NATIONAL SPORTS ACADEMY
"VASSIL LEVSKI"

DEPARTMENT "WATER SPORTS"

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# Effect of Applying Real-Time Feedback System for Mastering the Rowing Technique of Students from the Technical University in Sofia

## AUTHOR'S SUMMARY OF DISSERTATION

Sofia, 2024

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**AUTHOR’S SUMMARY OF DISSERTATION**

for acquiring the educational and scientific degree PH.D. in professional field 7.6. Sport, Ph.D. program “Theory and Methods of Sports Science”

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The dissertation has been discussed and directed to official defense by the Department “Water Sports” at NSA “Vassil Levski”.

It comprises 143 standard pages and includes 25 tables and 67 graphs. The reference list contains 151 literary sources, of which 39 are in Cirillyc and 112 in Latin.

The dissertation defense will be held on 15.05.2024 at 2 p.m. in Hall A3 at NSA “Vassil Levski”, Students’ Town, Sofia.

## CONTENTS

## INTRODUCTION

Rowing, being a human motor activity, is a people’s ability to move on the water's surface by different kinds of boats and oars, using their own skills and strength. It has been developing as a sport for centuries. The design of the boats and oars has been perfected, leading to differentiating various rowing sports united by a single criterium – a boat and oars. The variety of boats and oars has led to differences in the purpose, nature of movements, and components of rowing sports. Academic rowing is practiced in narrow, long boats with an outrigger locking system, portable chairs (slides), rowing foot stretchers, and long oars. The rowers sit in the boat facing the stem (opposite to the moving direction) and hold one or two oars (sweep rowing or sculling). The motor activity is purposeful and specific and includes not only the motor side of the action as a physical activity but also all the elements and processes participating in the regulation, management, and energy supply of the movements and ensuring their efficiency.

According to a number of authors (1,4,13,19,33,34,36,54,76), rowers’ sports results depend on: a) movement efficiency and precise rowing technique and b) power of the mechanical work depending on the functional and physical preparation. Although the movement technique is crucial for achievement in all sports, academic rowing is considered a sport requiring an extremely high level of technical precision in order to achieve a high result. There is no point in developing a high level of physical qualities and/or functional abilities if they cannot be used effectively in increasing the speed of the boat.

The rowing technique supposes excellent coordination abilities between different body segments (legs, arms, and trunk) and between the muscle coordination of the major muscle groups responsible for performing rowing motions. While learning the proper technique, a realization of athletes' full-strength potential is possible; they achieve approximate maximum values in the range of 50 to 100 kg.

Here, the coach's role is crucial for acquiring and mastering the rowing technique from the very beginning of athletes' preparation. Coaches should create a proper technical model and perfection of each technical detail in future preparation. This task is full of numerous challenges, and few coaches can cope with it well enough. In the last few years, with the development of science and technologies, a lot of systems and devices providing real-time feedback to athletes about their movements and rowing techniques have been developed. These also help coaches and are frequently used in elite rowers' training to master details from the rowing stroke and for technique control. Still, we have not found any publications related to technological systems that provide feedback on beginner rowing. In this relation, we will attempt to examine the effect of the BioRowTech system on teaching novice rowers-students.

## Working hypothesis

After reviewing literary sources about the development of the rowing technique and the peculiarities of the rowing stroke, the methodological sequence of novice rowers' training, the means used, and the popular feedback systems for optimizing the technical indicators, we formulated the working hypothesis.

Using a system that provides feedback to novice rowers training on a rowing machine will engage and motivate them to perform each rowing stroke accurately. This will further reduce the common mistakes made by novice rowers and the time needed to master good coordination of the movements of the different body segments—legs, trunk, and arms.

## II. AIM, TASKS, METHODS, AND ORGANIZATION OF THE RESEARCH

### II.1 Aim and tasks

The main aim of the research was to establish the effect of using the BioRowTech system providing feedback on a rowing machine while teaching novice rowers – students.

**Tasks**

1. To examine and analyze the development of university rowing, the history of the rowing technique, and the methodological sequence, means, and facilities used to teach rowing.
2. To examine and analyze feedback systems implemented in practice while teaching and mastering rowing techniques and select the appropriate one for this research.
3. To conduct training with the feedback system BioRowTech on a rowing machine in the rowing classes of the students from the Technical University in Sofia.
4. To research the technical, speed, and force parameters of the rowing stroke.
5. To analyze the obtained results and to establish the effect of the applied methodology.

## II. 2. RESEARCH METHODS

**The subject** of the research was the technical, speed, and force indicators recorded by the feedback system BioRowTech on a rowing machine:

- Technical indicators: the beginning of the work phase (catch factor), the rowing style, and the end of the work phase (finish factor).
- Speed indicators – average and maximum handle velocity; velocity of the different segments – legs, trunk, and arms.
- Force indicators – average and maximum handle force; average and maximum power.

### Participants

The research was conducted with 18 first-year students from the Technical University in Sofia. They had chosen rowing as one of their compulsory sports classes. Their mean age was 19.5 years ±0.5. There were 17 men and one woman, distributed randomly in two groups: control and experimental.

### Design

The research was conducted during the first semester of the 2021-2022 academic year. After the beginning of the academic year and the students' selection of the kind of sport for their sports classes, the students from the two groups (experimental and control groups) had ten classes at a rowing swimming pool and on a rowing machine. These classes aimed to familiarize the students with the rowing stroke. The first test (assessment test) was conducted on a rowing machine equipped with the feedback system BioRowTech in the middle of October. During two rowing classes, the students had to perform ten strokes with a speed of 20, 22, and 24, with a two-minute rest between the strokes. The data were recorded in the system for further analysis.

During the next three months, the experimental group had classes on a rowing machine with the BioRowTech system twice a week, on the days set in the sports and training curriculum. Each student performed two intervals of 15 and 20 minutes of rowing every 15 minutes, emphasizing the correct technical execution of the rowing stroke. The control group performed the same tasks on a rowing machine but without the BioRowTech system.

The two groups' second final test was conducted after three months on two consecutive days in mid-January 2022. The requirement was the same: maintain a speed of 20, 22, and 24 for ten rowing strokes, with two-minute rests between each stroke. The researched parameters were recorded for further analysis.

**Main Research Methods.**

1. Research of literary sources – we researched different specialized publications, scientific works, and Internet sources.
2. Analysis of the test results – to summarize the results and outline conclusions and recommendations.
3. Equipment – a rowing machine „Concept 2“ model D and a

feedback system BioRowTech

4. Mathematical-statistical methods:
    - variation analysis;
    - correlation analysis;
    - sequence analysis.

The equipment used in the experiment was a rowing machine, „Concept 2“ model D, and the feedback system, BioRowTech.

The rowing machine „Concept 2“ model D is a standard rowing machine widely used and suitable for preparing both elite rowers and beginners. It works on the basis of an air-resistance flywheel with a damper control (1-10) for adjusting the drag factor – the feel of the stroke. During the research, the students worked with the middle power of 5 (fig. 1).

**Fig. 1.** Training session with the system BioRowTech

Specialists use the BioRowTech system for a rowing machine to correct the rowing technique. It measures three variables: the position and velocity of the handle, slide, and trunk (at the level of the shoulder joint).

It uses linear potentiometers and tensometric sensors to record force parameters. The velocities of the legs, trunk, and arms are recorded at the measurement positions and used for analysis. Three indicators provide a rower real-time information – the catch factor, the rowing style, and the finish factor.

The system works with a tablet with a modified BioRowTel software for Windows, which allows recording the results, visualizing the mean curves and values, and analyzing the differences between the rowers and the different indicators.

The data about the velocity and path of the different body segments are registered by three rotational potentiometers attached steadily to the rowing machine and connected to the handle, slide, and the rower's body. The resistance created by the measuring string is less than 1 N, and basically, it is not noticed by the rower and does not affect the movements. The data from the three sensors are united in a central module where they are filtered, modified, and transmitted to a cable-connected tablet or computer.

## III. RESULTS AND ANALYSIS

### Results and Analysis

All the data recorded for the individuals who were researched are included in the appendices. Here, we will present the mean values of the variables from the two tests conducted with the control and experimental groups.

**Table 1**. Mean results from the two tests performed with the control group and growth

| | | | | | | | | Force | | Maximal Speed (m/s) | | | Avg. | Peak |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stroke Rate (str/min) | Average Handle Velocity (m/s) | Max.Handle Velocity (m/s) | Catch Factor (ms) | Rowing Style Factor (%) | Finish Factor (ms) | Rowing Power (W) | Max. Force (N) | Average Handle Force (N) | Legs (m/s) | Trunk (m/s) | Arms (m/s) | Rowing Power (W) | Rowing Power (W) |
| **Rate 20** | | | | | | | | | | | | | | |
| Avg Trial 1 | 20.1 | 1.0 | 1.4 | 21.5 | 64.5% | -4.0 | 99.4 | 423.7 | 193.6 | 0.8 | 0.6 | 1.1 | 99.4 | 551.9 |
| Avg Trial 2 | 20.8 | 1.1 | 1.6 | 32.9 | 59.9% | -8.9 | 131.6 | 528.8 | 234.6 | 0.9 | 0.6 | 1.1 | 131.4 | 748.1 |
| | 0.8 | 0.1 | 0.1 | 11.4 | -4.6% | -4.8 | 32.2 | 105.1 | 40.9 | 0.1 | 0.0 | 0.0 | 32.0 | 196.1 |
| **Rate 22** | | | | | | | | | | | | | | |
| Avg Trial 1 | 21.9 | 1.1 | 1.6 | 15.6 | 64.6% | -13.3 | 137.4 | 510.2 | 239.1 | 1.0 | 0.8 | 1.3 | 137.4 | 752.3 |
| Avg Trial 2 | 23.0 | 1.1 | 1.6 | 18.8 | 64.2% | -4.3 | 144.0 | 544.7 | 250.0 | 1.0 | 0.6 | 1.2 | 148.6 | 791.6 |
| | 1.1 | 0.0 | 0.0 | 3.2 | -0.4% | 9.0 | 6.6 | 34.5 | 10.9 | 0.1 | -0.1 | 0.0 | 11.2 | 39.3 |
| **Rate 24** | | | | | | | | | | | | | | |
| Avg Trial 1 | 24.5 | 1.3 | 1.8 | 15.1 | 66.0% | -47.0 | 184.0 | 505.0 | 235.6 | 1.1 | 0.8 | 1.2 | 148.2 | 755.4 |
| Avg Trial 2 | 24.1 | 1.3 | 1.8 | 19.2 | 65.3% | -20.9 | 178.3 | 559.3 | 251.6 | 1.1 | 0.6 | 1.2 | 149.2 | 791.1 |
| | -0.5 | 0.0 | 0.0 | 4.1 | -0.7% | 26.1 | -5.8 | 54.3 | 16.0 | 0.0 | -0.1 | 0.0 | 1.0 | 35.7 |

Table 1 shows the mean results of the control group in the two tests and the difference in the values. There was no improvement in the handle velocity – neither in the average nor in the maximum values. There was no increase in the velocity of the body segments of the rower's body (legs, back, and arms) at all intensity levels (speed) of rowing. There was an increase in the mean values of the catch factor indicator at the three intensity levels with a positive sign – with 11.4ms at a speed of 20, 3.2ms at a speed of 22, and 4.1ms at a speed of 24. This shows that the synchrony between the handle and the slide at the beginning of the work phase did not improve, and the trunk was extended too early.

The rowing style did not improve, and values were lower than 70%. In this case, the two tests showed an early arm bent and trunk extension that was too early.

The mean values of the finish factor at a speed of 20 (from -4.0 to -8.9ms) and a speed of 22 (from -13.3 to -4.3ms) show that the subject brought the trunk too much backward, and this indicator was not improved. The results for the speed of 24 are interesting. The mean value from the first test was -47.0ms, which is very close to the optimal value, but in the second test, the mean value was -20.9%, which shows a deterioration of this indicator.

There was a growth in the mean force indicators – the most considerable growth was observed in the lower rowing speed (speed 20), and accordingly, the average handle velocity was increased with 40.9N on average, and the average rowing power – with 32W. At the higher rowing speeds, the growth is little or lacking. The maximum force indicators were also increased – the maximum force and the maximum power for a single stroke at the three intensity levels. The most significant growth was observed at a speed of 20 with 105.1N and 196.1w, respectively.

Figures 2, 3, and 4 graphically present the results in Table 8 regarding the three intensity levels in groups of indicators: technical, speed, and force.

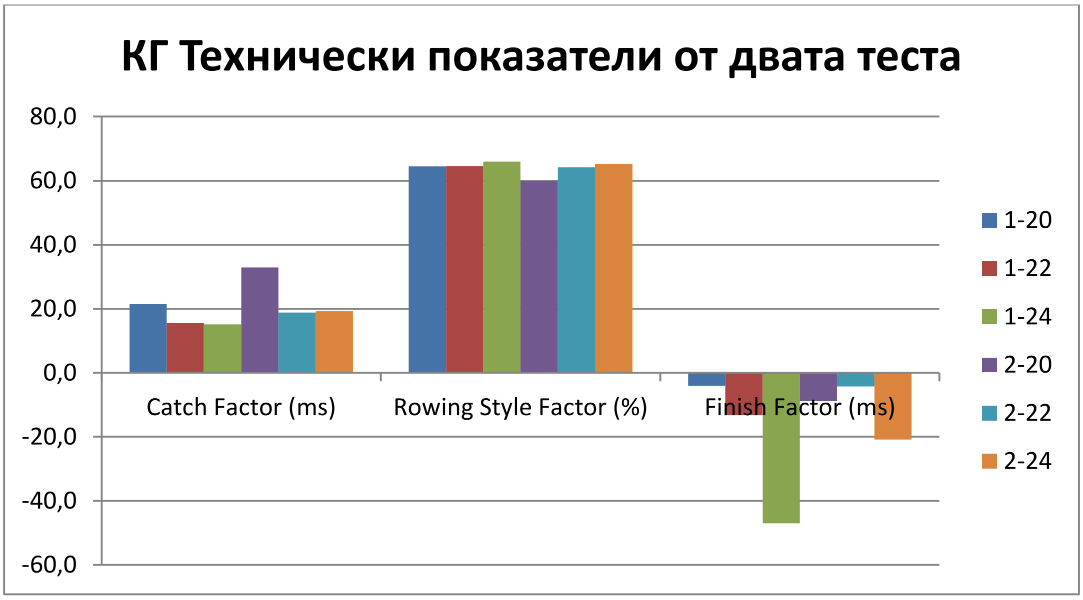


**Fig.2** Technical indicators of the control group from the two tests for the three intensity levels

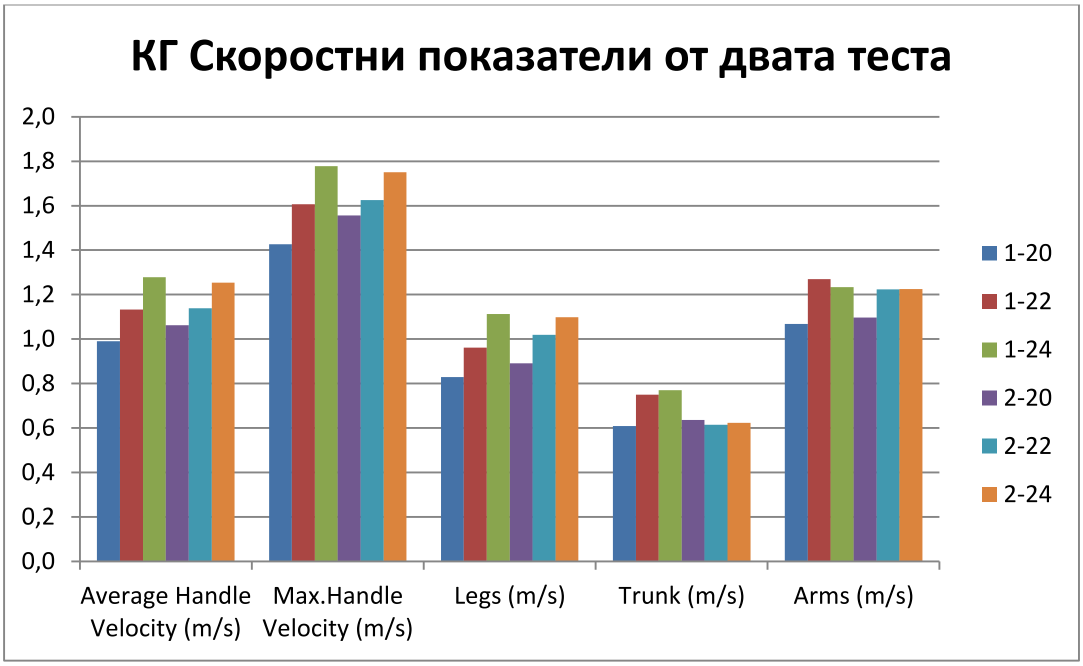


**Fig.3** Speed indicators of the control group from the two tests for the three intensity levels

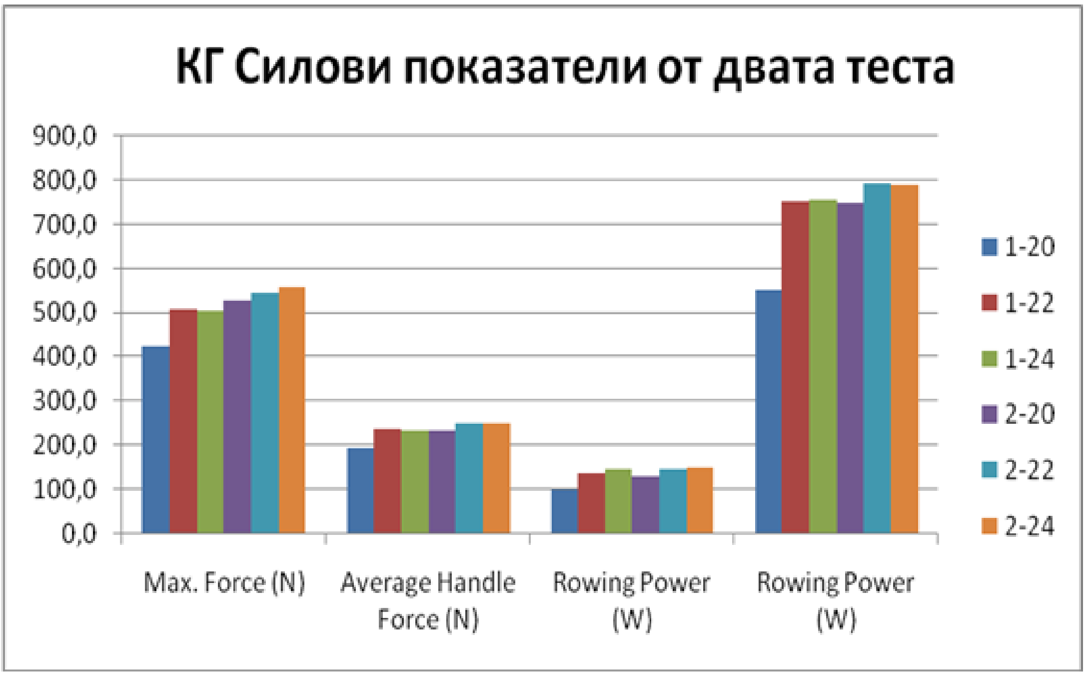


**Fig.4** Force indicators of the control group from the two tests for the three intensity levels

The graphical presentation of the mean results from the two tests shows a growth in the force indicators, although a minimum one, at a speed of 20 (figure 4). There was no increase in the speed indicators (Figure 3), and the technical indicators got even worse (figure 2).

We can conclude that there was no improvement in the results regarding the technical indicators recorded in the second test, and the rowers from the control group did not achieve results close to the optimal results for the different factors. In our opinion, this is due to the rowers' incorrect idea of the coordination of the movements they performed, and the period of one semester was not enough for them to master the rowing technique. The results of the speed indicators also confirmed this – there was no improvement in the second test. They are directly dependent on the proper coordination of the movements of the different segments – legs, trunk, and arms. There were better results for the force indicators in the second test – both in the average and maximum values. This can be explained by regular training on a rowing machine, a proven way to improve rowers' physical qualities. Compared to the first test, the best results were observed at the lowest speed of 20, which, in our opinion, is again due to the novice rowers' inefficient coordination and movement technique. After increasing the rowing intensity, they still could not increase the power and force indicators.

Table 2 presents the mean results from the two tests conducted with the experimental group at the three intensity levels with the calculated differences.

**Table 2.** Mean results from the two tests performed with the experimental group and growth

| | | | | | | | | Force | | Maximal Speed (m/s) | | | Avg. | Peak |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stroke Rate (str/min) | Average Handle Velocity (m/s) | Max.Handle Velocity (m/s) | Catch Factor (ms) | Rowing Style Factor (%) | Finish Factor (ms) | Rowing Power (W) | Max. Force (N) | Average Handle Force (N) | Legs (m/s) | Trunk (m/s) | Arms (m/s) | Rowing Power (W) | Rowing Power (W) |
| **Rate 20** | | | | | | | | | | | | | | |
| Avg Trial 1 | 19.3 | 1.1 | 1.5 | 14.3 | 71.6% | -56.4 | 131.4 | 559.0 | 255.4 | 1.0 | 0.7 | 1.1 | 132.8 | 787.5 |
| Avg Trial 2 | 19.7 | 1.3 | 1.8 | 15.0 | 86.0% | -33.2 | 173.4 | 807.3 | 334.5 | 1.2 | 0.9 | 1.3 | 173.4 | 1281.5 |
| | 0.4 | 0.2 | 0.3 | 0.8 | 14.4% | 23.2 | 42.0 | 248.3 | 79.1 | 0.3 | 0.3 | 0.2 | 40.5 | 494.1 |
| **Rate 22** | | | | | | | | | | | | | | |
| Avg Trial 1 | 21.9 | 1.2 | 1.7 | 13.4 | 71.2% | -50.9 | 175.9 | 671.5 | 295.5 | 1.1 | 0.8 | 1.3 | 175.4 | 1017.1 |
| Avg Trial 2 | 22.4 | 1.4 | 1.9 | 7.9 | 86.7% | -46.1 | 203.8 | 852.1 | 340.0 | 1.4 | 1.1 | 1.5 | 203.8 | 1417.9 |
| | 0.5 | 0.1 | 0.2 | -5.5 | 15.5% | 4.9 | 27.9 | 180.6 | 44.6 | 0.2 | 0.3 | 0.2 | 28.4 | 400.9 |
| **Rate 24** | | | | | | | | | | | | | | |
| Avg Trial 1 | 24.3 | 1.3 | 1.8 | 10.1 | 70.4% | -57.6 | 221.5 | 764.4 | 336.2 | 1.2 | 0.9 | 1.4 | 220.6 | 1243.8 |
| Avg Trial 2 | 24.0 | 1.4 | 1.9 | 4.3 | 89.7% | -64.3 | 214.2 | 850.8 | 335.9 | 1.4 | 1.1 | 1.6 | 214.2 | 1274.5 |
| | -0.4 | 0.0 | 0.1 | -5.8 | 19.3% | -6.7 | -7.3 | 86.4 | -0.3 | 0.2 | 0.2 | 0.1 | -6.4 | 30.7 |

There was an improvement in the results regarding the three technical indicators at the lower speed (20 and 22). The most significant improvement was observed in the factor rowing style at the three intensity levels, where the values recorded in the second test were close to the optimal 90% and had an increase of 14.4% at a speed of 20, 15.5% at a speed of 22, and 19.3% at a speed of 24. This shows the improved coordination of the rower's body segments and the advantage of the leg work at the beginning of the work phase. There was a reduction in the mean values of the catch factor at speeds of 22 and 24 with -5.5ms and -5.8ms, respectively. However, this slight improvement shows that the subjects reduced the too-early trunk inclusion at the beginning of the work phase.

As for the finish factor, we can see a worsening of the result at a speed of 20 – from a mean value of -54.4ms in the first test; it fell to -33.2ms in the second test, which means that striving to achieve a longer amplitude, the subjects began to bring the torso backward more than necessary. The results along this indicator were the best at a speed of 22, but the trend to get the trunk too much backward was preserved. We can see the opposite at a speed of 24. With the increase in speed, the novices began changing the trunk's direction too early, losing the power at the end of the work phase. As a whole, the results of this indicator were not improved, and more work is needed at the end of the work phase.

The results of all speed indicators recorded in the second test increased, both in the handle velocity and the velocity of the different body segments (legs, trunk, and arms).

As for the mean force indicators, we can see a growth in the average handle force at a speed of 20 with 79.1N and at a speed of 22 with 44.6N. There was no change in the values at a speed of 24. The results regarding the average rowing power were similar. We had an increase in the values with 40.5W at a speed of 20 and 28.4W at a speed of 22. At a speed of 24, the mean value recorded in the second test was even 6.4W lower. This confirms the conclusion above about the early inclusion of the trunk at the end of the work phase. The same trend is observed in the indicators “maximum force” and “maximum power” at the three intensity levels, where the growth at a speed of 20 was the highest – 248.3N for the maximum handle force and 494.1W maximum power. At a speed of 24, the growth reduced significantly to 86.4N for maximum force and 30.7W for maximum power.

Figures 5, 6, and 7 graphically present the results in Table 2 regarding the three intensity levels in groups of indicators: technical, speed, and force.

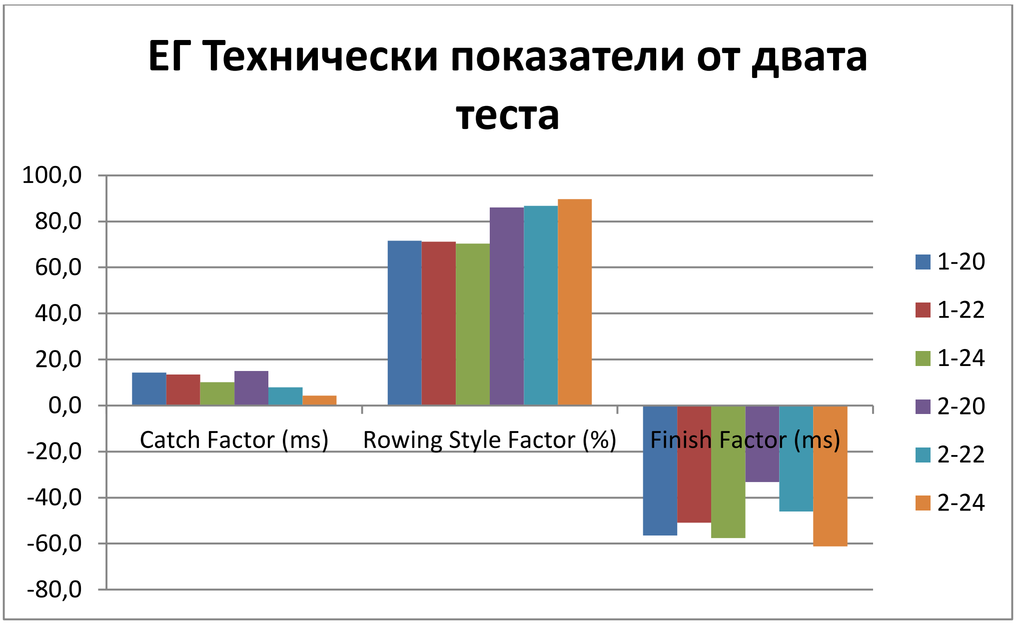


**Fig. 5** Technical indicators of the experimental group from the two tests for the three intensity levels

The graphical presentation of the results regarding the technical indicators recorded in the two tests conducted with the experimental group (Figure 5) shows that the factor "rowing style" had the most significant growth at the three intensity levels, and the values were close to the optimal 90%. There was minimal growth in the catch factor at speeds of 22 and 24. As for the finish factor, the most considerable growth was observed at a speed of 22, where the values were close to the optimal - 50ms.

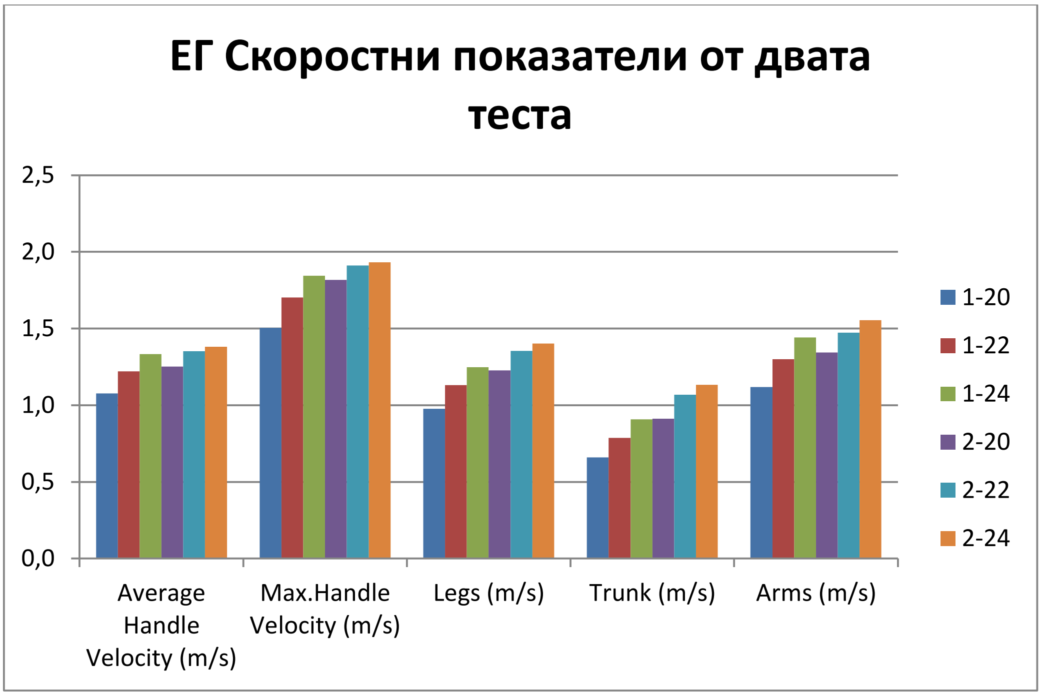


**Fig. 6** Speed indicators of the experimental group from the two tests for the three intensity levels

Figure 6 graphically presents the results regarding the speed indicators of the experimental group. We can clearly see the growth in all indicators at all intensity levels recorded in the second test. This means that the rowers managed to increase the rowing speed in the work phase, not just to accelerate the slide and handle in the air phase.

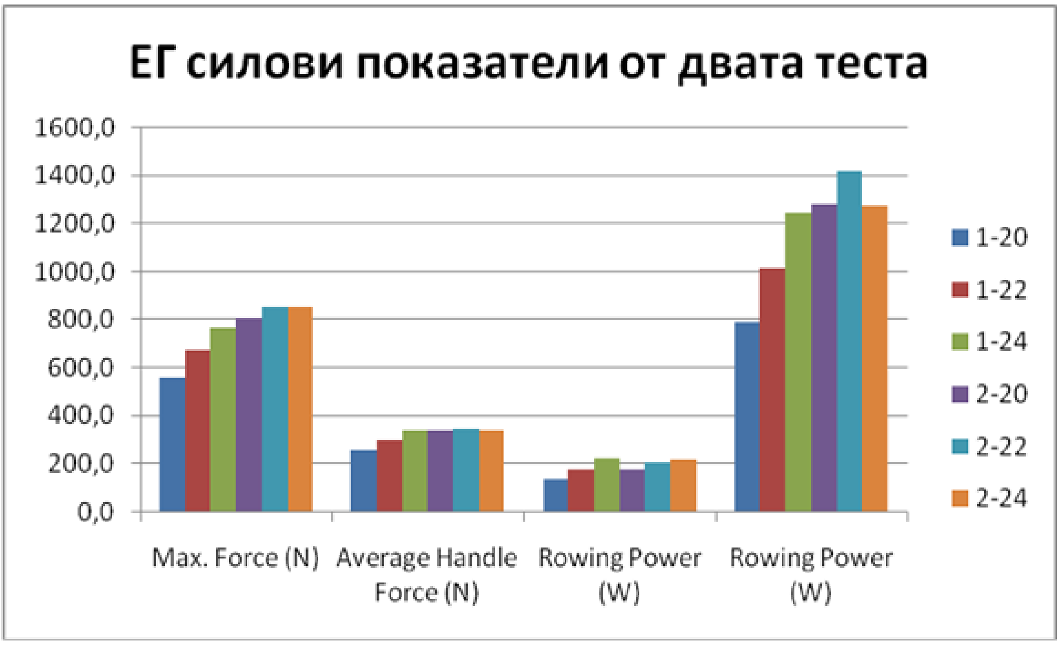


**Fig. 7** Force indicators of the experimental group from the two tests for the three intensity levels

Figure 7 presents the results regarding the group's force indicators. In the second test, we can see a significant improvement in the maximum handle force and the maximum power. The average power values grew, but not so pronouncedly. The average handle force increased at speeds of 20 and 22, but at a speed of 24, the subjects did not improve their results in the second test.

We can conclude that the experimental group increased the technical indicators, primarily expressed in the "rowing style" factor at all intensity levels. The group also had a slight improvement in the catch factor and the finish factor, which means an improvement in the coordination of the movements of the muscle groups and better technique of the execution of the rowing stroke. There was also an increase in the speed indicators of the handle and the body segments. In our opinion, this is due to the improved coordination and the better rowing technique, which allows the subjects to accelerate both the handle and the body segments during the work phase of the rowing stroke with increased rowing speed. We believe that these results were achieved thanks to the training sessions held with the feedback system BioRowTech and the possibilities it provides for following a model of proper technique of execution of each rowing stroke. The feedback system motivates athletes to strive for the appropriate execution of each rowing stroke, and in this way, they can improve their technique for a shorter period.

There was an increase in the force indicators - average and maximum at the different rowing intensity levels. We think it is due to the regular training sessions with a rowing machine during the semester and the use of the feedback system BioRowTech. Besides having a positive effect on learning and mastering the technique, the training sessions with the system also improve the specific strength qualities of the athletes because by improving the movement coordination, they improve their efficiency and increase the applied force and power.

In Figures 8, 9, and 10, we compare the control and experimental groups' results recorded in the first test of the researched indicators.

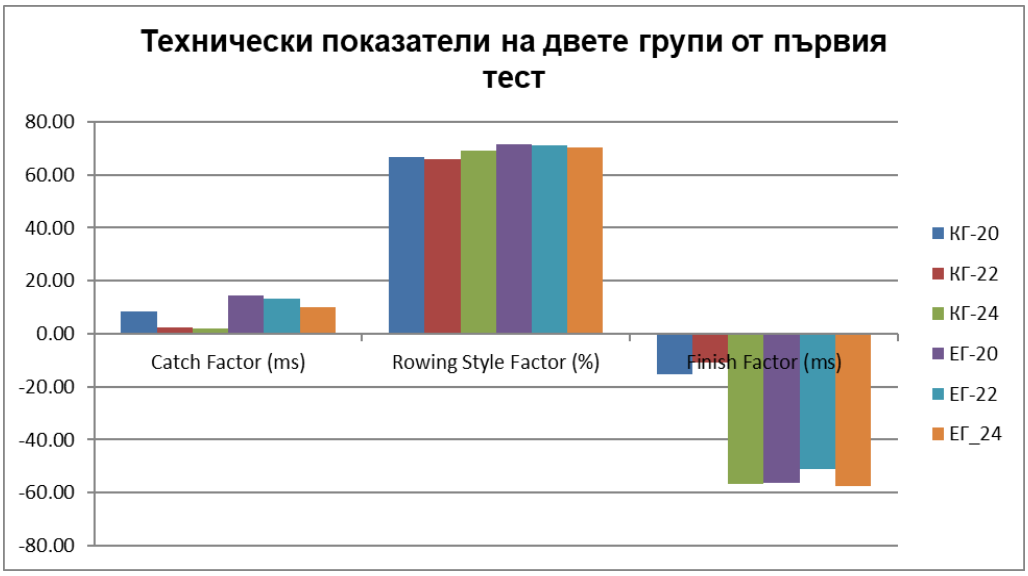


**Fig. 8** Technical indicators at the three intensity levels (speed 20, 22, and 24) of the two groups – control and experimental – test 1

The catch factor results in Figure 8 show positive values for both groups. The control group's values were slightly better than those of the experimental group because they were closer to zero. The rowers from the two groups included the trunk too early at the beginning of the work phase, thus weakening the legs and disrupting the coordination of the different body segments.

Regarding the second factor, "rowing style," the results of both groups were very close at the three intensity levels—from 62% to 70%—but this is far from the optimal value of 90% for this indicator.

Comparing the results obtained for the two groups regarding the finish factor, we can say that the rowers from the control group achieved values close to zero at speeds of 20 and 22. This indicates that they brought the trunk too far backward. The control group's result at a speed of 24 and the experimental group's results at all speeds were close to -60ms, which means the subjects lost power at the end of the work phase and it was not efficient enough.

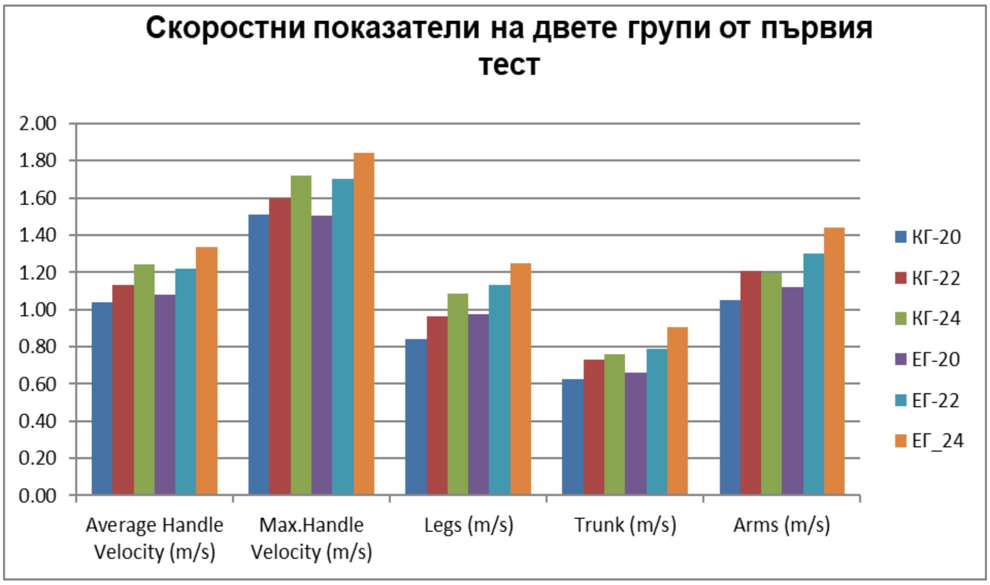


**Fig. 9** Speed indicators at the three intensity levels (speed 20, 22, and 24) of the two groups – control and experimental – test 1

Figure 9 shows the results of the recorded speed indicators in the first test. We can see that the average and maximum handle velocities were almost the same for the two groups at speeds of 20 and 22 at the three intensity levels. The experimental group achieved slightly better results at a speed of 24. Regarding the velocities of the different segments (legs, trunk, and arms), the experimental group's results were slightly better for the leg velocity at all speeds. The trunk and arm velocities were also better at the higher speeds (22 and 24).

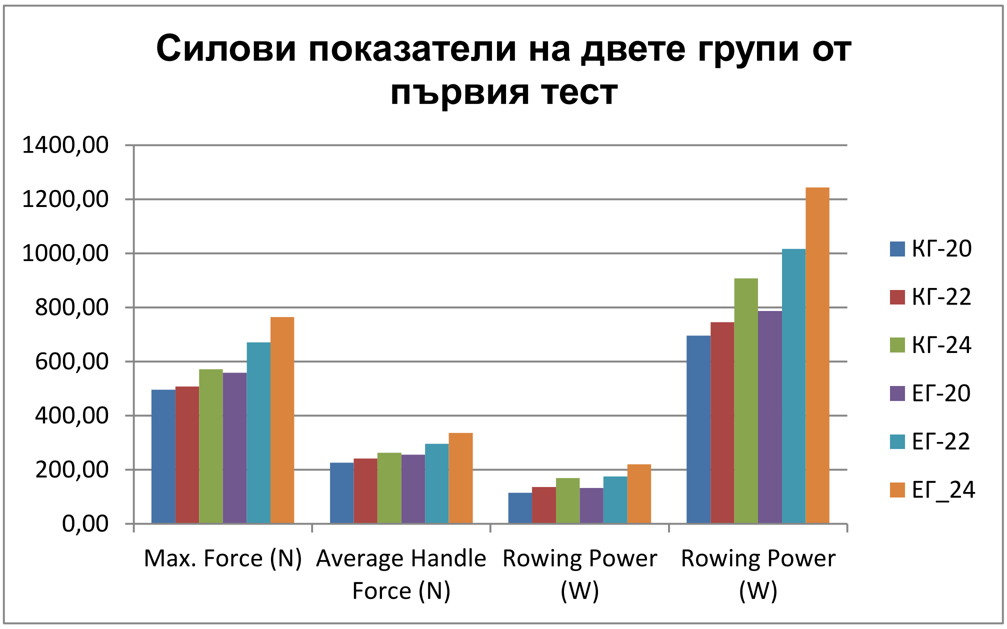


**Fig. 10** Force indicators at the three intensity levels (speed 20, 22, and 24) of the two groups – control and experimental – test 1

The results of the force indicators (Figure 10) showed that the experimental group had higher maximum force and maximum power. In contrast, the differences were insignificant for the average handle force and the average power.

Comparing the results from the first test conducted with the control and the experimental groups, we can conclude that the results achieved by the subjects from the two groups regarding technical parameters were very similar and that the two groups started the experiment with relatively low technical skills. The subjects from the experimental group achieved slightly better results regarding speed parameters at speeds of 22 and 24, but again, the results achieved by the subjects from both groups were low. The experimental group's results regarding force indicators were better for maximum power and handle force. Still, the average results of force and power were similar, and we can conclude that the abilities of the rowers from the two groups were almost the same.

In Figures 11, 12, and 13, we compare the indicators' results in the second test conducted with the control and experimental groups.

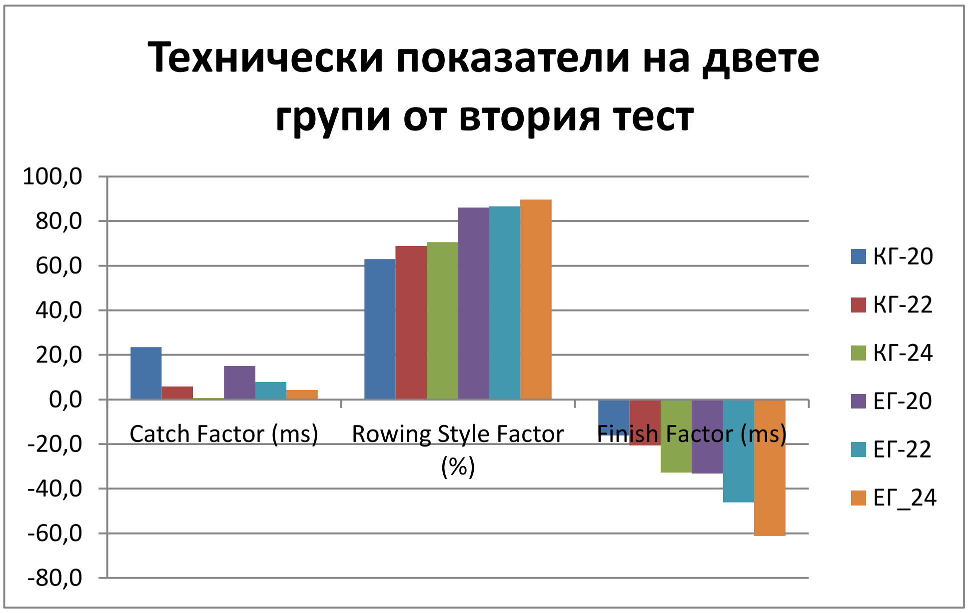


**Fig. 11** Technical indicators at the three intensity levels (speed 20, 22, and 24) of the two groups – control and experimental – test 2

The technical indicators recorded in the second test conducted with the two groups (Figure 11) regarding the catch factor had positive values. The experimental group achieved better results along the factor “rowing style” than the control group at the three intensity levels, and the values were close to 90%. The experimental group achieved better results for the finish factor than the control group, and at speeds of 22 and 24, the subjects from this group achieved values close to the optimal -50ms.

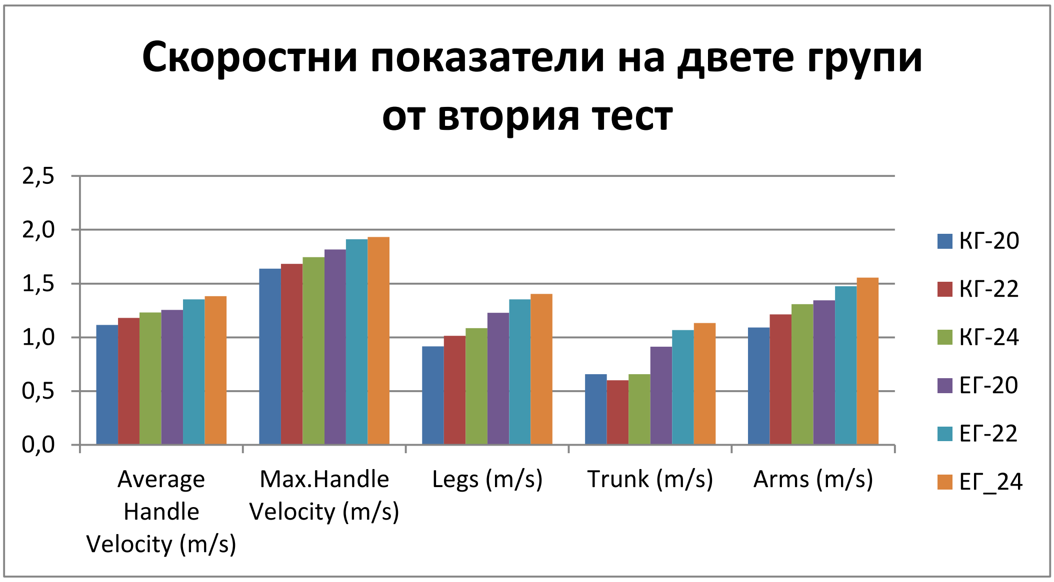


**Fig. 12** Speed indicators at the three intensity levels (speed 20, 22, and 24) of the two groups – control and experimental – test 2

If we compare the results presented in Figure 12, which shows the handle velocity and the velocity of the different segments, we can see that the experimental group achieved higher results along all indicators. The most significant difference was observed in the velocity of the trunk, where the subjects from this group managed to increase the speed of this muscle group with an increase in the speed. Conversely, the control group achieved the highest velocity at 20. At speeds of 22 and 24, the velocity did not improve, which, in our opinion, was due to a lack of improvement in the technical indicators.

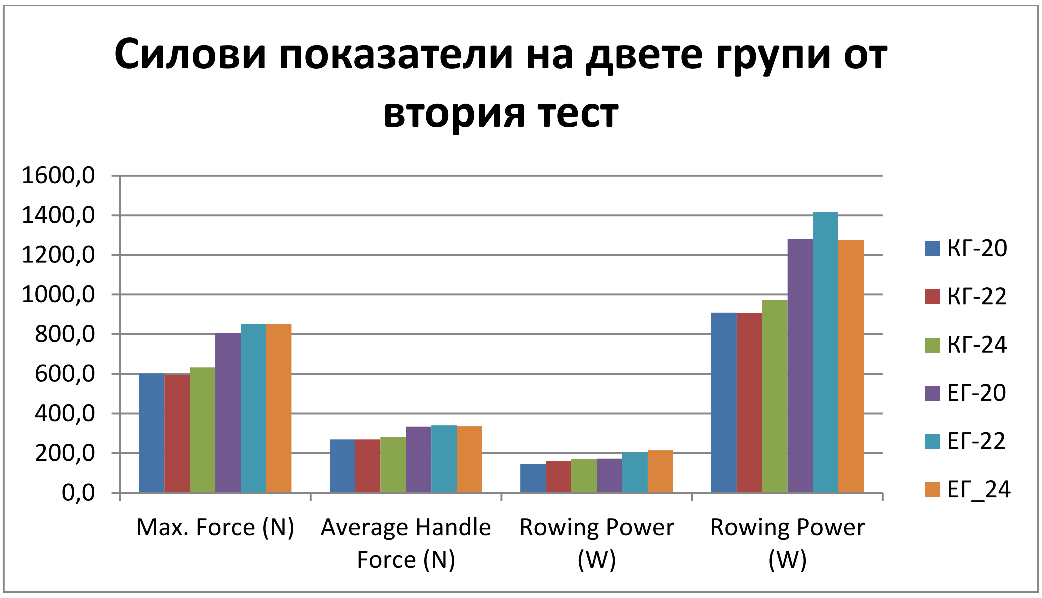


**Fig. 13** Force indicators at the three intensity levels (speed 20, 22, and 24) of the two groups – control and experimental – test 2

When we compare the results of the force indicators recorded in the second test (Figure 13), we can see that the experimental group achieved better results at all intensity levels, both for the average force and power values and the maximum values.

We can conclude that the experimental group achieved better results than the control group in terms of all indicators, including technical, speed, and force.

Table 3 shows the growth in the mean results from the two tests conducted with the control and experimental groups. Figures 14, 15, and 16 show the two groups' increase in the technical, speed, and force indicators, presented graphically to improve visualization and analysis.

**Table 3.** Difference (growth) in the mean values from the two tests – experimental and control group

| | | | | | | | | | Force | | Maximal Speed (m/s) | | | Avg. | Peak |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intensity | Sample ID | Stroke Rate (str/min) | Average Handle Velocity (m/s) | Max.Handle Velocity (m/s) | Catch Factor (ms) | Rowing Style Factor (%) | Finish Factor (ms) | Rowing Power (W) | Max. Force (N) | Average Handle Force (N) | Legs (m/s) | Trunk (m/s) | Arms (m/s) | Rowing Power (W) | Rowing Power (W) |
| Rate 20 | Exprimental group average values | 0.4 | 0.2 | 0.3 | 0.8 | 14.4% | 23.2 | 42.0 | 248.3 | 79.1 | 0.3 | 0.3 | 0.3 | 40.5 | 494.1 |
| Rate 20 | Control group average values | 0.8 | 0.1 | 0.1 | 11.4 | -4.6% | -4.8 | 32.2 | 105.1 | 40.9 | 0.1 | 0.0 | 0.0 | 32.0 | 196.1 |
| | | | | | | | | | | | | | | | |
| Rate 22 | Exprimental group average values | 0.5 | 0.1 | 0.2 | -5.5 | 15.5% | 4.9 | 27.9 | 180.6 | 44.6 | 0.2 | 0.3 | 0.2 | 28.4 | 400.9 |
| Rate 22 | Control group average values | 1.1 | 0.0 | 0.0 | 3.2 | -0.4% | 9.0 | 6.6 | 34.5 | 10.9 | 0.1 | -0.1 | 0.0 | 11.2 | 39.3 |
| | | | | | | | | | | | | | | | |
| Rate 24 | Exprimental group average values | -0.4 | 0.0 | 0.1 | -5.8 | 19.3% | -6.7 | -7.3 | 86.4 | -0.3 | 0.2 | 0.2 | 0.1 | -6.4 | 30.7 |
| Rate 24 | Control group average values | -0.5 | 0.0 | 0.0 | 4.1 | -0.7% | 26.1 | -5.8 | 54.3 | 16.0 | 0.0 | -0.1 | 0.1 | -5.8 | 23.3 |

Table 3 clearly shows that the experimental group increased all the indicators at speeds of 20 and 22. The most significant improvement in the technical parameters compared with the control group was observed in the rowing style, where the increase in speed led to a rise in the mean values: 14.4% at a speed of 20, 15.5% at a speed of 22, and 19.3% at a speed of 24. Conversely, the control group decreased along this technical indicator (Figure 14).

The mean values of the experimental group for the catch factor at the different speeds reduced their values, which means an improved unison between the handle and slide at the beginning of the work phase. Meanwhile, the values of the control group for this indicator increased, which shows a lack of unison between the different muscle groups at the beginning of the work phase (Figure 14).

Figure 15 shows the differences in the mean values of the speed indicators of the two groups. The experimental group had an increase in all results – in the handle velocity and the velocity of the different segments – legs, trunk, and arms. The control group had a minimal increase, and the results even worsened regarding the handle velocity at speeds of 22 and 24, the trunk at speeds of 22 and 24, and the arms at a speed of 22 (Figure 15).

Table 3 and Figure 16 show the increase in the two groups' mean values of the force indicators. We can see that the experimental group achieved significantly higher results for maximum force, average handle force, and average power. The experimental group's increase in the maximum force at a rowing speed of 20 was 248.3N, the control group's increase was 105.1N; at a speed of 22, respectively - 180.6N and 34.5N; at a speed of 24 - 86.4N and 54.3N. The mean values of the average handle force of the experimental group at a speed of 20 was 79.1N, and of the control group - 40.9N; at a speed of 22, respectively - 44.6N and 10.9N; at a speed of 24 - 0.3N and 16.0N. There was no improvement in the experimental group's results regarding the average force, and the control group showed a minimal increase. The increase in the average power achieved by the experimental group at a speed of 20 was 40.5W, the growth of the control group was 32.0W; at a speed of 22, respectively - 28.4W and 11.2W, and at a speed of 24, no increase was achieved by both groups (-6.4W and -5.8W). Still, there was a drop in the values. The experimental group significantly increased the maximum power at speeds of 20 and 22 - 494.9W and 400.9W, respectively. The results of the control group for this indicator at speeds of 20 and 22 were 196.1W and 39.9W, which was relatively lower. Both groups achieved a similar increase at a speed of 24 - 30.7W for the experimental group and 23.9W for the control group.

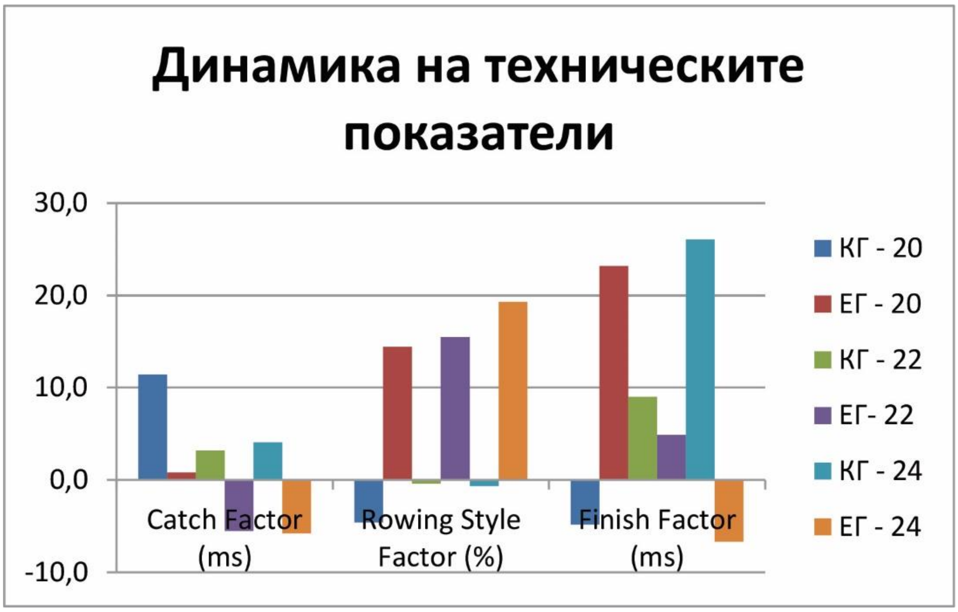


**Fig.14** Dynamics of technical indicators at the three intensity levels – control and experimental groups – tests 1 and 2


**Fig.15** Dynamics of speed indicators at the three intensity levels – control and experimental groups – tests 1 and 2

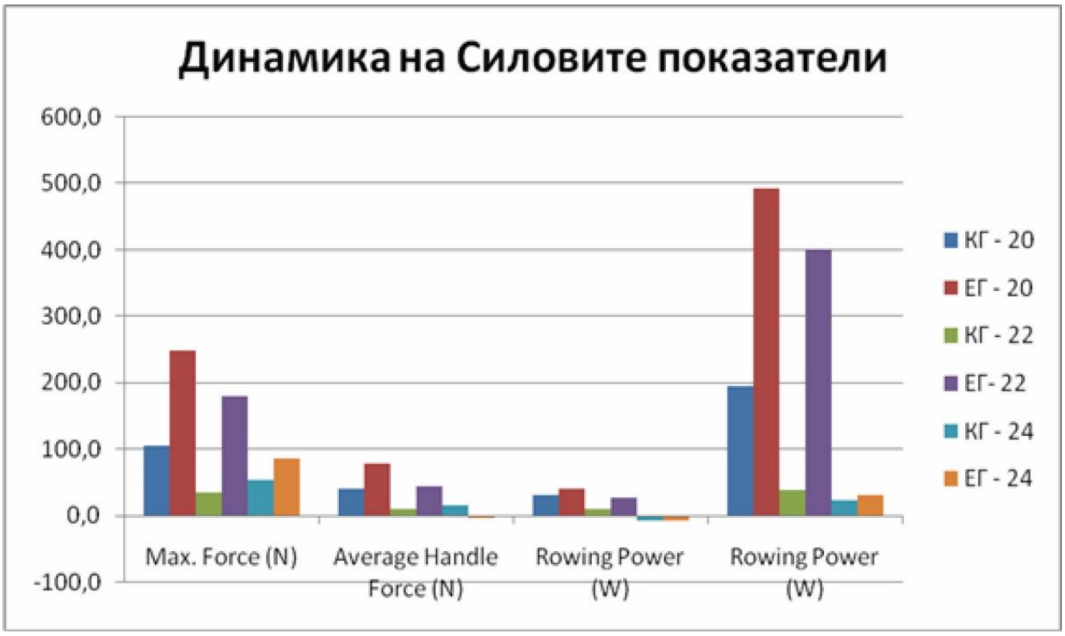


**Fig.16** Dynamics of force indicators at the three intensity levels – control and experimental groups – tests 1 and 2

In conclusion, the experimental group's results in the second test of the technical indicators at all intensity levels were significantly better than those of the control group. The speed indicators also increased, which was due to the improved technique of the rowing stroke. This confirms the benefit of working with the BioRowTech system for correct learning, mastering novice rowers' technical skills, and avoiding common mistakes.

We established an increase in the force and power indicators – both in the average and maximum values of the two groups – control and experimental, although the training sessions aimed at mastering the rowing technique, not developing the physical qualities. The experimental group had a more considerable increase in the force indicators, which, in our opinion, was again due to training with the BioRowTech system and the feedback it provides for each rowing stroke. The system makes the rowers follow a curve model, and, in each stroke, they strive for a better performance. This positively affects the acquisition and mastery of the rowing technique and improves rowers' specific strength qualities because by improving the coordination of rowing movements, their efficiency is also enhanced. This leads to an increase in the applied force and power during the work phase.

The research results were analyzed statistically using SPSS 19. We used variation, correlation, and sequence analysis.

The statistical analysis and results confirm the higher growth in the experimental group's results in the technical, force, and power indicators.

The mean growth of the catch factor at the three intensity levels was d%= 75.17 for the experimental group and d%= 55.46 for the control group, which shows a difference of about 20%. The mean growth of the rowing style was d%= 23 for the experimental group and d%= -4.48 for the control group, which is a considerable difference. The mean increase in the finish factor was d%=33.86 for the experimental group and d%= -0.74 for the control group, which again shows a significant difference in favor of the experimental group and confirms the positive results.

This trend was more pronounced in the mean growth in the force and power results—maximum force, average handle force, and average and maximum power. The mean growth of the maximum force at the three intensity levels was d%= 42.02 for the experimental group and d%= 9.49 for the control group.

The mean growth of the average handle force at the three intensity levels was d%=35.61 for the experimental group and d%=8.0 for the control group.

The mean growth in the average power at the three intensity levels was d%= 29.62 for the experimental group and d%= 8.82 for the control group. The mean growth in the maximum power was—d%= 58.83 and d%= 11.87 for the experimental and control groups, respectively, which was the most significant difference in the growth of all indicators.

We can conclude that the statistical analysis also confirmed the improvement in the experimental group's results. Both groups performed the same training sessions during the academic semester. Our working hypothesis was confirmed. Using the feedback system BioRowTech on a rowing machine with novice rowers positively affects learning the proper technical rowing movements. This can reduce the time needed to perfect the coordination of the movements of the different body segments and the handle at various intensity levels. There was an increase in the results of the novices' indicators for specific force and power, most probably due to the improved coordination of the movements and their efficiency.

# IV. CONCLUSIONS AND RECOMMENDATIONS

## IV.1 Conclusions

1. Based on research on the development of university rowing worldwide, we can conclude that this sport has a long history and traditions. The level of development has varied in different countries over the years, but nowadays, it is developed at the top level at US colleges and universities. These universities attract students from all over the world, have the most rowers-students, and have the strongest university regattas.

2. There is a much more apparent trend toward unifying teaching methods and rowing techniques worldwide. Some general principles are outlined, and rowers' individual characteristics and qualities are considered.

3. The rowing machine is a proven equipment for rowing training and developing rowing-specific physical qualities. Its drawback is its inability to provide feedback for the rower's technical performance. It just shows the statistics of the results in real-time. Its use, together with accessible feedback systems applied in the field of sports for all, can improve movement coordination and reduce the difficulties in maintaining students' attention.
4. Based on the results and analysis, we found that using the BioRow Tech system positively affected teaching and mastering the rowing technique. Despite the relatively short period of one academic semester and the few classes, the technical indicators improved at a lower rowing intensity—speeds of 20 and 22.
5. The lack of improvement in the researched technical indicators at the higher speed of 24 was expected because the novices did not fully acquire the movements. The movement coordination of the different body segments was disturbed when the speed was increased. Future research is needed with a longer and more significant number of classes using a feedback system to establish the period necessary for improvement in the results at a high rowing speed.
6. The results for specific force and power among the researched individuals from the control and experimental groups increased due to the regular training sessions during the semester. The growth of the experimental group's results at speeds of 20 and 22 was significant due to working with the feedback system, which motivated the subjects to perform every rowing stroke technically correctly and with an optimal effort.

## IV.2 Recommendations

1. We recommend using the BioRow Tech system on a rowing machine when teaching and mastering the rowing technique. The novice rower cannot distinguish between right and wrong movements, making learning the technique difficult. We believe that the system's real-time feedback is crucial for learning the proper rowing movements.

2. The BioRowTech system is an accessible and efficient instrument for mastering the rowing technique for rowers with different levels of experience. We recommend regular training sessions with this system on a rowing machine because this will also develop rowing-specific biomechanical characteristics such as power and applied force in the handle.

3. We recommend using the system BioRowTech on a rowing machine to master the rowing technique in the training process, especially in the winter period of rowers' preparation when training on the water is impossible. This will allow the athletes to perfect efficient coordination of the main muscle groups participating in the rowing stroke. After returning to the boat in the water in spring, they will adapt more easily.

## IV.3 Contributions

1. The author reviewed numerous literary sources about the development of university rowing, the development of the rowing technique, and the history of teaching rowing, enriching the theoretical knowledge about the sport.
2. The author conducted a survey of the modern technological feedback systems used to master the rowing technique. This

information provides valuable information to coaches seeking new achievements.

3. The feedback system BioRow Tech was used in Bulgaria for the first time with novice rowers, and its positive effect on mastering the technical elements of the rowing technique and improving the speed and specific force indicators of the rowing stroke was established.
4. This dissertation will provide rowing coaches and specialists with new, scientifically justified methodological guidelines, allowing for more efficient teaching of the rowing technique and learning the coordination of the muscle groups participating in the rowing stroke.

## V. Scientific publications related to the dissertation


1. Ivanova-Kunzova, K., D. Oronova-Hristova (2022). Study on the Effect of Using BiorowTech System for Improving Some Technical Indicators of the Rowing Stroke with Novice. International Scientific Congress “Applied Sports Sciences”, DOI: 10.37393/ICASS2022/20
2. Ivanova-Kunzova, K., D. Oronova-Hristova (2023). Izsledvane na niakoi tehnicheski pokazateli pri nachinaeshti grebtsi-studenti sled zanimaniya sus sistemata za obratna vruzka Biorow Tech na greben ergometer. (Technical parameters of novice rowers-students after training with the feedback system Biorow Tech on a rowing machine). Sport and Science, issue 5, ISSN:1310-3393