

Modelling the kinematic structure of movements of qualified canoeists

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Abstract:

The significant differences in the kinematic structure of the rowing technique on the old and modern design boats, and in the kinematic structure of the techniques of physical efforts in the qualified canoeists and the advanced world sportsmen on modern design boats were revealed in this study. The methods of improving the rowing technique in the contest season were optimized due to increasing the amount of hours dedicated to the technical preparation, directed impacts on the improvement of the separate components of qualified canoeists technical actions and the use of control over the quantitative parameters of the kinematic structure of rowing movements. The study results were implemented for the preparation of the Kyiv city canoe rowing combined team, and used in the course of lectures 'Biomechanical features of athletic technique for students.

Key words: rowing technique, kinematics structure of motions, technical preparation, modelling.

Introduction

The modern preparation of rowers-canoeists is a complicated process composed of the technical, tactical, physical and psychological components. The technical preparation of sportsmen is one of the priority directions of sportive training (Guo, 2007; Hrybovskyy, 2015; Briskin, 2016; Galan, 2016, 2017). In the course of studying the process of rowers' training, many authors investigated the features of the sportsmen's technical preparation. In modern science, different aspects of this issue were studied: the degree of impact of different parameters of canoeists' motion activity on the stroke cycle working phase performance was established, the dependence of environment resistance on the canoe velocity for rowers of different weight was studied; the complex analysis of biomechanical characteristics of coordination structure of movements in rowing on canoes with the use of instrumental methods was conducted, features of movement control in canoe rowing were established; underwater spatial and dynamic vector stroke building was studied, the biomechanical model of canoe stroke was created, features of the boat translational motion kinematics were established, hydrodynamic resistance counteracting the vessel movement and factor of influence on its value were defined; dynamics of muscular work providing the optimal structure of rowers' movements, was studied, interconnections between the dynamics of applying force to the oar, torso rotation and intermuscular coordination were established; mean group model characteristics of the technical preparation of rowers-canoeists of high qualification were developed, the degree of compliance of mean group model characteristics of separate sportsmen was defined; the system for pedagogical control of sportive and technical preparation with regard to the dynamics of insertion processes in rowing was developed; biomechanical features of the stroke formation were defined, correlation and factorial structures of the technical preparation and discriminative signs of techniques of sportsmen of different qualification were defined, methods for programming and correction of the rowing technique characteristics were developed (Sanders, 1992; Kropta, 2003; Zhyrnov, 2007; Kerr, 2008; Ivashchenko, 2017; Gorshova, 2017).

It should be emphasized that the information submitted was obtained in the course of the research and analysis of rowing locomotion technique on the old design boats.

One of the important directions defining the modern sport progress is development and use of new sportive inventory radically influencing on the change of sportive techniques and the methods of sportsmen's preparation (Zhyrnov, 2008; Briskin, 2011, 2016; Choszcz, 2012; Melnyk, 2017). The boat width reduction led to the water medium front resistance decrease at the boat movement and its velocity increase which caused changes in the rowing techniques. It is confirmed by the results of studies in the course of which the comparative analysis of the boat velocity dynamics, rate and rhythm characteristics and work capacity on the old and new design boats was conducted and the features of the stroke dynamic characteristics on the new design boats were studied (Kropta, 2004; Guo, 2008; Zhyrnov, 2008; Bohuslavska, 2017).

At the same time, the sportsman's rational body position and the kinematic structure of movements in different stroke cycle phases, which greatly influence on the boat velocity at rowing on the new design boats, require further research.

The increase of the training process management efficiency can be related to the use of different models of rowing locomotion technique: mathematical, biomechanical, physical, etc. (Priymakov, 2003; Zhyrnov, 2008; Zanevskyy, 2016). Mathematical models of the optimal kinematic stroke structure having functional dependencies allow forecasting the variants of techniques oriented at the desired performance achievement.

At rowing on the new design boats, the improvement of rowing locomotion technique of qualified sportsmen based on development of models of optimal kinematic structure of movements becomes topical.

Materials and methods

The following study methods were used for solving set tasks and obtaining objective data: the analysis of special scientific and methodological literature, pedagogical observation, pedagogical experiment, anthropometric measurements, video shooting, video and computer analysis of motion kinematic characteristics, modelling methods, mathematical statistics methods.

The three-phase study was conducted at the Department of Kinesiology of the National University of Physical Education and Sports of Ukraine and the water sports facilities of the State Physical Culture and Sport Complex 'Lokomotiv', Physical Culture and Sport Organization 'Dynamo' and the Kyiv Sports Boarding Lyceum. 17 qualified rowers-canoeists were enrolled for the study.

Results

As a result of the analysis of the literary sources, we established that technical preparation is one of the leading factors influencing the achievement of high sports results.

At the present stage of development of rowing sports, improvements in the design of sports boats took place. As a result, the boat's width decreased, which led to a change in the motor structure of the rowing locomotion technique. Moreover, we established that the methods of technical preparation of the qualified canoeists nowadays require scientific justification with regard to the new design peculiarities of boats, as peculiarities of rowing on the new design boats were studied poorly, the data about quantitative inconsistencies of characteristics of the elements of the rowing technique on boats of different design are unavailable, biomechanical features of canoeists's postures and the kinematic structure of rowing movements performance are studied poorly, quantitative efficiency criteria for of the rowing technique for canoeists of different qualification are unavailable, and the samples of optimal kinematic structure of the rowing technique, which could stimulate the development of the model of technical actions of rowers of different qualification.

The practice shows that today the methods of improving the rowing technique of qualified sportsmen require optimization with regard to changes in design of rowing boats and the check of its efficiency in the conditions of experimental studies. In connection with the change of boat design, we conducted the comparative analysis of the kinematic structure of the rowing technique on different design boats, resulting in the revealing of the reliable inconsistencies in the temporal structure of rowing movements: rowing rhythm on the new design boats was 2:1, and on the old design boats, 2,2:1. Duration of all stroke cycle periods on the old design boats is higher than that on the new design boats: support period on the left – by 0,04 s ($p<0,05$), on the right – by 0,02 s ($p<0,05$), and without supports - 0,02 s ($p<0,05$).

Moreover, the reliable inconsistencies in spatial and spatial-temporal structures of rowing movements and in the boat velocity dynamics in the stroke cycle (Table 1) were revealed.

Table 1. Characteristics of the rowing technique in the leading world rowers on boats of different design

Parameter measured	Old design boats (n=10)		New design boats (n=10)	
	\bar{x}	S	\bar{x}	S
The average the boat velocity for the stroke cycle, $m \cdot s^{-1}$	4,97	0,11	5,14*	0,16
Rowing rate, $st \cdot min^{-1}$	122,9	1,12	126,4*	0,99
Oar blade shift for the support period, m				
on the right	1,46	0,03	1,42*	0,02
on the left	1,47	0,05	1,4*	0,07
The average oar blade velocity for the support period, $m \cdot s^{-1}$				
on the right	6,75	0,05	6,82*	0,08
on the left	6,74	0,05	6,82*	0,09

Note.* – $p<0,05$

In order to determine the influence of anthropometric indicators of a canoeist's body on the rowing

technique, interrelations between these indicators and characteristics of the kinematic structure of rowing movements performance technique were analysed. As a result of analysis, we received only one significant coefficient of correlation between the sum indicator (shoulder width + stretched arm strength) and the stroke length ($r=0,69$, $p<0,05$). Based on the data obtained, we can conclude that in the qualified sportsmen-canoeists who participated in our experiment, there is almost no influence of the anthropometric body sizes on the various parameters of the kinematic structure of rowing movement performance technique and the boat velocity in the stroke cycle.

The differences in rowing locomotion technique in sportsmen of different qualification at rowing on the new design boats were revealed. The excursion of angle in the elbow joint of the pulling hand, for the support phase in the leading world sportsmen is, in average, lower by 8° ($p<0,05$), angle of oar attack in sagittal plane in the first half of support phase in leading world rowers is higher by 11° ($p<0,05$).

The average oar blade velocity for the support period in the leading world sportsmen is higher by $0,07 \text{ m} \cdot \text{s}^{-1}$ ($p<0,05$). The most significant difference of the oar blade velocity dynamics is observed in the second carry half. For this period, the blade velocity in high qualified sportsmen is higher by $1,8 \text{ m} \cdot \text{s}^{-1}$ ($p<0,05$).

The average boat velocity for the stroke cycle in high qualified sportsmen is higher by $0,43 \text{ m} \cdot \text{s}^{-1}$ ($p<0,05$). Moreover, it was found that changing the boat velocity for a stroke cycle in leading world sportsmen is lower by $0,32 \text{ m} \cdot \text{s}^{-1}$ ($p<0,05$), than in the qualified canoeists.

The data obtained indicate at the reliable inconsistencies in the rowing technique of sportsmen of different qualification, which formed a basis for developing the models of rowing locomotion technique for leading world rowers and qualified canoeists.

From the analyzed 106 characteristics of the kinematic structure of movement actions of the rowers-canoeists of different qualifications, we marked out those having the greatest influence on the boat velocity. Based on the correlation analysis data, we established significant relationships between the separate parameters of the kinematic structure of rowing movements and the average boat velocity for the stroke cycle.

We defined seven the most informative parameters that had the greatest impact on the rowing technique efficiency, namely: shift ($r=0,76$) and velocity ($r=0,85$) of the oar blade in the support period, the support period ($r=0,79$) and the carry phase ($r=0,8$) duration, angle between the oar and the water plane in the capture moment ($r=0,71$), angle in the elbow joint of the pulling hand ($r=0,74$).

The revealed inconsistencies in technical actions of sportsmen of different qualification allowed building statistical intermediate group models of the sportsmen's technical preparation.

Based on statistical mean group models of the sportsmen's technical preparation, the method of improving the technical skill of qualified canoeists was reasoned, developed and implemented into the training process. It is based on modelling the specific parameters of the kinematic structure of the sportsmen's movement actions and their quantitative characteristics.

According to the specialists (Kropta, 2004; Zanevskyy, 2007; Choszcz, 2012), the efficiency of the use of generalized and group models for the training process optimization and correction may be especially high at the preparation of sportsmen who did not achieve the height of sportive art.

The main criterion of the performance efficiency in rowing is the boat velocity. All the parameters included in the model are closely interrelated and influence the principle criterion to a large extent.

The group models don't allow taking into account the individual peculiarities of separate rowers' technique and may differ significantly from the model of the separate sportsman's technical preparation. In connection with this, we developed regression models predicting the given average boat velocity in the rowing cycle depending on the model of the separate sportsman's technical preparation (table 2).

Table 2. Mathematical models of assessing the rowing technique of qualified canoeists

No	Multiple regression equation	Multiple regression coefficient	Model error
1	$Y = 1,701 - 0,0401x_1 + 0,611x_2 + 0,0137x_3 + 0,0098x_4 - 0,0028x_5 + 0,2979x_6 + 0,0989x_7$	0,724	1,12
2	$Y = 2,09 - 0,96305x_1 + 0,0215x_3 + 0,06x_7$	0,698	0,87

Notes: Y – boat velocity, $\text{m} \cdot \text{s}^{-1}$; x_1 – support period duration, s; x_2 – carry phase duration, s; x_3 – rowing rate, $\text{st} \cdot \text{min}^{-1}$; x_4 – angle of oar attack in the moment of capture start, degrees; x_5 – angle in the elbow joint of the pulling hand in the moment of the support period completion, degrees; x_6 – oar blade shift for the support period, m; x_7 – the average oar blade velocity for the support phase, $\text{m} \cdot \text{s}^{-1}$;

1 – expanded regression equation;

2 – regression equation for the operative control

The use of models developed by us in the training process greatly facilitates the conduct of stage or operational control and allows conducting the differential assessment of the technical preparation of qualified canoeists.

Based on models of the technical preparation of sportsmen of different qualification we developed the methods of technical improvement of qualified canoeists.

The technique offered is aimed at improving the rowing locomotion technique due to the correction of separate elements of the kinematic structure of rowing movements in the qualified canoeists, defined as solving the following tasks: increasing the efficiency of the specialized movement actions, forming the basis for rowing technique; improvement of the structure of movement actions taking into account the individual peculiarities of separate sportsmen; increasing reliability and performance of the rowing techniques.

The main features of this technique are: decrease of the volume of technical preparation of qualified canoeists in transfer period and its increase in the contest season, the use of special exercises recommended by us in the contest season which have the selective impact on separate parameters of the kinematic structure of the rowing technique movements, the use of the groove machine for correcting the stroke spatial characteristics, the conduct of current and stage control with the use of the efficiency of the rowing technique developed by us.

In the process of experiment, when performing special physical exercises, conditions were created to complicate or simplify the performance of movement actions: the use of weights and hydrobraking devices, rowing on the wave and in team boats, oar grasp change, etc.; the performance of rowing movements in unusual conditions (rowing at side wave, wind, current). During the experiment, two training sessions were conducted during the day, with six training days per week. The offered special exercises were used four times a week in the main part of the session. To provide the strength of the motor skills formation, simulation physical exercises were used daily as a part of special warm-up. In order to ensure the strength of the formation of motor skill, simulation physical exercises were used daily as a part of special warm-up.

For correction and operational control of technical actions of qualified canoeists we developed a groove machine allows optimizing the spatial characteristics of the oar blade movement in the support period: water capture start point, the blade distance from the board in the moment of carry completion, stroke length. The application of this device provides visual control of movements by the rower. The system includes markers applied on the boat, remote contact sensors and a light signalling device. This device can be installed on any canoe model, as well as on different rowing ergometers, and to function at any intensity of rower's work.

The control of biomechanical characteristics was conducted during the experiment via video shooting and computer analysis of movements. The efficiency of the experimental method of improving the rowing technique of qualified canoeists was defined in the course of the pedagogical experiment conducted on the bases of the State Physical Culture and Sport Complex 'Lokomotiv', Physical Culture and Sport Organization 'Dynamo' and the Kyiv Sports Boarding Lyceum in the natural conditions of the educational and training sessions in the contest season of the annual cycle of preparation of rowers for eight weeks. The registration of the studied indicators of the kinematic structure of rowing locomotion technique was carried out at the beginning and at the end of the experiment. Eight qualified canoeists in the experimental group and nine in the control group were enrolled. The sportsmen of the control group were training according to the conventional methods, and the sportsmen of the experimental group, according to the methods of the rowing technique improvement offered by us.

The obtained data concerning the kinematic structure of the rowing technique showed that canoeists of the control and the experimental group had no reliable inconsistencies at the beginning of the contest season under all the studied parameters ($p > 0,05$). Prior to the experiment completion, sportsmen of both groups demonstrated positive changes in the kinematic structure the rowing technique, which, probably, is the result of preparation and educational work conducted during the studies. The use of the techniques offered by us in the experimental group favoured reliable changes of the average values of five of seven studied parameters, namely: support period duration decreased by 0,02 s ($p < 0,05$), stroke length increased by 0,04 m ($p < 0,05$), angle of oar attack in the moment of capture start increased by 6° ($p < 0,05$), angle in the elbow joint of the pulling hand, in the moment of support period completion decreased by 7° ($p < 0,05$), the average oar blade velocity for the support stage increased by $0,04 \text{ m} \cdot \text{s}^{-1}$ ($p < 0,05$), the average the boat velocity in the stroke cycle increased by $0,07 \text{ m} \cdot \text{s}^{-1}$ ($p < 0,05$), which confirms the efficiency of our proposed technique (table 3).

In the control group, only two studied indicators of seven improved reliable, and the average the boat velocity in the stroke cycle increased only by $0,03 \text{ m} \cdot \text{s}^{-1}$ ($p < 0,05$).

The developed methods of technical preparation allow us to optimize the training process of qualified canoeists, with regard to the features both of the whole group and of the separate sportsmen.

Table 3. Characteristics of the rowing technique parameters in sportsmen of experimental and control group prior to and after conducting the experiment

Parameter measured	Characteristics value							
	The control group (n=9)				The experimental group (n=8)			
	before the experiment	the	after the experiment	the	before the experiment	the	after the experiment	the
	\bar{x}	S	\bar{x}	S	\bar{x}	S	\bar{x}	S
Rowing rate, st. \cdot min ⁻¹	124,2	4,8	124,9	3,9	124,6	5,1	124,8	4,9
Support period duration, s	0,34	0,008	0,34	0,009	0,34	0,008	0,32*	0,01
Carry duration, s	0,2	0,009	0,22*	0,007	0,2	0,008	0,2	0,01
Oar blade shift for the support period, m	1,33	0,09	1,35	0,03	1,34	0,02	1,38*	0,02
Oar blade velocity, m \cdot s ⁻¹	6,71	0,03	6,79*	0,04	6,72	0,04	6,79*	0,03
Angle between the oar and the water plane, degrees	42	3,5	44	3,8	43	3,0	49*	3,2
Angle in the elbow joint, degrees	71	4,7	68	3,9	69	3,4	62*	3,9
The boat velocity, m \cdot s ⁻¹	4,8	0,01	4,83*	0,01	4,81	0,02	4,88*	0,04

Note.* – p<0,05

Discussion

The analysis of special literature, the generalization of the leading specialists' experience and our own pedagogical observations allow us to conclude that technical preparation is one of the leading factors influencing on the achievement of high sports results. It was established that technical preparation of qualified canoeists so far is carried out without the sufficient consideration of the new design features of the boats. Quantitative criteria for assessing the rowing locomotion technique on the new design boats are missing, and the methods of technical preparation of sportsmen on these boats require optimization.

As a result of the studies conducted, inconsistencies in characteristics of the rowing technique of leading world sportsmen, on old and new design boats were revealed. For example, the rate of rowing movements on the new design boats is higher by 3,4 st \cdot min⁻¹ (p<0,05), and the stroke cycle duration is lower by 0,10 s (p<0,05). The stroke cycle rhythm structure is also different: at rowing, on the new design boats the rhythm is 2:1, and on the old design boats – 2,2:1. The difference of the oar blade velocity during the carry is defined: on the new design boats it is higher by 0,08 m \cdot s⁻¹ (p<0,05). The average boat velocity in the stroke cycle at rowing on the new design boats is higher by 0,19 m \cdot s⁻¹ (p<0,05).

Quantitative characteristics of technical actions of canoeists allowed us to define the reliable inconsistencies in the kinematic structure of the rowing technique on the new design boats in sportsmen of different qualification. In the leading world rowers, the rate of rowing movements is higher by 1,6 st \cdot min⁻¹ (p<0,05), and the stroke cycle duration is lower by 0,06 s (p<0,05). The temporal structure of the stroke cycle support period is different: in high qualified canoeists, carry duration is higher by 0,04 s (p<0,05), and the oar capture and lift duration is lower by 0,02 s (p<0,05) and 0,02 s (p<0,05), respectively. Oar blade shift for the support period in the leading world sportsmen is higher by 0,08 m (p<0,05) than in the qualified canoeists. The average oar blade velocity for the support period in the leading world sportsmen is higher by 0,07 m s⁻¹ (p<0,05). The most significant difference of the oar blade velocity dynamics is observed in the second half of the carry. In this period, the blade velocity in these sportsmen is higher by 1,8 m s⁻¹ (p<0,05). The average boat velocity in the stroke cycle in the leading world sportsmen is higher by 0,33 m \cdot s⁻¹ (p<0,05).

The methods of improving the rowing technique of qualified canoeists should be based on models of quantitative characteristics rowing locomotion technique with regard to structural interrelationships between them and the changes occurring with the growth of sports qualifications. Such approach provides an objective justification of the means and methods of their application in the training process in accordance with the individual features of each sportsman's technique.

In the investigation process, we received three data groups: confirming data, supplementing data and absolutely new data.

As a result of the studies, we confirmed the data about quantitative indicators of temporal, spatial and spatial-temporal structures of the rowing technique on the old design boats, and concerning the fact that at rowing on the new design boats, the kinematic structure of the rowing technique changed.

The data concerning the kinematic structure of the rowing technique on the new design boats, in particular, concerning the boat velocity dynamics during the stroke cycle, quantitative indicators of rowing rate and stroke length on different competition distances, were supplemented. The new data include: quantitative indicators and evaluation criteria for the rowing technique on the new design boats; statistical models of the

kinematic structure of the rowing technique of canoeists of different qualification on the new design boats; the methods of improving the rowing technique of the qualified canoeists.

Thus, the data obtained as a result of our study provides for planning the content and the direction of the technical preparation of the qualified rowers-canoeists in the contest season, improving and controlling the rowing locomotion technique.

Conclusions

1. Statistical processing of the results of biomechanical analysis of rowing locomotion allowed defining the parameters of the kinematic structure of movements having the most impact on the boat velocity, namely: shift ($r=0,76$) and velocity ($r=0,85$) of the oar blade in the support period, support period duration ($r=0,79$) and carry phase ($r=0,8$), angle between the oar and the water plane in the moment of water capture start ($r=0,71$), angle in the elbow joint of the pulling hand in the moment of the carry phase completion ($r=0,74$).

2. The methods for improving the rowing technique of the qualified canoeists in the contest season were developed. Its typical features are: redistribution of the amount of hours dedicated to technical preparation; directed influence on the improvement of separate elements of technical actions, the use of objective control of quantitative parameters of the kinematic structure of rowing movements.

3. The groove machine used to control spatial characteristics of the blade motion in the support period: the point of water capture start, stroke length, the blade distance from the board in the moment of carry completion, was developed. The system includes the following: the boat marking, remote contact sensors and light indicator. The principle of use of the groove machine with the feedback is based on visual control of the rower's own movements qualified as the efficiency criteria of the rowing locomotion technique.

4. The data obtained as a result of the development pedagogical experiment allowed us to confirm the efficiency of the methods of improving the kinematic structure of the rowing technique of qualified canoeists offered by us. During the experiment the positive changes of characteristics of the kinematic structure of rowing movements occurred: the supporting phase duration decreased by 0,02 s ($p<0,05$), stroke length increased by 0,04 m ($p<0,05$), oar blade velocity in the supporting phase increased by $0,04 \text{ m} \cdot \text{s}^{-1}$ ($p<0,05$), angle between the oar and the water plane in sagittal plane decreased by 6° ($p<0,05$), angle in the elbow joint of the pulling hand, in the moment of carry completion decreased by 7° ($p<0,05$); the average boat velocity for the stroke cycle increased by $0,07 \text{ m} \cdot \text{s}^{-1}$.

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