Evaluation of the power of movements of rowers-canoeists based on the spatial reconstruction of the stroke

UDC 797.122.3

Dr. Hab., Professor **V.P. Sushchenko**[1]
PhD **V.E. Vasyuk**[2]
PhD **D.A. Lukashevich**[2]
D.I. Huseynov[2]
Dr. Hab., Professor **V.L. Pashuta**[3]
[1]Peter the Great St. Petersburg Polytechnic University, St. Petersburg
[2]Belarussian National Technical University, Minsk, Republic of Belarus
[3]Military Institute of Physical Culture, St. Petersburg

Corresponding author: vlad.bakaev@gmail.com

Received by the editorial office on 13.05.2023

Abstract

Objective of the study was to determine the biomechanical characteristics of rowing and their relationships in the "oar-water-boat" system. Show new methods for quantifying movement technique in canoeing.

Methods and structure of the study. The experiment involved elite athletes (women aged 20 to 27 years) who specialize in canoeing: masters of sports (2 people) and masters of sports of international class (4 people). The criterion for exclusion from the study was the absence of a doctor's admission to training. In this work, we used the method of stroke spatial reconstruction based on the use of inertial sensors, which with high accuracy make it possible to measure important kinematic parameters that indirectly reflect the stroke power generated by an athlete.

Results and conclusions. For highly efficient promotion of the "sportsman-boat" system and the realization of the propulsive potential, the athlete needs to maintain the force applied to the oar to provide the most dense and stable support. Having visualized the data characterizing the dynamics of the angular velocity of the handle of the simulator and the oar, we identified two types of curves: one of which is typical for all athletes when performing test tasks on a rowing ergometer, and the other - when rowing in a boat. The power of canoeists' movements is one of the key factors of competitive performance. The inertial sensors we used with a high degree of accuracy make it possible to measure important kinematic parameters that indirectly reflect the stroke power generated by the athlete, on which the effectiveness of the boat's advancement directly depends. However, in order to form a holistic picture that characterizes the performance of an athlete, primarily in the aquatic environment, it is also necessary to register the kinematic parameters of the "athlete-oar-boat" system and the dynamic parameters of the stroke, by using wearable sensors synchronized with each other.

Keywords: *canoeing, rowing ergometer, stroke spatial reconstruction, inertial sensor.*

Introduction. A distinctive feature of rowing is the interaction of the elements of the “paddle-water-boat” system, and the main task of the athlete is to most effectively cover the competitive distance, taking into account the impact of exogenous environmental factors [1, 3, 7].

One of the factors of systematic movements is the rowing style of an athlete, which is a portrait of his personality: anthropometry, the level of development of power and speed-strength abilities, endurance, flexibility, balance, stability and other features [6]. There is no information in the literature as to which factors reflect the ideal technique in canoeing and which style may be the most effective [5].

Objective of the study was to determine the biomechanical characteristics of rowing and their relationships in the “oar-water-boat” system and to substantiate effective methods for quantitative assessment of the technique of movements in canoeing.

Methods and structure of the study. The study involved elite athletes (women aged 20 to 27 years) who specialize in canoeing: masters of sports (2 people) and masters of sports of international class (4 people). The criterion for exclusion from the study was the absence of a doctor’s admission to training.

The study was carried out in two stages:

Stage I - during the training camp from January 18 to January 27, 2021, on the basis of the educational institution “Belarusian State University of Physical Culture”. In the course of the study, athletes (n=6) performed test tasks on a rowing ergometer for the Sokol canoe. To standardize the testing conditions, the same level of load was set for all subjects (set by changing the size of the flywheel opening and the value of the suspended load to the movable base - m = 6 kg), with a regulated mode of operation in terms of heart rate:

- Test 1a - 20 strokes with a heart rate of 130-140 bpm;
- Test 2a - 20 strokes at a heart rate of 150-160 bpm.

The maximum intensity work mode was not used, since such loads were not combined with the work plan approved by the coach at this stage of training.

Before testing, all athletes performed a standard warm-up, the duration of which was 30 minutes. Each test task began with working out to the lower limit of the regulated heart rate range, after which each athlete performed another 20 strokes in this range. The rest time between tasks varied from 2 to 3 minutes in order to restore the pulse regime.

Inertial sensors Delsystrignoavanti (Delsys, Inc., Massachusetts, U.S.A) with built-in three-axis accelerometer, gyroscope, and magnetometer were used to record the spatio-temporal parameters of the stroke. The data logging frequency was set at 1000 Hz. By means of a bandage, the sensor was attached to the distal end of the handle of the simulator. The inner surface of the bandage is made of an anti-friction material that prevents the sensor from moving. Signals from the sensor were recorded wirelessly using the DelsysAcquisitionSoftware hardware-software complex (Delsys, Inc., Massachusetts, U.S.A).

Stage II - during the training camp from May 24 to May 26, 2021, on the basis of the “Brest Regional Center for Rowing Olympic Reserve”. In the course of the study, athletes (n=4, all masters of sports of international class), who also took part in the first stage of the study, performed test tasks in natural rowing conditions as part of C-2 canoe crews. The tasks were carried out according to the training plan for athletes developed by their coach and included the performance of 3 segments of the distance with submaximal intensity by the interval method, lasting 10 (Test 1b), 30 (Test 2b) and 30 seconds (Test 3b), respectively, with rest between them 1 minute. The rest process was accompanied by rowing locomotions with low intensity.

Before testing, all athletes performed a standard warm-up under the guidance of a coach, the duration of which was 30 minutes. The start of each test task was carried out at the command of the coach from the move.

Delsystrigno Avanti inertial sensors were also used to register the spatio-temporal parameters of the rowing locomotions of the athletes in the C-2 crew. One sensor was attached to the stern to register the peculiarities of changes in boat acceleration during rowing. The signals from the sensors were synchronously recorded and transmitted via a Bluetooth wireless data transmission channel to a mobile phone with a pre-installed EMG Logger data recording program (Delsys, Inc., Massachusetts, U.S.A). The mobile phone was placed in the boat with the athletes, which made it possible to freely record data.

The criterion for identifying rowing cycles is the intersection of the gyroscope signal with the isoline (in this case, the zero line). Depending on the polarity of the gyroscope signal, the supporting and unsupported parts of the stroke are distinguished. An example of a characteristic curve is shown in Figure 1.

Results of the study and their discussion. The data of the test results of the first (on the rowing er-

Table 1. *Biomechanical indicators of the studied parameters of athletes’ movements when performing Test 1a and Test 2a on the “Sokol” rowing ergometer*

Athlete		t_{sup}, s	t_{uns}, s	t_c, s	t_{sup}/t_c, %	Rate, c/min	S, c.u.	P, c.u.
Test 1a								
1	mean±SD	0.928±0.015	1.183±0.058	2.111±0.049	44.0±1.5	28.5±0.7	35.6±3.7	89.9±7.8
2	mean±SD	1.028±0.023	1.085±0.047	2.113±0.046	48.6±1.4	28.4±0.6	55.9±1.7	133.5±4.4
3	mean±SD	0.764±0.010	0.706±0.010	1.470±0.011	52.0±0.6	40.8±0.3	46.3±1.8	142.0±2.4
4	mean±SD	0.898±0.016	1.090±0.043	1.988±0.034	45.1±1.3	30.2±0.5	46.4±3.5	110.2±2.1
5	mean±SD	0.982±0.022	1.199±0.048	2.181±0.031	45.1±1.5	27.5±0.4	58.6±3.0	137.4±11.2
6	mean±SD	1.069±0.025	1.127±0.065	2.196±0.046	48.7±2.0	27.3±0.6	50.1±9.0	82.6±15.5
Test 2a								
1	mean±SD	0.753±0.011	0.788±0.041	1.541±0.031	48.9±1.6	38.9±0.8	32.3±1.2	110.2±3.7
2	mean±SD	0.805±0.011	0.731±0.026	1.536±0.022	52.4±1.1	39.1±0.6	61.6±2.0	163.0±3.0
3	mean±SD	0.839±0.011	0.730±0.022	1.569±0.017	53.5±1.0	38.2±0.4	56.7±2.2	155.0±5.0
4	mean±SD	0.713±0.018	0.866±0.048	1.579±0.041	45.1±1.7	38.1±0.9	42.2±1.5	140.2±3.1
5	mean±SD	0.936±0.028	1.112±0.079	2.047±0.061	45.7±2.4	29.4±0.9	60.1±3.8	147.5±5.0
6	mean±SD	0.966±0.036	1.081±0.057	2.037±0.055	47.0±1.6	29.5±0.8	51.5±2.9	103.0±4.0

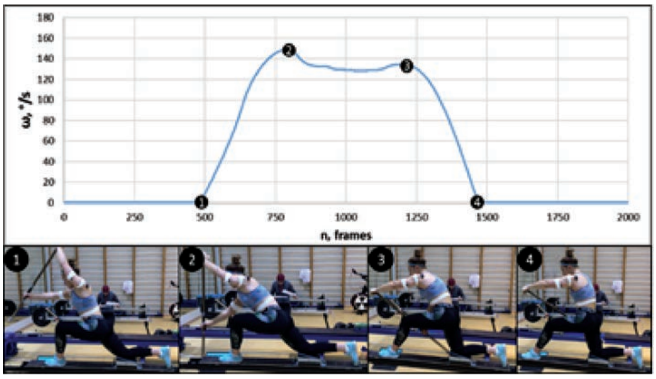

Figure 1. *Gyrogram of the supporting part of the stroke when performing a test task on the "Sokol" rowing ergometer*

gometer; table 1) and the second (in the boat; table 2) stages for each athlete are presented in a generalized form for the studied parameters using the mean value and standard deviation. Athletes in the tables are presented in the form of serial numbers (this number corresponds to a certain athlete in both stages I and II). Athletes with serial numbers 5 and 6 did not take part in the second stage of testing.

Table 2 presents the data in the form corresponding to the composition of the crews (crew 1 - athletes 1 and 2; crew 2 - athletes 3 and 4).

Having visualized the data characterizing the dynamics of the angular velocity of the handle of the simulator and the oar, we identified two types of curves (Figure 2), one of which is typical for all athletes when performing test tasks on a rowing ergometer (fragment 1 in Figure 2), and the other - when rowing in a boat (detail 2 in figure 2).

The first type of curve - fragment 1 is characterized by a peak-like beginning (corresponding to the toe phase), then a decrease in the angular velocity by 10-20% and a peak at the end of the supporting part of the stroke. As was already mentioned when describing the key points of the gyrogram, in our opinion, this is due to the design features of the rowing ergometer and the intensity of the athlete's movements. The magnitude of this peak-like change may depend on the initial speed of movement, as well as the level of speed-strength fitness of the athlete.

The second type of curve, fragment 2, is characterized by a bell-shaped shape. In their study, Gomesetal (2015) write that the maximum stroke performance can be achieved when the curve is rectangular [4]. Thus, it can be concluded that in order to increase the propulsive efficiency of the stroke in natural rowing conditions, the athlete must strive to rationally increase the power of the supporting part of the stroke and hold it without significant loss by the end of the stroke. This will allow, due to a short-term decrease in the environmental resistance force, to increase the length of the boat rental per stroke, which, in turn, will increase the average speed of overcoming the competitive distance [2].

Conclusions. The power of canoeists' movements is one of the key factors of competitive performance. Technological innovations and their introduction into the training process of canoeists (high-tech boats and

Table 2. *Biomechanical indicators of the studied parameters of the movements of crews 1 and 2 when performing tests during rowing in natural conditions*

Athlete		t_{sup}, s	t_{uns}, s	t_c, s	t_{sup}/t_c, %	Rate, c/min	S, c.u.	P, c.u.
Crew 1								
Test 1b								
1	mean±SD	0.637±0.021	0.275±0.024	0.912±0.023	70.0±2.0	65.4±1.6	97.1±3.2	152.6±2.9
2	mean±SD	0.642±0.042	0.278±0.053	0.918±0.026	69.7±5.1	65.5±1.9	95.8±2.8	149.6±5.9
Test 2b								
1	mean±SD	0.700±0.031	0.321±0.039	1.021±0.046	68.5±3.0	58.9±2.7	101.1±3.2	144.6±4.2
2	mean±SD	0.687±0.022	0.335±0.045	1.022±0.048	67.2±3.1	58.9±2.8	96.9±3.6	141.1±6.0
Test 3b								
1	mean±SD	0.580±0.028	0.259±0.024	0.839±0.024	69.2±2.6	71.4±2.0	94.2±3.2	162.6±5.9
2	mean±SD	0.579±0.019	0.260±0.025	0.839±0.024	69.0±2.4	71.4±2.0	92.7±2.9	160.3±4.1
Crew 2								
Test 1b								
3	mean±SD	0.595±0.036	0.209±0.023	0.804±0.016	73.9±3.1	74.8±1.4	104.1±3.5	175.3±6.1
4	mean±SD	0.622±0.055	0.187±0.043	0.809±0.021	76.8±5.3	74.1±1.8	108.6±4.6	175.2±7.7
Test 2b								
3	mean±SD	0.787±0.025	0.328±0.027	1.115±0.029	70.656±1.9	53.7±1.4	112.3±2.3	142.7±3.6
4	mean±SD	0.795±0.018	0.324±0.032	1.109±0.031	71.1±2.2	53.6±1.5	117.2±2.6	147.6±2.7
Test 3b								
3	mean±SD	0.649±0.016	0.266±0.021	0.915±0.017	70.8±1.9	65.7±1.3	106.6±2.4	164.5±4.9
4	mean±SD	0.671±0.016	0.243±0.027	0.914±0.018	73.4±2.5	65.6±1.3	109.8±2.4	163.6±3.6

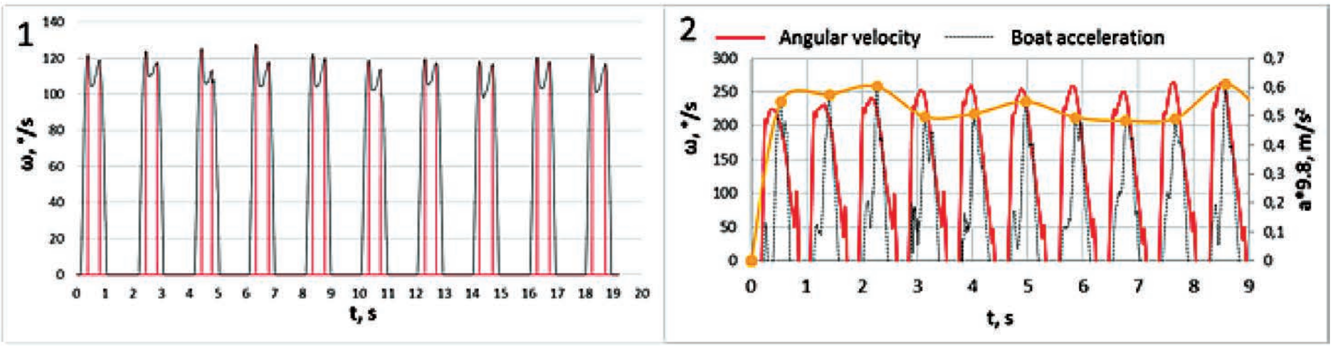

Figure 2. *Characteristic portraits of the dynamics of the angular velocity when performing test tasks on a rowing ergometer and in a boat*

oars, rowing ergometers, information and measurement systems for monitoring and evaluating various aspects of preparedness) open up wide opportunities for deeper research.

The inertial sensors we used with a high degree of accuracy make it possible to measure important kinematic parameters that indirectly reflect the stroke power generated by the athlete, on which the effectiveness of the boat's advancement directly depends. However, in order to form a holistic picture that characterizes the performance of an athlete, primarily in the aquatic environment, it is also necessary to register the kinematic parameters of the "athlete-oar-boat" system and the dynamic parameters of the stroke, by using wearable sensors synchronized with each other. Such an approach will make it possible to individualize the process of complex analysis of recorded data, determine the optimal rowing strategy and most effectively eliminate the athlete's motor errors.

References

1. Verlin S.V., Semaeva G.N., Maslova I.N. Faktory, opredelyayushchiye effektivnost tekhniki grebli [Factors determining the effectiveness of rowing technique]. Uchenye zapiski un-ta im. P.F. Lesgafta. 2014. No. 4 (110). pp. 29-34.
2. Issurin V.B. Biomekhanika grebli na baydarkakh i kanoe [Biomechanics of kayaking and canoeing]. Moscow: Fizkultura i sport publ., 1986. 111 p.
3. Pomerantsev A.A., Aksenov V.A. Sistematizatsiya faktorov, ogranichivayushchikh kachestvennyy biomekhanicheskiy analiz [Systematization of the factors limiting the qualitative biomechanical analysis]. Izvestiya Tulskogo gosudarstvennogo universiteta. Fizicheskaya kultura. Sport. 2021. No. 1. pp. 105-115.
4. Gomes B.B. et al. Paddling force profiles at different stroke rates in elite sprint kayaking. Journal of Applied Biomechanics. 2015. Vol. 31, iss. 4. pp. 258-263.
5. López C.L., Serna J.R. Quantitative analysis of kayak paddling technique: definition of an optimal stroke profile. RevistaAndaluza de Medicina del Deporte. 2011. Vol. 4, iss. 3. pp. 91-95.
6. Lundström P., Borgen J.S., McKenzie D. The canoe/kayak athlete. Handbook of Sports Medicine and Science Canoeing. 2019. p. 40.
7. Nickl R.W., Ankarali M.M., Cowan N.J. Complementary spatial and timing control in rhythmic arm movements. Journal of neurophysiology. 2019. Vol. 121, iss. 4. pp. 1543-1560.