The vital point of the Parameters of Morpho-functional State of Gymnasts for the Assessment of Physical Development at the Stage of Sports Perfection

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The article presents the data of the assessment of the physical development and functional state of highly qualified gymnasts engaged in rhythmic gymnastics. It was found that high-skilled gymnasts have heterogeneity of somatotypes determined according to the B. Heath-J. Carter scheme and heterogeneity of types of autonomous nervous regulation of heart rate variability, systolic, diastolic blood pressure and respiration, determined on the spiroarteriorhythmocardiograph device. Highly qualified gymnasts have vago- and normotonic types of regulation of heart rate variability; normal-sympathetic- and hypersympathicotonic types of regulation of the variability of systolic blood pressure and diastolic blood pressure, vagotonic type of regulation of the variability of the respiratory rhythm. Statistically significant differences gymnasts, successful in the medal standings at the international competitions and gymnasts participating, but not in high prizes in competitions, consist in the ability to resist fatigue while performing strenuous mental work (differences were revealed in 10-letter “Mental performance” at a constant speed (p > 0.0001), and 3-letter test (p > 0.001)), data stabilometric test “Target” indicator “Time stability on the left foot” (R > 0.039) with the advantage of a high performing gymnasts artists. Fleshed out the possibility of using the parameters of the morphofunctional state of gymnasts in training for the qualitative evaluation of the physical development of gymnasts, evaluation set their sports uniforms indicated the possibility of developing the reference parameters of the morphofunctional status of gymnasts and recommendations on the frequency of the survey of morphological and functional status of gymnasts involved in rhythmic gymnastics.

Keywords: rhythmic gymnastics, highly qualified athletes, anthropometry, somatotype, functional state, sports form

Rhythmic gymnastics is one of the most popular and rapidly developing sports in Russia and around the World [47]. However, modern rhythmic gymnastics imposes the highest demands on the body of female athletes, forcing the physiological systems to work at the highest possible level, and female athletes to show results on the verge of human capabilities [5, 25, 46]. Currently, the technological basis for the training of Russian gymnasts is the concept of integrated training, which includes all its types: technical, physical, functional, tactical, and theoretical training [2].

The sport’s conditions during the competition in the modern world have strict requirements. They are
pointed on the selection of gymnasts, and therefore the scientific justification of competent medical and biological support for the training and competitive activities of female athletes is of great importance [16, 20, 37, 47]. It is establish that rhythmic gymnastics classes place high demands on the psyche and functional state of female athletes [51], as there is a constant complication of competitive programs, dictated by changes in international rules for this sport [40]. Now the development of world gymnastics, the study of the morphological and functional state of gymnasts is the one of fundamental scientific importance and applied interest, as it allows for timely sports selection and assessment of the adaptive potential of gymnasts. Therefore, there is a need for an in-depth study of the issue from the point of view of normal physiology to understand the physiological mechanisms of expanding the functional reserves to find how the gymnasts faces with the influence of various complex coordination loads [18, 24, 26, 48].

The purpose of the work is to find the significance of the features of the morphofunctional state of highly qualified gymnasts engaged in rhythmic gymnastics for assessing their physical development, prospects, and success in the medal standings at competitions according to literary sources.

In modern sports physiology, there are many physiological classifiers that reveal the features of the functional state of athletes and the success of a person in specific sports: belonging to a certain type of constitution [6, 11, 14, 44] and rhythm variability [1, 34, 49] and others.

Scientific research shows that a certain type of autonomic nervous regulation of heart rate variability corresponds to different degrees of severity of stress manifestations of functional systems that reflect the adaptive capabilities of a person in sports (blood circulation, respiration, Central Nervous system, immune system, etc.) [3, 45].

Currently, in the field of sports physiology, the concept of “functional state” is widely used (abroad, the term “functional status” is more often used) both the entire body as a whole and its individual parts (for example, the functional state of the cardiovascular, respiratory, or endocrine system). I. V. Levshin, A. S. Solodkov, and others note that a detailed examination of the concept of “functional state” reveals theoretical gaps in knowledge about the integrative activity of the body and methodological control over it [22]. The term becomes an abstract concept that implies something more than the individual physiological terms “process”, “property”, “function”. Therefore, it is necessary to determine exactly what physiological processes, reactions, responses to the effects of the environment and the internal environment are meant by this definition. Some authors define the functional state as the background activity of the central nervous system, in which any human activity is performed, also including not only the physiological state of the body and its systems, but also the psychological component [19, 27, 30].

From this point of view, the functional state could be characterized as the ability of a person to perform a certain activity at a given level, with the determination of the price of this very activity. According to the hereby, it is not quite correct to use the concept of “physiological state”, although in Russian science at the moment, these concepts are often identified. It should be the normal functioning of the body, the opposite to pathological and dysfunctional states, usually implied. At the level of a complete living organism, functioning is determined by the processes occurring in the body, its structural elements, the connections between them, and the exchange of information at a certain point in time, which emphasizes the term “functional state” [12].

In classical physiology, N. N. Danilova (1985) defines the functional state as the background activity of nerve centers and correlates with the characteristics of the nervous tissue: reactivity, lability, excitability.

I. P. Pavlov associated this state with the tone of the cerebral cortex [32]. P. S. Kupalov (1962) [21] in
his works showed that the dynamics of the functional state is reflected in changes in the reactivity, excitability, and lability of the brain. A. M. Zimkina estimated the functional state by the average values of these parameters.

Based on the hereby, the functional state should be considered “...as a special psychophysiological phenomenon with its own laws, which is embedded in the architecture of modulating functional systems and which manifests itself at the biochemical, physiological, behavioral and psychological (subjective) levels” (Pavlov, 2008, p.) [27].

The functional state has two sides: subjective, which includes mental phenomena, and objective, which relates to physiological processes. The subjective side is the leading one for the functional state, since it is determine by the properties of the nervous system. In the literature, there is a distinction between the concepts of “functional state of the body” and “functional state of a person”: The first implies a physiological meaning, the second—a systemic psychophysiological phenomenon. This differential approach allows us to find the difference between both sides of the functional state and its components [27].

Thus, the functional state is an integrative characteristic of the functioning of the body’s systems, reflecting the features of the adaptation process in a certain period of time, that can be consider at the level of the mechanisms of mental and physiological regulation. In conditions of intensive muscle activity, the main task of adaptation is to maintain homeostasis with adequate work of the central nervous system. The body tries to adapt to constantly changing conditions, to keep the constants of the internal environment. Changes in homeostasis activate the regulatory mechanisms of the body’s systems, and the range of adaptation to the conditions of physical activity depend on their reliability and stability.

The success of activity in gymnastics is determine by the complex of personality. It should include the five qualities: morphological status, specific physical qualities, coordination abilities, the state of analyzers and functional systems of the athlete’s body, psychophysiological characteristics and psychological types of reactions of higher nervous activity [6, 16, 25, 45, 47, 48].

S. I. Lyasotovich (1989), A. L. Vasilchuk and Yu. K. Gaverdovsky (1985), and N. N. Zakhar’eva (2016) note the importance of belonging to a specific morphotype for the success of performing gymnastic exercises [21,44,47]. According to K. E. Fadeeva (2014), the majority of gymnasts of the candidates for master of sports and master of sports have a height of 6% lower in comparison with healthy untrained girls; the body weight of highly qualified gymnasts has a wide range of values, but, in general, 23% lower in comparison with trained peers. It is mentioned that the level of physical development of MS gymnasts can increase in terms of body weight per year from 2.5 to 1.7%, growth from 2 to 7%, chest circumference from 4.5 to 25.4% [10].

E. K. Fadeeva (2014) found that the indicators of physical development of highly qualified gymnasts are in feedback with the indicators of heart rate (r = -0.94) and systolic blood pressure (r = -0.72) when performing exercises with objects [10].

According to E. A. Kokorina (2007), it was found that the strongest representatives of sports aerobics are characterized by a mesomorphic type with a large percentage of bone and muscle components—the ectomesomorphic type [18].

In jump acrobatics, athletes are characterized by the following types of morphological data and body types: height below average and average, negative values of the Brock height-weight index, for upper and middle gymnasts, the obvious advantages of the retrograde type of physical development of the mesomorphic type with a narrow pelvis are described; for athletes of the lower type, the advantages are medium and high levels of
Attention is paying to the fact that a clear advantage for artistic and artistic gymnastics is the length of the limbs: Gymnasts who were engaged in artistic and artistic gymnastics with long limbs have clear advantages in sports results, in comparison with gymnasts with short limbs.

Thus, the level of sports achievements of gymnasts largely depends on the morphological status and belonging to a particular type affects the ability to develop physical qualities that determine the sports result.

According to K. V. Gobuzeva (2006) [13], the system of model perspective characteristics—gymnasts engaged in rhythmic gymnastics-juniors—includes the following elements:

1. Anthropometric data: muscular-asthenic body type, elongated muscle shape; coefficient of height and weight index (from -10 to -12);

2. Sufficient level of development of motor abilities, flexibility (active and passive); coordination abilities (static and dynamic balance); power abilities (actually power and especially speed-power) [13].

The research conducted in the Department of Physiology and Chemistry Associate Professor V. M. Chenerin and Professor Ph.D. S. N. Kuchkin (1983-1994), it found that for athletes involved in gymnastics, the characteristics of retardation at the beginning of specialized training: inhibited the development of adipose tissue. Such processes occur with increased production of male sex hormones. The component composition of the body is dominated by muscle tissue. The ratio of muscle and adipose tissue is close to the male type (the percentage of adipose tissue is 10-15% and the percentage of muscle tissue is 39-44%) [9].

With age, with an increase in the length of training in artistic gymnasts, there is a delay in the age-related increase in all components of body weight and especially the length of the gymnasts’ body. According to M. Ya. Nabatnikova (1982), it was noted that the delay in age-related weight gain and its fat component is combined with the retardation of puberty [29]. V. M. Chenegin (1994) identifies as a positive criterion for predicting high sports skill in rhythmic gymnastics the delayed manifestation and low rates of development of sexual secondary sexual characteristics [9].

A. L. Vasilchuk and Yu. K. Gaverdovsky (1985) note the importance of belonging to the brachymorphic morphotype for the success of performing jumping gymnastic exercises, and representatives of the brachymorphic type are successful in the qualitative performance of turns relative to the longitudinal axis [43].

S. D. Ustinov shows that the effect of a non-inertial turn depends on the constitutional data of the gymnast: With an equal body weight in the performance of the turn, the one with the greater height, or, in other words, the one with the elements of the body mass more “stretched” along the longitudinal axis of the system, has a preference. Currently, such a complex jump as a backflip with a 1080° turn is much more often performed by women, whose morphotype is more consistent with the requirements for the performer of super-complex turns. Of great importance for the evaluation of the anthropometric factors of a gymnast is the circumference of the body. It is noted that the higher the physical development of the gymnast, the more pronounced the relief of the shoulder circumference.

In the scientific works of T. S. Lisitskaya (1982-1987), the following factors are identified as significant factors determining the success of gymnasts engaged in rhythmic gymnastics: the level of physical development, functional capabilities, and the degree of puberty [23].

As the observations of S. I. Lyasotovich (1989) show, in each age period, gymnasts are characterized by...
their own specific morphological data, which determine the possibility of further development of physical qualities, the formation of the necessary reserves and features of the functional state leading to a successful sports result [21].

O. Yu. Strizhkova (2012) studied the features of the functional state of highly qualified gymnasts. It is noted that for highly qualified gymnasts in conditions of relative rest, the absence of tension of regulatory mechanisms is characteristic. In the competitive period, the author describes that in comparison with the transition period, athletes are characterized by increased functional activity of the brain and increased economization of heart activity; in the preparatory period—increased time for memorizing complex coordination movements and a decrease in the stability of attention [38].

Rhythmic gymnastics places great demands on the ability to assimilate and accurately reproduce complex movements. This imposes requirements on the memory of gymnasts, as well as on such qualities as performance, clarity, and completeness of visual representations, accuracy of movement reproduction. A. V. Posokhov notes the need for artistry and expressiveness when performing FU (physical exercises) dictates to gymnasts the need to develop abilities for self-control, for differentiated inhibition of muscle efforts, the ability to concentrate attention, quick response to different situations, and speed of thinking.

In the laboratory, research Center of Sports (Institute for Sport and Sports Medicine Russian State University of Physical Education, Sport, Youth and Tourism(SCOLIPE) (2013-2020) N. N. Zaharyeva and her students (Z. R. Gainutdinova (MS), D. A. Belyakov, I. D. Konyaev (KMS), A. V. Tarabrina (MS), E. G. Pomiluyko—world champion in social pair dance in 2015)) present the results of physiological testing of 68 highly qualified gymnasts engaged in artistic and aesthetic gymnastics, actively performing at competitions, aged 17-24 years, with experience in gymnastics from 10 to 20 years, including seven world champions, 61 gymnasts—MS. It is establish that the gymnasts of the highly qualified athletes have a heterogeneity of somatotypes determined according to the scheme of B. Heath-J. Carter and heterogeneity of types of autonomic nervous regulation of heart rate variability, systolic, diastolic blood pressure and respiration, determined on the SACR (spiroarteriorhythmocardiograph) device. According to our data, highly qualified gymnasts are more likely to have ectomesomorphic, less often mesoectomorphic and ectomorphic types of constitution (B. Heath-J. Carter) and vago- and normotonic types of regulation of heart rate variability; normal-sympathetic-and hypersympathicotonic types of regulation of the variability of systolic blood pressure and diastolic blood pressure, vagotonic type of regulation of the variability of the respiratory rhythm (determined by R. I. Baevsky (1986), N. I. Shlyk (2009)) [47].

The greatest differences of the regulatory mechanisms and physical qualities were established by us, when comparing these gymnasts with the vago- and sympathicotonic types of heart rate variability. In the wave structure of the spectrum, significant differences were found in the parameters of systolic blood pressure rhythm variability (TP (mm2), VLF (mm2); LF (mm2); HF(mm2) (p > 0.001) in the values of respiratory rhythm variability (TP SP mm2); HFSP (mm2) gymnasts artists are masters of sports of international class and sportswomen—gymnasts lower qualifications and competitive performance (p > 0.01) that clarifies the distinction of regulatory systems responsible for the homeostasis of the organism gymnasts various sports skills at the stage of sports perfection. According to our research, there are significant differences between gymnasts, who are successful in the medal standings at responsible international competitions and MS gymnasts, who participate, but do not take high prizes at competitions, which are expressed in differences in the ability to resist fatigue when performing strenuous mental work (differences were revealed in the 10-letter constant speed test
“Mental Performance” (URA), V. V. Sonkin (2009) (p > 0.0001) and 3-letter test (p > 0.001)). In addition, differences were found in the same comparison groups in the data of the Target stabilometric test in the indicator “Stability time on the left leg” (p > 0.039) with the advantage of highly effective artistic gymnasts [16].

In the dissertation work of the Candidate of Pedagogical Sciences V. E. Gorokhova (2002): “Special physical training of gymnasts to perform a series of elements increased difficulty” is noted, that the implementation of elements of advanced gymnasts involved in rhythmic gymnastics is required to enhance the sensitivity of sensory systems that has a positive impact on the ability to differentiate spatial and temporal dynamic motion parameters and improves the ability to balance technical skills [15].

E. N. Medvedeva and co-authors (2014) evaluate the functional state of gymnasts with urgent adaptation to physical exertion before and after training when performing operational load correction in shock and retraction microcycles [26]. It was found that gymnasts-member of the Russian national team, at the stage of shock microcycle, the maximum value of the volume observed in the first four days of training microcycle on the second training session (i.e., Monday-Thursday), and then decrease to the end of the week is equal to the second day microcycle; however, on the 5th and 6th day of shock microcycle amount of load on the first exercise again rises sharply. When performing the retracting microcycle, the load volumes of MSMC gymnasts are reduced.

Starting from the 3rd day of the microcycle, the number of correctly completed tasks begins to increase unreliably, and by the 6th day there are significant differences and a clear positive dynamics of the motor accuracy of the completed tasks in exercises with ribbons and clubs (r = 0.85). The authors note the maximum waves in the parameters of the functional state of gymnasts performing work with the performance of individual microcycles in the preparatory period on the 2nd day and the 6th day of training.

In general, it was noted, that the indicator of the psychoemotional state of gymnasts before the first training session was significantly higher than before the second by 9-30%. Timely implementation of operational control can optimize the physical activity of gymnasts [26, 28, 31, 32, 36].

The scientific works of V. K. Makarenko and I. B. Belousova (2014) consider the results of operational control of the functional state of gymnasts engaged in rhythmic gymnastics after performing each physical exercise with the subject to optimize the recovery process. The authors describe the dynamics of changes in the indicators of the test of the “Critical frequency of flicker”, jumping endurance, tremor, and statometry after warming up and performing exercises with objects. The authors single out statometry as the most informative method, which has the highest reliability index when assessing the dynamics of fatigue. The remaining indicators of determining the critical frequency of merging light flashes and jumping endurance were reliable after three of his exercises (p > 0.05) [24].

One of the features of the functional state of highly qualified gymnasts engaged in rhythmic gymnastics at the present stage is pre- and clearly pathological changes in bone and muscle tissue, which are formed as a result of constant exposure to stress and heavy physical exertion, so there are violations in the bone tissue in the form of demineralization and the effect of reabsorption with the development of scoliosis and pathological changes in posture [44].

E. V. Beklemisheva says that physical exercises of rhythmic gymnastics impose significant requirements on the cardiovascular and respiratory systems of the body is involved. This is evidenced by the increase in the heart rate when performing the exercises of the classification program to about the limit, the significant size of
the oxygen debt and oxygen demand. Training sessions are held with high intensity (during the training, the pulse rate is on average 148 beats/min). In this regard, highly qualified gymnasts characterized by a high functional level of vegetative maintenance systems [4].

Assessing the functional state of the autonomic systems, in particular the cardiovascular system, it should had a resting heart rate of 66-72 beats/min, which reflects the economization of functions at rest and the phenomenon of sports bradycardia. The level of maximum blood pressure is on average, according to the author, 113 mm Hg (from 90 to 120 mm Hg) [10].

According to N. O. Vengerova and I. O. Solovyova (2009), a significant increase in the intensity of the training process in rhythmic gymnastics has a negative impact on the functional state of the cardiovascular system [44]. The authors found that when physical activity does not exceed the threshold (systolic blood pressure no more than 144 mm Hg), there is a biological adequacy of the developed complexes. Physical activity was evaluated by the authors according to the “intensity index” of E. A. Zemsky (1971) who modified by L. Ya. Arkaev for gymnasts engaged in rhythmic gymnastics. Physical activity in the pre-competition stage for gymnasts of the female gymnasts of high qualification increased by twice in intensity and amounted to 2.6-2.7 elements per minute. The maximum response of the cardiovascular system to intense physical activity noted by the authors at the age of 12 years in comparison with the cardiovascular system gymnasts at the ages of 14 and 17 years.

Gymnasts-artists of the highly qualified athletes, experiencing high sports loads, are distinguished by the expansion of the heart’s shock volumes of systolic volume and minute blood volume, with the formation of hypertrophy of the left ventricular muscle and the “sports heart”. A. A. Svetlichkina and O. I. Dorontsev (2017) analyzed the functional state of the cardiovascular system, in artistic gymnasts according to ECG data (electrocardiogram) in the survey of 122 athletes with high qualifications. The authors noted, that the gymnasts-artists highly qualified athletes quite often: sinus arrhythmia, supraventricular tachycardia, conduction disturbances in the form of sinoatrial blockade of the 1st degree and a change in the length of PQ interval and left ventricular hypertrophy, indicating that the development of “sports heart” on the background of specific physical exertion in high fitness athletes justify the need for monitoring the functional state of the SSS before and after the competition when carrying the maximum load gymnasts [34].

A. S. Zhumanova, V. N. Avsieievich, and T. M. Omasheva (2017) present the characteristics of the functional state of female gymnasts of various ages, including at the age of 14, when girls have high sports categories, living in various regions of Kazakhstan. It was found that according to the obtained data on the parameter of the vital capacity of the lungs, when practicing rhythmic gymnastics, athletes had annual increases of this parameter of about 10% annually. According to the parameter vital index, which reflects the state of the respiratory system, the vast majority of indicators are high 66% which indicates good respiratory reserves of gymnasts engaged in rhythmic gymnastics.

However, about 38% of the surveyed gymnasts have low indicators of this parameter and the parameter of strength of the muscles of the hands of both hands [15].

E. K. Fadeeva (2014) found that the indicators of physical development of highly qualified gymnasts are in feedback with the indicators of heart rate (r = -0.94) and systolic arterial pressure (r = -0.72), when performing exercises with objects. The average negative relationship between the indicators of vital capacity of the lungs, age, and the quality of performances of gymnasts is at competitions (r = -0.44). Draw attention to the decrease in the strength of the muscles of the hand. According to various authors, this percentage is 12.5-31%
for the right hand and from 7 to 29.3% for the left hand in both the left and right hands of highly qualified gymnasts [43].

Conclusion: Assessment of the parameters of the morphofunctional state of gymnasts of high sports qualification is an accurate reflection of the process of growth and development of gymnasts, allows you to qualitatively assess the health of athletes, their physical development, their set of sports uniforms, and develops reference parameters of morphofunctional status with the allocation of typological differences depending on the physiological classifier (type of constitution, type of HRV, type of Nervous system, dominance of the severity of the development of physical qualities, etc.). It is desirable to evaluate the morphofunctional state of gymnasts highly qualified female athletes weekly reporting of the coach and the athletes in the form of a specially developed questionnaire——“map of the morphofunctional development of the gymnast” and the execution of the Protocol of the annual cycle of development of morphofunctional state for each gymnast. Using these data, it is possible to create reference morphofunctional parameters of the peak of a gymnast’s athletic form, which can be a reference point for correcting the training process in different periods of sports training.

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