Features of the aerobic energy supply system as a result of the activity of the cardiorespiratory system

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Abstract

Objective of the study was to identify the features of the aerobic energy supply system as a result of the activity of the cardiorespiratory system, depending on the age of athletes involved in cyclic sports, during bicycle ergometric testing.

Methods and structure of the study. The subjects were athletes involved in endurance sports and, depending on age, the following groups of subjects were formed: 15-16 years old, 17-21 years old, 22-35 years old and 36-60 years old. All of them performed work on a bicycle ergometer with a power of 50, 100, 150 and 200 watts. Each stage of the load lasted 3 minutes, during which the differential rheogram according to Kubizek was recorded, modified by Yu.S. Vanyushin et al., and the indicators of the cardiovascular system were determined: heart rate, stroke volume, minute volume of blood circulation. With the help of a pneumotachograph, indicators of external respiration were determined: respiratory rate, tidal volume, minute respiratory volume. The oxygen utilization coefficient was calculated according to the generally accepted formula.

Results and conclusions. A comprehensive study of the process of adaptation of the cardiorespiratory system of athletes of different ages involved in endurance sports allowed us to identify the possibilities of the aerobic method of energy supply, which depends on the age of the athletes.

In athletes aged 15-16 and 36-60 years, according to the results of our research, it is advisable to develop an external respiration system aimed at increasing the minute volume of respiration, since in this case the aerobic method of energy supply functions better.

Athletes aged 17-21 years should develop a circulatory system that increases the performance of the pumping function of the heart (stroke volume, minute volume of blood), which affects the ability of the heart to eject a larger volume of blood. This will have a positive effect on the aerobic way of energy supply.

Athletes aged 22-35 years should stimulate the gas exchange function associated with an increase in the oxygen utilization factor (UFO2), which is the most optimal. In athletes of this age, apparently, it is advisable to develop this particular method of energy supply.

Keywords: *cardiorespiratory system, exercise, respiration, blood circulation, gas exchange, athletes.*

Introduction. It is expedient to consider functional systems and their functions in connection with ideas about the features and patterns of development of the adaptation process [1, 6, 7]. In the functional systems themselves, transformations occur that contribute to the adaptation process [5, 8, 9], that is, there is a relationship between functional systems and the adaptation process:

Functional → Adaptation
systems ←

Adaptation, as a process of adapting functional systems to motor activity, has attracted numerous minds of scientists for decades. This was based on the approaches of P.K. Anokhin [1] in the study of functional systems and the concept of A.A. Ukhtomsky [10] about the dominant focus of excitation in the CNS, the readiness of the organism for a certain type of activity when other foci of excitation, insignificant for a given period of time, are inhibited. PC. Anokhin [1] believed that "a functional system is understood as such a dynamic organization of the structures and processes of the body, which involves them regardless of the anatomical, tissue and physiological certainty." In his opinion, in this case, one of the criteria for the involvement of components in a particular system is "the ability to contribute to obtaining the final adaptive result."

Currently, one of the most important functional systems that can contribute to obtaining the final adaptive result, namely, providing the body with oxygen, is the oxygen transport system, or a system that represents the totality of respiratory and circulatory functions, that is, the cardiorespiratory system. It should be attributed to the systems of the first type, the activity of which is aimed at maintaining the constancy of the internal environment of the body. Systems of the second type contribute to the implementation of behavioral acts, which is an important component not only for optimizing the process of sports training, but also for the development of the entire theory and practice of physical education and sports [8, 13, 15].

Considering the cardiorespiratory system, it is necessary to pay attention to the fact that its activity is associated with aerobic energy supply, which is important for the development and improvement of endurance. Especially if sports exercises are related to cyclic sports. With an aerobic energy supply system, the formation of ATP in muscles (mitochondria) occurs with the participation of oxygen. As a result, high efficiency is observed and there are no harmful decomposition products. Such shortcomings are observed in anaerobic alactate and anaerobic lactate energy supply systems [8].

Objective of the study was to identify the features of the aerobic energy supply system as a result of the activity of the cardiorespiratory system, depending on the age of athletes involved in cyclic sports, during bicycle ergometric testing.

Methods and structure of the study. The subjects were athletes involved in endurance sports and, depending on age, the following groups of subjects were formed: 15-16 years old, 17-21 years old, 22-35 years old and 36-60 years old. All of them performed work on a bicycle ergometer with a power of 50, 100, 150 and 200 watts. Each load step lasted three minutes, during which a differential rheogram was recorded according to Kubitschek [14], modified by Yu.S. Vanyushina et al. [2, 3], and indicators of the cardiovascular system were determined: heart rate (HR), stroke volume (SV), minute volume of blood (MVB). With the help of a pneumotachograph, external respiration indicators were determined: respiratory rate (RR), respiratory volume (RV), respiratory minute volume (RMV). The oxygen utilization factor (UFO_2) was calculated according to the generally accepted formula [11].

Results of the study and their discussion. When analyzing the activity of functional systems of the first type, which are homeostatic, one should pay attention to the cardiorespiratory system, whose work is aimed at providing the body with oxygen necessary for aerobic energy supply. This circumstance plays a key role in the development and improvement of general endurance. This is especially true for those athletes who are involved in cyclic sports associated with the development of endurance, as well as those who care about their health, developing endurance to improve physical performance and increase the level of life. Therefore, in a comprehensive study of the process of adaptation of the cardiorespiratory system of athletes, it was not by chance that we chose such a wide age range: from 15 to 60 years.

Previous studies [4] considered several areas related to the study of the cardiorespiratory system. In this work, we want to dwell on the direction that is relevant for athletes developing endurance, namely, on supplying their body with oxygen for the process of energy supply through aerobic reactions. For this purpose, we selected a contingent of subjects involved in endurance sports, and proposed a test load in the form of work on a bicycle ergometer from 50 to 200 W. Every 50 W and 3 min, the load gradually increased, which, in our opinion, will help to identify the predominant reactions from the cardiovascular and respiratory systems in athletes of different ages (Table 1).

During muscular activity, as is known, the activity of almost all visceral systems of the body is noted, which is associated with increased oxygenation and the flow of nutrients to working muscles. Consequently, the capabilities of the oxygen transport system increase, which affects the ability of the heart, as a pump, to pump a significant amount of blood and the work of the respiratory system.

The most preferred response in athletes aged 22-35 years was the reaction with an increase in the oxygen utilization factor (UFO_2), which indicates a more rational energy supply to the body of athletes when performing endurance work. The next type of reaction capable of satisfying the oxygen demand when working on a bicycle ergometer was an increase in the parameters of the cardiovascular system, to which we attributed the minute volume of blood circulation (MVB). This was noted in male athletes aged 17-21 years, which was 20.38 ± 0.46 l/min at a load of 200 W. In highly qualified athletes, this indicator, as a rule, reaches 40–45 l/min [12]. From

Table 1. *Indicators of a comprehensive study of the process of adaptation of the cardiorespiratory system of athletes of different ages involved in endurance sports*

Load	Indicators	Groups of athletes			
		15-16 years old	17-21 years old	22-35 years old	36-60years old
Initial state	HR	77.51±4.63	62.20±2.14+	65.29±2.19*	65.40±2.07v
	SV	62.55±3.55	79.37±2.22+	82.28±3.21*	79.32±2.52v
	MVB	4.77±0.28	4.95±0.24	5.29±0.19	5.23±0.27
	RMV	9.37±0.81	10.24±0.40	9.59±0.61	10.15±0.47
	UFO_2	21.36±1.98	22.73±0.82	23.71±1.15	22.44±0.61
50 W	HR	105.62±5.21	90.42±2.09+	85.65±2.09*	87.23±1.75v
	SV	81.09±3.44	106.00±3.82+	115.98±3.68*	101.61±3.95v
	MVB	8.46±0.50	9.62±0.49	9.95±0.44*	8.88±0.42
	RMV	25.76±1.74	22.85±0.87	23.41±1.00	27.25±1.01x
	UFO_2	28.52±1.86	34.30±1.37	34.76±1.03	32.35±0.81
100 W	HR	133.13±6.05	108.79±1.95+	103.86±1.71*	104.16±2.04v
	SV	80.07 ±3.45	122.82±3.69+	131.40±4.17*	117.98±3.65v
	MVB	10.53±0.41	13.30±0.38+	13.59±0.39*	12.22±0.42v
	RMV	40.35±3.04	33.11±1.27+	33.50±1.44*	37.87±0.89x
	UFO_2	33.39±2.02	39.45±1.43+	39.85±1.30*	38.18±0.93x
150 W	HR	161.24±6.25	130.50±2.39+	123.72±2.18*o	125.20±2.39v
	SV	77.83±4.60	129.86±3.30+	141.72±4.95*o	130.80±4.46v
	MVB	12.35±0.56	16.92±0.43+	17.44±0.54*	16.28±0.47v
	RMV	54.15±3.21	45.96±1.28+	46.49±1.60*	56.55±2.15x
	UFO_2	36.35±2.56	43.31±1.28+	43.36±1.20*	39.89±1.03x
200 W	HR	178.10±6.98	151.44±3.09+	142.44±2.82*o	147.32±2.69v
	SV	73.30±5.45	136.31±4.45+	141.19±4.22	129.52±5.55v
	MVB	12.90±0.87	20.38±0.46+	20.03±0.57*	18.93±0.69v
	RMV	68.57±3.84	59.34±1.48+	59.55±1.79*	75.65±3.26x
	UFO_2	40.82±1.64	44.30±1.00	47.64±1.17*0	40.37±1.21x

Note. + – statistical significance of differences between groups 1 and 2; * – statistical significance between groups 1 and 3; v – statistical significance between groups 1 and 4; o – statistical significance between groups 2 and 3; x – statistical significance between groups 2 and 4; . – statistical significance between groups 3 and 4.

this we can conclude that in our studies, a load of 200 W is not intense enough or young athletes have not yet reached the level of high skill in cyclic sports that develop endurance.

In our opinion, a less significant response to exercise performance during bicycle ergometric testing is an increase in external respiration, the main requirement of which is to maintain arterial blood plasma gas homeostasis, adequate to the metabolic needs of the body during exercise. These indicators should include a significant increase in RMV. We observed this reaction from the respiratory system in adolescents aged 15-16 years and veteran athletes aged 36-60 years. This characterizes the activity of their organism on the part of the cardiorespiratory system as uneconomical, capable of consuming significant reserves of the oxygen transport system, in particular, oxygen, which is significantly consumed by the work of the skeletal muscles of the respiratory system.

Therefore, the last type of aerobic energy supply considered by us is considered ineffective. However, age-related features of the maturation of individual parts of the cardiorespiratory system do not always allow the use of other methods of providing the body with oxygen during motor activity. In this regard, in adolescent athletes 15-16 years old, it is necessary to develop and improve the respiratory capabilities of the oxygen transport system to perform aerobic loads that are adequate to the requirements of the body.

Conclusions. Thus, a comprehensive study of the process of adaptation of the cardiorespiratory system of athletes of different ages involved in endurance sports allowed us to identify the possibilities of the aerobic method of energy supply, which depends on the age of the athletes. In athletes aged 15-16 and 36-60 years, according to the results of our research, it is advisable to develop an external respiration system aimed at increasing the RMV, since in this case the aerobic method of energy supply functions better. Athletes aged 17-21 years should develop a circulatory system that increases the performance of the pumping function of the heart (SV, MVB), which affects the ability of the heart to eject a larger volume of blood. This will have a positive effect on the aerobic way of energy supply. Athletes aged 22-35 years have a gas exchange function associated with an increase in the oxygen utilization factor (UFO_2), which is the most optimal. In athletes of this age, apparently, it is advisable to develop this particular method of energy supply.

References

1. Anokhin P.K. Uzlovyye voprosy teorii funktsionalnoy sistemy [Nodal issues of the theory of functional systems]. Moscow: Nauka publ., 1980. 197 p.
2. Vanyushin Yu.S., Khairullin R.R. Kardiorespiratornaya sistema kak indikator funktsionalnogo sostoyaniya organizma sportsmenov [Cardiorespiratory system as an indicator of the functional state of the body of athletes]. Teoriya i praktika fizicheskoy kultury. 2015. No. 7. pp. 11-14.
3. Vanyushin Yu.S., Khairullin R.R., Elistratov D.E. Znacheniye koeffitsiyenta kompleksnoy otsenki kardiorespiratornoy sistemy dlya diagnostiki funktsionalnogo sostoyaniya sportsmenov [The value of the coefficient of a complex assessment of the cardiorespiratory system for the diagnosis of the functional state of athletes]. Teoriya i praktika fizicheskoy kultury. 2017. No. 5. pp. 59-61.
4. Vanyushin Yu.S., Khairullin R.R., Elistratov D.E., Fedorov N.A. Fedorov Adaptatsiya kardiorespiratornoy sistemy sportsmenov k dvigatelnoy deyatelnosti [Adaptation of the cardiorespiratory system of athletes to motor activity]. Teoriya i praktika fizicheskoy kultury. 2020. No. 2. pp. 30-32.
5. Ivanova N.V. Faktory, opredelyayushchiye funktsionalnoye sostoyaniye kardiorespiratornoy sistemy sportsmenov [Factors that determine the functional state of the cardiorespiratory system of athletes]. Teoriya i praktika fizicheskoy kultury. 2013. No. 5. pp. 108-111.
6. Olyashev N.V., Varentsova I.A., Pushkina V.N. Pokazateli kardiorespiratornoy sistemy u yunoshey s raznymi tipami krovoobrashcheniya [Indicators of the cardiorespiratory system in young men with different types of blood circulation]. Ekologicheskaya fiziologiya. 2014. No. 4. pp. 28-33.
7. Pavlov I.P. Izbrannyye trudy Izbrannyye trudy [Selected works]. Natochin Yu.V. [ed.]. Moscow: Meditsina. 1999. 445 p.
8. Platonov V.N. Dvigatelnyye kachestva i fizicheskaya podgotovka sportsmenov [Motor qualities and physical training of athletes]. Moscow: Sport publ., 2019. 656 p.
9. Sudakov K.V. Fiziologiya. Osnovy i funktsionalnyye sistemy [Physiology. Fundamentals and functional systems]. Course of lectures. Moscow: Meditsina publ., 2000. 784 p.
10. Ukhtomsky A.A. Dominanta [Dominant]. St. Petersburg: Piter publ., 2002. 448 p.
11. Fedorov N.A., Elistratov D.E., Vanyushin Yu.S. Kompleksnaya otsenka funktsionalnogo sostoyaniya studentov [Comprehensive assessment of the functional state of students]. Kazan: Otechestvo publ., 2014. 86 p.
12. Bassett, L.R.Jr. Limiting factors for maximum oxygen uptake and determinants of endurans performance. L.R.Jr.Bassett, E.T. Howley. Medicine. Science in Sports. Exercise. 2000. No 32. P. 70-84.
13. Hottenrott, K. Ist das Superkompesations Model nach aktuell? K. Hottenrott, G. Neumann. Leitungssport, Marz. 2010. pp.13-19.
14. Kubicek W.G. The Minnecota impedance cariograph-theory and application. – Biomed. Engin. 1974. V.9. No. 9. pp. 410-416.
15. Lu Xu. On the stucture of movement preparation: Inferences from motor schema theory. Lu Xu, W. Sommer, H. Masaki. Sports Performance, 1st ed. Tokyo: Sprinoper. 2015. pp. 59-66.