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Functional characteristics of the cardiovascular system in Paralympic powerlifters

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Abstract. The purpose of the study is to assess the functional status of the cardiovascular system in Paralympic powerlifters. Materials and methods. Parameters of central hemodynamics and autonomic regulation of heart rate in Paralympic powerlifters were studied depending on qualification and experience. Assessment of vegetative functions was performed according to the method of R. Baevsky with the help of the POLYSPECTR equipment (Neurosoft, Ivanovo). The Omron M3 Comfort tonometer (Japan) was used to measure heart rate and blood pressure (BPs - systolic and BPd - diastolic); the calculation of hemodynamic indicators was carried out based on generally accepted formulas. Results. The results describing the features of the cardiovascular system of Paralympic powerlifters with various sports experience are obtained. Conclusion. The development of strength in athletes with disorders of the musculoskeletal system and their adaptation to physical activity is accompanied by the functional stress of the cardiovascular system.

Keywords - functional status, cardiovascular system, disabled athletes, Paralympic sport, powerlifting.

I. INTRODUCTION

The effectiveness of the body's adaptation to physical activity is largely determined by the regulatory mechanisms of the blood circulation system. Davidenko D.N. [1] notes that, from the point of view of the system of functional reserves, physiological resources are its central element. According to the research of R. Baevsky et al. [2] a holistic adaptive reaction of the body, aimed at achieving an optimal adaptive response, is ensured by the participation of multilevel reactions of the circulatory system and is implemented by several control loops. Moreover, the reaction can change its parameters over time to achieve the optimal adaptive result.

Adaptation to regular physical activity of Paralympic athletes with disorders of the musculoskeletal system proceeds against the course of the underlying disease and has its own features that must be taken into account for both the training process and the recovery of athletes. The issues of biomedical support of adaptive sports and changes that characterize the adaptation of the cardiovascular system of Paralympics to regular physical activities still require further research.

A distinctive feature of strength-related physical activities is their low-dynamic and highly static nature [3], which exerts a complex effect on the body and contributes to the formation of specific changes in the cardiovascular system in healthy athletes [4, 5] .

II. MATERIALS AND METHODS

The study involved powerlifters with disorders of the musculoskeletal system (n = 23, from masters of sports of international class to the II sports category). The nature of disorders is presented as follows: congenital (arthrogryposis, hip dysplasia, achondroplasia) and acquired forms (amputation of one or both lower extremities at the level of the upper (lower) third of the thigh). The functional abilities of Paralympic athletes were evaluated in accordance with the functional classification adopted in Paralympic sports [6]. The average age of participants was 26.4 ± 2.1 years. All participants were divided into groups depending on the level of sports qualification and powerlifting experience. The first group included athletes of the level of master of sports of international class (n = 5) with the experience of 6.2 ± 1.1 years; the second group - masters of sports and candidates for master of sports (n = 9), experience - 3.5 ± 0.4 years; the third group - athletes of I and II categories (n = 9), experience - 1.8 ± 0.7 years. Voluntary informed consent was an inclusion criterion for the study. The exclusion criterion was refusal to participate, acute diseases or exacerbation of chronic diseases, the absence of regular training loads. The study was conducted in accordance with ethical standards established by the Declaration of Helsinki.

The study was conducted at rest, in the morning, after a day of rest. Using an automatic Omron M3 Comfort blood pressure monitor (Japan), heart rate (HR) and blood pressure (APs – systolic pressure; APd – diastolic pressure) were measured. Based on the data obtained, the following indicators were calculated: pulse pressure (PP), minute blood volume (MBV), stroke volume (SV), cardiac index (CI). Depending on the value of the cardiac index, the type of blood circulation was determined [7]. The mechanical activity of the heart and the status of the blood circulation system as a whole were characterized by the double product (DP) [8].

To assess vegetative functions and identify the type of adaptation, an ECG was recorded with a mathematical analysis of heart rate according to R. Baevsky. The ECG

was performed with the help of the POLYSPECTR equipment for individual control of functional abilities (Neurosoft, Ivanovo). To study the autonomic regulation of heart rate, the indicators of variational pulsometry were used, such as: heart rate (heart rate, bpm), standard deviation of RR intervals (SDNN, ms), coefficient of variation (cV,%), variational range (dX, ms), mode (Mo, ms), standard deviation of the duration of RR intervals (RMSSD, ms), the index of autonomic balance (ABI, c.u.), the vegetative rhythm indicator (VRI, c.u.) and the regulatory processes adequacy index (RPAI, c.u.).

From the spectral characteristics of heart rate variability, the following were analyzed: total spectrum power (TP, ms), high-frequency oscillations (HF%), low-frequency oscillations (LF%), very low-frequency oscillations (VLF%). The interpretation of the results obtained was based on literature data on the relationship between HF oscillations and heart rate vagal monitoring, LF oscillations and the predominantly sympathetic nervous system, VLF component with the suprasegmental mechanisms of autonomic regulation [2, 9]. Statistical processing of the research results was carried out using the statistical software package Microsoft Excel 2003 and Statistica v.6. The results are presented in the form M±m, where M is the average value, m is the standard error of the mean. A check for normality of the distribution was carried out using the Kolmogorov – Smirnov criterion. The significance of differences was determined using the non-parametric Mann-Whitney test for pairwise comparisons (critical significance level p <0.05).

III. Results and Discussion

The study revealed a number of statistically significant differences characterizing the multidirectional nature of the changes in the cardiovascular system and their features in different groups. An assessment of central hemodynamics showed that low-skilled inexperienced athletes demonstrated signs of a hypokinetic type of blood circulation (CI - 1.9±0.1 l / min / m2), while highly skilled athletes were characterized by the changes in the cardiovascular system that are typical for the hyperkinetic type of blood circulation (CI –3.3±0.1 l / min / m2) (Table I).

TABLE I. INDICATORS OF CENTRAL HEMODYNAMICS IN POWERLIFTERS WITH DIFFERENT EXPERIENCE

Parameter	Group		
	I (n =5)	II (n =9)	III (n = 9)
HR, bpm	86.1 ± 3.2*	71.4 ± 2.7#	80.2 ± 3.3^
APs, mmHg	132.3 ± 5.3*	122.1 ± 2.1	116.2 ± 4.4
APd, mmHg	83.2 ± 3.3*	84.1 ± 1.6	75.3 ± 2.5^
DP, c.u.	126.2 ± 0.3*	88.1 ± 4.2#	93.1 ± 4.2
PP, mmHg	47.5 ± 2.1*	40.8 ± 2.7	40.3 ± 3.8
SV, ml	62.1 ± 0.3*	59.8 ± 1.3	51.9 ± 0.5^
MBV, l/min	5.7 ± 0.3*	4.3 ± 0.8#	4.2 ± 0.2
CI, l/min/m^2	3.3 ± 0.1*	2.9 ± 0.4	1.9 ± 0.1^

*Note. The statistical significance of differences (p <0.05) was established: * - between groups I and III, # - between groups I and II, ^ - between groups II and III.*

A quantitative assessment of the energy potential of athletes based on the double product allowed establishing the good functional status of the athletes of the second group (DP - 88.1±4.2 c.u.) and a decrease in the functional abilities of the cardiovascular system of athletes of the first (DP - 126.2 ± 0.3 c.u.) and the third (DP - 93.1 ± 4.2 c.u.) groups (Table I).

In powerlifters, the baseline characteristics of autonomic regulation were evaluated. Highly skilled athletes (first group) revealed statistically significant features, which are manifested in high indicators of variability, activity of the parasympathetic nervous system (Mo, SDNN, RMSSD) (Table II), and low total spectrum power (TP - 1794.8 ±234.1 ms) (Table III).

Indicators of autonomic regulation in the second and third groups did not have significant differences. Athletes of these groups had relatively low rates of heart rate variability (cV, SDNN, dX) (Table II, III). A distinctive feature of athletes of these groups are manifestations of distress (SI in the second group - 176.6–30.8 c.u.; in the third group - 192.4 –35.1 c.u.) (p< 0.05) and higher total spectrum power in comparison with the athletes of the first group (TP in the second group - 2395.6±178.3 ms; in the third group - 2356.6±154.9 ms) (table III).

TABLE II. BASELINE INDICATORS OF TIME-DOMAIN AND STATISTICAL ANALYSIS OF HEART RATE VARIABILITY IN ATHLETES, M±m

Parameter	Group		
	I (n =5)	II (n =9)	III (n = 9)
R-Rmin, mc	*640.2±45.9*#*	*568.4±36.4*	592.7±45.6
R-Rmax, mc	1119.4±156.5*#	807.8±85.6	785.3±24.7
SDNN, ms	116.7±39.9*#	55.6±17.1	38.7±9.7
RMSSD, ms	823.2±191.3#	493.8±228.2	212.6±51.2
ABI, c.u.	95.45±35.2*#	319.4±137.2	311.6±35.1
VRI, c.u.	3.8±1.3*#	9.6±3.2	8.1±1.6
RPAI, c.u.	33.2±8.3*#	76.2±19.2	77.7±7.4

*Note. The statistical significance of differences (p <0.05) was established: * - between groups I and II, # - between groups I and III.*

In the second and third groups, the index of autonomic balance (ABI) is biased towards the predominance of the sympathetic nervous system (Table II), while in the first group the autonomic regulation prevails. The regulatory processes proceed most adequately among highly qualified athletes, as evidenced by the value of RPAI 33.2-8.3 c.u. The regulatory processes in low-skilled inexperienced powerlifters are accompanied with tension of regulatory mechanisms (RPAI in the third group - 77.7–7.4 c.u.) (Table II).

TABLE III. BASELINE INDICATORS OF MATHEMATICAL AND SPECTRAL ANALYSIS OF HEART RATE VARIABILITY IN ATHLETES, M±m

Parameter	Group		
	I (n = 5)	II (n =9)	III (n =9)
cV, %	11.9±3.1#	7.7±1.8	5.7±1.6
dX, %	27.4±4.3*#	46.1±8.9	53.7±4.9
Mo, ms	945.1±114.7*#	645.2±46.4	691.7±16.7
HR, bpm	70.7±8.4	90.5±7.5	88.1±2.7
SI, c.u.	125.7±5.1*#	176.6±30.8	192.4±35.1
TP, ms	1794.8±234.1*#	2395.6±178.3	2356.6±154.9
HF, %	41.2±6.7#	43.9±7.8^	26.5±5.4
LF,%	39.4±4.3#	37.4±4.1^	55.1±6.5
VLF,%	19.4±4.4	18.7±4.1	18.4±2.4

*Note. The statistical significance of differences was established (p <0.05): * - between groups I and II, # - between groups I and III, ^ - between groups II and III*

The analysis of the spectral characteristics of heart rate variability showed the predominance in the first and second groups of the high-frequency component of the spectrum power (HF in the second group - 43.9–7.8%, in the first group - 41.2–6.7%). Adaptation to the loads of the cardiovascular system in low-skilled inexperienced powerlifters takes place with active sympathetic regulation and the predominance of slow waves (LF in the third group - 55.1- 6.5% (Table III)).

IV. Conclusion

The results of the study showed that the adaptation of Paralympic athletes with disorders of the musculoskeletal system to physical loads is largely determined by their experience and the duration of load.

During adaptation, a number of changes are formed, which are manifested in a hyperkinetic type of blood circulation and an increase in systolic blood pressure at rest. At the same time, the autonomic regulation of the cardiovascular system is accompanied by a decrease in the total spectrum power, an increase in variability, and a predominance of autonomic regulation. Identified changes are accompanied by adequate responses of regulatory systems.

For low-skilled Paralympic athletes, adaptation to loads is accompanied by significant stress in the functional mechanisms of hemodynamics, an increase in the activity of the central regulation loop and the sympathetic nervous system. Adaptation to loads in highly skilled powerlifters is characterized by a series of multidirectional reactions of adaptation mechanisms, manifested primarily in the growth of autonomic stress and use of the functional resources of the cardiovascular system, but not beyond the limits of the adequate functioning of the body.

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