



Developing an Individual Technical Preparedness Profile for a Highly Qualified Sprint Canoeist Using Biomechanical and Functional Indicators

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Abstract

Background. Technical preparedness in sprint canoeing depends on the coordinated interaction of the athlete, paddle, and boat. Isolated assessment of separate indicators may not reveal the specific factors limiting stroke effectiveness. An individual profile integrating biomechanical and functional data can identify these relationships and support decisions on technique, equipment, and seating configuration.

Objectives. To develop an individual technical preparedness profile of a highly qualified canoeist and substantiate individualized directions for technique, equipment selection, seating calibration, and training.

Materials and Methods. A single-case study involved an international-level canoeist; two additional canoeists provided reference data for selected indicators. Methods included surface electromyography, strain-gauge assessment of stroke parameters with Braca and Erbi paddles, kinematic analysis, 150-m speed testing in Nelo, Vajda, and Plastex boats, analysis of support interactions before and after seating calibration, and strength and functional assessments. The profile was developed through data processing, within-athlete comparison, consistency checking, classification into interpretative levels, and substantiation of coaching decisions.

Results. The algorithm identified strengths in the stability of the paddle attack angle, speed performance in the Plastex and Vajda boats, and support stability after seating calibration. The main reserves concerned force transmission through the “leg–trunk–arm–paddle” chain, trunk stability during the final stroke phase, and shoulder-girdle speed-strength endurance. Compared with Braca, Erbi produced greater work per stroke (73.0 vs 49.3 J), a larger effective stroke portion (45.6 vs 25.8 J), and a higher proportion of effective work (62.3% vs 53.0%). Mean speed was 3.99 m·s⁻¹ in Plastex, 3.95 m·s⁻¹ in Vajda, and 3.80 m·s⁻¹ in Nelo. Seating calibration reduced center-of-pressure displacement in all support zones. No confirmed limiting factors were identified.

Conclusions. Integrating biomechanical and functional indicators into an individual profile provides a scientifically grounded basis for personalizing technical preparation in sprint canoeing.

Keywords: sprint canoeing, technical preparedness, individual profile, biomechanical indicators, electromyography, stroke dynamics, center of pressure, athlete–boat interaction.

Introduction

Technical preparedness in sprint canoeing is one of the key factors of sports performance, because the effectiveness of the stroke cycle determines the athlete's ability to realize strength, functional, and coordination potential in boat velocity over the distance. In the system of canoeist preparation, technical

training should be distinguished as a targeted pedagogical process, whereas technical preparedness reflects the achieved level of the athlete's technical mastery (Altukhov & Shynkaruk, 2026c). In contemporary rowing and paddling biomechanics, technique is considered as an integrated system of interaction between the athlete, paddle, and boat that includes force application to the paddle, the kinematic structure of the stroke, body-position stability, coordinated work of muscle groups, and the ability to maintain an effective movement structure under different intensity modes (Gomes et al., 2015; Michael et al., 2012; Zahálka et al., 2011).

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The use of instrumented paddles, strain-gauge systems, video analysis, surface electromyography, tools for assessing support interactions, and functional monitoring makes it possible to obtain a broad dataset on the canoeist's technique. These methods allow researchers to assess force and work per stroke, the effective part of the stroke cycle, stability of angular characteristics, neuromuscular support of movement, boat velocity, characteristics of body interaction with the boat's support zones, and functional conditions for technique realization (Bonaiuto et al., 2020; Kong et al., 2020; Niu et al., 2019; Trevithick et al., 2007).

At the same time, the availability of a large number of separate biomechanical and functional indicators does not by itself ensure a justified coaching decision. Separate analysis of stroke force, electromyographic activity, kinematic parameters, boat velocity, and support interactions does not provide a complete understanding of which factors limit the technical effectiveness of a specific athlete. Therefore, not only the measurement of individual parameters is relevant, but also the development of a clear algorithm for integrating them into an individual technical preparedness profile.

For C1 sprint canoeing, this issue is especially important because of the asymmetric nature of the motor task caused by one-sided force application from a kneeling position. This specificity creates uneven loading of the body's support structures, trunk-stabilizing muscles, and lower limbs, which requires an individualized analysis of support interactions in the boat. Previous studies show that asymmetric loading in canoeing may be associated both with muscular imbalances and with morphofunctional adaptations of highly qualified athletes to the specific demands of the sport (Štryncl et al., 2021; Álvarez-Yates et al., 2024).

Modern scientific approaches to canoe paddling technique emphasize the need to combine biomechanical, kinematic, dynamic, and functional analyses for an objective assessment of athletes' technical preparedness (Altukhov & Shynkaruk, 2026b). Bibliometric analysis also confirms that current research is mainly focused on separate aspects of stroke biomechanics, kinematics, force dynamics, and sports performance, whereas the issue of forming an individual technical preparedness profile of a canoeist remains insufficiently developed (Altukhov & Shynkaruk, 2026a). Therefore, an approach that makes it possible to integrate heterogeneous indicators into a single interpretive matrix and use it to identify strengths, limiting factors, and priority directions for correction of technique, equipment selection, boat-seat calibration, and training-process planning is scientifically and practically important.

The aim of the study was to form an individual technical preparedness profile of a highly qualified sprint canoeist using biomechanical and functional indicators and to substantiate directions for individual correction of technique, equipment, boat seating position, and the training process.

Materials and Methods

Study Design

The study was conducted as a case-oriented comprehensive biomechanical analysis of the technical preparedness of a qualified sprint canoeist. The methodological basis of the work was the combination of several levels of assessment:

neuromuscular support of the paddling movement, dynamics of force application to the paddle, the kinematic structure of technique, velocity realization of boat movement, support interactions within the "athlete-boat" system, and functional conditions for technique realization.

The individual technical preparedness profile was considered not as a total score, but as a structured interpretive matrix combining indicators of different nature and allowing the identification of the athlete's strengths, technique-limiting factors, and targeted directions for correction. The central position in the profile was occupied by indicators directly related to stroke effectiveness: dynamic parameters of work with Braca and Erbi paddles, kinematic characteristics of the stroke cycle, velocity of Nelo, Vajda, and Plastex boats over the control segment, and stability of support interactions after individual calibration of the athlete's seating position in the boat.

The methodological logic of profile formation included the following sequential stages: primary registration of indicators in each diagnostic block; quality control of primary data; selection of suitable stroke cycles, series, or test attempts; calculation of mean values, variability, and stability; intra-individual comparison of results under different testing conditions; identification of indicators with positive or limiting significance for technique; formation of the final interpretive matrix; and substantiation of coaching decisions regarding paddle selection, boat selection, seating position, technical emphases, and training effects.

Study Participants

The main participant was a highly qualified athlete, Master of Sports of Ukraine of International Class, and a member of the national sprint canoeing team of Ukraine: male, 23 years old, height 186 cm, body mass 88 kg. At the time of assessment, the athlete was at the stage of maximal realization of individual capabilities and had experience in international competitions.

Two qualified athletes of the same specialization and comparable level of mastery were additionally included for reference interpretation of selected strength, speed-strength, and functional indicators. Their data were used only as a basis for individual interpretation of the main athlete's results and were not used for between-group statistical comparison.

Research Organization

The study was organized as a sequential comprehensive assessment of the athlete under laboratory and specific on-water conditions. First, neuromuscular support of the paddling movement was assessed during specialized tasks on paddling ergometers. Then, dynamic stroke parameters were analyzed during work with two paddles: Braca and Erbi. After that, kinematic analysis of technique and assessment of boat velocity characteristics were performed while paddling in Nelo, Vajda, and Plastex boats.

A separate stage was devoted to the analysis of support interactions in the boat before and after individual calibration of the athlete's seating position. Calibration included correction of the support zones and the production of individual pads under the forefoot, a knee pad, and a fixing footrest. After that, changes in the area and direction

of center-of-pressure displacement and the stability of the main support points were assessed.

The final stage included additional assessment of strength and speed-strength capacity, functional state of the respiratory system, body composition, hemodynamic indicators, and heart rate variability. These blocks were used as auxiliary blocks to explain the functional conditions for technique realization, but they did not replace the main biomechanical analysis of the paddle, boat, stroke cycle, and support interactions.

Research Methods

The biomechanical block of the study included electromyographic, strain-gauge, and kinematic analysis of the paddling movement. Primary data were processed according to the type of registration. For each block, a separate data matrix was formed, in which the rows represented test tasks, series, or individual stroke cycles, and the columns represented registered and derived indicators. Further summarization was performed in the specialized software of the corresponding hardware-software systems with additional spreadsheet processing in Microsoft Excel.

Bioelectrical activity of the leading muscle groups was registered by surface electromyography using the “M-TEST” electroneuromyographic system (DX-System, Ukraine). The pectoral muscles, biceps and triceps brachii, deltoid muscles, rectus abdominis, rectus femoris, and teres major muscles of the back were assessed with bilateral electrode placement and real-time visualization of the athlete’s muscle activity. Testing was performed during three specialized tasks: 1-min aerobic work on a paddling ergometer, 30-45 s acceleration on a paddling ergometer, and work in a statodynamic mode on the specialized “Gorka” kayak paddling simulator. For each muscle group, the amplitude of bioelectrical activity, mV, and the percentage contribution to total work were determined. Leading and insufficiently involved muscle groups were determined by the percentage contribution within each test task, and the neuromuscular profile was summarized according to the rank structure of muscle activity across the three tests.

Dynamic stroke parameters were determined during series of 20 consecutive strokes using two paddle models: Braca and Erbi, equipped with strain-gauge sensors for blade load. Registration and primary analysis of the strain-gauge signal were performed in the specialized software of the corresponding hardware-software system. For each stroke, paddle-blade load, work per stroke, the effective part of the stroke, and the percentage of the effective part of the stroke relative to total work were determined. The effective part of the stroke was calculated as the part of the work performed in the segment of the stroke cycle where blade load exceeded 70% of the maximum value in that stroke. The percentage of the effective part of the stroke characterized the athlete’s ability to maintain productive effort in the propulsive part of the stroke cycle. Braca and Erbi paddles were compared by mean values, variability, and stability of dynamic indicators, which allowed assessment of the efficiency of force transfer from the athlete to the boat (Gomes et al., 2015; Kong et al., 2020; Michael et al., 2012).

Kinematic analysis of technique was performed using video recordings followed by frame-by-frame goniometric analysis of stroke-cycle phases with the Contemphas mobile

biomechanical system and Contemphas movement-analysis software. The analysis was conducted during paddling in Nelo, Vajda, and Plastex boats in combination with Braca and Erbi paddles. Six to eight technically complete stroke cycles in each series were included in the processing when the phases of blade entry into the water, the propulsive part of the stroke, and stroke completion with transition to paddle recovery were clearly identifiable. For each cycle, paddle attack angle, trunk inclination, knee-joint angle of the swing leg, and knee-joint angle of the support leg were determined. Analysis of these indicators in three phases of the stroke cycle made it possible to evaluate not only the magnitude of angular parameters but also the reproducibility of the movement structure under different stroke conditions (Tilden et al., 2024; Zahálka et al., 2011).

For strain-gauge and kinematic indicators, the mean value, standard deviation, coefficient of variation, and coefficient of stability were calculated. The coefficient of variation was defined as the ratio of the standard deviation to the mean value, expressed as a percentage. The coefficient of stability was calculated as the difference between 100% and the coefficient of variation and was used to assess the repeatability of stroke cycles for the corresponding parameter. Higher coefficient-of-stability values were interpreted as better reproducibility of the corresponding element of the movement structure.

Boat velocity characteristics were determined while the athlete covered a 150 m control segment with a task emphasizing speed and power of distance completion (Contemphas mobile biomechanical system with video-analytical registration of spatiotemporal movement characteristics; additional spreadsheet data processing in Microsoft Excel). Nelo, Vajda, and Plastex boats were compared by maximum velocity in the propulsive part of the stroke cycle, minimum velocity during paddle recovery, and mean velocity over the control segment. This block was used to determine the individual suitability of the boat for the specific athlete, considering velocity realization of the paddling movement.

Support interactions between the athlete’s body and the boat were assessed in three support zones: swing-leg foot, support-leg knee, and support-leg foot on the footrest (strain-gauge system for pressure-distribution and center-of-pressure displacement analysis; Tekscan I-Scan pressure mapping system, Tekscan, USA). The area of center-of-pressure displacement, anteroposterior and mediolateral center-of-pressure oscillations, displacement-vector direction, and pressure force in each support zone were determined. The assessment was performed before and after individual calibration of the athlete’s seating position in the boat. This block was used to evaluate the stability of the “athlete-boat” system, asymmetry of support interactions, and effectiveness of force transfer under the specific posture of a canoeist (Štryncl et al., 2021; Álvarez-Yates et al., 2024).

Strength and speed-strength capacity were assessed using tests that characterize the functional capabilities of the lower limbs and shoulder girdle: “barbell squats for 30 s,” “20 vertical jumps,” “bench pull to the chest,” and “standing pull to the chest.” For jump tests, the OptoJump optoelectronic system (OptoJump, Microgate, Italy; OptoJump Next software) was used; it enables determination of jump height, duration of support and flight phases, rhythm,

tempo, and power in jump tests. For barbell exercises, a linear displacement sensor / movement-power analyzer was used. The number of repetitions, mean, maximum, and peak power, relative power, peak force, movement-speed characteristics, and fatigue resistance were recorded.

The functional state of the respiratory system was assessed by spirometry with registration of a series of forced inspirations using hardware-software tools for assessing external respiratory function and respiratory-muscle strength (POWERbreathe K5 mobile ergospirometry system with Breathe-Link software). Mean and maximum inspiratory power, mean and maximum inspiratory velocity, and mean and maximum inspiratory volume were analyzed. These indicators were used to determine the functional reserve of the respiratory system and the feasibility of including individualized breathing exercises in the athlete's preparation.

Body composition was determined by bioimpedance analysis (Tanita MC-780MA body composition analyzer, Tanita Corporation, Japan; Tanita / GMON software). Body mass index, fat and fat-free mass, active cell mass, body-water compartments, basal metabolic rate, phase angle, and skeletal muscle mass were assessed. Hemodynamic indicators were considered an auxiliary functional block of the individual profile and were used to characterize the conditions of technique realization, not as an independent criterion of technical preparedness.

Heart rate variability (CardioPlus diagnostic system, Metekol, Ukraine) was analyzed using a short-term 5-min electrocardiographic recording (lead I, sensitivity 10 mm/mV) at rest in a sitting position, according to standard requirements for short-term registration (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Before calculating the indicators, the quality of the primary RR series was controlled by checking the correctness of registration and the presence of extrasystolic intervals. Records with pronounced rhythm disturbances or incorrect registration were not included in further analysis. Heart rate, SDNN, coefficient of variation of heart rhythm, stress index (SI), centralization index (CI), activity index of regulatory systems (PARS), power of HF, LF, and VLF waves, and total spectral power (TP) were calculated according to the method of mathematical analysis of heart rhythm by R. M. Baevisky (Baevisky & Chernikova, 2017), which includes construction of a cardiointervalogram, histogram of RR-interval distribution, and scattergram (Poincare plot) for qualitative control of recording homogeneity. Model ranges of HRV indicators were formed based on the database of assessments of qualified sprint canoeists at the Research Institute of the National University of Ukraine on Physical Education and Sport and were used as an indicative range for qualitative interpretation. Cardiorhythmographic indicators were used as an auxiliary functional block of the individual profile and were interpreted considering the case-oriented design, the stage of the training process, and the need to control training load and recovery (Plews et al., 2013).

Algorithm for Developing an Individual Profile of Technical Preparedness

The individual profile of technical preparedness was developed as a structured interpretative matrix integrating

biomechanical and functional indicators of different types. The profile was not treated as a composite integral score because the indicators under investigation had different units of measurement, differed in biomechanical significance, and varied in the degree of their direct association with stroke effectiveness.

No weighting coefficients were applied. In the practical interpretation, priority was given to indicators that directly characterized force transmission to the paddle, stability of the stroke cycle, boat speed performance, and support interactions within the "athlete – boat" system.

At the first stage, data preparation, recording, and primary processing were performed. Testing conditions, the athlete's functional state before assessment, the sequence of tests, measurement-equipment settings, and equipment parameters were standardized. Following primary data recording, the completeness and correctness of the signals were verified, technical noise and distortions were identified, invalid recording fragments were excluded, and technically complete movement cycles were selected. Mean values, variability and stability indices, work per stroke, the effective portion of the stroke, and speed and support characteristics were then calculated.

The obtained indicators were grouped according to the main profile components: neuromuscular support of the stroke, dynamics of force application to the paddle, kinematic structure of the stroke cycle, boat speed performance, support interactions in the boat, and the athlete's functional state. Key informative indicators were identified for each component: the amplitude and relative contribution of muscle groups, work per stroke, the effective portion of the stroke, the proportion of effective work, paddle attack angle, trunk inclination, angular characteristics of the lower limbs, mean and maximum boat speed, the area and direction of center-of-pressure displacement, as well as strength, respiratory, hemodynamic, and cardiorhythmographic indicators.

At the second stage, within-athlete comparisons were performed across test tasks, paddle and boat models, and before and after seating calibration. The consistency of findings across the different diagnostic domains was then examined. An individual indicator was considered practically meaningful when its changes were reproducible across repeated trials, supported by findings obtained using other methods, or associated with changes in work per stroke, technique stability, or boat speed.

At the third stage, the results were operationally classified into four interpretative levels: "strength," "acceptable level," "reserve for correction," and "limiting factor." Classification was not performed by mathematically combining the indicators into a single score but by comparing them with model values, reference data, within-athlete results obtained under different testing conditions, and qualitative biomechanical interpretation.

Strengths included indicators that corresponded to model or reference values, demonstrated high reproducibility, and were associated with greater stroke effectiveness or better boat speed performance. Indicators were classified as acceptable when they met the functional requirements of stroke execution, showed no pronounced unfavorable deviations, and did not limit technical performance.

Reserves for correction included indicators characterized by lower stability, less effective force transmission, reduced

boat speed performance, a lower relative contribution of individual muscle groups, or moderate asymmetry of support interactions, whose influence on performance required further confirmation. Limiting factors included recurrent unfavorable characteristics supported by findings from several interrelated diagnostic domains or directly associated with a reduction in the effective portion of the stroke, impaired stability of the stroke cycle, or lower boat speed.

At the same stage, the results were integrated into a structured individual profile in which the current status, practical interpretation, and correction priority were determined for each component.

At the fourth stage, the individual profile was used to substantiate coaching decisions concerning paddle and boat selection, maintenance of the calibrated seating configuration, correction of trunk position during the final phase of the stroke, improvement of force transmission through the “leg-trunk-arm-paddle” chain, development of speed-strength endurance of the shoulder girdle, optimization of inspiratory mechanics, and monitoring of the balance between training load and recovery.

Following the implementation of corrective interventions, repeated standardized testing and updating of the individual profile were planned. Positive changes in the target indicators, together with improvements in work per stroke, technique stability, or boat speed, were regarded as confirmation of the validity of the initial interpretation and the coaching decision adopted.

The classification of profile components is operational rather than normative and is intended for within-athlete analysis. Classification of an indicator as a limiting factor cannot be based on a single isolated value or solely on its deviation from a model range. The determining criteria are the reproducibility of the result, its consistency with findings from other diagnostic domains, and its association with indicators of stroke effectiveness or boat speed (Fig. 1).

Justification of Model Values

The model values used to interpret selected indicators of the individual profile were formed based on a long-term database of comprehensive assessments of athletes of the Ukrainian national kayaking and canoeing team conducted at the Research Institute of the National University of Ukraine on Physical Education and Sport (2010-2025; $n = 750$ person-assessments for each method of assessing the functional state of athletes).

Model ranges were formed by summarizing repeated assessments of national-team athletes, taking into account specialization, level of sports qualification, stage of preparation, and correspondence of indicators to the competitive demands of sprint canoeing. Model values were not considered universal norms for the entire population of athletes; they were used as internal reference ranges for interpreting the individual indicators of a highly qualified canoeist.

When forming the individual profile, model values were used only as an auxiliary criterion for assessing the correspondence of selected functional and biomechanical indicators to the level of national-team athletes. The main principle of interpretation remained intra-individual comparison of the athlete's results under different testing conditions: between Braca and Erbi paddles, between Nelo, Vajda, and Plastex boats, and before and after individual calibration of the seating position in the boat. This approach made it possible to avoid incorrect generalization and to use model indicators as a tool for individualizing technical preparation.

Statistical Analysis

Statistical processing was performed using descriptive statistics in Microsoft Excel. For quantitative indicators, the arithmetic mean, standard deviation, coefficient of variation, coefficient of stability, and absolute and relative differences between testing conditions were calculated.

The coefficient of variation was defined as the ratio of the standard deviation to the mean value, expressed as a percentage. Values below 30% were considered a sign of relative homogeneity of the measurement series, and values below 10% were interpreted as low dispersion. The coefficient of stability was defined as the difference between 100% and the coefficient of variation. Values above 90% were interpreted as high stability, 85-90% as above average, 75-85% as average, 70-75% as below average, and below 70% as low stability.

For electromyographic indicators, muscle groups were ranked by their percentage contribution to total work in each task, followed by calculation of the sum of ranks across the three tests. The effectiveness of paddles, boats, and changes in seating position was compared using absolute and relative differences in mean values, coefficients of variation and stability, and qualitative biomechanical interpretation of the observed changes.

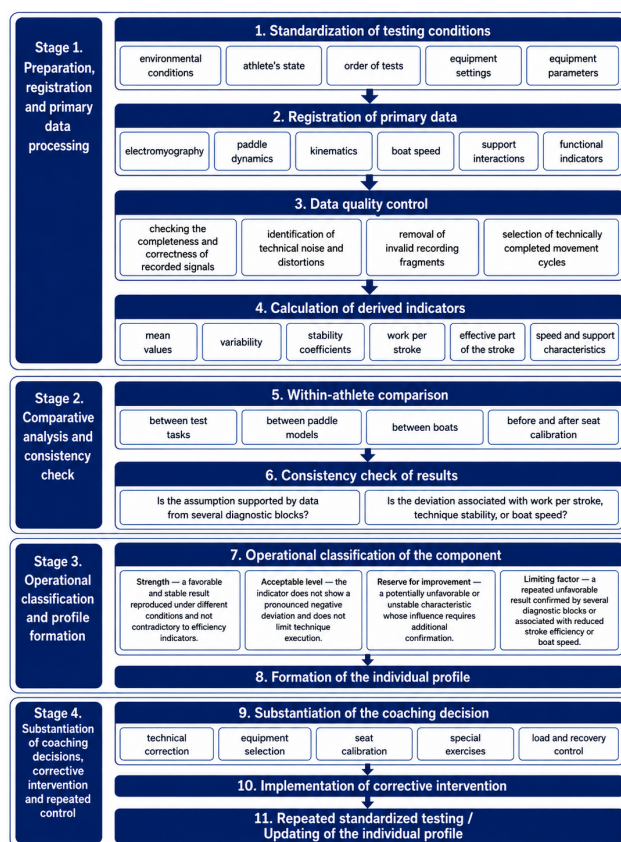


Fig. 1. Algorithm for developing an individual profile of a canoeist's technical preparedness and substantiating coaching decisions

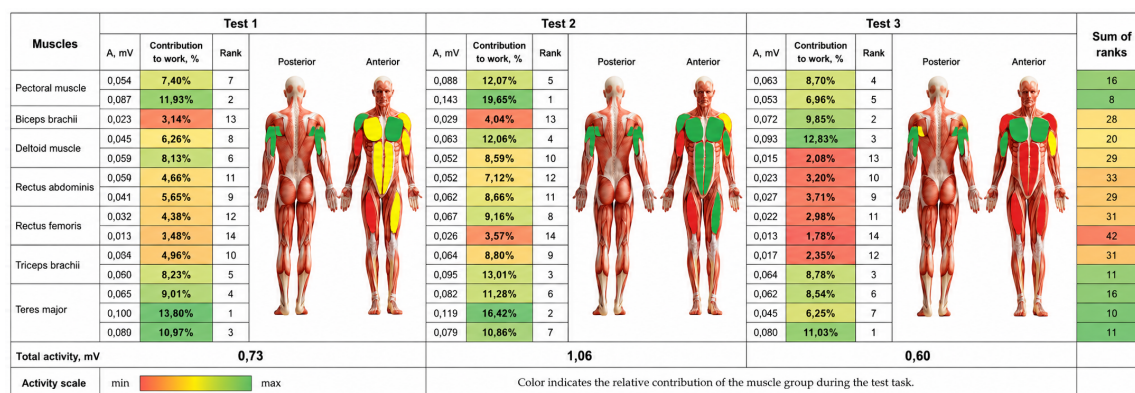


Fig. 2. Bioelectrical activity of leading muscle groups of the canoeist during three specialized test tasks (n = 1, Master of Sports of Ukraine of International Class)

Considering the case-oriented design of the study, the main analysis was aimed not at testing group statistical hypotheses, but at intra-individual comparison of the athlete's indicators under different testing conditions. Individual stroke cycles, movement series, and test attempts were used to assess repeatability, stability, and variability of indicators, but were not considered independent observations for between-group statistical analysis. Therefore, methods of statistical hypothesis testing were not applied.

Limits of Generalization

The results of the study characterize the individual profile of a specific highly qualified canoeist and cannot be directly extrapolated to a broader population of athletes without further experimental verification, because the purpose of the study was not to establish universal norms but to demonstrate an algorithm for integrating heterogeneous indicators for individualizing technical preparation.

Results

The results of the comprehensive assessment sequentially characterized individual components of the technical preparedness of the qualified sprint canoeist: neuromuscular support of the paddling movement, effectiveness of force

application to the paddle, kinematic stability of the stroke cycle, boat velocity characteristics, support interactions within the "athlete-boat" system, strength capacity, and functional state. Each block was interpreted in terms of its contribution to the formation of the athlete's individual technical preparedness profile and the identification of technique-limiting factors.

Analysis of bioelectrical activity of the leading muscle groups showed that the structure of muscle involvement changed depending on the nature of the test task. Total activation of the neuromuscular system was 0.73 mV during aerobic work on the paddling ergometer, increased to 1.06 mV during acceleration, and decreased to 0.60 mV in the statodynamic mode on the specialized "Gorka" kayak paddling simulator (Table 1).

Table 1 shows that as work intensity increased, the structure of muscle activation changed: in the acceleration test, total activity was highest, whereas during statodynamic work a more localized redistribution of activity occurred toward the shoulder-girdle muscles, pectoral muscles, and back muscles. For the individual profile, this indicates the need to improve coordinated force transfer from the support links through the trunk to the paddle.

In the first test task, the greatest contribution to total work was made by the teres major muscles of the back, the left pectoral muscle, and the triceps brachii. Minimal

Table 1. Neuromuscular profile of the paddling movement according to electromyography (n = 1, Master of Sports of Ukraine of International Class)

Test task	Total activity, mV	Leading muscle groups	Muscles with minimal contribution	Relevance to profile formation
Aerobic work, 1 min	0.73	Teres major muscles of the back; left pectoral muscle; triceps brachii	Right biceps brachii; right rectus femoris	Basic structure of muscular support of the stroke movement under moderate intensity was identified
Acceleration, 30–45 s	1.06	Pectoral muscles; rectus abdominis; left biceps brachii; left rectus femoris	Right biceps brachii; right rectus femoris	Maximum neuromuscular mobilization and muscle groups more actively involved during intensive work were revealed
Statodynamic work	0.60	Pectoral muscles; right biceps brachii; triceps brachii; right teres major muscle of the back	Selected lower-limb muscles	Redistribution of muscle activity in the propulsive part of the stroke cycle and reserves for coordination of the trunk, shoulder girdle, and support links were identified

activity was demonstrated by the right biceps brachii and the right rectus femoris. In the second test, which modeled acceleration, the contribution of the pectoral muscles, rectus abdominis, left rectus femoris, and left biceps brachii increased (Fig. 2).

In the third test, which modeled the statodynamic mode of specialized work, the greatest activity was concentrated in the pectoral muscles, right biceps brachii, triceps brachii, and right teres major muscle of the back. This indicates the leading participation of these muscle groups in force application during the propulsive phase of the stroke. Leading muscle groups were identified according to the largest percentage contribution to total bioelectrical activity during each test task. Muscles with minimal contribution were considered potential reserves for improving the coordination of the support links, trunk, and shoulder girdle in the paddling movement.

Thus, the electromyographic block showed that the neuromuscular component of the athlete's individual profile is characterized by the leading participation of the back muscles, pectoral muscles, and shoulder-girdle muscles in supporting the paddling movement. The lower contribution of selected lower-limb muscles indicates a reserve for improving sequential force transfer in the biomechanical chain "leg - trunk - arm - paddle."

Comparative analysis of dynamic stroke parameters showed differences in the nature of effort realization when using Braca and Erbi paddles. With the Braca paddle, the athlete demonstrated a higher mean blade load of 20.5 kg with a high coefficient of stability of 93.5%. At the same time, mean work per stroke was 49.3 J, the effective part of the stroke was 25.8 J, and the share of effective work in total work was 53.0% (Fig. 3).

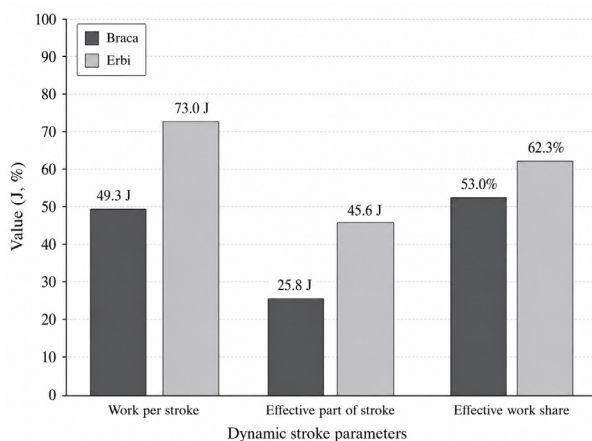


Fig. 3. Comparison of Braca and Erbi paddle effectiveness according to key dynamic stroke indicators (n = 1, Master of Sports of Ukraine of International Class)

When using the Erbi paddle, mean blade load was lower at 18.5 kg; however, work per stroke increased to 73.0 J, the effective part of the stroke increased to 45.6 J, and the share of effective work increased to 62.3%. For three of the four main parameters, the coefficient of stability was higher when using the Erbi paddle.

Thus, the dynamic block showed that the Braca paddle provided a higher mean blade load, whereas the Erbi paddle facilitated more effective effort realization according to work

per stroke, the effective part of the stroke, and the share of effective work. For the individual profile, this means that the limiting factor was not the athlete's ability to generate force, but the efficiency of its transfer throughout the stroke cycle. Therefore, stroke-dynamics indicators provided the basis for recommending gradual adaptation of the athlete to the Erbi paddle.

Goniometric analysis of stroke technique in boats from different manufacturers showed an overall high level of stability in key angular parameters. The coefficient of stability of the paddle attack angle was 96.6-98.3%, indicating high reproducibility of paddle position during entry and force application. Stability of trunk inclination in the first phase of the stroke was 94.5-98.2%, and stability of the angular indicators of the swing-leg knee joint in the first phase was 96.8-98.5%.

Mean values of the paddle attack angle ranged from 59.3° to 63.0°. Trunk inclination decreased from the first to the third phase of the stroke, from 41.5-57.1° to 30.2-47.5°. At the same time, the angle in the swing-leg knee joint increased from 84.0-91.0° in the first phase to 135.0-150.0° in the third phase, whereas the angle in the support-leg knee joint decreased from 118.0-134.0° to 77.0-88.0°. The lowest stability was recorded for trunk inclination in the third phase of the stroke - 85.2-93.8% - which makes it possible to identify the final phase of the stroke cycle as a zone of technical reserve.

Over the 150 m control segment, the highest velocity indicators were recorded when paddling in the Plastex boat. Maximum boat velocity in the support phase of the stroke was 5.15 m/s in the Nelo boat, 5.24 m/s in the Vajda boat, and 5.30 m/s in the Plastex boat. Minimum velocity in the non-support phase was also highest in the Plastex boat at 2.68 m/s, whereas it was 2.65 m/s in the Vajda boat and 2.24 m/s in the Nelo boat. Mean velocity over the control segment was 3.80 m/s in Nelo, 3.95 m/s in Vajda, and 3.99 m/s in Plastex (Table 2).

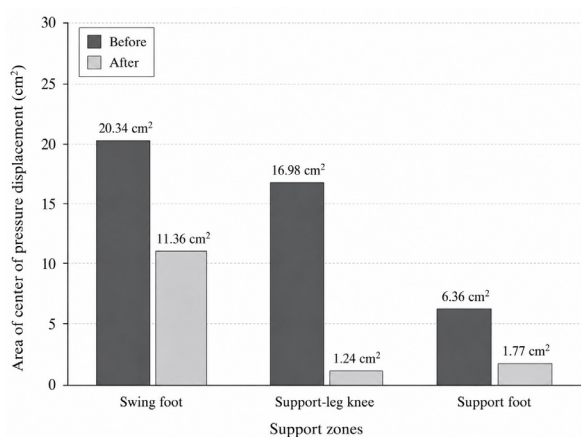
The kinematic component of the profile demonstrated a high level of stability of the paddle attack angle and lower-limb positions in most phases of the stroke cycle. The least stable indicator was trunk inclination in the third phase of the stroke, which allows the final phase to be identified as a zone of technical reserve. The velocity block showed that the Vajda and Plastex boats better matched the athlete's individual technical characteristics, whereas in the Nelo boat a greater decrease in velocity was observed during the non-support phase. For profile formation, this had practical significance because it linked technical efficiency not only with the athlete's movements but also with the individual suitability of sports equipment.

Three-zone analysis of support interactions showed that before individual seat calibration the athlete demonstrated asynchronous effort application within the "athlete-boat" system. This was manifested by increased pressure on the support-leg knee, displacement of the pressure vector of the swing foot toward the outer edge of the foot, and insufficiently effective pressure of the support foot on the footrest (Fig. 4).

After individual seat calibration, substantial improvement in the stability of support interactions was registered. The area of center-of-pressure displacement in the swing-foot zone decreased from 20.34 to 11.36 cm²; in the support-leg knee zone, from 16.98 to 1.24 cm²; and

Table 2. Key biomechanical indicators of equipment and the stroke cycle (n = 1, Master of Sports of Ukraine of International Class)

Assessment block	Indicator	Main result	Relevance to profile formation
Stroke dynamics with Braca paddle	Blade load	20.5 kg; Cst = 93.5%	High force load with lower work effectiveness
Stroke dynamics with Erbi paddle	Work per stroke; effective part of the stroke	73.0 J; 45.6 J	Better realization of effort throughout the stroke
Paddle attack angle	Coefficient of stability	96.6–98.3%	High reproducibility of a basic technical element
Trunk inclination in the third phase	Coefficient of stability	85.2–93.8%	Zone of technical reserve
Nelo boat	Mean velocity	3.80 m/s	Lower individual suitability according to velocity characteristics
Vajda boat	Mean velocity	3.95 m/s	Suitable equipment option for the athlete
Plastex boat	Mean / maximum velocity	3.99 m/s; 5.30 m/s	Best velocity characteristics for the athlete

**Fig. 4.** Changes in center-of-pressure displacement area in support zones before and after individual seat calibration (n = 1, Master of Sports of Ukraine of International Class)

in the support-foot zone, from 6.36 to 1.77 cm². The most pronounced reduction in the area of center-of-pressure displacement was observed in the support-leg knee zone, where the indicator decreased by 13.7 times (Fig. 5).

Anteroposterior center-of-pressure oscillations also decreased in all support zones: in the swing-foot zone from 15.20 to 10.63 cm, in the support-leg knee zone from 11.85 to 3.20 cm, and in the support-foot zone from 3.07 to 1.40 cm. Mediolateral oscillations decreased from 4.37 to 2.11 cm, from 2.90 to 0.95 cm, and from 5.16 to 2.81 cm, respectively.

The obtained results showed that individual seat calibration substantially increased the stability of support interactions within the “athlete-boat” system.

For the formation of the individual profile, this means that the seating position in the boat is not an auxiliary organizational factor but an independent biomechanical reserve for improving technical efficiency. Therefore, center-of-pressure displacement indicators were included in the profile as criteria of support-interaction stability and force-transfer effectiveness.

Results of strength and speed-strength tests showed a sufficient level of preparedness of the lower limbs and

shoulder girdle for realization of an effective paddling movement: in the “barbell squats for 30 s” test, the athlete completed 34 repetitions with a mean power of 356.9 W, peak power of 654.4 W, and relative power of 4.1 W/kg; in the “20 vertical jumps” test, mean power was 1266.1 W, peak force was 1886.7 N, and relative power was 14.4 W/kg; in the “bench pull to the chest” and “standing pull to the chest” tests, 56 and 40 repetitions were recorded, respectively, with mean power values of 369.6 and 472.8 W and peak power values of 870.2 and 916.8 W. Spirometric testing showed high values of respiratory potential indicators: mean and maximum inspiratory power were 178.06 and 203.13 cm H₂O, inspiratory velocity was 9.47 and 10.63 L/s, and inspiratory volume was 4.81 and 5.52 L, respectively. This indicates a sufficient functional reserve of the respiratory system but points to the feasibility of further optimization of inspiratory mechanics.

According to bioimpedance analysis, the athlete’s body mass index was 22.45 kg/m², fat mass was 26%, active cell mass was 51%, and phase angle was 10.68°. Hemodynamic and cardiorythmographic indicators supplemented the characterization of the athlete’s current functional state: heart rate was 66 beats/min, cardiac output was 5.32 L/min, reserve coefficient was 81.9%, coefficient of variation of heart rhythm was 21.2%, stress index was 9 conventional units, and total spectral power was 6974 ms². The HRV spectral structure was characterized by predominance of the HF component (50.2%) over LF (44.4%) and VLF (5.3%); the centralization index was 1.0, and the activity index of regulatory systems was 6 conventional units. This combination of indicators points to tension of adaptive mechanisms and possible functional overstrain, which should be considered when planning loads, recovery, and further dynamic monitoring.

The functional block showed that strength, speed-strength, and respiratory potential generally created sufficient conditions for realization of paddling technique. At the same time, the remaining reserves were development of speed-strength endurance of the shoulder girdle, optimization of inspiratory mechanics, and control of the balance between load and recovery using cardiorythmographic indicators. These data were included in the individual

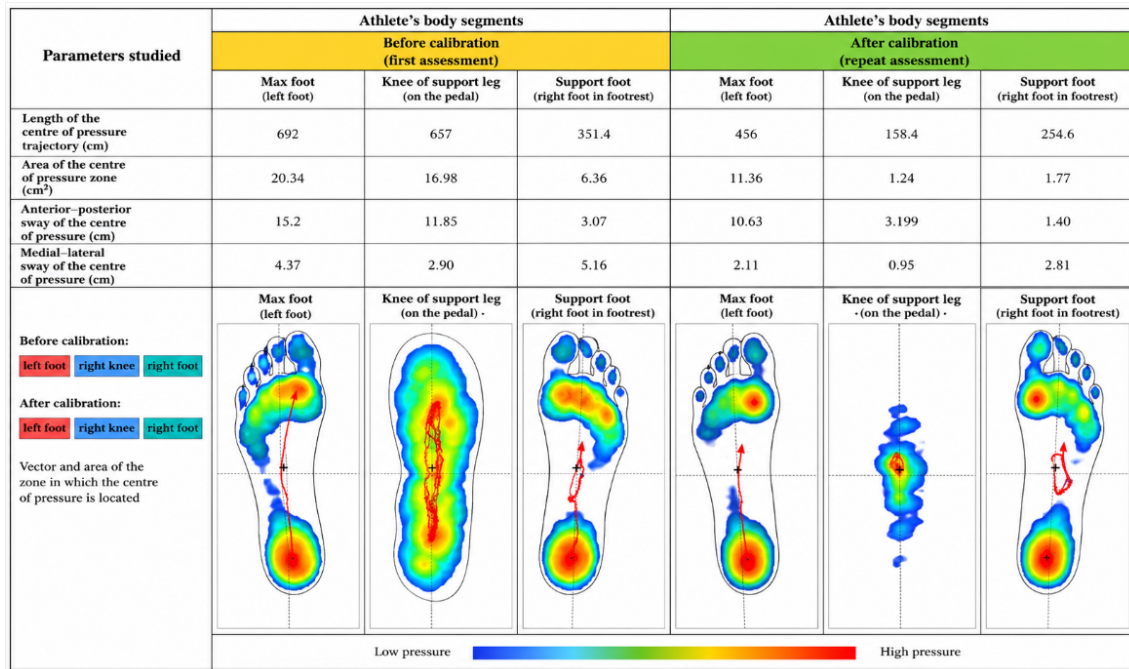


Fig. 5. Support-interaction indicators between the athlete's body and the boat before and after individual seat calibration (n = 1, Master of Sports of Ukraine of International Class)

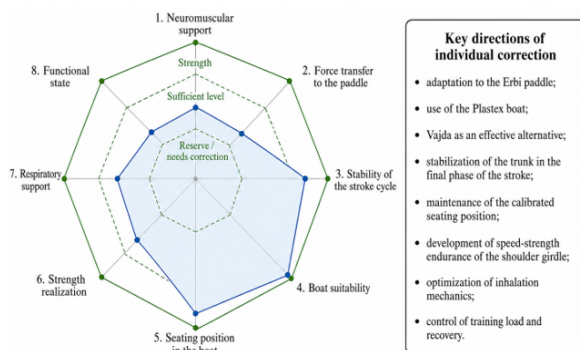


Fig. 6. Individual technical preparedness profile of the highly qualified canoeist based on the results of the comprehensive assessment

profile as a functional context that clarifies the conditions for realizing technical mastery but does not replace the main biomechanical analysis of the stroke, equipment, and support interactions.

Generalization of the results of all diagnostic blocks made it possible to form an individual technical preparedness profile of the canoeist, combining neuromuscular, dynamic, kinematic, velocity-related, support-related, strength, and functional characteristics. The profile is not reduced to a single indicator or an integral score; rather, it reflects the relationship between strengths, limiting factors, and practical reserves for improving technique (Fig. 6).

The formed individual profile showed that the athlete's strengths were high stability of basic elements of the stroke cycle, sufficient strength capacity, improved stability of support interactions after individual seat calibration, and high velocity realization of technique in the Plastex and

Vajda boats. The main reserves were improving force-transfer efficiency in the "leg - trunk - arm - paddle" chain, stabilizing trunk position in the final stroke phase, further adaptation to the Erbi paddle, development of speed-strength endurance of the shoulder girdle, optimization of inspiratory mechanics, and control of recovery dynamics during the training process (Table 3).

Discussion

An individual profile of a canoeist's technical preparedness should be developed not by summing separate test indicators, but by interpreting their functional interrelationships. Stroke effectiveness depends on the coordination of neuromuscular activation, force application to the paddle, kinematic stability, support interactions, and the translation of these factors into boat speed. Accordingly, the diagnostic value of an indicator increases when its deviation is confirmed by several methods and is associated with changes in work per stroke, technical stability, or boat speed. This principle corresponds to the current understanding of technical preparedness as a multicomponent system and makes it possible to distinguish the strengths, reserves for correction, and potential limiting factors of an individual athlete (Altukhov & Shynkaruk, 2026b; Shynkaruk & Altukhov, 2026).

The electromyographic data confirmed the leading role of the back, pectoral, and shoulder-girdle muscles, which is consistent with the findings of Trevithick et al. (2007). From a biomechanical perspective, this can be explained by the fact that the propulsive effort during the stroke is generated not through the isolated action of the upper limb, but through the sequential transmission of mechanical impulse from the support segments through the pelvis and trunk to the shoulder girdle, arm, and paddle. The contribution of the lower limbs to paddle force and boat

Table 3. Individual Profile of Technical Preparedness of the Examined Canoeist

Component of technical preparedness	Main informative indicators	Interpretation	Practical recommendations
Neuromuscular organization of the paddling movement	Ranking structure of electromyographic activity in three sport-specific tests; predominant activity of the back, pectoral, and shoulder-girdle muscles; lower relative contribution of individual lower-limb muscles	The predominant involvement of the trunk and shoulder-girdle muscles represents a well-developed component. The lower contribution of individual lower-limb muscles is considered a preliminary reserve for improving coordination rather than a confirmed local strength deficit.	Improve the coordination of force transmission through the “support segments–pelvis–trunk–shoulder girdle–paddle” chain. Confirm this interpretation using synchronized on-water electromyographic, kinematic, and force measurements.
Dynamic structure of the stroke	Braca: blade load, 20.5 kg; work, 49.3 J; effective portion of the stroke, 25.8 J; proportion of effective work, 53.0%. Erbi: 18.5 kg, 73.0 J, 45.6 J, and 62.3%, respectively	The ability to generate force was classified as an adequate level. The greater work and effective portion of the stroke obtained with the Erbi paddle represent a promising reserve for improving effectiveness that requires repeated verification.	Conduct a standardized period of adaptation to the Erbi paddle. Reassess work per stroke, stroke rate, kinematics, stability across stroke series, and boat speed. Peak or mean blade load should not be used as the sole criterion for paddle selection.
Kinematic stability	Stability of the paddle attack angle, 96.6–98.3%; stability of trunk inclination during the third phase, 85.2–93.8%	Reproducibility of the paddle attack angle is a strength. Variability of trunk position during the final phase represents a reserve for improvement, whose significance should be verified in relation to stroke dynamics and speed loss.	Use synchronized video and strain-gauge feedback. Correct only the component of trunk variability that is accompanied by reduced effective work or increased speed loss.
Individual boat suitability	Mean speed over 150 m: Nelo, 3.80 m·s ⁻¹ ; Vajda, 3.95 m·s ⁻¹ ; Plastex, 3.99 m·s ⁻¹ . Maximum speed: 5.15, 5.24, and 5.30 m·s ⁻¹ , respectively	Under the testing conditions, Plastex and Vajda were favorable individual options. Nelo represents a potential reserve for optimizing equipment suitability, but not a confirmed limiting factor.	Repeat the comparison with randomized trial order, identical stroke-rate instructions, and control of environmental conditions. Make the final selection after a series of repeated trials.
Support interactions and seating configuration	Reduction in the center-of-pressure displacement area: swing-leg foot, from 20.34 to 11.36 cm ² ; support-leg knee, from 16.98 to 1.24 cm ² ; support foot, from 6.36 to 1.77 cm ²	The response to seating calibration is a strength of the proposed individualized configuration. However, a direct increase in propulsive effectiveness was not separately demonstrated.	Maintain the individualized seating configuration provided that no discomfort occurs. In subsequent assessments, monitor the center of pressure, paddle force, kinematics, and boat speed synchronously.
Strength and speed-strength capacity	Power in squat and jump tests; indicators of pulling exercises performed in lying and standing positions; ability to reproduce sport-specific force repeatedly	General strength capacity was classified as an adequate level. The ability to maintain effective shoulder-girdle performance over time represents a reserve for improvement.	Develop sport-specific speed-strength endurance while monitoring the preservation of technical structure and the effective portion of the stroke under fatigue.
Respiratory support	Inspiratory power, flow rate, and volume; pattern of respiratory-maneuver execution	Respiratory capacity was classified as an adequate level and was not identified as a leading limiting factor. The forceful inspiratory pattern represents a complementary reserve for improving movement economy.	Improve the coordination of breathing with the structure of the stroke cycle. Respiratory indicators should not be interpreted separately from sport-specific performance and technical stability.
Functional state and recovery	Heart rate, hemodynamic indicators, time- and frequency-domain HRV characteristics, stress index, and index of regulatory systems activity	Single measurements characterize the current functional context but do not allow functional strain to be diagnosed or technical skill to be assessed directly.	Perform serial measurements under standardized conditions and compare them with training load, sleep, subjective well-being, sport-specific performance, and technical stability.

Table 3. Continued

Component of technical preparedness	Main informative indicators	Interpretation	Practical recommendations
Integrated “athlete–paddle–boat” interaction	Consistency among dynamic, kinematic, speed, neuromuscular, and support characteristics	The principal reserve is associated not with a single isolated indicator but with optimization of coordination and force transmission within the integrated biomechanical system.	Combine correction of trunk technique, verification of the Erbi paddle, use of the Plastex or Vajda boats, maintenance of the calibrated seating configuration, and development of sport-specific endurance. Confirm the effectiveness of the recommendations through repeated comprehensive testing.

Note. The profile categories are operational and intended for within-athlete interpretation. A “strength” denotes a favorable and stable indicator confirmed under different conditions or consistent with performance-related characteristics. An “adequate level” indicates the absence of evidence of a substantial limitation to technical execution. A “reserve for improvement” reflects a potentially unfavorable or unstable characteristic whose influence requires verification. The category “limiting factor” may be applied only when an unfavorable result is reproducible and confirmed by several diagnostic domains or is directly associated with reduced stroke effectiveness or boat speed

speed has been demonstrated in biomechanical models of paddling (Begon et al., 2010; Nilsson & Rosdahl, 2016). At the same time, the lower relative contribution of individual lower-limb muscles should not be interpreted unequivocally as a local strength deficit. It may reflect the athlete’s coordination strategy, the specific characteristics of the test task, or temporal inconsistency in muscle activation. This finding should therefore be considered a reserve for improving intersegmental force transmission, which requires confirmation through synchronized recording of electromyographic, kinematic, and dynamic indicators under on-water conditions.

The comparison of the Braca and Erbi paddles showed that a greater load on the blade does not necessarily result in greater mechanical effectiveness. The advantage of the Erbi paddle in terms of work and the effective portion of the stroke may be attributable to a more favorable temporal distribution of force, longer maintenance of effective force application, and a better match between blade geometry and the athlete’s individual movement pattern. This is consistent with evidence indicating that stroke performance depends not only on peak force but also on its temporal organization within the propulsive phase (Gomes et al., 2015; Michael et al., 2012). Instrumented paddles increase the objectivity of such analysis because they allow the amount and pattern of force application to be assessed directly during the sport-specific movement (Kong et al., 2020; Niu et al., 2019). Nevertheless, the observed differences may have been partly influenced by the athlete’s familiarity with each paddle model, the order of testing, stroke rate, and accumulated fatigue. The Erbi paddle should therefore be considered a promising individualized option whose effectiveness should be verified after a standardized adaptation period.

The high reproducibility of the paddle attack angle and most angular characteristics of the lower limbs indicates that the basic spatiotemporal structure of the movement was well established. The lower stability of trunk inclination during the final phase may be associated with the need to complete force application, maintain boat balance, and initiate the recovery phase simultaneously. Disturbance of the temporal coordination of these actions may alter the direction of the resultant force, increase rotational oscillations within the athlete–boat system, and intensify speed loss between

strokes. The importance of phase-related and angular characteristics for boat speed has been demonstrated in international studies of paddling kinematics (McDonnell et al., 2013; Zahálka et al., 2011). However, variability is not necessarily unfavorable, as a certain degree of movement variability may facilitate adaptation to boat instability and changing external conditions. Therefore, correction should target not trunk variability itself, but only the component that is consistently associated with reduced effective work or lower boat speed.

The better speed characteristics observed in the Plastex and Vajda boats indicate that, under the testing conditions, these models were more closely matched to the athlete’s individual anthropometric and coordinative characteristics. This compatibility may be determined by hull geometry, the positioning of support areas, system stiffness, and the boat’s response to the asymmetrical movements of a canoeist. However, the observed differences do not demonstrate the universal superiority of any particular model, as they may have been influenced by familiarity with the equipment, trial order, fatigue, and environmental conditions. The results therefore support prioritized further testing of the Plastex and Vajda boats, whereas the final selection should be based on repeated standardized trials.

Seat calibration reduced center-of-pressure displacement in all support zones, indicating increased mechanical stability of the athlete’s interaction with the boat. A more stable support base creates the prerequisites for more effective impulse transmission from the lower limbs through the pelvis and trunk to the paddle and reduces non-productive compensatory movements. The relationship between support forces, paddle dynamics, and boat speed has been demonstrated in recent biomechanical studies (Bonito et al., 2022; Klitgaard et al., 2021; Nilsson & Rosdahl, 2016). However, a reduction in the center-of-pressure displacement area does not provide direct evidence of increased propulsive effectiveness, because the relevant indicators were not recorded simultaneously before and after calibration. In addition, excessive stabilization may restrict the functionally necessary mobility of the pelvis and trunk. An optimal seating configuration should therefore increase support stability without reducing the amplitude of effective movements or causing localized discomfort.

The findings on support interactions are consistent with studies of morphofunctional adaptations to asymmetrical loading in canoeing (Štryncl et al., 2021; Álvarez-Yates et al., 2024). The specific canoeing position produces uneven loading of the support and non-support legs, pelvis, and trunk-stabilizing muscles. Such asymmetry may represent either a functional adaptation to the sporting technique or a source of excessive compensatory movements. In the present study, its assessment had direct practical relevance because the findings were used not merely to identify differences between support zones, but to individualize the athlete's seating configuration.

The functional indicators clarified the conditions under which technique was expressed but did not replace biomechanical analysis. The athlete's adequate strength and speed-strength capacity of the lower limbs indicates that the identified technical reserves were not attributable to a pronounced limitation in overall strength. At the same time, the reserve in speed-strength endurance of the shoulder girdle may limit the ability to maintain a stable force-application pattern under fatigue. This supports the view that paddling performance is determined not by the maximal strength of an isolated muscle group, but by the athlete's capacity to repeatedly express strength within a sport-specific coordination pattern (Michael et al., 2012; Nilsson & Rosdahl, 2016).

The respiratory indicators did not suggest that respiratory function was a major limiting factor. However, the forceful pattern of inspiration may increase the energetic cost of accessory respiratory-muscle activity and contribute to greater trunk tension. Optimization of inspiratory mechanics should therefore be regarded as a complementary intervention aimed at preserving movement economy and technical stability during high-intensity work rather than as the primary means of correcting paddling technique.

Cardiorhythmographic indicators characterize the current state of autonomic regulation but cannot be used as an independent criterion of technical preparedness or as evidence of functional strain. Their values depend on previous training load, sleep quality, psycho-emotional state, body position, and the athlete's individual baseline. Therefore, the dynamics of these indicators are more informative than a single measurement and should be interpreted together with the stress index, centralization index, spectral structure, training load, subjective well-being, and sport-specific performance. This approach is consistent with standards for the interpretation of short-term heart rate recordings and recommendations for monitoring athletes' adaptation (Task Force, 1996; Baevsky & Chernikova, 2017; Plews et al., 2013).

The scientific significance of the proposed approach lies in the transition from isolated assessment of separate indicators to their integrated within-athlete interpretation. The profile is neither a composite score nor a universal normative scale; rather, it functions as an algorithm for supporting coaching decisions. Classification of a component as a strength, acceptable level, reserve for correction, or limiting factor is based on the reproducibility of the indicator, its consistency with other diagnostic domains, and its association with stroke effectiveness or boat speed. This reduces the risk of misinterpreting isolated deviations and allows testable hypotheses to be formulated regarding the causes of technical limitations.

The practical value of profiling lies in the direct transition from test results to targeted decisions: adaptation to the Erbi paddle, further comparative testing of the Plastex and Vajda boats, maintenance of the calibrated seating configuration, correction of trunk position during the final phase, improvement of force transmission through the "leg-trunk-arm-paddle" chain, development of speed-strength endurance of the shoulder girdle, optimization of inspiratory mechanics, and monitoring of the balance between training load and recovery. The validity of these decisions should be confirmed through repeated standardized testing, because only targeted changes in the relevant biomechanical indicators, together with improvements in work per stroke and boat speed, can confirm the accuracy of the initial interpretation.

Future Research

Future research should test the proposed algorithm for forming an individual profile in a larger sample of canoeists of different qualification levels, sex, anthropometric characteristics, and dominant paddling side. This would make it possible to verify the reproducibility of the approach, clarify the informativeness of key biomechanical indicators, and determine its possible use for individualizing technical preparation in C1 sprint canoeing.

Limitations

The study was conducted as a case-oriented analysis of one qualified sprint canoeist; therefore, the obtained results characterize the individual profile of a specific athlete and cannot be directly extrapolated to the entire population of canoeists. The two additionally included athletes were used only as a reference context for interpreting selected strength and functional indicators, not for between-group statistical comparison.

A long-term pedagogical experiment was not conducted, which would have allowed assessment of the effect of the proposed technical and training recommendations on sports performance over time. The obtained data reflected the athlete's state during a specific period of preparation.

Despite this, the case-oriented design made it possible to analyze in detail the relationship between biomechanical indicators and the athlete's functional state and to substantiate their practical significance for individualizing technical preparation.

Conclusions

The developed individual profile showed that the principal reserve in the technical preparedness of the examined canoeist was associated not with a deficit in any single physical quality, but with the coordination of force transmission within the "athlete-paddle-boat" system. Work per stroke, the effective portion of the stroke, the stability of the kinematic movement structure, boat speed, and the characteristics of support interactions were the most practically informative indicators.

The neuromuscular support of the stroke was characterized by the predominant involvement of the back, pectoral, and shoulder-girdle muscles. The lower relative contribution of individual lower-limb muscles does not

provide sufficient evidence of a local strength deficit but indicates a potential reserve for improving intersegmental coordination and force transmission through the “leg–trunk–arm–paddle” chain.

Under the testing conditions, the Erbi paddle provided greater work per stroke, a larger effective portion of the stroke, and a higher proportion of effective work despite a lower mean blade load compared with the Braca paddle. This indicates that, for this athlete, stroke effectiveness depended more on the temporal organization and duration of effective force application than on maximum blade load. The Erbi paddle should therefore be considered a promising individualized option whose effectiveness should be confirmed after a standardized adaptation period and repeated testing.

The stability of the paddle attack angle and most angular characteristics of the lower limbs was identified as a strength of the athlete’s technique. The lower stability of trunk inclination during the final phase of the stroke cycle represents a specific reserve for correction. The appropriateness of such intervention should be evaluated according to whether changes in trunk position are accompanied by improved work per stroke, reduced speed loss, and greater movement stability.

Under the testing conditions, the Plastex and Vajda boats provided better speed performance than the Nelo boat. This finding indicates a better individual match between these boats and the examined athlete but does not demonstrate the universal superiority of either model. Final boat selection should be based on repeated trials with standardized trial order, stroke rate, fatigue level, and environmental conditions.

Individual seating calibration reduced center-of-pressure displacement in the support zones, confirming increased mechanical stability of the athlete’s interaction with the boat. However, the findings do not demonstrate a direct increase in propulsive efficiency because paddle force and boat speed were not recorded synchronously before and after calibration. The calibrated seating configuration should therefore be maintained provided that it does not cause discomfort or restrict the functionally necessary mobility of the pelvis and trunk.

The functional assessment provided no basis for attributing the identified technical reserves to pronounced limitations in strength, respiratory, or hemodynamic support. At the same time, the findings supported the development of shoulder-girdle speed-strength endurance, optimization of inspiratory mechanics, and systematic monitoring of the balance between training load and recovery. Cardiorhythmographic indicators should be interpreted longitudinally together with data on training load, recovery, and sport-specific performance rather than used as an independent criterion of functional strain.

The proposed algorithm enabled the identification of individualized priorities for technical correction through the integrated analysis of biomechanical and functional indicators. Its further validation requires repeated testing and assessment in a larger sample of athletes. Given the single-case study design, the developed profile should be regarded as an algorithm for supporting coaching decisions rather than as a universal normative model. The validity of the proposed recommendations should be confirmed through

repeated standardized testing after the implementation of corrective interventions.

Ethical Considerations

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and accepted requirements for research involving human participants. The participants were informed about the aim, content, and procedures of the assessment. All athletes provided informed consent to participate in the study and to use anonymized results for scientific purposes. Personal data were anonymized, and confidentiality was ensured at all stages of the study.

Data Availability Statement

The study data are part of a comprehensive individual assessment of the athlete and contain personalized information on technical preparedness and functional state. Due to confidentiality, the full primary dataset is not publicly available. The summarized results necessary for interpretation of the study are presented in the text, tables, and figures.

Artificial Intelligence Transparency Statement

The authors state that artificial intelligence was not used for the collection, analysis, or interpretation of primary research data. AI-based auxiliary software was used only for language and stylistic editing of the manuscript. The study design, methodological decisions, interpretation, conclusions, and final responsibility for the manuscript content belong to the authors.

Conflict of Interest

The authors declare no conflict of interest.

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References

- Altukhov, P., & Shynkaruk, O. (2026c). Tekhnichna pidhotovka ta pidhotovlenist v systemi pidhotovky sportsmeniv u vesluvanni na kanoe [Technical training and preparedness in the system of athlete preparation in canoe paddling]. In *Molod ta olimpiyskyi rukh: Zbirnyk tez dopovidei XIX Mizhnarodnoi konferentsii molodykh vchenykh* (pp. 58–59). <https://sur.li/foiblf>
- Gomes, B.B., Ramos, N.V., Conceição, F.A.V., Sanders, R.H., Vaz, M.A.P., & Vilas-Boas, J.P. (2015). Paddling force profiles at different stroke rates in elite sprint kayaking. *Journal of Applied Biomechanics*, 31(4), 258–263. <https://doi.org/10.1123/jab.2014-0114>
- Michael, J.S., Rooney, K.B., & Smith, R.M. (2012). The dynamics of elite paddling on a kayak simulator. *Journal of Sports Sciences*, 30(7), 661–668. <https://doi.org/10.1080/02640414.2012.655303>
- Zahálka, F., Malý, T., Malá, L., Doktor, M., & Větrovský, J. (2011). Kinematic analysis of canoe stroke and its

- changes during different types of paddling pace: Case study. *Journal of Human Kinetics*, 29, 25–33. <https://doi.org/10.2478/v10078-011-0036-7>
- Bonaiuto, V., Gatta, G., Romagnoli, C., Boatto, P., Lanotte, N., & Annino, G. (2020). A pilot study on the e-Kayak system: A wireless DAQ suited for performance analysis in flatwater sprint kayaks. *Sensors*, 20(2), Article 542. <https://doi.org/10.3390/s20020542>
- Kong, P.W., Tay, C.S., & Pan, J.W. (2020). Application of instrumented paddles in measuring on-water kinetics of front and back paddlers in K2 sprint kayaking crews of various ability levels. *Sensors*, 20(21), Article 6317. <https://doi.org/10.3390/s20216317>
- Niu, L., Kong, P.W., Tay, C.S., Lin, Y., Wu, B., Ding, Z., & Chan, C.C. (2019). Evaluating on-water kayak paddling performance using optical fiber technology. *IEEE Sensors Journal*, 19(24), 11918–11925. <https://doi.org/10.1109/JSEN.2019.2927304>
- Trevithick, B.A., Ginn, K.A., Halaki, M., & Balnave, R. (2007). Shoulder muscle recruitment patterns during a kayak stroke performed on a paddling ergometer. *Journal of Electromyography and Kinesiology*, 17(1), 74–79. <https://doi.org/10.1016/j.jelekin.2005.11.012>
- Štryncl, R., Bittner, V., Šifta, P., Tregler, M., Kubový, P., Jelen, K., & Ravník, D. (2021). Selected biomechanical aspects of the asymmetrical loading of the human postural system when riding the C1 speed canoe and their influence on the development of muscular imbalances. *Neuroendocrinology Letters*, 42(7), 446–458. <https://pubmed.ncbi.nlm.nih.gov/34969187/>
- Álvarez-Yates, T., Iglesias-Caamaño, M., Cuba-Dorado, A., Serrano-Gómez, V., Ferreira-Lima, V., Nakamura, F.Y., & García-García, O. (2024). Explanatory model for elite canoeists' performance using a functional electromechanical dynamometer based on detected lateral asymmetry. *Symmetry*, 16(3), Article 347. <https://doi.org/10.3390/sym16030347>
- Altukhov, P., & Shynkaruk, O. (2026b). Suchasni naukovi pidkhody doslidzhennia tekhniki u vesluvanni na kanoe [Modern scientific approaches to the study of technique in canoe paddling]. In *Problemy ta perspektyvni napriamy rozvytku suchasnoho sportu: Aktualni pytannia teorii ta praktyky: Zbirnyk tez Vseukrainskoi naukovo-praktychnoi konferentsii* (pp. 200–202). Kharkiv State Academy of Physical Culture. <https://surl.li/feifya>
- Altukhov, P., & Shynkaruk, O. (2026a). Current state and trends in scientific research on canoe paddling technique based on a bibliometric analysis of the Web of Science Core Collection database. *Sport Science Spectrum*, (1), 3–11. <https://doi.org/10.32782/spectrum/2026-1-1>
- Tilden, M.L., Oberoi, A.R., & Wakeling, J.M. (2024). Canoe slalom C1 stroke technique during international competitions. *Sports Biomechanics*, 23(10), 1443–1454. <https://doi.org/10.1080/14763141.2021.1942968>
- Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. (1996). Heart rate variability: Standards of measurement, physiological interpretation, and clinical use. *Circulation*, 93(5), 1043–1065. <https://doi.org/10.1161/01.CIR.93.5.1043>
- Baevsky, R.M., & Chernikova, A.G. (2017). Heart rate variability analysis: Physiological foundations and main methods. *Cardiometry*, 10, 66–76. <https://doi.org/10.12710/cardiometry.2017.10.6676>
- Plews, D.J., Laursen, P.B., Stanley, J., Kilding, A.E., & Buchheit, M. (2013). Training adaptation and heart rate variability in elite endurance athletes: Opening the door to effective monitoring. *Sports Medicine*, 43(9), 773–781. <https://doi.org/10.1007/s40279-013-0071-8>
- Shynkaruk, O., & Altukhov, P. (2026). Instrumental, sensor, and digital technologies of biomechanical movement control in canoe paddling. In *Biomechanics of sport, health-enhancing physical activity, physical culture and sports rehabilitation: Current problems, innovative projects and trends: Proceedings of the V All-Ukrainian electronic scientific-practical conference with international participation* (pp. 83–85). National University of Ukraine on Physical Education and Sport. <https://lnk.ua/v5kCcQYWC>
- Begon, M., Colloud, F., & Sardain, P. (2010). Lower limb contribution in kayak performance: Modelling, simulation and analysis. *Multibody System Dynamics*, 23(4), 387–400. <https://doi.org/10.1007/s11044-010-9189-8>
- Nilsson, J.E., & Rosdahl, H.G. (2016). Contribution of leg-muscle forces to paddle force and kayak speed during maximal-effort flat-water paddling. *International Journal of Sports Physiology and Performance*, 11(1), 22–27. <https://doi.org/10.1123/ijssp.2014-0030>
- McDonnell, L.K., Hume, P.A., & Nolte, V. (2013). A deterministic model based on evidence for the associations between kinematic variables and sprint kayak performance. *Sports Biomechanics*, 12(3), 205–220. <https://doi.org/10.1080/14763141.2012.760106>
- Bonito, P., Sousa, M., Ferreira, F.J., Justo, J.F., & Gomes, B.B. (2022). Magnitude and shape of the forces applied on the foot rest and paddle by elite kayakers. *Sensors*, 22(4), Article 1612. <https://doi.org/10.3390/s22041612>
- Klitgaard, K.K., Rosdahl, H., Brund, R.B.K., Hansen, J., & de Zee, M. (2021). Characterization of leg push forces and their relationship to velocity in on-water sprint kayaking. *Sensors*, 21(20), Article 6790. <https://doi.org/10.3390/s21206790>

Формування індивідуального профілю технічної підготовленості висококваліфікованого каноїста за біомеханічними і функціональними показниками

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 15 с., 3 табл., 6 рис., 22 джерела.

Актуальність. Технічна підготовленість у веслуванні на каное залежить від узгодженої взаємодії спортсмена, весла й човна. Ізольоване оцінювання показників не дозволяє визначити, які саме порушення обмежують ефективність гребка. Комплексне формування індивідуального профілю дає змогу виявити ці взаємозв'язки та обґрунтувати напрями корекції техніки, інвентарю й посадки в човні.

Мета. Сформувати індивідуальний профіль технічної підготовленості висококваліфікованого каноїста на основі комплексного аналізу біомеханічних і функціональних показників та обґрунтувати напрями індивідуалізації техніки, вибору інвентарю, калібрування посадки й тренувального процесу.

Матеріали і методи. Дослідження виконано за дизайном індивідуального випадку за участю каноїста міжнародного рівня. Для референтної інтерпретації окремих показників додатково обстежено двох каноїстів. Застосовано поверхневу електроміографію, тензометричну реєстрацію гребка з веслами Braca та Erbi, кінематичний аналіз, оцінювання швидкості човнів Nelo, Vajda і Plastex на 150 м, аналіз опорних взаємодій до і після калібрування посадки, методи оцінки сили, функціональні методи. Профіль формували через первинне опрацювання даних, внутрішньоіндивідуальне порівняння, перевірку узгодженості, розподіл результатів за рівнями та обґрунтування тренерських рішень.

Результати. Застосування алгоритму дозволило сформувати індивідуальний профіль технічної підготовленості каноїста. До сильних сторін віднесено стабільність кута атаки весла, швидкісну реалізацію техніки на човнах Plastex і Vajda та підвищення стабільності опорних взаємодій після калібрування посадки. Основними резервами визначено міжланкове передавання зусилля в системі «нога – тулуб – рука – весло», стабільність нахилу тулуба у завершальній фазі гребка та швидкісно-силову витривалість плечового поясу. Erbi порівняно з Braca забезпечувало більшу роботу за гребок – 73,0 проти 49,3 Дж, більшу ефективну частину гребка – 45,6 проти 25,8 Дж і вищу частку ефективної роботи – 62,3 проти 53,0 %. Середня швидкість становила 3,99 м·с⁻¹ на Plastex, 3,95 м·с⁻¹ на Vajda і 3,80 м·с⁻¹ на Nelo. Калібрування посадки зменшило площу переміщення центра тиску в усіх опорних зонах. Підтверджених лімітуючих факторів за результатами комплексного аналізу не встановлено.

Висновки. Інтеграція біомеханічних і функціональних показників в індивідуальний профіль створює науково обґрунтовану основу для персоналізації технічної підготовки каноїста.

Ключові слова: веслування на каное, технічна підготовленість, індивідуальний профіль, біомеханічні показники, електроміографія, динаміка гребка, центр тиску, взаємодія «спортсмен – човен».

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