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Monitoring the Functional Status of Highly Qualified Canoeing Female Athletes in the Training Process for Intensive Competitive Activities

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Abstract Improvement of training and its intensification are related to the possibilities of targeted management of the functional capabilities of athletes. One of the key elements of such management is a system of physiological measurements that provides feedback on the expressiveness and nature of the impact of a complex of influences on the body in the course of training. The aim is to monitor the functional status of female athletes in canoeing in the training process for intensive competitive activities. Methods: analysis of competitive activities (video analysis, analysis of result cards), pedagogical observation, methods of functional diagnostics using tools: "MetaMax 3b" gas-analytical complex, KayakPro C1N Canoe Ergometer, "Polar" heart rate monitors. The research involved four competitive female athletes, members of the national canoeing team of Ukraine. Differences in the functional status of female athletes based on the indicators of maximum oxygen consumption, working capacity, respiratory coefficient, heart rate, oxygen pulse, pulmonary ventilation, maximum power for 10s were established. This is due to the individual and age characteristics of the female athletes of the canoe group, their inclination to work in different orientations. The results of functional monitoring of female athletes also

depend on the main distances of 200, 500, 5000 m, in which female athletes usually perform and achieve the best time indicators. The monitoring of the functional status of female athletes made it possible to form a crew for the C-2500m distance, where work of a mixed anaerobic-aerobic nature is performed, and for the C-1200 m sprint distance. The recovery time of female athletes, technical interaction in the crew were taken into account. This distribution of crews allowed female athletes to take prize-winning places in the final of the 2021 Olympic Games (Tokyo, Japan).

Keywords Canoeing, Female Athletes, Monitoring, Functional Status, Recovery

1. Introduction

Management of the sports training process is aimed at optimizing the behaviour of athletes, appropriate development of their proficiency and degree of training to ensure the achievement of the highest sports results [1]. Management of the functional status of athletes is based on the common factors of the immediate training effect (the size and nature of shifts in functional systems caused by the training load), delayed and cumulative training effect. The delayed training effect is considered as one type of long-term adaptation in response to a high total training load of several (usually three to four) microcycles [2,3]. In skilled athletes, the cumulative effects of a series of training exposures over a period of time lead to a dramatic increase in degree of training and athletic performance. To manage the formation of the delayed training effect, it is important to determine the correspondence of the training load regime to the capabilities of the athlete's body based on the assessment of the overall intensity of the training process, the degree of fatigue-recovery (taking into account the different speed of recovery of different aspects of metabolism and functions that ensure the performance of loads of different orientation), readiness to perform the following training and competition programs, effectiveness of special recovery measures [4-6].

Improvement of training and its intensification are related to the possibilities of targeted management of the functional capabilities of athletes. One of the key elements of such management is a system of physiological measurements that provides feedback on the expressiveness and nature of the impact of a complex of influences on the body in the course of training. A specially organized system of such measurements, tests and assessments during long periods of training is referred to as physiological monitoring [7-10].

To implement management from a biological point of view, it is necessary to know the limits of the development of certain organs, systems, properties that determine the achievement of maximum special working capacity, and the means that allow ensuring the development process with the greatest efficiency in the optimal (minimum) terms, without losses associated with the inconsistency of the load regime to the adaptation capabilities of the organism [11,12].

In kayaking and canoeing as a cyclical kind of sport, which is characterized by the work of a speed and strength character, monitoring the functional status of athletes throughout the year, assessing their degree of training, enduring large training loads and recovery are an urgent issue, especially during the training period for the main competitions of the sports season [13-15].

1.2. The Aim

The aim of the research is to monitor the functional status of female athletes in canoeing in the training process for intensive competitive activities.

2. Materials and Methods

2.1. Methods

The following methods were used in the research: analysis of competitive activities (video analysis, analysis of result cards), pedagogical observation, methods of functional diagnostics (gas analysis, ergometry, pulsometry), methods of mathematical statistics.

Video analysis and analysis of result cards, pedagogical observation were carried out in dynamics at the pre-competitive stage and competitive microcycle of the competitive period – at the main competitions of the annual cycle – the 2021 Olympic Games in Tokyo in kayaking and canoeing.

Monitoring of the functional status was carried out using instrumental methods: a test with a stepwise increasing load on the rowing ergometer KayakPro C1N Canoe Ergometer. The duration of the steps was 1 minute. The indicators of pulmonary ventilation (VE), breathing rate and respiratory volume were recorded to determine the respiratory exchange ratio (RER), heart rate (HR), oxygen pulse (O_2/HR), partial pressure of O_2 and CO_2 in exhaled air, with the help of the gas analytical complex "MetaMax 3b". The test continued until failure, or the inability to maintain the specified power of work. The threshold of aerobic metabolism (TAMO1), the threshold of anaerobic metabolism (TAMO2), the level of maximum oxygen consumption ($V'O_2$) and the power of work (W) were determined during the stepwise load test. A 10-second maximal lactate power assessment test on the KayakPro C1N Canoe Ergometer was used to determine the speed and strength capabilities of the muscles. The greatest power of one rowing stroke was recorded.

Calibration of devices was carried out automatically

before and after testing each athlete. The error of registration of indicators was 0.02%. The composition and volume of the calibration mixture were 5% CO_2 and 17% O_2 in the N_2 balance (95%).

2.2. Statistical Analysis

Statistical data processing was carried out using the methods of non-parametric mathematical statistics using the STATISTICA 10.0 statistical package.

The median (Me) and the 25th (Q1) and 75th (Q3) percentiles were used to describe all empirical data i. e. values used to represent discrete variables or quantitative continuous variables with non-normal distribution, and non-parametric criteria for their comparison.

Since the center of the distribution was given using the median, the relative measure of variation was estimated by calculating the quartile coefficient of variation, which was calculated according to the formula:

$$V\_Q = (Q\_3-Q\_1)/2Me \cdot 100\%$$

In the case of VQ<33%, the presented sample populations were considered homogeneous by us.

2.3. Participants

The research involved four competitive female athletes, members of the national team of Ukraine in kayaking and canoeing, Masters of Sport of International Class, who at the time of the examination were at the pre-competitive stage of the competitive period in canoeing. These research results were used to form the squad for performance in individual and team S-2500m program numbers at the 2021 Olympic Games.

2.4. Ethical Approval

The research was carried out according to the ethical standards of the Act of Ukraine “On Higher Education” No. 1556-VII dated 01.07.2014 and the Letter from the Ministry of Education and Science of Ukraine “On the Academic Plagiarism Prevention” No. 1/11-8681 dated 15.08.2018. Informed consent was received from all individuals who took part in this research and who could refuse participation at any time.

3. Results

The training of the female athletes of the canoe group included two macrocycles, and each of them ended with the main start.

The pre-competitive stage of the competitive period was aimed at demonstrating the predicted time indicators, preserving the basic and maximally accessible development of special components of degree of training, ensuring full recovery and achieving the highest level of adaptation and readiness for the starts during the Olympic Games.

The correction of training of female athletes was based on the results of monitoring their functional status (Table 1).

Differences in the functional status of female athletes were established according to the indicators of $V'O_2$, VO_2/kg, W failure, W/kg, RER, HR, O_2/HR, V'E, Wmax10s, Wmax 10s/kg. This is due to the individual and age characteristics of the women of the canoe group, the tendency to work in different orientations (Fig. 1-5). It is worth noting that the results of monitoring the functional status of female athletes also depend on the main distances of 200, 500, 5000 m, at which female athletes usually perform and achieve the best time indicators. The maximum oxygen consumption ($V'O_2$) as an integral indicator characterized the power of the aerobic ATP resynthesis system, the ability of the cardiovascular and respiratory systems to adequately supply working muscles with oxygen. In the group of female athletes, it is possible to single out L-n athlete, who has sprinting qualities, as evidenced by the lowest indicator of maximum oxygen consumption in the group and the highest indicator of power when performing work for 10 seconds (Fig. 1-3).

Table 1. Results of monitoring the functional status of the elite group of canoeists, female athletes (n = 4)

Female athletes	Weight, kg	VO_2	VO_2/kg	W	W/kg	RER	HR	O_2/HR	VE	Wmax 10 s	Wmax 10s/kg
Ch-va	74.3	3.2	44	100	1.4	1.1	191	16.9	137.1	228	3.1
L-n	76.4	2.9	38	100	1.3	0.9	179	16.2	73.6	238	11
K-k	79.3	3.2	41	100	1.3	1	182	18.3	110.7	235	3
Ts-va	62.3	3	48	100	1.6	1.1	162	18.6	110.8	162	2.6
Me (25;75)	75.35 (68.3;77.85)	3.1 (2.95;3.2)	42.5 (39.5;46)	100 (100;100)	1.35 (1.3;1.5)	1.05 (0.95;1.1)	180.5 (170.5;186.5)	17.6 (16.55;18.45)	110.75 (92.15;123.95)	231.5 (195;236.5)	3.05 (2.8;7.05)

Note: V'O_2 – maximum oxygen consumption, [l / min]; VO_2/kg – maximum oxygen consumption per kg of weight, [ml / min / kg]; W – power of work until failure, [watt]; W / kg – power of work until failure per kg of weight, [watt / kg]; RER – respiratory exchange ratio, [c.u.]; HR – heart rate, [beats / min]; O_2/HR – oxygen pulse, [ml]; VE – pulmonary ventilation, [l/min]; Wmax 10 s – maximum power for 10 seconds, [watt]; Wmax 10 s/ kg – maximum power per kg of weight, [watt / kg]; Me – median; Ch-va, L-n, K-k, Ts-va – surnames of female athletes

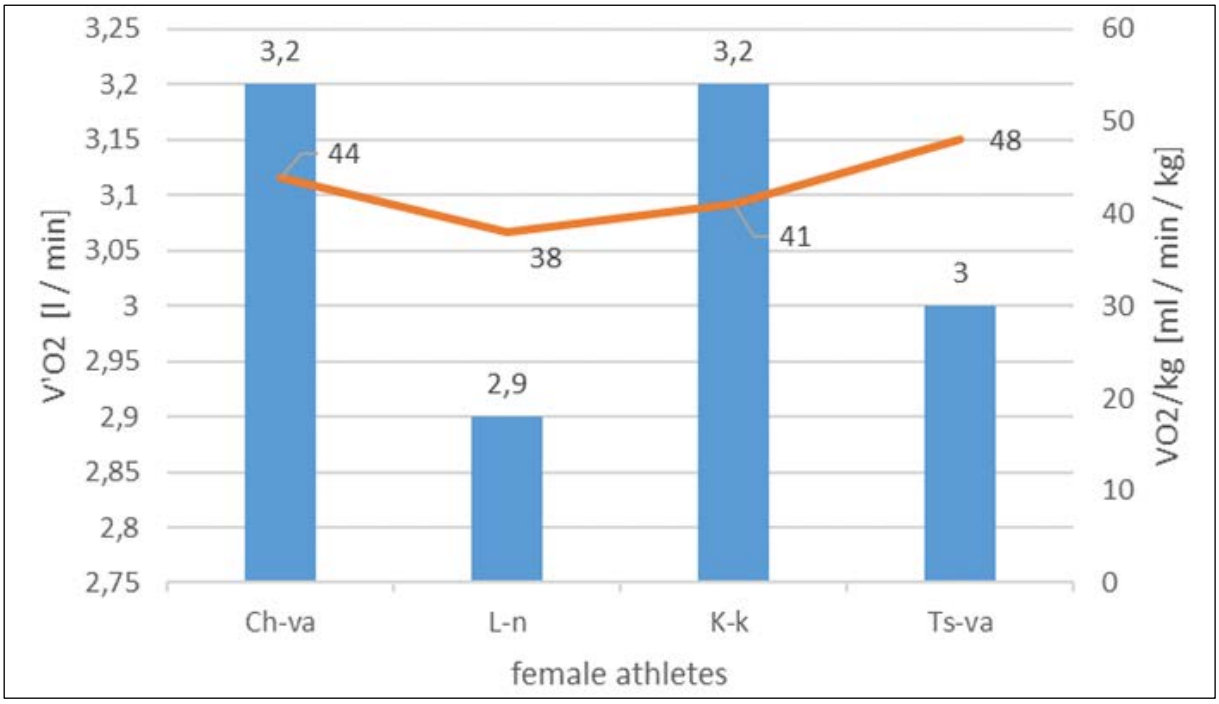

Figure 1. Indicators of oxygen consumption V'O_2 and VO_2 / kg of female athletes in the canoe group when performing a test on a rowing ergometer KayakPro C1N Canoe Ergometer

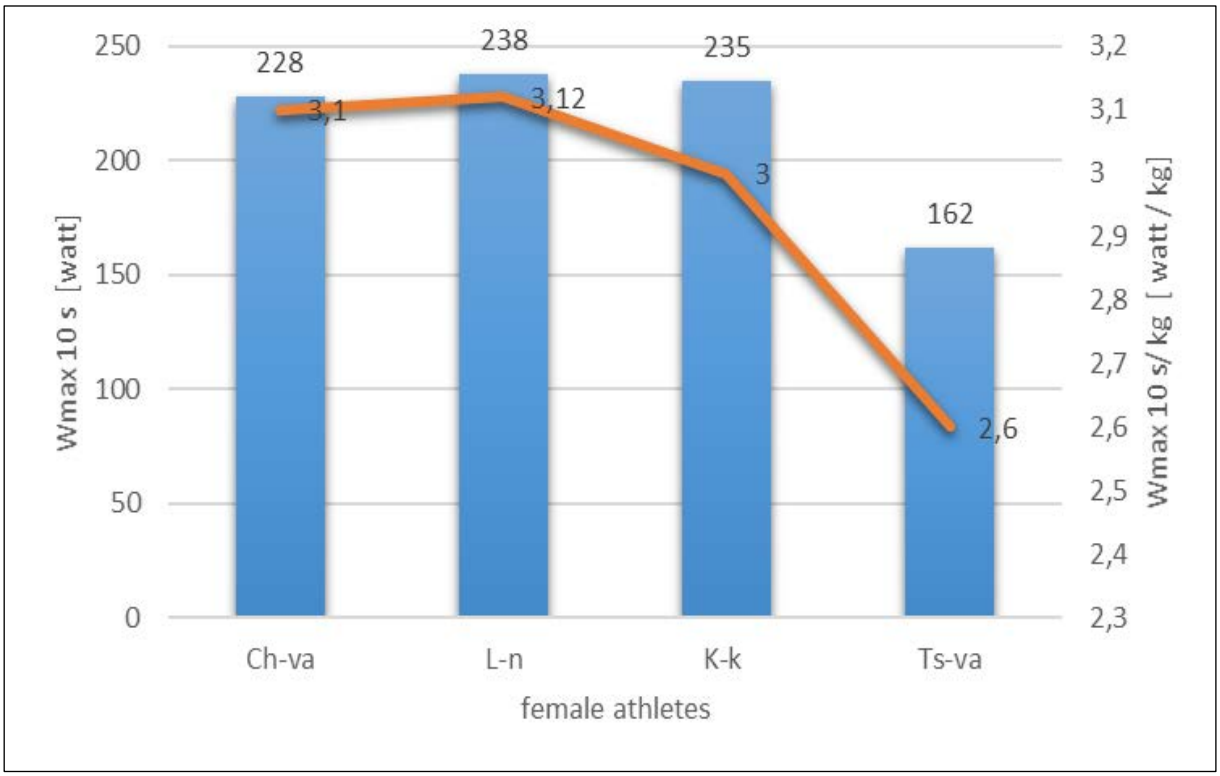

Figure 2. Indicators of the maximum power of work for 10 seconds Wmax 10 s and Wmax 10s / kg of female athletes of the canoe group when performing a test on a rowing ergometer KayakPro C1N Canoe Ergometer

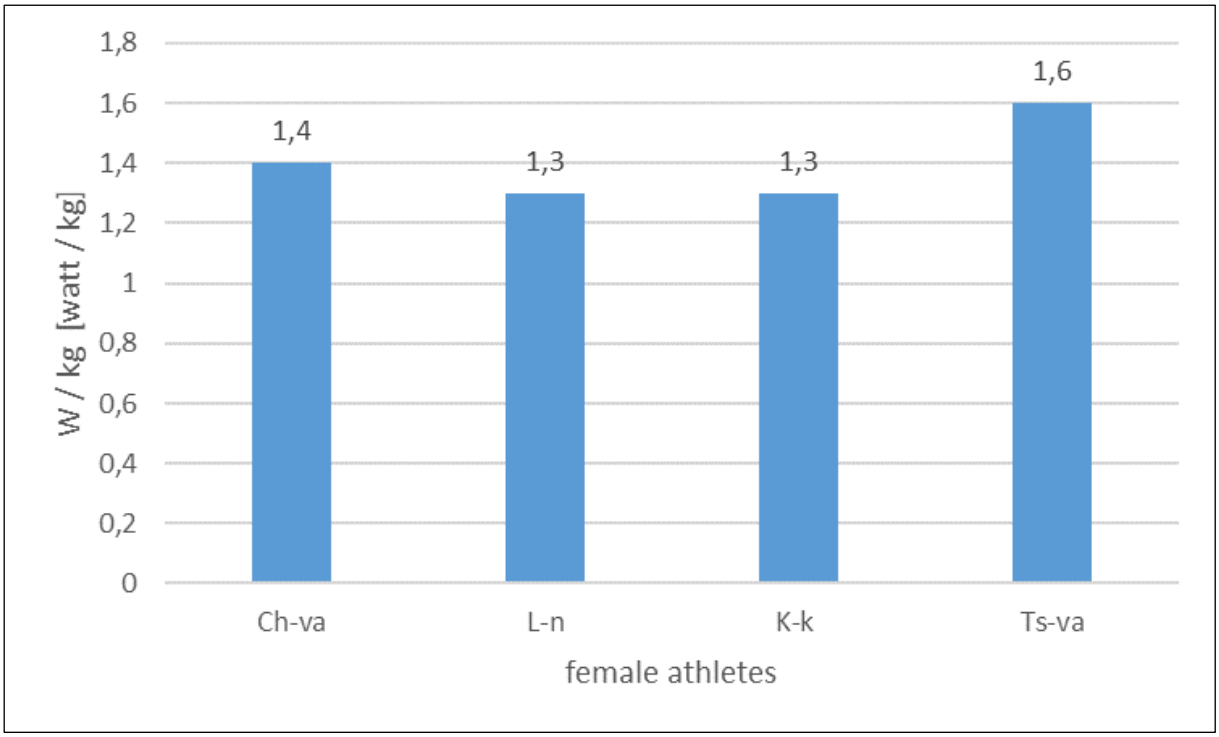

Figure 3. Indicator of work power W / kg of female athletes in the canoe group when performing a test to failure on a rowing ergometer KayakPro C1N Canoe Ergometer

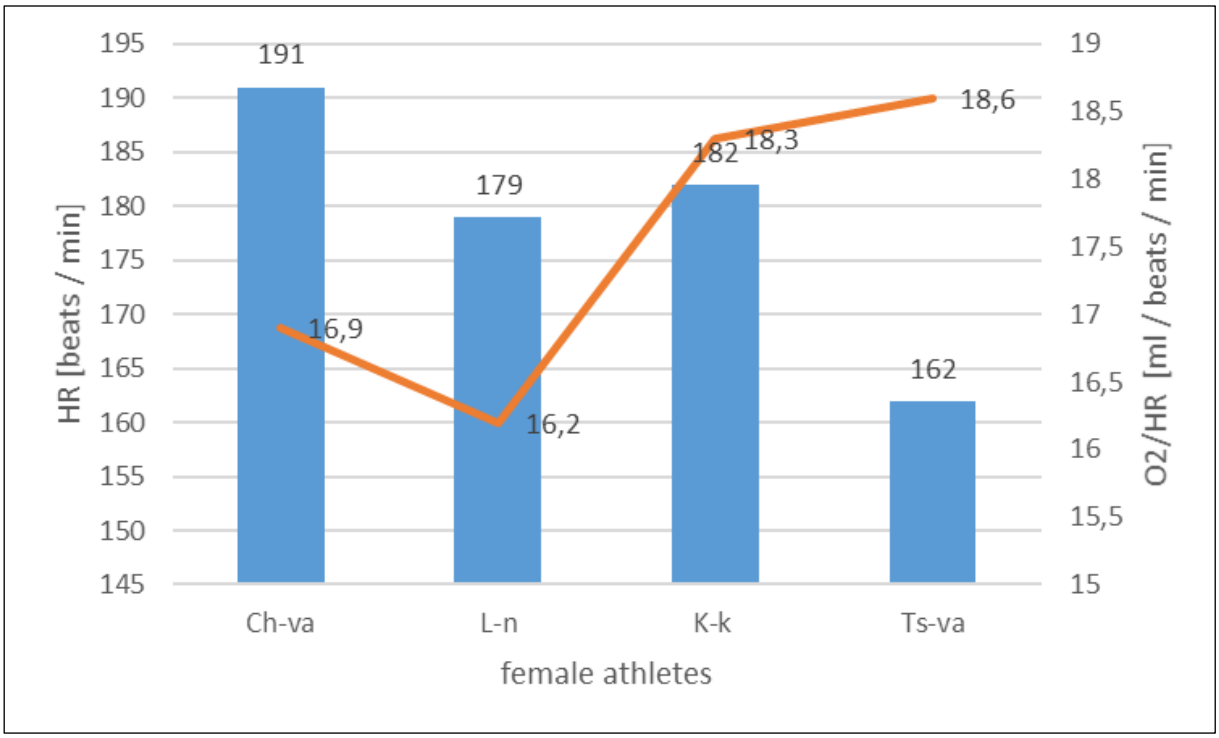

Figure 4. Indicators of heart rate and oxygen pulse O_2 / HR of female athletes in the canoe group when performing a test on a rowing ergometer KayakPro C1N Canoe Ergometer

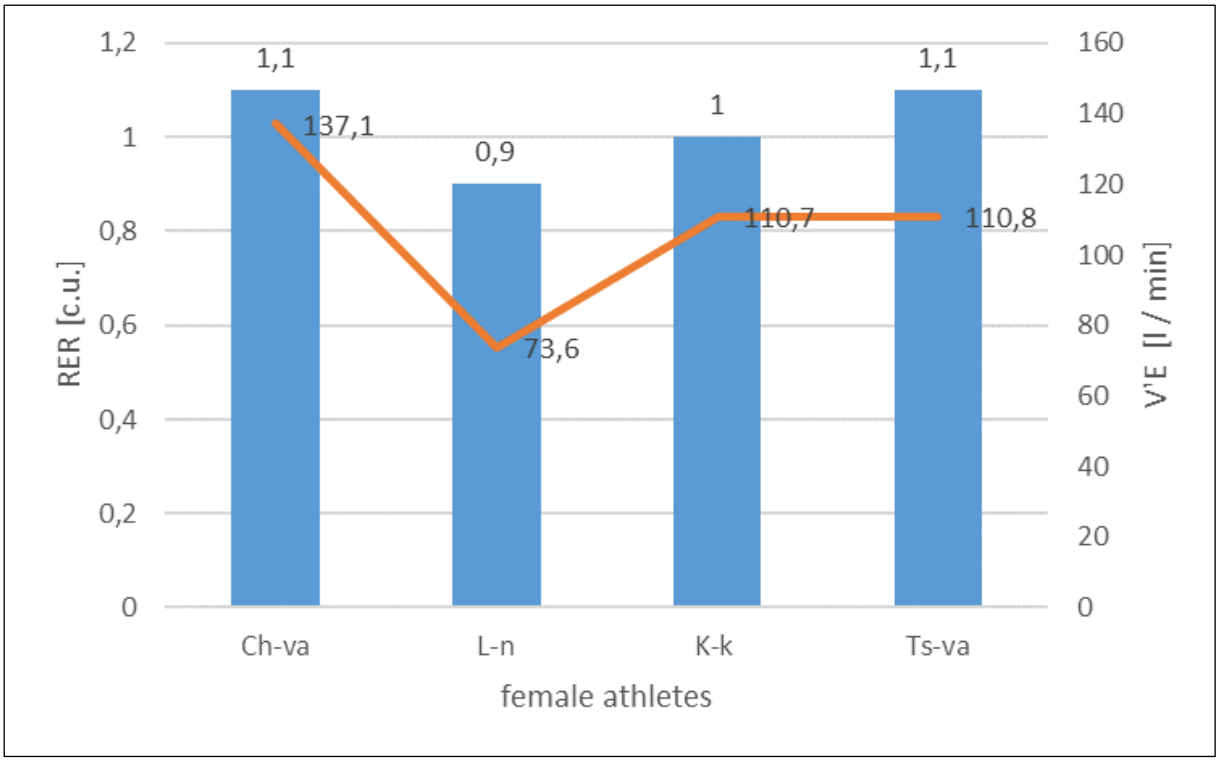

Figure 5. Indicators of the respiratory system – respiratory exchange ratio (RER) and pulmonary ventilation (VE) of women in the canoe group when performing a test on a rowing ergometer KayakPro C1N Canoe Ergometer

The oxygen pulse (O_2/HR) reflects the dynamics of increasing the efficiency and effectiveness of the functioning of the body's physiological systems during maximal muscle work in parallel with the growth of special degree of training of female athletes. The oxygen pulse as a ratio of oxygen consumption to heart rate in the test indicated the efficiency of the cardiovascular system (Fig. 4).

The HR [1/min], O_2/HR [ml] indicators of the sportswoman L-n indicate the functional reserves of the body, the efficiency of the work of the cardiovascular system (Fig. 4). Ch-va athlete demonstrates average indicators for the group, has a high maximum heart rate and the oxygen pulse indicator testifies to reserves on the part of the cardiovascular system. At the same time, Ts-va athlete, who is the winner of many international starts at the distance of 5000 m, has the highest rate of oxygen consumption per 1 kg of weight.

The respiratory exchange ratio (RER) shows the ratio between CO_2 released and O_2 consumed. Its increase by more than 1 occurs as a result of the formation of a non-metabolic "excess" of carbon dioxide, due to the activation of anaerobic glycolysis and the neutralization of hydrogen ions (H+) entering the blood, with the formation of CO_2. The appearance of a "non-metabolic" excess of carbon dioxide leads to a sharp increase in pulmonary ventilation and a decrease in the efficiency of the respiratory system. We indirectly judged the activation of anaerobic glycolysis processes by this indicator: the faster the RER increases (greater than 1), the greater the share of anaerobic glycolysis in the body's energy supply. Ch-va and K-k athletes have a respiratory coefficient greater than 1, which indicated the use of anaerobic glycolytic mechanisms of energy supply when performing work before failing the test (Fig. 5).

4. Discussion

4.1. Comparison of the Obtained Results with the Findings of Other Scientists in this Field

The systematization of physiological approaches and methods used in the practice of monitoring the status of athletes allows us to distinguish three approaches of physiological analysis, which are aimed at determining the structure of the functional capabilities of the athlete's body and its subsequent correction to increase special working capacity [16-18].

The first approach is the use of models of elite athletes, with which the data of examinations of a particular athlete are compared. Another approach is based on the analysis of the complex of leading factors limiting working capacity, which is characteristic of competitive activities in a specific sports discipline. The third approach is aimed at determining the specialized physiological capabilities of the body in accordance with the requirements of competitive activities, where the dynamics of

physiological processes and functional properties, the regulation of physiological functions in the process of competitive activities and the impact of the development of fatigue on them are assessed. At the same time, control can be focused on an integral assessment of the main physiological properties that determine certain components of competitive activities [1,16,18].

The second approach is a natural continuation of the first one, where the complex of physiological indicators that ensure the limits of metabolic capacity and functional productivity of the athlete's body are taken into account. The most important physiological parameters that ensure a stable level of metabolism and high working capacity of the athlete at a load close to competitive are identified, physiological factors of overcoming fatigue, compensation of hypoxia and metabolic acidosis (or respiratory alkalosis), removal of lactate and heat, etc. are analyzed [8,19].

The requirements for the functional degree of training of athletes and the corresponding criteria of physiological control are related to the analysis and comparison of the requirements of competitive activities and indicators of the athlete's functional potential. The discrepancy between the functional capacity of the body's organs and systems and the requirements of competitive activities can be compensated for by a high level of development of the physiological properties of these organs and systems. On this basis, a complex of generalized physiological properties is distinguished, which determines the degree and nature of realization of potential opportunities in competitive activities [20-23]. One of these approaches is focused on the characteristics of metabolism, where the power, capacity and efficiency of metabolic processes are assessed. Another option of this approach is the assessment of power, productivity and fatigue coefficient, which allow assessing the energy resource of athletes. This is the third approach, which is based on the assessment of the effectiveness of the dynamics (kinetics) of functions and metabolism, not in general, but in the process of competitive activities. This is determined by the perfection of specialized stable regulation against the background of developing fatigue. The improvement of such regulation is aimed at the optimal implementation of the potential of the athlete's organs, functions and body in general [24,25].

When using the third approach, the most important elements of the dynamics of physiological reactions typical for competitive activities are assessed, as well as the maximum values of the peak levels of metabolism and functions; speed of their development and recovery time in conditions close to competition; stability of high levels of metabolism and efficient performance. A decrease in efficiency well reflects the development of fatigue during competitive activities.

In the structure of the functional capabilities of female athletes, the functional and metabolic power, mobility, stability of these processes, efficiency and realizability in the specific conditions of the competition of the physiological properties and the general potential of the body are analyzed [7,20,23].

The scientists [2,5,8,11 et al.], who investigated functional degree of training in female canoeing, provide little information about the specifics of energy supply and working capacity characteristics, which does not allow to assess and interpret the existing quantitative and qualitative characteristics of functional degree of training as model ones, and to use them in the process of managing physical training. The works [2,17,20,26] considered the issues of functional degree of training, especially the structure of functional support for the special working capacity of kayakers and canoeists.

The obtained data confirm the research results of mane scientists [4,14,23,27,28] that special working capacity is functionally ensured by the characteristics of fast kinetics, steady state, compensation and fatigue. They are most clearly revealed when overcoming a distance of 500 m, in the process of training female canoeist-sprinter, when an increase in steady state provides a high level of working capacity, compensation of fatigue, and, as a result, the depth of impact and effects of training load.

4.2. Theoretical and Practical Implications

The results obtained during the experiment allowed expanding the system of knowledge about the functional fitness and functional reserves of the body of athletes in cyclic kinds of sports and directly in canoeing, to create a database of functional indicators of female athletes specializing in canoeing.

According to the results of the research, recommendations were given to the coach on the functional state and readiness of female athletes in the process of their preparation for the competition, to adjust the load and bring them to the main starts. The results of experimental studies allow us to observe the dynamics of changes in functional indicators during the year.

4.3. Limitations of the Study

During the research, we did not take into account the age characteristics of the female athletes, the level of their physical fitness, etc. The female athletes who participated in the research are members of the national team and were considered to be reliably identical to each other, trained according to the same plan, during the experiment were in the same standardized conditions of the laboratory of the research institute and were tested on the same day, observing the requirements of testing, in turn. The investigation was carried out on standardized equipment that has passed metrological examination and verification. This allowed us to form the experiment in one day with a time interval of two hours for one study. This approach

allows us to obtain the most objective data.

4.4. Prospects for Further Research

This research created the prerequisites for a comparative analysis of the functional capabilities of women in different disciplines of rowing: kayak and canoe at distances of 200, 500, 1000m.

5. Conclusions

In the course of the research, we obtained data and revealed three approaches to monitoring the functional status of female athletes as an important component of monitoring degree of training, load transfer and recovery in female canoeing, aimed at determining the structure of the functional capabilities of the body of female athletes and its subsequent correction to increase special working capacity. Functional and metabolic power, mobility, stability of these processes, efficiency and realizability in specific competition conditions of physiological properties and general potential of the body are analyzed in the structure of functional capabilities of female athletes. Special working capacity is functionally provided by the characteristics of fast kinetics, steady state, compensation and fatigue. They are most clearly revealed when overcoming a distance of 500 m, in the process of training female canoeist-sprinter, when an increase in steady state provides a high level of working capacity, compensation of fatigue, and, as a result, the depth of impact and effects of training load.

Monitoring of the functional status of female athletes made it possible to form a canoe-double crew for the C-2 500 m distance, in which work is performed of a mixed anaerobic-aerobic nature, and singles for the C-1 200 m sprint distance. The recovery time of the female athletes, and technical interaction in the crew were taken into account. This distribution of the crew allowed Ch-va and L-n athletes to take the 2nd place in the final of the 2021 Olympic Games (Tokyo, Japan) in kayaking and canoeing with a result of 1:57.49, and L-n female athlete in single canoe to take the 3rd place in the distance of 200 m with a result of 47.034 seconds.

Disclosure Statement

No author has any financial interest or received any financial benefit from this research.

Conflict of Interest

The authors state no conflict of interest.

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