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Analysis of Main Ergometric Parameters of Elite Kayak Athletes Specialized in Different Distance Events

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Abstract

The purpose of the study was to determine the level of the general functional potential of the body of elite kayak rowers for its subsequent effective realization under conditions of special training and competitive loads. The study involved 38 elite athletes, who had been the members of the Ukrainian national kayaking team. This article presents the results of the assessment of the functional state of elite athletes specialized in kayaking and canoeing. It was determined that athletes at a race distance of 1000 m under conditions of work at maximum aerobic capacity had the highest level of the power of the respiratory system (in terms of the level of pulmonary ventilation). The lowest level of the power of the respiratory system and a less economical type of breathing were observed in rowing athletes at a race distance of 200 m. Under conditions of maximum-intensity physical load with the engagement of the anaerobic glycolytic and aerobic systems to energy supply, which simulated the conditions of 500 m and 1000 m races in kayaking, significant differences ($p<0.05$) were found in the maximum level of aerobic capacity and relative contributions of the anaerobic and aerobic metabolism in the overall energy production. The results of our study indicate that the level of general (basic) functional (aerobic and anaerobic potential of the body of elite rowing athletes is important for its subsequent realization.

Keywords: *functional capabilities, rowing athletes, kayaker, kayak, distance*

Introduction

One of the most crucial objectives in predicting the level and features of the specific working capacity in elite athletes specialized in kayaking is to identify the criteria and indicators that are most appropriate for an unbiased evaluation of the functional capabilities of the body systems critical for supporting motor activity in a given sport (Trivun, Vukovic, & Pasic, 2011; Kropta et al., 2017; Bohuslavska, Furman, Pityn, Galan, & Nakonechnyi, 2017; Zhyrnov et al., 2017; Winchcombe, Binnie, Doyle, Hogan, & Peeling, 2019). Athletes of different sports specializations typically have a high physical working capacity, primarily in the types of muscle activity that are familiar to them. Typically, this should be associated with the corresponding morpho-functional and physiological adaptation mechanisms (Valeria et al., 2017; Galan, Andrieieva, & Yarmak, 2019) The specificities of sports technique, which require a strictly defined response of physiological systems to various conditions of muscular activity in different sports, make it impossible to reliably predict characteristics and the level of specific working capacity, as well as the degree to which the functional potential of the body of elite rowing athletes is realized, from any single set of

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functional parameters even in similar sports disciplines (Lysenko, Shinkaruk, Samuilenko, Rossokha, & Spichak, 2004). For example, the indicators of functional capabilities of the cardiorespiratory system that can be used for this purpose in cycling do not objectively reflect the motor abilities of rowers or runners, even if the intensity and duration of competitive activity in these sports are approximately identical (Korobeynikov et al., 2019).

This problem is especially difficult when it us necessary to predict the characteristics of the specific working capacity in athletes at the stage of maximum realization of individual capabilities and at the stage of maintenance of athletic excellence. In this context, in addition to considering competitive activity, an important condition for a reliable and informative evaluation is to take into account the individual characteristics of the body of elite athletes, as well as to identify indicators that describe the reserve capabilities of the body, their realization under conditions of competitive activity and, as a result, predetermine an increase in specific working capacity and competitive performance.

The purpose of the study was to define the grade value of the body's overall functional potential of elite kayak athletes for further effective implementation in the framework of special training and competitive exertion.

Methods

At the first stage, specialist literature was analysed to identify current approaches to improving the realization of functional capabilities of elite athletes, taking into account the role of physiological mechanisms of adaptation of the body to the conditions of a particular physical activity. Much attention was paid to studying the conceptual framework of modern sports science, as well as to addressing particular issues related to the search for new data regarding the realization of the functional capabilities of a healthy person under conditions of intense physical activity and, in particular, related to the realization of the functional capabilities of kayak athletes. The most relevant ideas were modified in relation to the training system for kayak athletes.

At the second stage, we formed a group of 38 elite kayak rowers who consistently attained high athletic performance at 200 m, 500 m, and 1000 m race distances.

We assessed the physical working capacity and the cardiorespiratory system response to conditions of maximum and standard physical workload to determine the aerobic and anaerobic capabilities of the body in elite athletes.

Athletes' functional capabilities were assessed using cardiopulmonary diagnostic equipment, including an Oxycon Pro apparatus (Jager, Germany) and a relevant methodological approach. Athletes' central haemodynamics, blood pH shifts, and physical working capacity were studied with ergometric testing workloads of different durations and intensities that enabled evaluating the capabilities of different energy systems. The power of the aerobic energy system was estimated using the power output at critical intensity workload (WCr) when performing a graded exercise test to volitional exhaustion, as well as using the power output at the anaerobic threshold (WAnT). We used a 105-second (1 min 45 s) maximum-intensity test that simulated the conditions of a 500 m rowing race (Wmax-500); and a 225-second (3 min 45 s) maximum-intensity test that simulated a 1000 m race (Wmax-1000). Ergometric parameters of workload including power, maximum time or the total amount of performed work were used as indicators of the achieved adaptation effect.

Results

To examine the characteristics of top-ranking kayak rowers, who specialized in different distance events, under conditions of 105-second (1 min 45 s) maximum-intensity test that simulated the conditions of a 500 m-rowing race and 225-second (3 min 45 s) maximum-intensity test that simulated a 1000 m race, the following evaluation parameters of the ergometric tests were assessed: average and maximum power output during physical work, average stroke rate (number of strokes per minute), distance per stroke in metres, total distance travelled during the test, and estimated time to complete a race over 500 m and 1000 m.

The most important time characteristic of physical work in rowing is stroke rate. This parameter is especially valuable because it is easy to measure: the duration of two full stroke cycles (four strokes) is recorded, then the number of strokes per minute (spm) is calculated. In kayaking, the maximum stroke rate is observed at short segments and at the start of a 500 m race, where it reached up to 140 spm; while in the middle and at the finish of a race, the stroke rate is 105–120 spm in a 500m race and slightly lower in a 1000 m race. Despite significant individual differences, the stroke rate is reliably and closely related to the speed of the kayak. During the training session, it is extremely important to control the stroke rate when performing high-speed exercises, as well as to develop a "sense of pace" in athletes, that is, the ability to assess subjectively the stroke rate with sufficient accuracy.

An analysis of the study results revealed that elite kayak rowers, who specialized in different distance events (200 m, 500 m, and 1000 m races), differ in the maximum and average power output, as well as in the stroke rate, which affects the distance per stroke in metres, estimated time to complete a race over 500 m and 1000 m, and the total distance travelled with these parameters of physical work. Table 1 presents the main ergometric parameters of the tests that simulate the conditions of 500 m and 1000 m races in elite athletes specialized in different distance events.

As can be seen from Table 1, significant differences in the power output during the 105s maximum-intensity test (Wmax-500, $p<0.05$) were found between the top-ranking kayak rowers specialized in different distance events. In particular, the highest physical working capacity was recorded in top-ranking athletes specialized in a 1000 m race (Wmax-500 = 3.69 W·kg-1; S = 0.06 W·kg-1, $p<0.05$) and the lowest value was in high-ranking athletes specialized in a 200m race (Wmax-500 = 3.15 W·kg-1; S = 0.14 W·kg-1, $p<0.05$). An analysis of performance in the 225 s maximum-intensity test (Wmax-1000, Table 1) revealed the more pronounced significant differences in the level of physical working capacity and functional capabilities of the body between top-ranking athletes specialized in 200 m, 500 m, or 1000 m events ($p<0.05$). The highest level of physical working capacity was observed in top-ranking athletes specialized in a 1000m race (Wmax-1000 =3.52 W·kg-1; S = 0.11 W·kg-1, $p<0.05$), while the lowest level was found in high-ranking athletes specialized in a 200m race (Wmax-1000 = 2.57 W·kg-1; S = 0.14 W·kg-1, $p<0.05$) and the average level of physical performance was in high-ranking athletes specialized in a 500 m race (Wmax-

Table 1. The main evaluated ergometric parameters of performance test in elite kayak rowers specialized in different distance events (N=38)

Parameters	Top-ranking athletes specialized in different distance events			p<0.05
	1000 m, n=13	500 m, n=15	200 m, n=10	
	1	2	3	
	M±SD	M±SD	M±SD	
Test simulating a 500 m race				
Maximal power output (Wmax-500), W	303.47±11.97	287.20±12.62	274.03±14.82	1-3
Maximal power output (Wmax-500) per kilogram of body weight, W·kg-1	3.69±0.06	3.43±0.08	3.15±0.14	1-2, 3; 2-3
Average power output (Wav-500), W	248.50±4.99	239.63±5.89	227.01±4.14	1-3; 2-3
Average power output (Wmax-500) per kilogram of body weight, W·kg-1	3.26±0.21	2.85±1.19	2.61±0.13	1-3
Average to maximum power output ratio %	81.89±0.15	83.44±0.14	82.83±0.09	-
Distance travelled, m	482.06±9.99	474.02±9.98	462.04±8.69	1-3
Estimated time to complete a 500 m race, s	109.03±1.21	116.10±2.09	126.05±0.99	1-2, 3; 2-3
Test simulating a 1000 m race				
Maximal power output (Wmax-1000), W	291.60±15.25	246.78±45.17	223.50±48.39	1-3
Maximal power output (Wmax-1000) per kilogram of body weight, W·kg-1	3.52±0.11	2.98±0.19	2.57±0.14	1-3
Average power output (Wav-1000), W	215.04±9.08	189.90±5.79	179.03±2.54	1-2, 3
Average power output (Wmax-1000) per kilogram of body weight, W·kg-1	2.81±0.39	2.24±0.19	2.06±0.09	1-2, 3
Average to maximum power output ratio %	73.73±2.54	76.54±2.95	80.01±1.05	
Distance travelled, m	939.02±6.89	823.00±3.86	807.09±1.96	1-2, 3; 2-3
Estimated time to complete a 1000m race, s	239.80±10.96	298.21±8.04	302.83±2.98	1-2, 3

Legend: statistically significant difference at the level of p<0.05 in the leading athletes during the distances of 1 - 1000 m; 2 - 500 m; 3 - 200 m

1000 = 2.98 W·kg-1; S = 0.19 W·kg-1, p<0.05).

Furthermore, top-ranking athletes specialized in a 1000 m race were found to demonstrate, for a given level of power output, the greatest distance travelled in combination with a shorter estimated time to complete a race over 500 m and 1000 m, that allowed us to conclude that they can reach a higher speed under conditions of competitive activity. The shortest distance travelled during the test and the longest estimated time to complete a race over 500 m and 1000 m were observed in top-ranking athletes specialized in a 200 m race.

Thus, a higher stroke rate combined with a lower stroke force is more effective for realizing the general aerobic capacity of kayak rowers and for demonstrating specific physical working capacity in a race over 1000 m. To realize the potential of an elite kayak rower in a race over 500 m, a lower stroke rate and a higher stroke force are more efficient.

The results of the analysis of blood lactate concentration (HLa, mmol·L-1) at the 3rd minute of recovery after performing various tests, shown in Table 2, indicate that an activation of anaerobic glycolytic processes involved in energy production occurred.

However, there were no significant differences in the activity of anaerobic processes among top-ranking athletes: blood lactate level varied between 13.0-14.4 mmol·L-1 in the test simulating a 500 m race and between 14.4-15.3 mmol·L-1 in the test simulating a 1000 m race.

Significant differences (p<0.05) between top-ranking athletes made it possible to reveal the analysis of the ratio between the power of physical work and blood lactate concentration (W/HLa, W·mmol-1·L-1). The obtained results indicate the power of work performed, which accounts for each 1 mmol·L-1 increase in blood lactate concentration during physical work and characterizes the efficiency of metabolic processes (Table 2).

The greatest efficiency of metabolic processes under the test conditions was recorded for elite rowers specialized in a 1000 m race, while the least efficiency of metabolic processes was observed in athletes specialized in a 200 m event. It should be noted that an increase in the duration and functional strain of the work led to an increase in the differences between elite kayak rowers specialized in different distance events (p<0.05).

The analysis based on a comparison of individual levels of maximum achieved power output at maximum intensity with blood lactate concentrations showed that top-ranking rowers can achieve high levels of physical working capacity at different race distances in many ways as well as with various proportions of energy supplied through aerobic and anaerobic metabolism.

It becomes more and more obvious that with an increasingly equal energy and functional potential of the body's organs, functions, and physiological systems, which are important for a given sport, an athlete who realizes that potential better under the particular conditions of competition has an advantage over the opponents. For a top-rank athlete, the ability to achieve maximum realization of his functional potential under the particular conditions of competitive activity ("realizability") becomes key to success. Analysis of the athlete's realization capabilities can be carried out on the basis of an assessment of the

Table 2. The average values for parameters describing the activity of glycolytic processes in energy production during physical performance tests of different durations (N=38)

Parameters	Top-ranking athletes specialized in different distance events			p<0.05
	1000 m, n=13	500 m, n=15	200 m, n=10	
	1	2	3	
	M±SD	M±SD	M±SD	
Graded exercise test to volitional exhaustion				
Blood lactate concentration at 3rd minute of recovery, HLa, mmol·L-1	9.6±3.22	12.9±2.26	13.6±3.45	
Efficiency of metabolic processes, W/HLa, W·mmol-1·L-1	37.5±4.42	26.2±2.48	18.4±3.31	1-2, 3; 2-3
105 s maximum intensity test that simulate a 500 m race				
Blood lactate concentration at 3rd minute of recovery, HLa, mmol·L-1	13.0±0.55	14.4±0.52	13.4±0.12	1-2
Efficiency of metabolic processes, W/HLa, W·mmol-1·L-1	23.7±0.19	20.4±0.19	21.6±0.31	1-2
225 s maximum intensity test that simulate a 1000 m race				
Blood lactate concentration at 3rd minute of recovery, HLa, mmol·L-1	14.5±0.44	14.4±0.63	15.3±0.25	
Efficiency of metabolic processes, W/HLa, W·mmol-1·L-1	21.0±0.28	17.7±0.19	14.8±0.27	1-3

Legend: statistically significant difference at the level of $p < 0.05$ in the leading athletes during the distances of 1 - 1000 m; 2 - 500 m; 3 - 200 m.

nature of optimizing the response of functional systems and energy systems that ensure achieving high performance in sporting activity. Furthermore, the analysis of the study results shows that there is a need to isolate a set of physiological properties such as functional and metabolic power, stability, ability to respond and efficiency, which fully take into account the requirements for the main aspects of the functioning of the athlete's functional systems under conditions of intense physical loads of various nature.

Discussion

Elite athletes with different levels of long-term adaptation have specific characteristics that ensure the functioning of the cardiorespiratory system under conditions of various types of physical work. High performance in sport is rare and often unique. In order to achieve it, an athlete needs not only to possess genetically determined biological prerequisites, which provide the main basis for demonstrating specific working capacity but also to search new ways to realize them in the process of training and competitive activity.

The rational use of aerobic and anaerobic mechanisms of energy production with the leading role of the cardiorespiratory system forms the basis for the effectiveness of the competitive activity of kayak rowers, which is because modern-day kayaking is a high-intensity sport that places great demands on the main functional systems of the body. Moreover, unlike a number of other sports, it requires the near-maximum development of an entire set of physical qualities, such as strength and speed endurance and speed-strength capabilities, as well as a high level of development of all aspects of the energy production systems (Lysenko, 2008).

The need to maintain a high speed of the boat throughout a race significantly increases the requirements for efficient energy supply of the work and for the functional capabilities of the entire body of the rowing athlete (Briskin, Pitin, & Boguslavskaya, 2016). Kayaking is currently characterized by very high energy expenditures: performance in competitive activity is ensured to a large extent by the limits of the energy and functional capabilities of an athlete, as well as by their effective realization under particular conditions of motor activity (Trivun, Tosic, Vukovic, & Pasic, 2012; Skopek, Bacakova, Bily, & Tunkova, 2019; Hogan, Binnie, Doyle, Lester, & Peeling, 2020).

The results of this study provide additional evidence with respect to the earlier findings (Lysenko et al., 2004; Spichak, 2008; Shynkaruk, Lysenko, & Fedorchuk, 2019) regarding the structure of the functional preparedness of elite kayak rowing athletes specialized in different distance events.

Specific preparedness of an athlete under conditions of competitive activity in kayak rowing can be characterized, first of all, by the parameters of working capacity, power, strength, pace, and other dynamic characteristics of rowing performance in a race over distances of 500 m and 1000 m, as well as through an assessment of the energy systems providing the energy for the work (i.e., the limits and efficiency of aerobic and anaerobic energy production). The presented data indicate the interdependence of the ergometric parameters of specific physical working capacity (average and maximum power output during physical work, average stroke rate (number of strokes per minute), distance per stroke in metres, and total distance travelled) measured in performance tests simulating conditions of a 500 m and a 1000 m kayak rowing races with the main characteristics of the cardiorespiratory system response.

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Conflict of Interest
The authors declare that there is no conflict of interest.

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