotachometric sensor "PC Spirometry Schiller Computer Spirometry System". The following parameters were analyzed: body length and weight, body mass index, systolic and diastolic blood pressure, muscle strength of both hands, accuracy of muscle efforts of both hands, heart rate variability parameters, and pulmonary ventilation parameters. ***Results.*** It was found that students involved in game and cyclic sports have multidirectional changes in the parameters of muscle effort accuracy, autonomic reactivity, and pulmonary ventilation. There are differences in the accuracy of muscle efforts for the left hand, which may be due to the specificity of the game sport. In addition, among representatives of game sports, there is a relative tension of regulatory mechanisms, accompanied by a predominance of innervation of the sympathetic division of the autonomic nervous system and a decrease in parasympathetic regulation. Representatives of game sports also have increased activity of the central mechanism of cardiac regulation. This is manifested by differences in the parameters pNN50, MxDMn, SDNN, RMSSD, SI, and LF/HF. Changes in pulmonary ventilation, which are expressed by shifts in the vital capacity of the lungs and respiratory volume, cause a more intensive increase in the elasticity of the lungs among representatives of cyclic sports. The study of correlation dependencies between the studied indicators demonstrated some features in groups of different sports. ***Conclusions.*** The specificity of the sport can affect the dynamics of changes in the indicators of dynamometry, vegetative balance and pulmonary ventilation. The identified features must be taken into account when organizing the educational and training process, which will increase its effectiveness.
Key Words*:* sports training, anthropometric parameters, vegetative balance, game sports, cyclic sports

Introduction

Human sports activity is a specific type of motor activity that is associated with the activation of the body's reserve and adaptive capabilities (Venevtseva et al., 2023). The influence of training and competitive loads causes shifts in homeostasis and specific adaptive changes in physiological functions (Djaoui et al., 2017; Tiwari et al., 2021; Kolokoltsev et al., 2021). It is known that motor activity, first of all, causes changes in the

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functioning of the cardiovascular and respiratory systems. This is manifested by a change in the autonomic response of the heart rate, pulmonary and tissue gas exchange (Stark et al., 2011; Allado et al., 2022; Klawitter et al., 2023). These changes in functional characteristics are manifested not only during training, but also during the recovery period and relative rest (Fullagar et al., 2017; Bocharin et al., 2021; Scheer et al., 2022). With regular exposure to physical activity, a cascade of reactions of the physiological systems of the body occurs, which is manifested in the expansion of their functional reserves of the body (Marasingha-Arachchige et al., 2020; Lefaucheur, 2023). Consequently, one of the main factors of successful training and competitive activity of an athlete is the implementation of periodic monitoring of the functional state of the body and its leading systems, which ensure optimal adaptive reactions during physical work and recovery (Sikora et al., 2024). The simplest and most accessible method of monitoring physical activity is the analysis of the dynamics of heart rate (Christiani et al., 2021).

The fundamental principle of successful physical work is the harmony of functional interactions of the physiological systems of the body to achieve a certain result. The main life support system of the body is the cardiorespiratory system, which is considered as an indicator of a certain reactivity of the body (Vitale et al., 2019; Mejia-Mejia et al., 2020; Bocharin et al., 2022) and the state of training of the athlete. For example, shifts in the parameters of heart rate variability can be considered as a marker of the activity of the autonomic nervous system, which ensures the functioning of many functional systems of the body (Kataev et al., 2023). The established disturbances in the autonomic innervation of the heart allow the researcher to characterize the early signs of a decrease in the reserve capacity of the body to unfavorable factors of the external or internal environment (Li Volsi, et al., 2023). Registration of autonomic regulation disorders can diagnose early cardiovascular pathology (Uhlig et al., 2020), which continues to be a pressing issue in human sports activities due to severe complications. Analysis of the balance between the parts of the autonomic nervous system can be a diagnostic tool in managing the training process and helps prevent the development of pathological processes in the body that are associated with physical activity (Flatt et al., 2020). Assessing the level of functional state, as an integral component of human physical health, can be considered an important part of a comprehensive assessment of his motor culture (Snezhitsky et al., 2022).

A timely response to a stress factor in the form of physical activity is manifested in a change in the activity of the autonomic regulation and respiratory system, which is ensured by changes in regulatory mechanisms (Maffiuletti et al., 2016). Studies of autonomic reactivity and pulmonary ventilation indicators are necessary to study the adequacy of the proposed physical activity, monitor compensatory reactions and functional changes in the body of the athlete. At the same time, in the training process, it is important to monitor the strength capabilities of the body, which can be realized using the dynamometry procedure (Pronin et al., 2023). In our opinion, insufficient coverage in the scientific literature of the relationship between cardiorespiratory characteristics and strength abilities of athletes in various areas of sports activity does not allow the full use of the potential of training loads. We believe that the definition of correlation relationships between these indicators can allow us to more deeply reveal the mechanisms of the total effect of regulatory effects for personalization of the training process and monitoring adequate functional changes in the body during physical work.

Purpose. To evaluate the characteristics of the parameters of the cardiorespiratory system and strength capabilities of students involved in game and cyclic sports.

Material & methods

31 students of the Medical University of Altai region (Russia) took part in the study. The average age of the young men was 18.8±1.7 years. The participants in the experiment had sports training in the chosen sport and were members of the university's national sports teams. According to their health status, they had the main group (I functional group) for physical education and sports. The observed young men were divided into 2 groups: students - athletes of game sports (n=19) and students - athletes of cyclic sports (n=12).

Before participating in the study, all volunteers signed an informed voluntary consent and could refuse to continue participating in the experiment at any time. The study does not contradict the ethical principles of the 2008 Helsinki Declaration, which apply to medical and biological experiments involving humans.

All observed athletes were determined for length (BL, cm) and body weight (BW, kg), body mass index (BMI, kg / m2), systolic and diastolic blood pressure (SBP, DBP, mm Hg), muscle strength of the right and left hands (kg), accuracy of muscle efforts for the right and left hands (AME, points). To calculate anthropometric indicators, floor scales with a height meter and the ability to calculate the body mass index VMEN-200-50 / 100-ST-A (Russia) were used. To determine the strength of the hand muscles, an electronic hand dynamometer DMER-120-0.5-D (Russia) was used. The calculation of the accuracy of muscle efforts was carried out using the formula: AME = (MU1: 2 – MU2) x 100%, where AME is the accuracy of muscle efforts, ML1 is the first muscle load, ML2 is the second muscle load. The results were assessed using a five-point scale (Mandrikov, & Mitsulina 2006). The vegetative balance of cardiac activity was studied based on the results of recording cardiointervalograms of athletes lasting at least 5 minutes. The hardware and software complex "NS-

Polyspectrum-Neurosoft" (Russia) was used. The ECG signal was recorded in the second standard lead, in the supine position. The study was conducted in a quiet room, in the complete absence of extraneous stimuli, the subject was in a state of relative physiological rest. The lung volumes were measured using a hardware and software complex with a pneumotachometric sensor "PC Spirometry Schiller Computer Spirometry System" (Switzerland).

The heart rate variability indices were assessed using the following parameters: pNN50 (%), SDNN (ms), RMSSD (ms), MxDMn (ms), SI (con. un.), LF/HF (con. un.), as well as the pulmonary ventilation parameters: inspiratory and expiratory reserve volumes (IRV, ERV, liter), vital capacity of the lungs (SVC, liter) and tidal volume (TV, liter).

Statistical processing was performed using Excel tables and the Statistica program. The arithmetic mean (M) was determined, and the standard error of the mean (m) was calculated. The normality of the sample distribution was determined using the Kolmogorov-Smirnov and Shapiro-Wilk criteria. Due to the lack of normality in the distribution of the sample in this study, the reliability of differences between different observed groups was tested using the Mann-Whitney U-test. The analysis of relationships between the characteristics under study was performed using the nonparametric Spearman correlation test. Differences were considered statistically significant at $p<0.05$.

Results

At the initial stage of the study, the main anthropometric indicators, features of strength characteristics and accuracy of muscle efforts, as well as indicators of autonomic reactivity and pulmonary ventilation in athletes of different training orientations were analyzed, Table 1.

Analysis of anthropometric parameters did not reveal statistically significant differences in the values of body length and weight indicators, as well as body mass index between athletes of both groups ($p> 0.05$).

Table 1. Values of anthropometric indicators, accuracy of muscle efforts, heart rate variability parameters and pulmonary capacity in students involved in game and cyclic sports, M±m

Indicator	Type of sport	
	Game (n=19)	Cyclic (n=12)
Body length, cm	179.4±7.7	181.4±3.7
Body weight, kg	77.6±8.7	80.2±13.0
Body mass index, kg/m^2	23.2±2.9	24.4±3.5
SBP, millimeters of mercury	132.2±13.2	134.5±15.3
DBP, millimeters of mercury	73.8±10.7	75.8±7.8
Right hand strength, h	51.4±6.7	50.5±10.0
Left hand strength, h	50.8±7.1	29.3±12.5*
The accuracy of muscle effort of the right hand, %	0.12±0.03	0.11±0.04
The accuracy of muscle effort of the left hand, %	0.12±0.03	0.12±0.03
pNN50, %	25.2±21.5	41.2±23.7*
HR, beats/min	86.8±18.1	77.8±12.4*
SDNN, ms	43.4±15.0	51.5±13.1*
RMSSD, ms	45.3±18.2	56.0±21.8*
MxDMn, ms	208.2±56.9	423.8±144.2*
SI, con. un.	188.4±137.8	138.9±72.6
LF/HF, con. un.	1.7±0.7	1.5±0.6*
IRV, l	1.7±0.8	1.7±0.7
ERV,l	1.6±1.2	1.6±0.7
SVC, l	4.4±0.9	5.2±1.6*
TV, l	1.1±0.5	1.7±0.5*

*Note: * - the reliability of differences between indicators is statistically significant, $p<0.05$ (Mann-Whitney test)*

The strength of the muscles of the right hand is uniform among representatives of both groups (51.4±6.7 h for game players and 50.5±10.0 h for cyclic sports, $p>0.05$). However, statistically significant differences are noted for the left hand. In students involved in game sports, the strength of the left hand exceeds similar characteristics in those involved in cyclic sports by 73.4% ($p<0.05$). This may be due to the specifics of game sports, in particular basketball, where an athlete must have equal control over both upper limbs to achieve an optimal result in a game situation. It is noteworthy that no statistically significant differences were found in terms of the accuracy of muscle effort. Athletes from both groups showed results at the level of the maximum score (the range of relative values among young men from 0 to 6.6%).

When analyzing the results of the study of the vegetative balance using the registration of heart rate variability, it was found that among representatives of team sports, a tendency was recorded for the predominance of central regulatory mechanisms relative to students involved in cyclic sports. Thus, the value of the pNN50 indicator (the percentage of intervals differing from the average value by 50 ms or more) among gamers was statistically significantly lower relative to the second group of athletes by 38.8% ($p<0.05$). In the variation range of the cardiointerval (MxDMn), a decrease of 50.8% in the value of the indicator is also noted among representatives of game sports compared to athletes of cyclic sports (208.2±56.9 ms and 423.8±144.2 ms, respectively, $p<0.05$).

An increase of 35.6% in the SI index (an integral parameter of the presence or absence of a stress state) was found in team sports athletes relative to track and field athletes and orienteers ($p<0.05$). This indicates a tendency toward an increase in the degree of stress in the regulatory systems.

The ratio of the values of the low and high frequency spectrum power indicators (LF/HF) differed. Among basketball players and football players, this ratio was statistically significantly higher than among track and field athletes and orienteers (1.7±0.7 and 1.5±0.6 con. un, respectively, $p<0.05$). In addition, the decrease in the activity of parasympathetic regulation is reflected by the SDNN and RMSSD indicators. Among representatives of team sports, the SDNN parameter is set at the lower limit of the standard (43.4±15.0 ms), and among representatives of cyclic sports it is higher and amounted to 51.5±13.1 ms ($p<0.05$). The RMSSD indicator value in the group of basketball players and football players was 23.6% lower than in the other group of subjects. Thus, the structure of heart rate variability indicates an increase in the tension of the regulatory systems in the group of game-oriented athletes, an increase in sympathetic and neurohumoral regulation, which may be due to the specifics of the sport and the focus of the training process.

The study of pulmonary ventilation parameters showed multidirectional changes in the parameters of this functional system. It was found that in athletes of cyclic sports, the value of the vital capacity of the lungs was 18.2% higher, the respiratory volume was 54.5% higher compared to athletes involved in sports games, $p < 0.05$. In the values of the inspiratory and expiratory reserve volume indicators, statistically significant differences between the groups were not found.

At the next stage of the study, correlation relationships were determined between the studied indicators in each group of student-athletes. In the group of athletes of game sports (Figure 1), positive correlations of moderate strength are noted between BMI and systolic blood pressure, accuracy of left hand muscle efforts and respiratory volume, heart rate-tidal volume-low-to-high frequency power spectrum ratio of the heart rate, SI and respiratory volume, vital capacity of the lungs and LF/HF, $p<0.05$.

	BL	BW	BMI	SBP	DBP	Right hand s	Left hand s	The accurac	The accurac	pNN50	HR	SDNN	RMSSD	MxDM	SI	LF/HF	IRV	ERV	SVC	TV
BL	1.00	0.09	-0.19	-0.42	-0.47	0.16	0.16	-0.37	-0.19	-0.06	0.14	-0.04	-0.07	-0.11	0.10	0.05	0.13	0.27	0.44	-0.16
BW	0.09	1.00	0.75	0.54	0.29	0.17	0.35	0.13	-0.13	-0.02	0.08	-0.08	-0.01	-0.24	-0.03	0.01	0.37	-0.06	0.07	-0.28
BMI	-0.19	0.75	1.00	0.59	0.14	-0.08	0.10	0.17	-0.10	0.13	-0.09	0.17	0.14	0.08	-0.27	-0.18	0.34	-0.28	-0.24	-0.17
SBP	-0.42	0.54	0.59	1.00	0.73	-0.21	-0.11	0.03	-0.09	-0.03	0.01	0.07	0.01	0.12	-0.19	0.05	0.20	-0.16	-0.12	-0.20
DBP	-0.47	0.29	0.14	0.73	1.00	-0.25	-0.20	0.34	0.25	-0.14	0.12	-0.15	-0.12	-0.05	0.04	0.23	0.08	-0.01	0.01	-0.08
Right hand strength	0.16	0.17	-0.08	-0.21	-0.25	1.00	0.83	-0.13	-0.53	0.24	-0.38	0.06	0.26	-0.01	-0.14	-0.08	0.22	0.01	0.04	-0.29
Left hand strength	0.16	0.35	0.10	-0.11	-0.20	0.83	1.00	0.05	-0.49	0.31	-0.20	0.04	0.29	-0.02	0.01	-0.08	0.05	0.16	0.02	-0.35
The accuracy of musc	-0.37	0.13	0.17	0.03	0.34	-0.13	0.05	1.00	0.59	0.33	-0.30	0.19	0.29	0.15	-0.13	-0.28	-0.16	-0.17	-0.47	0.06
The accuracy of musc	-0.19	-0.13	-0.10	-0.09	0.25	-0.53	-0.49	0.59	1.00	-0.08	0.06	0.01	-0.12	-0.05	0.08	-0.04	-0.16	-0.28	-0.34	0.52
pNN50	-0.06	-0.02	0.13	-0.03	-0.14	0.24	0.31	0.33	-0.08	1.00	-0.71	0.90	0.99	0.81	-0.75	-0.84	0.15	-0.13	-0.37	-0.41
HR	0.14	0.08	-0.09	0.01	0.12	-0.38	-0.20	-0.30	0.06	-0.71	1.00	-0.68	-0.75	-0.59	0.75	0.65	-0.30	0.37	0.47	0.33
SDNN	-0.04	-0.08	0.17	0.07	-0.15	0.06	0.04	0.19	0.01	0.90	-0.68	1.00	0.92	0.92	-0.88	-0.91	0.11	-0.14	-0.37	-0.39
RMSSD	-0.07	-0.01	0.14	0.01	-0.12	0.26	0.29	0.29	-0.12	0.99	-0.75	0.92	1.00	0.84	-0.82	-0.86	0.17	-0.15	-0.38	-0.46
MxDMn	-0.11	-0.24	0.08	0.12	-0.05	-0.01	-0.02	0.15	-0.05	0.81	-0.59	0.92	0.84	1.00	-0.84	-0.79	-0.11	-0.03	-0.39	-0.41
SI	0.10	-0.03	-0.27	-0.19	0.04	-0.14	0.01	-0.13	0.08	-0.75	0.75	-0.88	-0.82	-0.84	1.00	0.86	-0.21	0.20	0.38	0.49
LF/HF	0.05	0.01	-0.18	0.05	0.23	-0.08	-0.08	-0.28	-0.04	-0.84	0.65	-0.91	-0.86	-0.79	0.86	1.00	-0.11	0.22	0.46	0.33
IRV	0.13	0.37	0.34	0.20	0.08	0.22	0.05	-0.16	-0.16	0.15	-0.30	0.11	0.17	-0.11	-0.21	-0.11	1.00	-0.52	0.10	-0.02
ERV	0.27	-0.06	-0.28	-0.16	-0.01	0.01	0.16	-0.17	-0.28	-0.13	0.37	-0.14	-0.15	-0.03	0.20	0.22	-0.52	1.00	0.71	-0.58
SVC	0.44	0.07	-0.24	-0.12	0.01	0.04	0.02	-0.47	-0.34	-0.37	0.47	-0.37	-0.38	-0.39	0.38	0.46	0.10	0.71	1.00	-0.35
TV	-0.16	-0.28	-0.17	-0.20	-0.08	-0.29	-0.35	0.06	0.52	-0.41	0.33	-0.39	-0.46	-0.41	0.49	0.33	-0.02	-0.58	-0.35	1.00

Fig. 1. Correlation matrix of relationships between weight-height parameters, accuracy of muscle efforts, heart rate variability parameters and lung capacity among students involved in team sports

Positive strong dependencies were recorded between the parameters of body weight and body mass index, systolic and diastolic blood pressure, the results of dynamometry of the right and left hand, pNN50-SDNN-RMSSD-MxDMn indicators, heart rate-SI-LF/HF, expiratory reserve volume and vital capacity of the lungs, $p<0.05$. Negative correlations of medium strength were found between the dynamometry indicators of the strength of the hand of the right and left hand - the accuracy of muscle efforts for the left hand, vital capacity of the lungs and the accuracy of muscle efforts for the right hand, inspiratory and expiratory reserve volume, expiratory reserve volume and tidal volume ($p<0.05$). Negative correlations of high strength were recorded between pNN50-HR-SI-LF/HF, SDNN-SI-LF/HF, RMSSD-HR-SI-LF/HF, MxDMn-RMSSD-SDNN ($p<0.05$). The results of the correlation analysis in the group of cyclic sports are presented in Figure 2.

	BL	BW	BMI	SBP	DBP	Right ha	Left hand	The accu	The accu	pNN50	HR	SDNN	RMSSD	MxDMn	SI	LF/HF	IRV	ERV	SVC	TV
BL	1.00	0.57	0.38	0.31	-0.14	0.09	-0.26	-0.32	-0.40	-0.01	0.21	0.06	-0.25	-0.15	-0.23	-0.12	0.10	0.31	0.47	-0.07
BW	0.57	1.00	0.98	0.21	-0.07	0.70	0.25	-0.07	-0.71	-0.30	0.05	0.11	-0.33	0.09	-0.17	0.00	0.47	0.29	0.65	0.20
BMI	0.38	0.98	1.00	0.16	-0.05	0.76	0.34	0.00	-0.69	-0.33	0.01	0.13	-0.29	0.15	-0.14	0.02	0.50	0.24	0.61	0.23
SBP	0.31	0.21	0.16	1.00	0.41	-0.25	-0.39	-0.33	-0.30	-0.34	0.43	-0.21	-0.59	-0.25	0.26	0.06	0.27	-0.47	0.06	0.38
DBP	-0.14	-0.07	-0.05	0.41	1.00	0.19	0.32	0.28	0.17	-0.02	-0.18	-0.08	-0.10	-0.56	0.08	-0.09	0.33	-0.27	-0.44	0.48
Right hand strength	0.09	0.70	0.76	-0.25	0.19	1.00	0.61	0.18	-0.43	-0.17	-0.21	0.04	-0.08	0.00	-0.08	0.16	0.56	0.26	0.24	0.25
Left hand strength	-0.26	0.25	0.34	-0.39	0.32	0.61	1.00	0.88	0.26	-0.10	-0.64	0.10	0.08	0.17	-0.20	-0.07	0.25	0.27	0.10	0.21
The accuracy of muscle	-0.32	-0.07	0.00	-0.33	0.28	0.18	0.88	1.00	0.56	-0.02	-0.65	0.14	0.16	0.22	-0.23	-0.22	-0.01	0.17	-0.01	0.05
The accuracy of muscle	-0.40	-0.71	-0.69	-0.30	0.17	-0.43	0.26	0.56	1.00	0.12	-0.37	-0.07	0.25	0.03	-0.18	-0.11	-0.09	-0.10	-0.27	-0.18
pNN50	-0.01	-0.30	-0.33	-0.34	-0.02	-0.17	-0.10	-0.02	0.12	1.00	-0.53	0.74	0.89	-0.04	-0.54	-0.67	-0.38	0.50	-0.08	-0.65
HR	0.21	0.05	0.01	0.43	-0.18	-0.21	-0.64	-0.65	-0.37	-0.53	1.00	-0.50	-0.55	0.07	0.40	0.48	0.06	-0.69	-0.26	0.20
SDNN	0.06	0.11	0.13	-0.21	-0.08	0.04	0.10	0.14	-0.07	0.74	-0.50	1.00	0.78	0.08	-0.69	-0.92	-0.25	0.40	0.30	-0.66
RMSSD	-0.25	-0.33	-0.29	-0.59	-0.10	-0.08	0.08	0.16	0.25	0.89	-0.55	0.78	1.00	0.04	-0.60	-0.72	-0.39	0.43	-0.12	-0.69
MxDMn	-0.15	0.09	0.15	-0.25	-0.56	0.00	0.17	0.22	0.03	-0.04	0.07	0.08	0.04	1.00	-0.24	0.13	0.06	-0.05	0.19	-0.38
SI	-0.23	-0.17	-0.14	0.26	0.08	-0.08	-0.20	-0.23	-0.18	-0.54	0.40	-0.69	-0.60	-0.24	1.00	0.68	-0.02	-0.44	-0.35	0.46
LF/HF	-0.12	0.00	0.02	0.06	-0.09	0.16	-0.07	-0.22	-0.11	-0.67	0.48	-0.92	-0.72	0.13	0.68	1.00	0.33	-0.34	-0.21	0.54
IRV	0.10	0.47	0.50	0.27	0.33	0.56	0.25	-0.01	-0.09	-0.38	0.06	-0.25	-0.39	0.06	-0.02	0.33	1.00	-0.21	0.25	0.21
ERV	0.31	0.29	0.24	-0.47	-0.27	0.26	0.27	0.17	-0.10	0.50	-0.69	0.40	0.43	-0.05	-0.44	-0.34	-0.21	1.00	0.51	-0.19
SVC	0.47	0.65	0.61	0.06	-0.44	0.24	0.10	-0.01	-0.27	-0.08	-0.26	0.30	-0.12	0.19	-0.35	-0.21	0.25	0.51	1.00	-0.16
TV	-0.07	0.20	0.23	0.38	0.48	0.25	0.21	0.05	-0.18	-0.65	0.20	-0.66	-0.69	-0.38	0.46	0.54	0.21	-0.19	-0.16	1.00

Fig. 2. Correlation matrix of relationships between weight-height parameters, accuracy of muscle efforts, heart rate variability parameters and lung capacities among students involved in cyclic sports

Positive correlations of moderate strength are present between the parameters of body length and weight, body weight-inspiratory reserve volume-vital capacity of the lungs, BMI-inspiratory reserve volume-vital capacity of the lungs, HR-systolic blood pressure, dynamometry of the strength of the right and left hand, accuracy of muscle efforts of the right and left hand, HR-LF/HF, pNN50-expiratory reserve volume-RMSSD, SI-LF/HF-tidal volume, expiratory reserve volume-vital capacity of the lungs ($p<0.05$). High-strength relationships were found between body weight-BMI, BMI-right hand muscle strength, left hand muscle strength-right hand muscle effort accuracy, pNN50-RMSSD, SDNN-RMSSD ($p<0.05$).

Negative medium-strength correlations were observed between body length-left hand muscle effort accuracy, systolic blood pressure-RMSSD, diastolic blood pressure-MxDMn, HR-left hand muscle strength-right hand muscle effort accuracy, pNN50-LF/HF, HR-expiratory reserve volume, SDNN-HR, SDNN-SI, SDNN-tidal volume, pNN50-RMSSD, pNN50-tidal volume ($p<0.05$). Inverse relationships of high strength are noted between the parameters of body mass-accuracy of muscular efforts of the left hand, SDNN-LF/HF, RMSSD-LF/HF ($p<0.05$).

Dicussion

A constant increase in the volume and intensity of training loads requires the creation of functional characteristics of individuals involved in sports, depending on their sports specialization (Fernández-Lázaro D et al., 2021). Adaptive reactions of the body during physical work are provided by compensatory shifts, primarily among the indicators of the cardiorespiratory system (Vitale et al., 2019; Mejia-Mejia et al., 2020). The physical performance of the body of a person involved in sports is associated with structural changes and improvement of regulatory mechanisms at all levels of functioning (Stark et al., 2011; Allado et al., 2022; Klawitter et al., 2023). Disturbances in the functioning of the circulatory system, respiratory system and autonomic regulation can lead to a decrease in performance and the emergence of pre-clinical and premorbid conditions. This is indicated by the studies of a number of authors (Flatt et al., 2020; Vorozheikin et al., 2020). Thus, there is a need to search for information on the patterns of restructuring of the autonomic regulation and the respiratory system during the impact of training loads of various directions, depending on the period and stage of the training and competitive processes, which necessitates research in this area. It has been established that students involved in game and cyclic sports have multidirectional changes in the indicators of the accuracy of muscle efforts, autonomic reactivity and pulmonary ventilation. There are differences in the accuracy of muscle efforts for the left hand, which may be due to the specificity of a certain type of motor activity in various sports. In addition, among representatives of game sports, there is a relative tension of regulatory mechanisms, accompanied by an increase in the tone of the sympathetic division of the autonomic nervous system and a decrease in parasympathetic regulation, as well as an increase in the activity of the central circuit of heart rate regulation. This is manifested by differences in the values of the pNN50, MxDMn, SDNN, RMSSD, SI and LF/HF indicators.

Our results of the analysis of heart rate variability parameters in student-athletes are consistent with the findings of other researchers, who indicate that in cases of disturbances in cardiac activity, its regulation through central control mechanisms increases and autonomy decreases (Hayano et al., 2019). At the same time, the more centralized the neurohumoral mechanism of cardiac activity control, the more difficult it is for a person to adapt to physical activity. This condition occurs in an athlete in case of overexertion or overtraining of the body (Jiménez Morgan, & Molina Mora, 2017). The importance of monitoring cardiac activity and the features of its regulation is very important for student-athletes who experience not only significant physical exertion during sports, but also the impact of the educational process. We believe that the results of this study allow us to individualize the training process, which helps maintain the health of athletes.

The changes in pulmonary ventilation revealed during the study, which are expressed by shifts in the vital capacity of the lungs and tidal volume, cause a more intensive increase in the elasticity of the lungs among representatives of cyclic sports. It should be noted that sports that are associated with the formation of the motor quality of endurance are accompanied by increased pulmonary ventilation. This leads to an increase in the elasticity of the lung tissue and contributes to an increase in the strength of the respiratory muscles of the chest and diaphragm under the influence of regular training (Baranova, & Kapilevich, 2013). These data are consistent with the results of our study of pulmonary gas exchange. Representatives of sports associated with the formation of endurance have a higher value of VC and tidal volume of the lungs, which may be associated with a more intensive increase in the elasticity of the lungs and the strength of the respiratory muscles due to cyclic loads in such athletes. The study of correlation dependencies between the studied indicators of the cardiorespiratory system, strength abilities demonstrated some features in groups of students who practice different sports. The identified features of the relationship between the parameters studied allow the coaching staff to carry out more individualized educational and training work taking into account the type of sport and the state of the cardiorespiratory system, strength abilities, precision of muscle effort and other indicators.

Conclusions

It was found that student-athletes of team sports are characterized by a more stable distribution of muscle strength in the upper limbs, compared to representatives of cyclic sports, where the muscle strength of the left arm was recorded at a lower value of the dynamometry indicator, $p < 0.05$.

Analysis of the results of the study of the vegetative balance of the heart rhythm demonstrated the presence of relative tension of the regulatory systems, increased sympathetic activity and neurohumoral regulation, as well as a decrease in the activity of the parasympathetic nervous system in athletes of team sports compared to representatives of cyclic sports. This may be due to the specificity of the sport and the characteristics of the training process.

In the group of student-athletes of cyclic sports, higher values of the external respiration system were established. This indicates a more intensive increase in the elasticity of the lung tissue, the strength of the respiratory muscles due to the impact of the specificity of the training process in this group of examined student-athletes. The identified features of the cardiorespiratory system and anthropometric indicators must be taken into account when organizing the training process for athletes of various sports specializations, which will improve its effectiveness.

Conflicts of interest. The authors declare no conflict of interest.

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