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**Original Article**

# Reaction of the organism to repeated training loads, directed to improve the performance of the qualified rowers of China

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**Abstract.** *Purpose:* The differences in the functional support of the rowers' performance during the four trails performed in the threshold zones of the load intensity are shown - in the zone of the aerobic (ventilatory) threshold, anaerobic glycolytic threshold, maximum O2 consumption, at the level of ergometric power of 115% VO2 max. High adaptive abilities of an organism to loads of relatively low intensity at the level of aerobic-anaerobic transition are noted. In conditions of loads performed with higher intensity, close to the competitive activity of athletes in rowing, the degree of stress of the cardiorespiratory system increases, the speed of recovery processes decreases. To the greatest extent, the level of reaction decreases under conditions of accumulation of fatigue, typical of the second half of the distance. *Participants.* The study involved 38 athletes (men) aged 18–27 years old, candidates and members of the national team of Shandong Province, China. The studies were conducted in a special preparatory period at the center for training national water sports teams (Beihai, China). *Results:* The article shows the differences in functional support of rowers in the process of performing four trails in the threshold zones of the load intensity - in the zone of the aerobic (ventilatory) threshold, anaerobic glycolytic threshold, maximum O2 consumption, at the level of ergometric power of 115% VO2 max. Significant differences ($p < 0.05$) were noted for the integral index of the response of the cardiorespiratory system - the training impulse in the process of fulfilling the last segments 1–2 and 3–4 of the trail, respectively - 5.15; 5.14; 4.77; 4.64. High adaptive abilities of an organism to loads of relatively low intensity at the level of aerobic-anaerobic transition were noted. In conditions of loads performed with higher intensity, close to the competitive activity of athletes in rowing, the level of cardiorespiratory system increases, the speed of recovery processes decreases.
**Keywords:** rowing, academic, functionality, working capacity, repeated loads

**Introduction.**

Purpose. Currently, the system of improving the special training of athletes is considered in strict accordance with the features of the implementation of the structure of competitive activity [Platonov V.N. (2013)].

It is well known that the generalized manifestations of the special performance of athletes in rowing largely depend on the efficiency of work in conditions of increasing fatigue in the process of training and competitive activity [Dyachenko A.Y. (2007), Hastings L., Felix Krainski, Peter G. Snell, Eric L. Pacini, Manish Jain, Paul S. Bhella, Shigeki Shibata, Qi Fu. (2012), Lacour J. R., Messonnier L., Bourdin M. (2007)].

Experts in rowing have shown that compensating fatigue in the process of training rowers can extend the sustainability phase of performance, perform a larger amount of training load without reducing the coordination and tempo structure of movement in the rowing cycle, achieve a deeper degree of fatigue, and as a result effect of training classes in the process of rationally organized recovery period [Kleshnev V.V. (2012)., Bourdin M., Messonnier L., Lacour J. J. (2004), Kim Chul-Ho, Wheatley Courtney M., Behnia Mehrdad, Johnson Bruce D Chul-Ho Kim (2016)]. In the process of competitive activity of rowers – academics, compensation for fatigue allows improving the performance of rowers in the 1000 (1,200) meters segment - 1,500 (1,700) meters. The performance of the rower in this racing distance largely influences the overall result and rower’s place after overcoming the competing distance of 2000 meters [Dyachenko A.Y. (2007), Urbanchek J. (2012)].

To improve the efficiency of compensating fatigue in the process of training and competitive activities, various methodological approaches have been proposed, which include:

- analysis of the structure of functional preparedness in conjunction with the structure of competitive activity and the development on the basis of developed physiological criteria for the reaction modes of special training sessions. Such modes included the implementation of a special warm-up and modes of operation aimed at


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increasing the deployment speed and stability of the cardiorespiratory system (CRS) reaction in the process of modeling the initial part and the average stationary racing distance. It was shown that on this basis the share of economical aerobic energy supply in the total energy balance of work can be increased, the rate of increase of acidemic shifts in the body, the  of their influence on the rate of fatigue accumulation [Hao Wu, Xing Huang, Bing Li Jian (2010), Messonnier Z., Freund H., Bourdin M., Belli A., Lacour J. (1996)] is reduced.

- optimization of tactical options for overcoming the racing distance when the search is conducted, the most optimal modes of competitive work, taking into account the individual special endurance of the rowers. At present, the implementation of such an approach seems to be rather difficult due to a clear tendency to unify tactical options for overcoming the racing distance when the differences in boat speed at specific segments of the distance among the world's leading rowers are statistically insignificant [Urbanchek J. (2012), Vu Khao. (2009)].
- the effects of genetic funds in the use of additional to the main training (in this work are not considered).

**Methods and organization of research**

**Participants.**

The study involved 38 athletes (men) aged 18–27 years old, candidates and members of the national team of Shandong Province, China. The studies were conducted in a special preparatory period at the center for training national water sports teams (Beihai, China).

**Procedure.**

The simulator (ergometer) Concept II was used to assess the special performance, equipped with a computer, which provided quantitative and qualitative indicators of health in a given mode of operation.

HR measurement was carried out by using a multi-channel analyzer with HR Polar meters (Finland). To estimate the indicator, a formula was used to calculate the training impulse, the integral indicator of the response of the cardiorespiratory system according to the HR indicators recorded during the entire period of work [MacDougal, J.D., Wenger, G.E., Green, G.J. (1998)]. For the analysis, HR average level for each 5 seconds were used (on the chart in 30 seconds).

The training impulse is determined by taking into account training time and data on the level of HR during physical activity, when HR reaches a steady state:

training impulse (arb.) = duration of training load (min.) x (average HR of work - HR rest) / (HR max. - HR of rest).

The level of the indicator is associated with the achievement of the level of reaction, speed of expansion and its stability during operation.

The blood lactate concentration was taked on an LP 420 automated biochemical analyzer (Dr LANGE, Germany) using a standard reagent kit. In the first test, blood was collected after completing trails 3 and 6. in the second - after 2 and 4 trails, in the third - after 1 and 2 trails. Blood sampling was carried out on the fifth minute of the recovery period in test 1 and 2, on the third and fifth minute in test 3 and 4. In the last two tests, the highest rates were taken into account.

Studies were conducted within 4 days. Every day, 38 athletes completed one of the test variants. The testing program is presented in table 1.

Table 1

**The testing program**

| The day, test | Load parameters | | Number of 6 minutes segments | Rest interval between segments, minutes | The period of blood sampling, the minute of the recovery period | HR measurement during recovery * |
|---|---|---|---|---|---|---|
| | Ergometerical power, W | Paddle stroke, rate per minute | | | | |
| 1 day, test 1 | 280–300 | 20-22 | 6 | 5 | 5 | Recovery period after the last leg |
| 2 day, test 2 | 320–340 | 26–28 | 4 | 5 | 5 | |
| 3 day, test 3 | 360–380 | 30–32 | 2 | 7 | 5 и 7 | |
| 4 day, test 4 | 400–420 | 34–36 | 1 | 7 | 5 и 7 | |

Note. * - analysis of the recovery rate of the heart rate to 120 beats · min-1 within 3-5 minutes of the recovery period after the last segment.

The test loads were selected in accordance with the target orientation of the physical training of rowers to improve functional fitness, its leading component of the power of aerobic energy supply. The duration of work on each segment was 6 minutes. Standardization of work time within six minutes of work is associated with the period of overcoming the racing distance and objectification of the comparison of quantitative indicators of the HR response.

**The following research equipment was used:**

1. For registration of indexes of the special performance and functional ability of rowers there was the used gas analyzer of Metamax 3b (Germany).
2. "Po1ar" (Finland) from telemetric registration of HR during loading and Hr- analyzer for the computer processing of data.
3. Laboratory complex for determination of lactat of blood of LP 400, "Dr Lange" Germany. The blood sample was researched by the specialists of Center of scientific researches in sport of province Shandong. The obtained data were used and analysed in relation to the tasks of work.
4. For standardization of measuring of the special performance rowing of "Concept II" (The USA) was used. The dynamic and average ergometerical power, time throughout the trail was registerd. "drag factor" progressed in accordance with gravimetric parameters and individual's rowing style.

**Statistical Analysis**

Statistical analyses is using the Statistical Package for the Social Sciences (SPSS 10.0). The following methods of mathematical statistics are: descriptive statistics, selective method, criterion of consent of Shapiro-Uilki, self-reactance criteria of Student's test and non-parametric criteria of Manna-Uyutni. The methods of descriptive (descriptive) analysis, including tabular presentation of separate variables and calculation of mean arithmetic value has been used -, standard deviation - S, and also indexes of individual differences - coefficient of variations of V. the sample data for compliance has been tested with the normal distribution law,Shapiro-Wilkie's . To determine the statistical significance of the differences between the samples, the distribution of which corresponded to the normal law, the Student's test was used. To determine the statistical significance of the differences between samples, the distribution of which corresponded to the normal law, nonparametric criteria for small samples were used (Wilcoxon test). A significance level (that is, the probability of error) was assumed to be p = 0.05. The informativeness of the tests and indicators was recorded, evaluated under standard conditions of measurement.of measuring.

Research results and discussion. Testing was performed using standard test loads performed in four zones of work intensity. Analyzed the response of the body to the load in the zone of aerobic (ventilatory) threshold (first day), anaerobic (glycolytic) threshold (second day), maximum O2 consumption (third day) [Dyachenko A.Y. (2004)], optimal balance of aerobic and anaerobic energy supply in conditions of strenuous exercise - ergometric power of work at the level of 115% VO2 max (fourth day) [Melbo J. (1996)]. Quantitative and qualitative characteristics of the load emerge the criteria for rowers in the threshold zones at the intensity level presented in the special literature [Dyachenko A.Y. (2007)].

In the process of analysis, it was taken into account that effective functional support of work is associated with the stability of t cardiorespiratory system reaction in conditions of increasing fatigue. According to the literature data under standard physical loads, the stability of the cardiorespiratory system reaction can be determined by the stability of the pulse, the degree of its fluctuation ("drift") in the process of performing a uniform standard load [Dyachenko A.Y. (2007)]. According to the "drift" of HR, the degree of stress of the functional systems of the body during work can be determined. The decrease in the stability of HR in the course of loading indicates the intensification of the process of accumulation of fatigue and its influence on the efficiency of the functional support of the special work of the rowers [Hastings L., Felix Krainski, Peter G. Snell, Eric L. Pacini, Manish Jain, Paul S. Bhella, Shigeki Shibata, Qi Fu. (2012)].

Table 2

**Indicators of the reaction of the body of qualified rowers of China to standard test loads (n = 38)**

| Length of work | Training impulse | | Lactate, mmol • $l^{-1}$ | | HR recovery time, seconds | |
|---|---|---|---|---|---|---|
| | $\bar{x}$ | S | $\bar{x}$ | S | $\bar{x}$ | S |
| Test 1, work in the zone of aerobic (ventilatory) threshold intensity | | | | | | |
| 1 | 4,52 | 0,11 | – | – | – | – |
| 2 | 4,47 | 0,11 | – | – | – | – |
| 3 | 4,70 | 0,12 | 2,9 | 0,2 | – | – |
| 4 | 4,97 | 0,12 | – | – | – | – |
| 5 | 4,85 | 0,11 | – | – | – | – |
| 6 | 5,15 | 0,12* | 3,5 | 0,3 | 167,5 | 27,1 |
| Test 2, work in the zone of anaerobic (glycolytic) threshold intensity | | | | | | |
| 1 | 4,56 | 0,13 | – | – | – | – |
| 2 | 4,85 | 0,12 | 5,7 | 0,2 | – | – |
| 3 | 5,08 | 0,12 | – | – | – | – |
| 4 | 5,14** | 0,14 | 6,1 | 0,3 | 214,6 | 21,5 |
| Test 3, work in the zone of maximum consumption of $O_2$ | | | | | | |
| 1 | 4,79 | 0,14 | 10,8 | 0,5 | – | – |
| 2 | 4,77 | 0,15 | 11,8 | 0,5 | 301,5 | 33,3 |
| Test 4, ergometric power level 115% $VO_2$ max | | | | | | |
| 1 | 4,64*** | 0,11 | 13,5 | 0,8 | 341,2 | 33,1 |

Notes: * - differences (increase) in the training impulse index 6 and 5 of the test segment 1 are significant at p <0.05;

** - differences (increase) in the indicator of training impulse 4 and 3 of the test segment 2 are significant at p <0.05;

*** - differences (decrease) in the training impulse index of 1 test segment 4 and 2 test section 3 are significant at p <0.05

The tendency to change the training impulse, the integral indicator of the reaction of cattle to standard loads is presented in Table 1 and schematically in Figure 1.

The table and figure show that the indicators of the training impulse had significant differences when working in the threshold zones of the response of the cardiorespiratory system. During the first and second trails, the cattle response indicators increased, and during the third and fourth, they decreased. The greatest differences in the response of cattle were observed when comparing the results of the fourth trail with the indicators that were recorded at a lower level of work intensity.

The results of measuring blood lactate concentration indicated that the work was performed in the zone of the aerobic (ventilatory) threshold and anaerobic glycolytic threshold, as well as in the intensity zone close to VO2 max, 115% VO2 max [Dyachenko A.Y. (2004)]. Attention is drawn to the increase in individual differences in lactate concentrations. To the greatest extent they are manifested in the results of the last fourth trail.

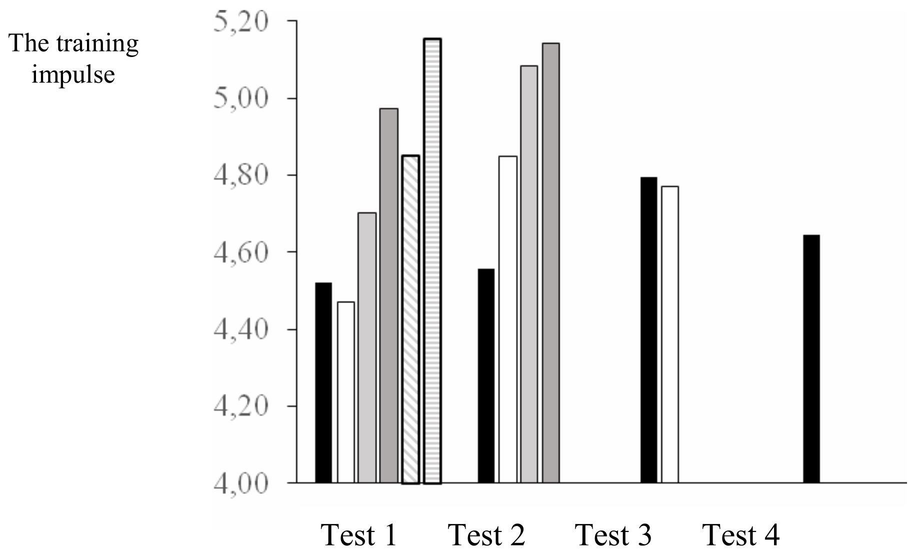


Fig. 1 Changes in the training impulse in the process of performing four test tasks performed in the threshold zones of the cardiorespiratory system reaction.

Segments of the test task, lasting 6 minutes:

1 - the first;
2 - the second;
3 - third;
4 - the fourth;
5 - the fifth;
6 - the sixth

Evaluation of the dynamics of recovery processes showed that after the first and second trails were completed, the recovery time corresponded to the accepted performance criteria - 120 beats / min – 1 for 3–5 minutes after work was completed [Dyachenko A.Y. (2007)]. The implementation of the third and fourth trail marked a higher voltage level of cattle in the process of work and a lower rate of recovery processes. After the fourth test, it did not meet accepted standards in most rowers.

Figures 2–5 show the data of the leading athletes of the province ( 4 pair rowers, second place at the All-China Games), which pointed to typological features and differences reaction in threshold areas of work intensity when re-performing test loads.

Figure 2 shows schematically the average HR dynamics of the four leading rowers of the province in the process of completing the first trail (test 1, rowing speed 18-20 g · min-1, ergometric work power (W) - 280-300 W). In test 1, it is clearly seen that in the process of performing all the work segments, a high stability of the pulse was maintained, the level of the reaction of cattle to the load after during the whole test tended to increase.

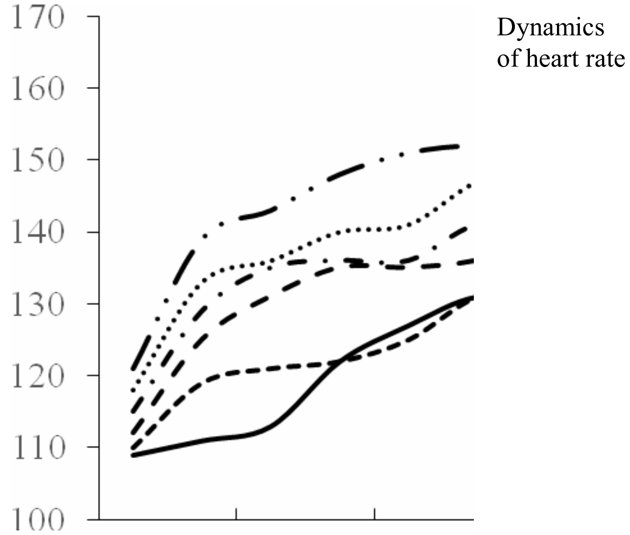


Fig. 2 Dynamics of heart rate in the process of performing 6 six-minute segments, performed at a pace of 20-22 rowing cycles per minute.

Segments of the test task, lasting 6 minutes:

1 - the first;
2 - the second;
3 - third;
4 - the fourth;
5 - the fifth;
6 - the sixth

Figure 3 shows schematically the average dynamics of athletes in the process of completing the second trail (test 2, rowing rate 26-28 g · min-1, W - 320-340 W). The figure clearly shows the trend in which a high level reaction is maintained throughout the entire period of work. This is evident from the presence of the HR sustainability phase and the period of its linear increase.

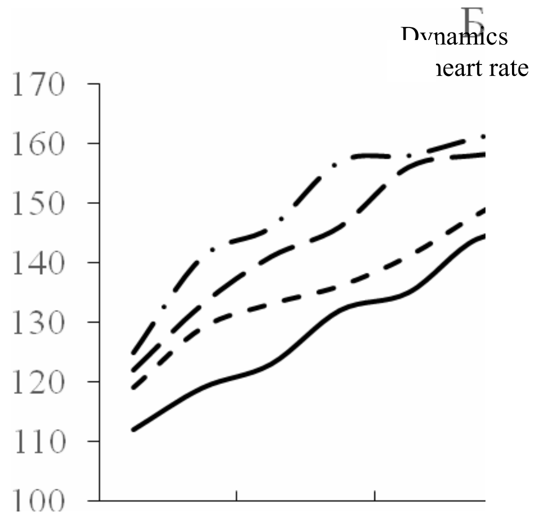


Fig. 3 Dynamics of heart rate in the process of performing 6 six-minute segments, performed at a pace of 26-28 rowing cycles per minute.

Trail lasting for 6 minutes:

1 - the first;
2 - the second;
3 - third;
4 - the fourth;

Figure 4 schematically shows that the reaction of cattle in rowers during the third trail (test 3, rowing rate 30-32 g · min-1, W - 360-380 W) indicated an increased functional support effort of the work. This is evidenced by the fluctuations of HR, the absence of a stability phase and a period of linear growth of the reaction characteristic of the final phase of work in the segment.

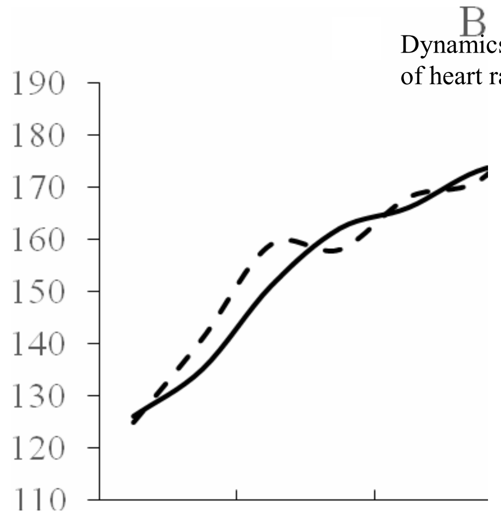


Fig. 4 Dynamics of heart rate in the process of performing 6 six-minute segments, performed at a rate of 30-32 rowing cycles per minute

Segments of the test task, lasting 6 minutes:

1 ___________ - the first;

2 - - - - - - - - - the second;

Figure 5 schematically shows the dynamics of the HR reaction of the four leading rowers of the province in the course of the last fourth trail (test 4, rowing speed 34-36 g · min-1, W - 400-420 W). These data showed that in the course of work, reduced rates of the body's response to the load were also recorded. The high voltage level of cattle (no phase of stability and a linear increase in HR), a reduced rate of recovery processes indicates an inadequate response of the systems of the functional support of work to the load in the specified intensity zone.

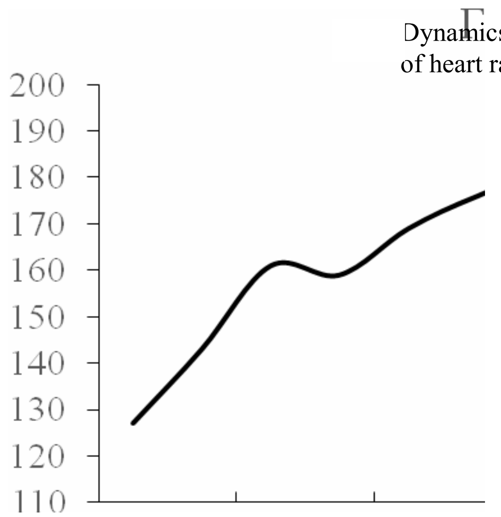


Fig. 5 Dynamics of heart rate in the process of performing 6 six-minute trail, performed at a pace of 34-36 cycles per minute

Thus, based on the above data, it can be stated that the leading rowers react differently to standard loads, which differ in their volume and intensity. The tendency is clearly visible when athletes respond most appropriately to loads of relatively low intensity, including during the period of accumulation of fatigue. As the load increases at a level close to competitive activity, the effort increases, the speed of recovery processes decreases, the range of individual differences in power of anaerobic glycolytic energy supply increases.

There is reason to believe that this type of reaction is connected with the content of the training process, in particular with the use of a significant amount of training work, which is little related to the specificity of the functional support of competitive activity. Obviously, all this affects the nature of the accumulation of fatigue and the body's ability to maintain a high level of efficiency in the second half of the competitive distance. Such conclusions are confirmed by the data of pedagogical observations of the training process of the leading crews of the province. Analysis of the speed of the boat, the tempo-rhythmic structure of the rower's special movement in the boat, the performance of up to 80% or more of the training work in the area of the aerobic-anaerobic transition does not allow to adequately activate the mechanisms of the functional support of the special work close to competitive activity in academic rowing. To a greater degree this problem manifests itself in conditions of accumulation of fatigue, with the tension of functions characteristic of the second half of the distance.

**Discussion.**

In the presence of certain successes in this direction, the differences in the speed of work on the average stationary racing distance of 500–1000 m and in conditions of increasing fatigue in the 1000–1500 m segment remain high 3.2 ± 1.1%. The leading athletes of China [Kim Chul-Ho, Wheatley Courtney M., Behnia Mehrdad, Johnson Bruce D Chul-Ho Kim (2016)], such differences are 6.3 ± 0.9%. This is due to the fact that the presented methodological approaches, to a greater extent, are focused on the formation of prerequisites for increasing endurance and special performance of rowers in conditions of fatigue which growing in the second half of the distance. The degree of compensation for fatigue largely depends on the individual reactivity of the body to then changes caused by the accumulation of near-limit hypoxic and acidemic changes, characteristics in the the second half racing distance [Dyachenko A.Y. (2004)].

Managing these processes in the process of sports training is extremely difficult due to the lack of reasonable modes of operation based on taking into account the laws of the biological adaptation of the body in conditions of increasing fatigue.

The solution to the problem is based on two interrelated areas of special analysis.

The first direction is associated with the analysis of existing approaches to improving the special endurance of the rowers, their systematization and clarification of the specialized focus of the training process based on the selection of the most effective training method aimed at improving the special performance of rowers in conditions of fatigue, growing in the second half of the distance.

The second is with the development of training modes of exposure based on taking into account the body's natural biological adaptation under loads of submaximal intensity in conditions of fatigue, growing in the second half of the distance.

The article presents an analysis aimed at the implementation of the first direction of research. It is associated with the study of the rower's body reaction to physical loads, performed in the threshold zones of the reaction of the cardiorespiratory system and aerobic energy supply in the process of repeat training loads.

**Conclusion**

The differences in the functional support of the rowers' performance during the four trails performed in the threshold zones of the load intensity are shown - in the zone of the aerobic (ventilatory) threshold, anaerobic glycolytic threshold, maximum O2 consumption, at the level of ergometric power of 115% VO2 max. Significant differences ($p < 0.05$) were noted for the integral index of the response of the cardiorespiratory system - the training impulse in the process of fulfilling the last segments 1–2 and 3–4 of the trail, respectively - 5.15; 5.14; 4.77; 4.64 .etc. At the same time, there was a tendency to an increase in the reaction during the trail 1 and 2. High adaptive abilities of an organism to loads of relatively low intensity at the level of aerobic-anaerobic transition are noted. In conditions of loads performed with higher intensity, close to the competitive activity of athletes in rowing, the degree of stress of the cardiorespiratory system increases, the speed of recovery processes decreases. To the greatest extent, the level of reaction decreases under conditions of accumulation of fatigue, typical of the second half of the distance. The reasons for continuing research in this direction are shown. They are associated with the systematization of factors that affect the effectiveness of adaptation processes in conditions of increasing fatigue in the process of executing loads with submaximal intensity and substantiation on this basis of specialized training tools, in particular, taking into account the features of the functional support of the rowers' competitive activities in the second half of the distance.

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