NATIONAL SPORTS ACADEMY „Vasil Levski”

Department: „Track and Field Athletics”

Serafim Pavlov Lazov

METHODOLOGY FOR DEVELOPING EXPLOSIVE STRENGTH IN THE LOWER LIMBS OF 19-20-YEAR-OLD VOLLEYBALL PLAYERS

Abstract

of a dissertation for awarding the educational and scientific degree "PhD in sport science" in the field of 7.6 Sports

Scientific Advisor:

Assoc. Prof. Plamen Nyagin, PhD

Official Reviewers:

Prof. Ivan Yotov, DSc
Assoc. Prof. Petar Peev, PhD

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The dissertation comprises 177 printed pages, including 66 tables and 40 figures. The bibliography contains 81 sources, 9 in Cyrillic and 72 in Latin.

The dissertation defense will take place on 5 February 2025, at 14:00 in Room A3 of the National Sports Academy "Vasil Levski," Student Town. Materials related to the defense are available in the NSA library.

Serafim Pavlov Lazov
Born on 15 September 1994 year in Sofia city

Edication:
- **Primary Education**: 149 Secondary School "Ivan Hadzhiyski"
- **Secondary Specialized Education**: Vocational High School for Electrical Engineering and Automation, specializing in "Discrete Production Automation"
- **Higher Education**: National Sports Academy "Vasil Levski"
  Bachelor's Degrees:
- Pedagogy - Physical Education Teacher
- Sports - Strength and Conditioning Coach
  Master's Degree:
- Sports and Security
  Doctoral Degree:
- Full-time doctoral student in the field of 7.6 Sports

Additional Training:
- Course: "Bodybuilding and Fitness," instructed by Prof. V. Boyanov

Employment:
- **2014-2017**: Strength and Conditioning Coach and Director at the "Pulse" fitness chain
- **2014-Present**: Freelance Strength and Conditioning Coach
- **2021.04 - 2021.10**: Strength and Conditioning Coach for the Bulgarian Volleyball Federation’s U19 National Team
- **2022.04 - 2022.10**: Strength and Conditioning Coach for the Bulgarian Volleyball Federation’s U19 National Team
- **2023-Present**: Lecturer at the "Bio Fit" Sports College, Sofia

Experience:
Extensive coaching experience with athletes at both club and national levels in various sports, including swimming, volleyball, basketball, and others.

Introduction

Modern sports are increasingly dynamic, requiring a high level of physical and motor preparation for athletes to stay healthy and achieve peak results. The successful mastery of sports techniques necessitates a well-developed motor skillset and an optimal balance between the development of motor abilities. This is achieved through ongoing efforts to enhance physical qualities such as speed, endurance, strength, and flexibility, which form the foundation for athletic performance and maintenance.

Physical preparation is an essential component of the training process in most sports as it ensures health and athletic resilience. General and specific physical preparation establish the necessary physical qualities for achieving high results in a short timeframe. Advances in training methods aim to rapidly and effectively develop athletes' capabilities to meet evolving sports demands and achieve set goals.

Volleyball requires specific conditioning due to the high demands on jumping ability and endurance. The sport involves frequent offensive and defensive jumping actions, necessitating the development of speed-strength qualities for maximum jump performance and game effectiveness. Physical preparation is critical for the successful execution of technical and tactical tasks and for achieving high results in volleyball.

I. Problem Relevance

The dissertation posits that a structured methodology can yield significant benefits. When modules are properly arranged, the methodology maximizes the potential of athletes undergoing methodological guidance focusing on the eccentric phase of jumping. "Maximum potential" refers to the highest achievable performance within the athletes' training period and condition.

II. Methodology

1. Objective

The main objective of the study is to enhance the speed-strength preparation of highly qualified volleyball players through the development and application of a methodology for developing explosive strength in the lower limbs.

2. Tasks

To achieve the primary objective, the following tasks were undertaken:

1. Review and analyze literature.
2. Develop a set of exercises targeting explosive strength development in the lower limbs of 19-20-year-old volleyball players.
3. Develop a methodology for incorporating the exercise set into the training process.
4. Conduct a sports-pedagogical experiment to assess the effects of the developed methodology.

3. Research Object

The methodology for developing explosive strength in the lower limbs of volleyball players.

4. Subject

Changes in biomechanical indicators during specific control exercises as a result of applying the methodology.

The study measured the following parameters. (table 1)

Таблица 1. Measured parameters and signs.

Parameter	Sign
Jump Height by Flight Time	cm
Jump Height by Force Impulse	cm
Peak Force	N
Net Impulse	N*s
Vertical Take-Off Velocity	m/s
Max Rate of Force Development	N/s
Reactive Strength Index by Flight Time	
Peak Power	Watt
Time to Stabilization	s
Contact Time	s
Braking Duration	s
Countermovement Time	s
Peak Braking Force	N
Average Braking Force	N
Braking Impulse	N*s
Average Braking Velocity	m/s
Peak Propulsive Force	N
Average Propulsive Force	N
Average Propulsive Power	Watt
Propulsive Duration	S
Propulsive Impulse	N*s

The selected parameters assess the athletes' strength indicators through jump height, peak force, force impulse, and vertical take-off velocity. Measurements were taken using flight time and force impulse to evaluate the influence of variables. The Reactive Strength Index and stabilization time during landing were also included to assess parameter interactions. Eccentric and propulsive phases were analyzed for their relationship to strength abilities.

5. Research Participants

The study included 16 highly qualified volleyball players aged 19-20, divided into two groups: a control group and an experimental group, with 8 participants in each group.

6. Research Methodology

The study employed the following research methods and apparatus-based methodologies:

Systematization, Processing, and Analysis of Data from Methodological Literature on Sports Training in Volleyball:

Over 130 scientific studies, books, and textbooks were reviewed. From these, the most relevant sources were selected. These included works describing the structure and functions of the muscular apparatus and studies comparing methods for developing strength capabilities. Additionally, scientific-methodological articles focused on the specificity of various types of jumps were analyzed. These served as the foundation for the literature review. After analyzing the gathered information, the need for a detailed refinement of existing tools and methods for developing explosive strength in the lower limbs emerged.

Sports-Pedagogical Experiment:

Each test jump was performed in two attempts by the participants, with the higher result from the two being recorded.

To investigate changes in the level of explosive strength in the lower limbs, the following control exercises (tests) were used:

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2. Experiment.

Each test jump was performed in two attempts by the participants, with the higher result from the two being recorded.

To investigate changes in the level of explosive strength in the lower limbs, the following control exercises (tests) were used:

- *Standing Vertical Jump Without Arm Involvement on a Force Plate*

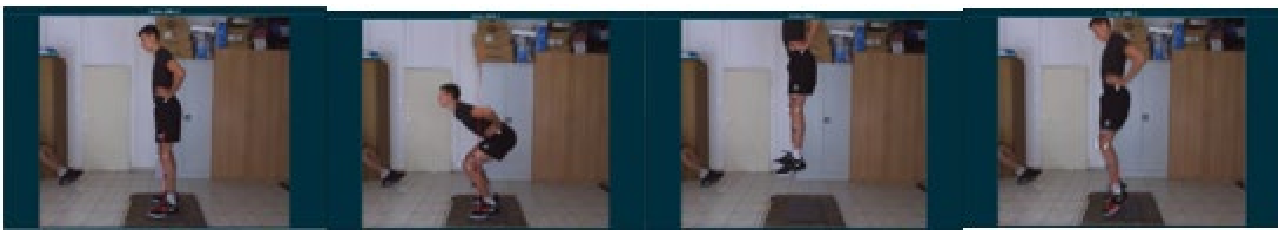

Fig. 1. Standing Vertical Jump Without Arm Involvement on a Force Plate

- *Vertical Jump After a Two-Step Approach on a Force Plate*

Fig. 2. Vertical Jump After a Two-Step Approach on a Force Plate

- *Two Consecutive Vertical Jumps on a Force Plate*

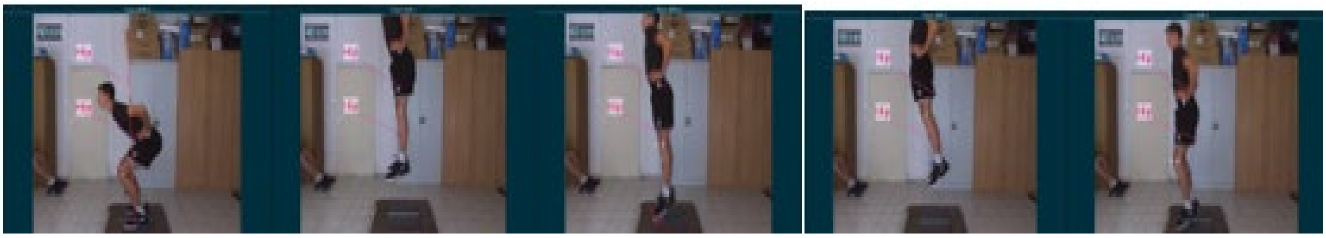

Fig. 3. Two Consecutive Vertical Jumps on a Force Plate

- Vertical Jump with Two Legs After an Approach

For each of the control exercises, two attempts were performed by each participant, with the higher result of the two used for analysis.

Apparatus-Based Methods

To measure the results of the control exercises, the following apparatus-based methodologies were employed:

Force Plate – MyoForce

The force plate used in the study had the following specifications:

Product Number: FP4060-PT

Dimensions: 600 x 400 x 55 mm (L x W x H)

Weight: 8 kg

Sensing Element: Strain Gauge

Capacity (FZ): 5,000 N

Capacity (FX, FY): 2,500 N

Portability: Yes

Accelerometry

The parameters of the accelerometer used were as follows:

Maximum Signal Frequency: 400 Hz

Anatomical Angle Accuracy: ±1.0 degrees (static); ±2.0 degrees (dynamic)

Angular Velocity: ±7,000 degrees/sec (internal frequency 1,600 Hz)

Accelerometers: ±200 g at 1,600 Hz frequency

Magnetometers: ±16 gauss; internal signal frequency 100 Hz

Internal Memory: 250 MB (up to 16 hours of recording)

Battery Operating Time: >8 hours

Charging Time: <4 hours

Sensor Dimensions: 4.45 cm x 3.3 cm x 1.22 cm (L x W x H)

Weight: <19 g

Video Recorder – MyoVideo

Videometry: This method was used to record the spatial-temporal characteristics of the participants. The study utilized the Noraxon MyoVideo system, which includes a high-speed camera capable of recording at up to 120 frames per second. This system allows tracking of reflective markers placed on key points relevant to the study

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- Angular Velocity: ±7,000 degrees/sec (internal frequency 1,600 Hz)
- Accelerometers: ±200 g at 1,600 Hz frequency
- Magnetometers: ±16 gauss; internal signal frequency 100 Hz
- Internal Memory: 250 MB (up to 16 hours of recording)
- Battery Operating Time: >8 hours
- Charging Time: <4 hours
- Sensor Dimensions: 4.45 cm x 3.3 cm x 1.22 cm (L x W x H)
- Weight: <19 g

Видеорегистратор – MyoVideo

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4. **Mathematical and Statistical Methods for Data Analysis**

- **Variation Analysis**

- **Correlation Analysis** – Calculation of correlation coefficients between variables affecting the jump performance.
- **Comparative Analysis Using Mann-Whitney Test**
- **Regression Analysis** – Assessment of the extent to which the variables influence the dependent variable (jump height).
- **Factor Analysis** – Identification of factors influencing jump height.

5. **Description of exercises comprised in the study for power development.**

To achieve the main objective of our study, we developed a set of the following exercises, which were incorporated into the training process of the participants:

Exercise 1. Jumping After a Depth Jump from 50 cm (Fig. 4)

Fig 4 Jumping After a Depth Jump from 50 cm

Starting Position:

Standing upright with arms slightly positioned backward.

Execution:

From the starting position, the body drops into a depth jump with arms moving backward. Upon contact with the ground, the arms actively swing forward, followed by a squat to a half-squat position and an explosive jump with knees raised high. The landing is performed softly in a squat position.

Methodical Instructions:

The ground contact should occur at the forefoot area, specifically from the fifth to the first metatarsal bones, with toes pointing upward (dorsiflexion).

The concentric phase begins with the greatest pressure exerted by the flexor hallucis longus (big toe flexor).

During landing, the pelvis should shift backward, and the torso should lean forward, mimicking the position of a barbell squat.

The landing must be as quiet as possible during amortization, and the subsequent concentric movement should be executed as quickly as possible.

Knees should remain mostly outward, and the feet should point forward. Due to the outward alignment of the feet during ground contact, the knees slightly fix outward during the amortization phase (preparation for the jump).

During the concentric phase, the force vector is directed toward the ball of the big toe, requiring the knees to draw closer together at the end of the phase before detachment (jumping phase).

After the jump, knees should be raised high toward the chest. Landing must be as silent as possible, transitioning gradually to the whole foot during amortization.

The jump and ground contact time should be minimized, despite the complex joint movement required. This is achieved by eliminating excessive amortization from the foot, ensuring that during the downward movement, toes are pointing upward (engaging the anterior tibialis muscles).

Exercise 2. Jump From Bulgarian Split Squat – From High to Low and Back (Fig. 5)

Fig. 5. Jump From Bulgarian Split Squat – From High to Low and Back

Starting Position:

Low position of a Bulgarian split squat.

Execution:

From the starting position, the supporting leg performs a jump downward. Upon quick contact with the ground, the athlete immediately jumps back to the starting position.

Methodical Instructions:

- Ground contact should occur at the forefoot. During landing, the pelvis should shift backward, and the torso should lean forward, resembling the position of a barbell squat.
- Perform the jump and ground contact as quickly as possible, minimizing the time spent in contact with the ground.
- To achieve minimal amortization, the toes of the grounded foot should point upward during the downward motion (activating the anterior tibialis muscles).
- Ensure smooth transitions and controlled movements to prevent injury and optimize performance.

Exercise 3. Squat – throw with medicine ball (fig. 6).

Fig 6. Squat – throw with medicine ball

Starting Position:

Squat position holding a medicine ball in front of the chest.

Execution:

From the starting position, extend the legs explosively, followed by extending the arms to throw the medicine ball upward. After the throw, catch the medicine ball and return to the initial squat position.

Methodical Instructions:

- Perform the exercise with a full range of motion.
- The concentric phase of the movement should be executed with acceleration to propel the ball upward.
- Minimize the involvement of the arms during the throw, emphasizing active participation of the lower limbs.

Exercise 4. Single-Leg Squat Jump with Weight (Fig. 7).

Fig. 7. Single-Leg Squat Jump with Weight

Starting Position:

A squat position on one leg, holding a medicine ball in front of the chest.

Execution:

From the starting position, the supporting leg extends explosively, performing a jump. The landing returns to the initial squat position.

Methodical Instructions:

- The weight used in this exercise is in the form of a medicine ball, with its mass varying based on the athlete's strength levels (typically 8-12 kg).
- During landing, the body must absorb the impact as quietly as possible.
- The amortization phase should emphasize stability and control, ensuring a soft landing to minimize joint stress.

Exercise 5. Squat with Forward Medicine Ball Thrust (Fig.8).

Fig. 8. Squat with Forward Medicine Ball Thrust

Starting Position:

Squat position holding a medicine ball in front of the chest.

Execution:

From the starting position, the legs extend forcefully while the torso angles slightly forward. After fully extending the legs, the arms push the medicine ball forward explosively. This is followed by stepping one leg forward to regain balance.

Methodical Instructions:

- The exercise should be performed with full range of motion in a half-squat position, holding the medicine ball at chest level.
- During the upward motion, the legs extend actively and quickly, aiming to achieve maximum speed in thrusting the ball forward.
- Ensure the movement is controlled and focused, with the arms extending rapidly as the ball is released.

Exercise 6. Lunge Jump with Alternating Leg Switch (Fig. 9)

Fig. 9. Lunge Jump with Alternating Leg Switch

Starting Position:

Lunge position with one leg forward and the other backward.

Execution:

From the starting position, perform an explosive jump. During the airborne phase, switch the positions of the legs dynamically (the front leg moves backward, and the back leg moves forward). Land softly back into the lunge position.

Methodical Instructions:

- Begin in a wide lunge stance with bent knees.
- During the jump, focus on maximizing height and ensuring the leg switch happens at the apex of the airborne phase.
- Land in the initial lunge position softly, absorbing the impact to minimize stress on the joints.
- Maintain proper posture throughout the movement, keeping the torso upright and stable.

Exercise 7. Vertical Hops on One Leg from the Ankle (Fig. 10)

Fig 9. Vertical Hops on One Leg from the Ankle

Starting Position:

Standing upright on one leg, with arms positioned slightly backward.

Execution:

Perform consecutive vertical hops on the same leg using only the movement generated from the ankle joint.

Methodical Instructions:

- Keep the ankle tight and the toes pointing upward during each hop (dorsiflexion).
- Ensure that the contact with the ground is made only with the forefoot.
- The focus should be on achieving quick and high vertical hops while minimizing the time spent on the ground.
- Maintain balance and stability throughout the exercise, ensuring precise and controlled movements.

7. Experiment

To demonstrate the effectiveness of the selected exercises for developing explosive strength in volleyball players, a sports-pedagogical experiment was conducted, during which the methodology for applying these exercises was implemented.

The experiment involved volleyball players aged 19 (+/-1) and lasted for 5 months as part of the preparation period before participation in a world championship. Sixteen respondents were divided into two groups of eight participants each: a control group (CG) and an experimental group (EG). Both groups trained simultaneously but followed different methodological guidelines and used different means during the final stages of their preparation, which included explosive strength training.

The distribution of the physical development periods for the experimental group is shown in Table 2 . The weekly training schedule for both groups over the 16-week period was as follows:

Table 2. Weekly schedule.

	Mon	**Tue**	**Wed**	**Thur**	**Fri**	**Sat**	**Sun**
Morning	Physical Preparation	Volleyball	Rest	Physical Preparation	Volleyball	Physical Preparation	Rest
Afternoon	Volleyball	Volleyball	Volleyball	Volleyball	Volleyball	Volleyball	Rest

Table 3. Monthly schedule.

Period	**18 May - 31 May**	**31 May - 17 June**	**21 June - 10 July**	**12 July - 27 July**	**1 August - 20 August**	**Participation in Major International Forum**
Focus	Prevention and localized strength endurance	Maximum strength development	Strength endurance	Explosive strength development	Speed-strength endurance	

In the experimental group, the third training period, described as "Strength Endurance" in Table 3, was modified. It included an increased volume of sets or repetitions at submaximal intensities ranging between 88-92% of the onerepetition maximum (1RM). Rest intervals were kept consistent at approximately 60-90 seconds, with five sets of five repetitions. This block incorporated three compound exercises, introducing innovation to the traditional training load system.

The purpose of this module was to prepare the athletes to demonstrate their strength capabilities with relatively quick recovery between efforts. This approach aimed to optimally develop the speed element in the subsequent training module.

For the experimental group, the "Explosive Strength Module" incorporated the developed exercises as part of the contrast training method planned for this period. The exercises were grouped and performed twice per week in paired sets, consisting of one primary compound strength exercise for the lower limbs and one speed-strength exercise.

Table 4. Grouping exercises

Main Exercise	Plyometric exercise	Sets	Reps
Barbell Squat	Depth jump from 50 sm	3	3/5
Front Squat	Jump after depth jump from 50 sm	3	3/5
Lunge backward	Jump from lunge with Alternating Leg Switch	3	5/8
Lunge backward	Jump From Bulgarian Split Squat – From High to Low and Back	3	5/8
Hip Thrust	Jump after depth jump from 50 sm	3	3/5

The control group followed a similar program but without the inclusion of the "Strength Endurance" module. For the "Explosive Strength" module, the training was based on considerations described in the literature review on page 51 of the dissertation.

In the "Speed-Strength Endurance" module, the control group utilized plyometric and ballistic exercises closely related to competition techniques. These exercises differed from those used by the experimental group and were conducted without specific methodological guidance.

Table 5. Module Distribution for the Control Group

<table>
<tr><td>Period</td><td>18 May - 31 May</td><td>31 May - 17 June.</td><td>21 June - 27 July</td><td>1 August - 20 August</td><td rowspan="2">Participation in Major International Forum</td></tr>
<tr><td>Focus</td><td>Prevention and Localized Strength Endurance</td><td>Maximum Strength</td><td>Explosive Strength</td><td>Speed-Strength Endurance</td></tr>
</table>

In the final module for the experimental group, "Speed-Strength Endurance," the exercises developed specifically for the pedagogical experiment were included. The goal was to transform the established strength qualities into precise, economical, and explosive movements that result in a higher jump during sports performance.

Table 6. Exercises in the Speed-Strength Endurance Module for the Experimental Group

Weeks	**Sessions per week**	**Number of exercises**	**Reps range**	**Sets range**	**Load(%)**	**Rest interval**
3	2	3	12-15	3-4	20-25%	30-60 сек

The methodology applied during this period is characterized by the following principles:

- **Explosive Movements and Ballistic Training:** Exercises include explosive movements involving detachment from the ground or ballistic actions, performed in a range of 8 to 12 repetitions and 3 to 5 sets. Rest intervals between sets are 30 to 45 seconds (depending on the athletes' preparation), with rest between exercises ranging from 90 to 120 seconds.
- **Methodical Guidelines:** These focus on pre-tensing or contracting the muscles involved in the movement before ground contact or before the direction of effort changes in ballistic exercises. This involves generating tension in the active muscles prior to the eccentric phase of the movement.
- **Joint Positioning Requirements:** Specific positions for joint segments are required at the start and end of the eccentric phase of the movement. These requirements ensure the utilization of the elastic properties of the muscles during the movement.
- **Exercise Progression:** Exercises are arranged in a sequence progressing from compound (multi-joint) to isolation (single-joint) movements during the training session.

Training Program Design

The training begins with activating exercises for the target muscle groups and ankle control, emphasizing stability and kinetic energy. Exercises incorporate specific positions, such as dorsiflexion, to ensure effective and safe landings that protect the joints and minimize ground reaction forces. Attention to landing technique and pre-tensioning of the muscles reduces injury risk and enhances optimal use of elastic forces. These requirements necessitate a high level of strength preparation to achieve maximum efficiency and safety.

Key Innovations in the Experimental Group

The control group followed traditional methods described in the literature review. In contrast, the experimental group's methodology introduced the following innovations:

1. **Added Strength Endurance Module:** This module utilized external resistance of 88-92%, with an increased number of sets (up to 5) and reduced rest intervals (60-90 seconds).
2. **Methodical Guidelines in the Explosive Strength Module:** These guidelines combined strength exercises with plyometric training to enhance the effectiveness of explosive strength development.
3. **Created Complexes of Exercises:** These complexes were included in both the "Explosive Strength" and "Speed-Strength Endurance" modules. The primary objective of the latter module was to transform the developed strength capabilities into sustainable power-speed performance over an extended period, maintaining optimal technical parameters and a high efficiency rate.

This innovative approach focused on refining the athletes' ability to perform explosive and efficient movements while ensuring long-term endurance and technical precision during competition. Let me know if additional sections or tables need further elaboration!

8. Organization of the Study

The study was conducted in four stages.

Stage One – Data Collection

The first stage of this research was carried out over a three-month period, from November 2021 to February 2022. It involved gathering information on the dissertation topic. Practical experience and advancements in physical preparation in recent years served as additional motivation for conducting the current study. During this phase, the dissertation title, thesis, and plan for the scientific work were developed.

Stage Two – Development of Additional Tools and Methods

The second stage focused on designing supplementary tools and methods to refine existing systems for developing explosive strength in volleyball players. The development was based on physiological, biomechanical, and biochemical characteristics of the motor apparatus, as well as established methods and systems. Exercises with specific methodological guidelines were created, along with their systematic sequence and defined application volume. This stage lasted three months, from February to May 2022.

Stage Three – Conducting the Pedagogical Experiment

The experiment was conducted in 2022, involving volleyball players aged 19 (+/-1). It lasted for five months during the preparatory period leading up to a major international competition. Sixteen respondents were divided into two groups:

- **Control Group (CG):** Utilized known tools and methods.
- **Experimental Group (EG):** Implemented newly developed tools and methods.

Both groups worked simultaneously but followed different methodological guidelines and used distinct tools in the final stages of their preparation, focusing on explosive strength. A preliminary assessment was conducted at the start of the physical preparation phase to register the baseline physical qualities of the respondents. After completing the physical preparation, a follow-up assessment was conducted to record and compare changes in the physical performance indicators.

Stage Four – Data Processing and Analysis

The final stage was the longest, lasting approximately ten months, from October 2022 to July 2023. During this period, the collected data was processed and analyzed. Finalization and revisions of the dissertation were carried out in the early months of 2024. Conclusions on the research problem were formulated, and recommendations and guidelines were developed based on the results of the study.

III. Analysis of the Results

1. Before Conducting the Pedagogical Experiment

1.1. Variation Analysis Before Conducting the Study

1.1.1. Standing Vertical Jump Without Arm Involvement

The presented indicators for jump height, measured by flight time and force impulse, reveal a difference between the mode and median, suggesting potential asymmetry in the data distribution. The mean values are closer to the median, indicating a symmetric or near-symmetric distribution. Significant variations are observed in the data, and values with greater deviations demonstrate a larger dispersion from the mean.

The coefficient of variation for indicators related to explosive qualities is high (above 30%), likely due to the varying levels of preparedness among participants. To successfully develop explosive efforts, specific attention must be given to this aspect during the training process.

The results of the Shapiro-Wilk test indicate a normal distribution for parameters such as flight time, jump height by flight time, peak force, and stabilization time. However, parameters such as jump height by force impulse, vertical take-off velocity, and concentric effort impulse exhibit a non-normal distribution ($p < 0.05$).

Table 7. Variation Analysis of Data for the Exercise "Standing Vertical Jump Without Arm Involvement" in the Experimental Group Before the Start of the Pedagogical Experiment

Parameter	Me	X	S	V	As	Ex	R
Jump Height by Flight Time, cm	37.745	37.756	1.705	4.5	-0.742	1.132	5.42
Jump Height by Force Impulse, cm	39.485	43.394	13.114	30.2	2.71	7.51	39.82
Peak Force, N	1843.185	1823.984	184.528	10.1	-0.269	-1.129	528.58
Force Impulse, N·s	216.565	219.386	35.017	16	0.913	0.873	106.77
Vertical Take-Off Velocity by Net Impulse, m/s	2.485	2.595	0.345	13.3	2.699	7.477	1.07
Force Gradient, N/s	6387.69	7243.654	2420.359	33.4	0.787	-1.063	6084.05
Reactive Strength Index by Flight Time	0.295	0.304	0.105	34.4	0.269	-1.304	0.29
Reactive Strength Index by Net Impulse	0.305	0.334	0.149	44.5	0.837	0.14	0.44
Peak Power, Watt	4464.37	4479.641	663.285	14.8	1.031	1.823	2133.45
Time to Stabilization, s	1.315	1.291	0.641	49.6	-0.332	-0.688	1.92
Peak Propulsive Force, N	1843.185	1823.984	184.528	10.1	-0.269	-1.129	528.58
Average Propulsive Force, N	1407.915	1398.852	219.814	15.7	-0.718	0.202	665.53
Average Propulsive Power, Watt	2164.535	2030.329	700.532	34.5	-1.417	3.335	2402.18
Propulsive Effort Duration, s	0.325	0.405	0.244	60.1	2.683	7.388	0.75
Propulsive Effort Impulse, N·s	451.63	496.269	184.455	37.2	2.182	5.501	598.55

Table 8. Variation Analysis of Data for the Exercise "Standing Vertical Jump Without Arm Involvement" in the Control Group Before the Start of the Pedagogical Experiment

Parameter	Me	X	S	V	As	Ex	R
Jump Height by Flight Time, cm	35.7	35.4	2.8	10	-0.3	-1.3	7.5
Jump Height by Force Impulse, cm	37.5	36.6	4	10	0.2	-0.2	12.4
Peak Force, N	1893.5	1899.3	285.2	20	0.9	3.1	1021.9
Force Impulse, N·s	218.1	218.4	21.4	10	-0.4	0	67.8
Vertical Take-Off Velocity by Net Impulse, m/s	2.7	2.7	0.1	10	0.1	-0.4	0.4
Force Gradient, N/s	6189.2	7189.6	2976.3	40	2	4.5	8977.9
Reactive Strength Index by Flight Time	0.4	0.5	0.3	70	1.9	4.4	1
Reactive Strength Index by Net Impulse	0.4	0.5	0.4	70	2.1	4.9	1.2
Peak Power, Watt	4404.6	4499	835.7	20	0.9	3.1	3005.4
Time to Stabilization, s	1.1	1.1	0.4	40	0.4	0.6	1.3
Peak Propulsive Force, N	1893.5	1899.3	285.2	20	0.9	3.1	1021.9
Average Propulsive Force, N	1419.8	1416	163.6	10	-0.1	-1.6	444.3
Average Propulsive Power, Watt	1853.9	1814.1	406.7	20	-0.5	-1.1	1125
Propulsive Effort Duration, s	0.3	0.4	0.2	40	1.8	2.7	0.5
Propulsive Effort Impulse, N·s	490.6	526.8	150.2	30	1.5	2	434.3

In summary, some of the measurements exhibit significant variation, which impacts the data and requires careful consideration when interpreting the results.

1.1.2. Jump after depth jump

The data show varying degrees of dispersion and variation in the indicators related to jump height and associated physical parameters. For jump height, the range is small (9.5 cm), and the standard deviation and coefficient of variation are low, indicating low dispersion and an approximately normal distribution (P-value 0.1). In contrast, the peak force shows a large range (562.2 N) and high standard deviation, highlighting significant variation, likely due to the different requirements for different player positions. However, the distribution remains approximately normal (P-value 0.7).

The force impulse and vertical take-off velocity also show a small range and low dispersion, with both indicators demonstrating an approximately normal distribution. The average jump height is 31.2 cm, with a standard deviation of 2.8 cm. The indicators for peak force and force gradient have a significant range and high variation, emphasizing the importance of correct interpretation of the data and the relevance of different parameters to jump height..

Table 9. Variation analysis of the data for the exercise "Jump After a Depth Jump" in the experimental group before the start of the pedagogical experiment.

Parameter	Me	X	S	V	As	Ex	R
Jump Height by Flight Time, cm	34.7	34.2	2.9	8.4	-1.7	3.8	9.5
Peak Force, N	1932.7	1903.9	197.1	10.4	-0.3	-0.9	562.2
Force Impulse, Ns	201.9	205.7	24.8	12.1	0.5	-0.5	73.7
Vertical Take-Off Velocity by Force Impulse, m/s	2.4	2.4	0.1	3.9	-1.7	3.6	0.3
Force Gradient, N/s	9259	8806	3805.1	43.2	0.7	0.5	11701.8
Reactive Strength Index by Flight Time	0.3	0.3	0.1	34.4	-0.3	-0.4	0.4
Peak Power, Watt	4253.7	4281.1	397.9	33.8	0	-1.7	1087.2
Eccentric Phase Duration, s	0.2	0.3	0.2	9.3	2.4	6.3	0.6
Time to Change Direction, s	0.9	1	0.5	66.3	2.2	5.3	1.7
Maximum Force During Eccentric Effort, N	1312.2	1474.1	389.3	56.3	0.5	-1	1127.8
Average Force During Eccentric Effort, N	941.4	1091.7	320.9	26.4	0.8	-0.4	954.6
Eccentric Effort Impulse, Ns	205.8	236.3	90.1	29.4	2.1	5.2	288.7
Average Velocity of Eccentric Effort, m/s	0.4	0.5	0.2	38.1	0.4	0.5	0.6
Maximum Propulsive Force, N	1932.7	1903.9	197.1	36.9	-0.3	-0.9	562.2
Average Propulsive Force, N	1530.4	1553.4	199.8	30	0.1	-1.8	504.7
Average Propulsive Power, Watt	2237.7	2258.9	373.5	8.4	0.3	-1.7	974.8
Propulsive Effort Duration, s	0.3	0.3	0	10.4	0.6	0.1	0.1
Propulsive Impulse, N*s	402.5	397.3	48.5	12.1	0.1	0.4	154.8

Table 10. Jump After a Depth Jump" in the control group before the start of the pedagogical experiment.

Parameter	Me	X	S	V	As	Ex	R
Jump Height by Flight Time, cm	31.4	31.2	2.8	8.8	-0.7	0.9	8.7
Peak Force, N	1955.6	1942.7	230.9	11.9	-0.8	1.2	753
Force Impulse, Ns	202	200.8	17.5	8.7	-0.1	-2.1	43.9
Vertical Take-Off Velocity by Force Impulse, m/s	2.5	2.4	0.1	4	-1.2	1.4	0.3
Force Gradient, N/s	7877.6	7858.1	1728.3	22	0.2	-0.3	5294
Reactive Strength Index by Flight Time	0.3	0.3	0.1	17.2	0.2	0.3	0.2
Peak Power, Watt	4210.5	4165.3	541.3	17.5	-0.4	-0.7	1612
Eccentric Phase Duration, s	0.2	0.3	0.1	13	1.8	3	0.3
Time to Change Direction, s	0.7	0.7	0.1	42	-0.6	-0.6	0.3
Maximum Force During Eccentric Effort, N	1457.2	1415.1	274.3	15.8	-0.2	-2.1	626.1
Average Force During Eccentric Effort, N	1077.7	1059.3	118.2	19.4	-1.2	1.8	366.6
Eccentric Effort Impulse, Ns	231.5	259.9	74.6	11.2	1.3	0.5	203
Average Velocity of Eccentric Effort, m/s	0.5	0.5	0.1	28.7	0	0.3	0.5
Maximum Propulsive Force, N	1955.6	1942.7	230.9	27.9	-0.8	1.2	753
Average Propulsive Force, N	1569.3	1535	177.4	11.9	0.2	-0.7	513.2
Average Propulsive Power, Watt	2074.2	2032.7	343.5	11.6	-0.2	-0.8	1019.2
Propulsive Effort Duration, s	0.3	0.3	0.1	16.9	0.6	1.4	0.2
Propulsive Impulse, N*s	411.6	419.9	45.6	18.1	0.3	-1.7	119.3

1.1.3. Jump after two steps approach

The data for jump height, peak force, force impulse, and vertical take-off velocity show varying degrees of variation and distribution, which are significant for the analysis. The average jump height during flight is approximately 48.3 cm, with moderate variation (standard deviation 5.1 cm), while peak force exhibits greater variability, with a standard deviation of 265.2 N. The mean force impulse is around 244 Ns and shows relatively low dispersion, similar to vertical take-off velocity, which also has low variation (standard deviation 0.2 m/s).

The results of the Shapiro-Wilk test indicate that some parameters, such as flight time and stabilization time, follow a normal distribution ($p > 0.05$), allowing for the use of parametric methods for analysis. Other parameters, such as jump height by flight time and vertical take-off velocity, have p-values below 0.05, suggesting a non-normal distribution and necessitating the use of non-parametric methods.

Furthermore, significant variation in parameters such as jump height and peak force reflects differences in the physical conditioning of participants. For parameters with p-values close to 0.05, such as vertical velocity, it is recommended to perform additional checks for normality or to use non-parametric approaches when necessary.

Table 11. Variation analysis of the data for the exercise "Jump After a Two-Step Approach" in the experimental group before the start of the pedagogical experiment.

Parameter	Me	X	S	V	As	Ex	R
Jump Height by Flight Time, cm	48.6	48.3	5.1	10.5	-0.8	1.1	16.6
Peak Force, N	2474.5	2375.8	265.2	11.2	-0.8	-1.2	651.8
Force Impulse, N*s	239.4	244	35.7	14.6	0.3	-1.7	91.2
Vertical Take-Off Velocity, m/s	2.9	2.9	0.2	8.6	-1.8	3.8	0.8
Force Gradient, N/s	54129.8	47521.4	16302.6	34.3	-0.8	-1.1	43503
Ground Contact Time, s	0.5	0.5	0	9.3	1.3	1	0.1
Reactive Strength Index by Flight Time	1.2	1.2	0.2	15.3	-0.6	-1.6	0.4
Peak Power, Watt	6215.8	6154.3	1349.3	21.9	1.3	2.2	4080.5
Stabilization Time, s	1.1	1	0.3	27	-0.3	-1.6	0.7

Таблица 12. Variation analysis of the data for the exercise "Jump After a Two-Step Approach" in the control group before the start of the pedagogical experiment.

	Me	X	S	V	As	Ex	R
Jump Height by Flight Time, cm	44.3	35.3	22.4	63.3	-1.2	-0.3	53.4
Peak Force, N	2276	1791.8	1128.1	63	-1.3	-0.2	2844.4
Force Impulse, N*s	222.2	186	118.7	63.8	-1.2	-0.3	291.1
Vertical Take-Off Velocity, m/s	2.9	2.3	1.4	62.5	-1.3	-0.1	3.4
Force Gradient, N/s	40970.6	33813.8	22366.6	66.1	-0.9	-0.6	58196.2
Ground Contact Time, s	0.4	0.3	0.2	62.7	-1.3	-0.1	0.5
Reactive Strength Index by Flight Time	1.1	0.9	0.5	63.3	-1.2	-0.3	1.4
Peak Power, Watt	4998.5	4122.7	2629.7	63.8	-1.2	-0.3	6721.1
Stabilization Time, s	1.3	1.1	0.8	70.1	-0.3	0.1	2.3

1.1.4. Jump after approach

The mean values and medians of both groups are close, suggesting an even distribution of the data. However, the second group (CG BEFORE) shows greater dispersion, with higher values for standard error and standard deviation.

The kurtosis in the first group (EG BEFORE) is positive, indicating a sharper peak in the distribution, whereas in the second group it is negative, suggesting a flatter peak and wider tails. The second group also exhibits a larger range in the data.

Table 1. Variation analysis of the data for the exercise "Vertical Jump After an Approach" for the control and experimental groups before conducting the pedagogical experiment.

	EG Before	*CG before*
Mean Value	347.875	333.625
Standard Error	3.435	5.973
Median	351	335.5
Mode	351	346
Standard Deviation	9.717	16.894
Variance	94.411	285.411
Kurtosis	5.922	-2.417
Skewness	-2.293	-0.021
Range	32	39
Minimum	325	315
Maximum	357	354
Sum	2783	2669
Count	8	8
Highest Value	357	354
Lowest Value	325	315

1.1.5. Summary

The analysis of the three types of jumps (evaluated with apparatus-based methods) reveals different aspects of lower-body strength and explosiveness. The standing jump emphasizes baseline strength with minimal variations, the depth jump highlights the speed of direction change, and the volleyball jump with an approach focuses on explosiveness and coordination. These differences underscore the need for personalized training tailored to the athletes' goals and requirements.

1.2. Comparative Analysis Before Conducting the Experiment

1.2.1. Significance of Differences at the Beginning of the Pedagogical Experiment for the Exercise "Standing Vertical Jump Without Arm Involvement"

After conducting a variation analysis to determine the homogeneity of the groups, we applied the Mann-Whitney test to assess the relationship between the groups before the start of the pedagogical experiment.

Table 2. Mann- Whitney Standing Vertical Jump Without Arm Involvement.

	t	df	p
Jump Height by Flight Time, cm	1.990	14.000	0.067
Jump Height by Force Impulse, cm	1.392	14.000	0.186
Peak Force, N	-0.627	14.000	0.540
Force Impulse, Ns	0.070	14.000	0.946
Vertical Take-Off Velocity by Net Impulse, m/s	-0.435	14.000	0.670
Force Gradient, N/s	0.040	14.000	0.969
Reactive Strength Index by Flight Time	-1.545	14.000	0.145
Reactive Strength Index by Force Impulse	-1.290	14.000	0.218
Peak Power, Watt	-0.051	14.000	0.960
Stabilization Time, s	0.651	14.000	0.526
Peak Propulsive Force, N	-0.627	14.000	0.540
Average Propulsive Force, N	-0.177	14.000	0.862
Average Propulsive Power, Watt	0.755	14.000	0.463
Propulsive Effort Duration, s	0.110	14.000	0.914
Propulsive Effort Impulse, Ns	-0.362	14.000	0.722
Note. Mann Whitney			

The table shows that there are no statistically significant differences between the experimental and control groups. This allows us to perform subsequent statistical analysis to determine how the pedagogical experiment impacts the groups after its implementation.

1.2.2. Significance of Differences at the Beginning of the Pedagogical Experiment for the Exercise "Jump After a Depth Jump"

After conducting a variation analysis to determine the homogeneity of the groups, we applied a T-test to assess the relationship between the groups before the start of the pedagogical experiment.

Table 3. T-test Jump After a Depth Jump

	t	df	p
Jump Height by Flight Time, cm	2.10	14.00	0.05
Jump Height by Force Impulse, cm	1.87	14.00	0.08
Peak Force, N	-0.362	14	0.723
Force Impulse, Ns	0.461	14	0.652
Vertical Take-Off Velocity by Force Impulse, m/s	-0.572	14	0.576
Force Gradient, N/s	0.641	14	0.532
Reactive Strength Index by Flight Time	0.482	14	0.637
Reactive Strength Index by Force Impulse	0.36	14	0.724
Peak Power, Watt	0.488	14	0.633
Eccentric Phase Duration, s	0.319	14	0.755
Time to Change Direction, s	1.23	14	0.239
Maximum Force During Eccentric Effort, N	0.35	14	0.731
Average Force During Eccentric Effort, N	0.268	14	0.793
Impulse of Eccentric Effort, Ns	-0.572	14	0.576
Average Velocity of Eccentric Effort, m/s	-0.497	14	0.627
Maximum Propulsive Force, N	-0.362	14	0.723
Average Propulsive Force, N	0.195	14	0.848
Average Propulsive Power, Watt	1.261	14	0.228
Propulsive Effort Duration, s	0.24	14	0.814
Propulsive Impulse, N*s	-0.962	14	0.352
Note. Mann – Whitney test			

For the parameter "Jump Height by Flight Time, cm," a statistically significant result (p = 0.05) indicates a difference in jump height between the two groups. This difference is attributed to the varying levels of preparedness between the respondents in the control and experimental groups. For the parameter "Jump Height by Force Impulse, cm," the p-value is close to 0.05 (p = 0.08), suggesting a potential trend toward statistical significance.

For the remaining parameters, the p-values are greater than 0.05, indicating no statistically significant differences between the groups. For some parameters, such as "Force Gradient" and "Average Concentric Power," the p-values are closer to 0.05 but do not reach statistical significance.

The majority of parameters show no statistically significant differences between the groups, as indicated by the p-values, suggesting that these parameters do not differ substantially between the groups.

In conclusion, the test does not reveal statistically significant differences between the groups for the various measured parameters analyzed. Further methodology could be developed to improve the indicators and evaluate the effectiveness and differences between the control and experimental groups.

1.2.3. Significance of Differences at the Beginning of the Pedagogical Experiment for the Exercise "Jump After a Two-Step Approach"

After conducting a variation analysis to determine the homogeneity of the groups, we applied the Mann–Whitney U test to assess the relationship between the groups before the start of the pedagogical experiment.

Table 4. „Jump After a Two-Step Approach“.

	t	df	p
Jump Height by Flight Time	44.000	14	0.227
Jump Height by Force Impulse	38.000	14	0.563
Peak Force, N	41.000	14	0.372
Force Impulse, N*s	39.000	14	0.495
Vertical Take-Off Velocity, m/s	31.000	14	0.958
Force Gradient, N/s	44.000	14	0.227
Ground Contact Time, s	56.500	14	0.011
Reactive Strength Index by Flight Time	43.000	14	0.269
Reactive Strength Index by Force Impulse	35.500	14	0.752
Peak Power, Watt	48.000	14	0.103
Stabilization Time, s	23.500	14	0.400
Note. Mann – Whitney test			

From this, we can conclude that there are statistically significant differences between the groups for the parameter Ground Contact Time, while for the other parameters, there are no statistically significant differences. This may be attributed to the overall higher values related to the explosive qualities of the respondents in the experimental group. A methodology could be implemented to further develop these indicators and evaluate the effectiveness and differences between the control and experimental groups

1.2.4. Significance of Differences at the Beginning of the Pedagogical Experiment for the Exercise "Vertical Jump After an Approach"

After conducting a variation analysis to determine the homogeneity of the groups, we applied a T-test to assess the relationship between the groups before the start of the pedagogical experiment.

Table 5. Vertical Jump After an Approach.

	ЕГ Before	*КГ Before*
Mean Value	347.875	333.625
Variance	94.41071	285.4107143
Observations	8	8
Pooled Variance	189.9107	
Hypothetical Difference	0	
Degrees of Freedom (df)	14	
t Stat	2.068093	
P(T<=t) One-Tail	0.028815	
t Critical One-Tail	1.76131	
P(T<=t) Two-Tail	0.057629	
t Critical Two-Tail	2.144787	

The mean value for EG Before is 347.875, while the mean value for CG Before is 333.625. EG Before appears to have a higher mean value compared to CG Before. The variance for EG Before is 94.41, while the variance for CG Before is 285.41. EG Before shows less variance compared to CG Before.
The t-statistic value is 2.07. The p-value for a one-tailed test is 0.03. Since this value is smaller than the commonly used alpha value (0.05), we can conclude that there is a statistically significant difference between the two data sets for the one-tailed test. The critical t-value for the one-tailed test is 1.76.
The p-value for the two-tailed test is 0.06. Since this value is greater than the commonly used alpha value (0.05), there is no statistically significant difference in the two-tailed test.

2. After conducting the experiment

2.1. Variation Analysis After Conducting the Experiment

2.1.1. Standing Vertical Jump Without arms

Таблица 6. Variation Analysis of Data After the End of the Pedagogical Experiment for the Experimental Group in the Exercise "Standing Vertical Jump Without Arm Involvement".

	Group	X	S	V	R	Min	Max
Jump Height by Flight Time, cm (EG)	EG	40.38	1.85	4.6	5.90	36.80	42.70
Jump Height by Flight Time, cm (EG Before)	EG Before	37.76	1.71	4.5	5.42	34.48	39.90
Jump Height by Force Impulse, cm (EG)	EG	44.24	13.20	29.8	40.50	36.10	76.60
Jump Height by Force Impulse, cm (EG Before)	EG Before	43.39	13.11	30.2	39.82	35.69	75.51
Peak Force, N (EG)	EG	2052.97	206.85	10.1	595.44	1727.55	2322.99
Peak Force, N (EG Before)	EG Before	1823.98	184.53	10.1	528.58	1533.34	2061.92
Force Impulse, Ns (EG)	EG	246.93	39.35	15.9	120.13	202.98	323.11
Force Impulse, Ns (EG Before)	EG Before	219.39	35.02	16	106.77	179.97	286.74
Vertical Take-Off Velocity by Force Impulse, m/s (EG)	EG	2.92	0.39	13.4	1.22	2.66	3.88
Vertical Take-Off Velocity by Force Impulse, m/s (EG Before)	EG Before	2.60	0.35	13.3	1.07	2.37	3.44
Force Gradient, N/s (EG)	EG	8154.51	2730.85	33.5	6867.28	5662.04	12529.32
Force Gradient, N/s (EG Before)	EG Before	7243.65	2420.36	33.4	6084.05	5024.70	11108.75
Reactive Strength Index by Flight Time (EG)	EG	0.31	0.12	37.5	0.34	0.17	0.51
Reactive Strength Index by Flight Time (EG Before)	EG Before	0.30	0.11	34.4	0.29	0.17	0.46
Reactive Strength Index by Force Impulse (EG)	EG	0.34	0.16	45.9	0.45	0.17	0.62
Reactive Strength Index by Force Impulse (EG Before)	EG Before	0.33	0.15	44.5	0.44	0.17	0.61
Peak Power, Watt (EG)	EG	5042.18	747.03	14.8	2400.24	4152.56	6552.80
Peak Power, Watt (EG Before)	EG Before	4479.64	663.29	14.8	2133.45	3681.74	5815.19
Stabilization Time, s (EG)	EG	1.21	0.60	49.9	1.80	0.22	2.02
Stabilization Time, s (EG Before)	EG Before	1.29	0.64	49.6	1.92	0.24	2.16
Peak Propulsive Force, N (EG)	EG	2052.97	206.85	10.1	595.44	1727.55	2322.99
Peak Propulsive Force, N (EG Before)	EG Before	1823.98	184.53	10.1	528.58	1533.34	2061.92
Average Propulsive Force, N (EG)	EG	1574.36	246.08	15.6	739.02	1120.26	1859.28
Average Propulsive Force, N (EG Before)	EG Before	1398.85	219.81	15.7	665.53	994.36	1659.89
Average Propulsive Power, Watt (EG)	EG	2285.13	788.41	34.5	2707.00	596.00	3303.00
Average Propulsive Power, Watt (EG Before)	EG Before	2030.33	700.53	34.5	2402.18	529.02	2931.20
Propulsive Effort Duration, s (EG)	EG	0.38	0.23	59.9	0.70	0.23	0.93
Propulsive Effort Duration, s (EG Before)	EG Before	0.41	0.24	60.1	0.75	0.25	1.00
Propulsive Effort Impulse, Ns (EG)	EG	558.59	207.80	37.2	673.92	369.04	1042.96
Propulsive Effort Impulse, Ns (EG Before)	EG Before	496.27	184.46	37.2	598.55	327.20	925.75

EG shows significant improvements compared to EG Before in almost all indicators, which is the result of training or other forms of intervention. Jump height, peak force, impulse, and take-off velocity have increased, demonstrating the development of muscle strength, coordination, and the ability to generate force rapidly. The EG Before group has lower values for these parameters, which is expected for the initial state before training.

The observed differences highlight the effectiveness of training interventions in improving standing jumps. Variations in values and standard deviations remain relatively similar between the groups, indicating stability in the distribution of results.

Table 7. Variation Analysis of Data After the End of the Pedagogical Experiment for the Control Group in the Exercise "Standing Vertical Jump Without Arm Involvement"

	Group	Me	X	S	V	R	Min	Max
Jump Height by Flight Time, cm	CG	36.50	36.13	2.99	8.3	7.80	32.00	39.80
Jump Height by Flight Time, cm	CG Before	35.73	35.42	2.84	8	7.46	31.56	39.02
Jump Height by Force Impulse, cm	CG	38.35	37.36	4.20	11.2	12.90	31.50	44.40
Jump Height by Force Impulse, cm	CG Before	37.49	36.64	4.05	11	12.35	31.18	43.53
Peak Force, N	CG	1937.14	1936.97	293.40	15.1	1056.50	1476.67	2533.17
Peak Force, N	CG Before	1893.51	1899.34	285.23	15	1021.91	1461.59	2483.50
Force Impulse, Ns	CG	222.83	222.71	22.41	10.1	70.94	182.63	253.57
Force Impulse, Ns	CG Before	218.11	218.38	21.42	9.8	67.83	180.77	248.60
Vertical Take-Off Velocity by Force Impulse, m/s	CG	2.74	2.70	0.15	5.6	0.46	2.49	2.95
Vertical Take-Off Velocity by Force Impulse, m/s	CG Before	2.68	2.65	0.14	5.4	0.43	2.46	2.89
Force Gradient, N/s	CG	6322.67	7331.38	3036.85	41.4	9205.62	5020.48	14226.10
Force Gradient, N/s	CG Before	6189.19	7189.58	2976.30	41.4	8977.94	4969.22	13947.16
Reactive Strength Index by Flight Time	CG	0.44	0.50	0.34	67.4	1.03	0.24	1.27
Reactive Strength Index by Flight Time	CG Before	0.43	0.50	0.33	67.5	1.01	0.24	1.25
Reactive Strength Index by Force Impulse	CG	0.46	0.53	0.40	74.2	1.20	0.24	1.44
Reactive Strength Index by Force Impulse	CG Before	0.45	0.52	0.39	73.9	1.17	0.24	1.41
Peak Power, Watt	CG	4499.64	4588.65	859.40	18.7	3096.53	3235.80	6332.33

Peak Power, Watt	CG Before	4404.64	4499.00	835.74	18.6	3005.41	3202.76	6208.17
Stabilization Time, s	CG	1.03	1.10	0.39	35.8	1.30	0.50	1.80
Stabilization Time, s	CG Before	1.05	1.12	0.40	35.7	1.32	0.51	1.83
Peak Propulsive Force, N	CG	1937.14	1936.97	293.40	15.1	1056.50	1476.67	2533.17
Peak Propulsive Force, N	CG Before	1893.51	1899.34	285.23	15	1021.91	1461.59	2483.50
Average Propulsive Force, N	CG	1448.42	1443.88	168.59	11.7	449.72	1213.33	1663.05
Average Propulsive Force, N	CG Before	1419.76	1415.99	163.63	11.6	444.33	1186.11	1630.44
Average Propulsive Power, Watt	CG	1891.00	1849.75	416.13	22.5	1144.00	1201.00	2345.00
Average Propulsive Power, Watt	CG Before	1853.88	1814.07	406.66	22.4	1124.96	1174.06	2299.02
Propulsive Effort Duration, s	CG	0.32	0.38	0.15	40	0.45	0.26	0.71
Propulsive Effort Duration, s	CG Before	0.32	0.39	0.16	39.9	0.46	0.27	0.73
Propulsive Effort Impulse, Ns	CG	500.44	537.28	154.23	28.7	445.42	411.19	856.61
Propulsive Effort Impulse, Ns	CG Before	490.58	526.75	150.19	28.5	434.26	403.13	837.39

The CG group shows slight improvements compared to CG Before in most indicators, including jump height, peak force, and power. This indicates that following the intervention (likely a training program), there were small but noticeable gains in strength and performance efficiency during the standing vertical jump. The differences are not significant, suggesting that these groups have a relatively similar physical profile and that the intervention had a moderate impact on the results. The improved values in CG suggest an increased capacity for force generation and better utilization of reactive forces, which are critical for achieving better jump performance.

The experimental group (EG) demonstrates significant improvements in almost all indicators after the experiment, while the control group (CG) shows only slight improvements. The results indicate that the pedagogical experiment had a positive effect on explosive strength, coordination, and control in EG, with increases in jump height, peak force, and power being significantly greater. This provides clear evidence of the effectiveness of the training methodology in developing physical performance indicators related to the standing vertical jump.

2.1.2. Jump After Depth Jump

Table 8. Variation Analysis of Data After the End of the Pedagogical Experiment for the Experimental Group in the Exercise "Jump After a Depth Jump"

Indicators	Group	Mo	Me	X	S	V	R	Min	Max
Jump Height by Flight Time, cm	EG	31.30	39.10	38.41	3.23	8.4	10.40	31.30	41.70
Jump Height by Flight Time, cm	EG Before	27.85	34.75	34.21	2.89	8.4	9.47	27.85	37.32
Jump Height by Force Impulse, cm	EG	31.30	38.60	37.61	2.90	7.7	9.10	31.30	40.40
Jump Height by Force Impulse, cm	EG Before	27.85	34.30	33.50	2.60	7.7	8.31	27.85	36.16
Peak Force, N	EG	1779.09	2176.21	2137.41	219.09	10.3	617.85	1779.09	2396.94
Peak Force, N	EG Before	1583.04	1932.68	1903.85	197.14	10.4	562.21	1583.04	2145.25
Force Impulse, Ns	EG	196.77	226.93	230.94	27.53	11.9	81.19	196.77	277.96
Force Impulse, Ns	EG Before	175.09	201.91	205.71	24.82	12.1	73.69	175.09	248.77
Vertical Take-Off Velocity, m/s	EG	2.48	2.75	2.72	0.11	3.9	0.34	2.48	2.82
Vertical Take-Off Velocity, m/s	EG Before	2.21	2.45	2.42	0.10	3.9	0.31	2.21	2.52
Force Gradient, N/s	EG	4711.83	10404.41	9882.45	4251.14	43	13047.40	4711.83	17759.23
Force Gradient, N/s	EG Before	4192.61	9258.98	8805.95	3805.05	43.2	11701.83	4192.61	15894.44
Reactive Strength Index by Flight Time	EG	0.17	0.39	0.39	0.13	34.1	0.41	0.17	0.58
Reactive Strength Index by Flight Time	EG Before	0.44	0.35	0.35	0.12	34.4	0.37	0.15	0.52

Reactive Strength Index by Force Impulse	EG	0.17	0.38	0.38	0.13	33.5	0.39	0.17	0.56
Reactive Strength Index by Force Impulse	EG Before	0.43	0.34	0.34	0.11	33.8	0.35	0.15	0.50
Peak Power, Watt	EG	4208.43	4772.56	4806.40	442.77	9.2	1190.34	4208.43	5398.77
Peak Power, Watt	EG Before	3744.68	4253.70	4281.10	397.86	9.3	1087.20	3744.68	4831.88
Eccentric Phase, s	EG	0.13	0.20	0.24	0.16	66.6	0.50	0.13	0.63
Eccentric Phase, s	EG Before	0.15	0.22	0.28	0.18	66.3	0.56	0.15	0.71
Time to Change Direction, s	EG	0.46	0.78	0.85	0.48	56.2	1.50	0.46	1.96
Time to Change Direction, s	EG Before	0.51	0.87	0.95	0.54	56.3	1.69	0.51	2.20
Maximum Force During Eccentric Effort, N	EG	1099.70	1474.76	1654.48	434.18	26.2	1252.50	1099.70	2352.20
Maximum Force During Eccentric Effort, N	EG Before	977.46	1312.18	1474.06	389.31	26.4	1127.75	977.46	2105.21
Average Force During Eccentric Effort, N	EG	797.50	1058.01	1225.28	357.93	29.2	1061.06	797.50	1858.56
Average Force During Eccentric Effort, N	EG Before	708.85	941.37	1091.71	320.88	29.4	954.55	708.85	1663.40
Eccentric Effort Impulse, Ns	EG	174.99	231.63	265.33	101.43	38.2	325.04	174.99	500.03
Eccentric Effort Impulse, Ns	EG Before	155.71	205.83	236.28	90.07	38.1	288.74	155.71	444.45
Average Velocity of Eccentric Effort, m/s	EG	0.22	0.48	0.52	0.19	36.9	0.63	0.22	0.85
Average Velocity of Eccentric Effort, m/s	EG Before	0.20	0.43	0.46	0.17	36.9	0.56	0.20	0.76
Maximum Propulsive Force, N	EG	1779.09	2176.21	2137.41	219.09	10.3	617.85	1779.09	2396.94
Maximum Propulsive Force, N	EG Before	1583.04	1932.68	1903.85	197.14	10.4	562.21	1583.04	2145.25
Average Propulsive Force, N	EG	1456.09	1720.05	1743.96	222.55	12.8	557.40	1456.09	2013.49
Average Propulsive Force, N	EG Before	1295.64	1530.42	1553.42	199.80	12.9	504.69	1295.64	1800.33
Average Propulsive Power, Watt	EG	2068.00	2516.00	2535.88	416.33	16.4	1083.00	2068.00	3151.00
Average Propulsive Power, Watt	EG Before	1845.38	2237.67	2258.89	373.53	16.5	974.75	1845.38	2820.13
Propulsive Effort Duration, s	EG	0.22	0.26	0.26	0.03	10.4	0.08	0.22	0.30
Propulsive Effort Duration, s	EG Before	0.25	0.29	0.29	0.03	10.1	0.09	0.25	0.34
Propulsive Impulse, Ns	EG	366.60	451.00	445.98	53.75	12.1	170.49	366.60	537.09
Propulsive Impulse, Ns	EG Before	325.85	402.45	397.27	48.51	12.2	154.84	325.85	480.69

In conclusion, we can state that the indicators improved after the pedagogical experiment while maintaining the coefficients of variation.

Table 9. Variation Analysis of Data After the End of the Pedagogical Experiment for the Control Group in the Exercise "Jump After a Depth Jump"

Parameter	Group	Mo	Me	X	S	V	R	Min	Max
Jump Height by Flight Time, cm	CG	26.50	32.05	31.86	2.86	9	8.90	26.50	35.40
Jump Height by Flight Time, cm	CG Before	26.06	31.42	31.25	2.76	8.8	8.65	26.06	34.71
Jump Height by Force Impulse, cm	CG	26.70	32.30	31.76	2.54	8	7.80	26.70	34.50
Jump Height by Force Impulse, cm	CG Before	26.25	31.67	31.15	2.45	7.9	7.57	26.25	33.82
Peak Force, N	CG	1511.41	2000.71	1981.43	240.57	12.1	782.56	1511.41	2293.97
Peak Force, N	CG Before	1495.98	1955.58	1942.74	230.89	11.9	753.01	1495.98	2248.99
Force Impulse, Ns	CG	180.65	206.05	204.73	18.34	9	47.25	180.65	227.90
Force Impulse, Ns	CG Before	178.81	202.01	200.76	17.49	8.7	43.94	178.81	222.75
Vertical Take-Off Velocity, m/s	CG	2.60	2.52	2.50	0.10	4.1	0.31	2.29	2.60
Vertical Take-Off Velocity, m/s	CG Before	2.25	2.47	2.45	0.10	4	0.30	2.25	2.55
Force Gradient, N/s	CG	5318.13	8059.18	8014.95	1773.23	22.1	5450.88	5318.13	10769.01
Force Gradient, N/s	CG Before	5263.83	7877.64	7858.12	1728.30	22	5294.02	5263.83	10557.85
Reactive Strength Index by Flight Time	CG	0.34	0.34	0.33	0.06	17.4	0.19	0.24	0.43
Reactive Strength Index by Flight Time	CG Before	0.24	0.33	0.33	0.06	17.2	0.18	0.24	0.42
Reactive Strength Index by Force Impulse	CG	0.34	0.33	0.33	0.06	17.7	0.19	0.24	0.43
Reactive Strength Index by Force Impulse	CG Before	0.24	0.32	0.32	0.06	17.5	0.18	0.24	0.42
Peak Power, Watt	CG	3289.00	4301.24	4248.28	562.97	13.3	1675.77	3289.00	4964.77
Peak Power, Watt	CG Before	3255.42	4210.55	4165.27	541.34	13	1612.00	3255.42	4867.42
Eccentric Phase, s	CG	0.17	0.22	0.26	0.11	43	0.32	0.17	0.49
Eccentric Phase, s	CG Before	0.17	0.22	0.25	0.11	42	0.31	0.17	0.48
Time to Change Direction, s	CG	0.76	0.73	0.70	0.11	15.6	0.32	0.51	0.83
Time to Change Direction, s	CG Before	0.52	0.75	0.72	0.11	15.8	0.33	0.52	0.85
Maximum Force During Eccentric Effort, N	CG	1115.46	1481.83	1442.93	280.67	19.5	635.10	1115.46	1750.56
Maximum Force During Eccentric Effort, N	CG Before	1090.15	1457.19	1415.10	274.30	19.4	626.09	1090.15	1716.24
Average Force During Eccentric Effort, N	CG	836.69	1095.76	1080.06	120.55	11.2	371.25	836.69	1207.94
Average Force During Eccentric Effort, N	CG Before	817.70	1077.74	1059.34	118.17	11.2	366.55	817.70	1184.25
Eccentric Effort Impulse, Ns	CG	202.50	235.29	265.06	76.29	28.8	208.32	202.50	410.82
Eccentric Effort Impulse, Ns	CG Before	198.53	231.50	259.94	74.59	28.7	202.97	198.53	401.50
Average Velocity of Eccentric Effort, m/s	CG	0.29	0.52	0.51	0.14	27.3	0.45	0.29	0.74
Average Velocity of Eccentric Effort, m/s	CG Before	0.28	0.51	0.50	0.14	27.9	0.45	0.28	0.73
Maximum Propulsive Force, N	CG	1511.41	2000.71	1981.43	240.57	12.1	782.56	1511.41	2293.97
Maximum Propulsive Force, N	CG Before	1495.98	1955.58	1942.74	230.89	11.9	753.01	1495.98	2248.99
Average Propulsive Force, N	CG	1333.83	1600.67	1565.45	184.27	11.8	527.28	1333.83	1861.11
Average Propulsive Force, N	CG Before	1311.47	1569.29	1535.02	177.43	11.6	513.15	1311.47	1824.62
Average Propulsive Power, Watt	CG	1516.00	2119.00	2073.00	353.74	17.1	1044.00	1516.00	2560.00
Average Propulsive Power, Watt	CG Before	1490.58	2074.18	2032.66	343.47	16.9	1019.22	1490.58	2509.80

Propulsive Effort Duration, s	CG	0.29	0.28	0.28	0.05	17.4	0.16	0.21	0.37
Propulsive Effort Duration, s	CG Before	0.30	0.29	0.28	0.05	18.1	0.17	0.21	0.38
Propulsive Impulse, Ns	CG	374.59	419.90	428.16	46.75	10.9	120.26	374.59	494.85
Propulsive Impulse, Ns	CG Before	367.25	411.63	419.91	45.58	10.9	119.30	367.25	486.55

The results for the control group after the pedagogical experiment show moderate improvements in the key physical indicators related to jumping. The slight increases in peak force, impulse, and jump height suggest that the program had some impact on the participants' physical capabilities, but to a lesser extent compared to the effect observed in the experimental group. These findings highlight that the training methodology used for this group did not have a significant influence.

2.1.3. Jump After a Two-Step Approach

Таблица 10. Variation Analysis of Data After the End of the Pedagogical Experiment for the Experimental Group in the Exercise "Jump After a Two-Step Approach".

Parameter	Group	Me	X	S	V	R	Min	Max
Jump height based on flight time, cm	EG	54.45	54.20	5.77	10.6	18.90	43.10	62.00
Jump height based on flight time, cm	EG BEFORE	48.60	48.27	5.08	10.5	16.56	38.46	55.02
Jump height based on force impulse, cm	EG	55.15	53.20	8.48	15.9	27.20	34.90	62.10
Jump height based on force impulse, cm	EG BEFORE	49.15	47.39	7.60	16	24.28	30.97	55.25
Peak force, N	EG	2781.10	2667.37	296.18	11.1	740.54	2211.17	2951.71
Peak force, N	EG BEFORE	2474.48	2375.85	265.21	11.2	651.81	1967.51	2619.32
Force impulse, Ns	EG	268.74	273.84	39.55	14.4	100.58	233.80	334.38
Force impulse, Ns	EG BEFORE	239.45	243.96	35.69	14.6	91.23	208.04	299.27
Vertical take-off velocity, m/s	EG	3.29	3.22	0.27	8.5	0.87	2.62	3.49
Vertical take-off velocity, m/s	EG BEFORE	2.93	2.87	0.25	8.6	0.78	2.32	3.10
Force gradient, N/s	EG	60913.26	53347.28	18277.26	34.3	48876.54	23751.91	72628.45
Force gradient, N/s	EG BEFORE	54129.81	47521.40	16302.58	34.3	43502.97	21111.70	64614.67
Support time, s	EG	0.41	0.42	0.04	9.4	0.12	0.38	0.50
Support time, s	EG BEFORE	0.46	0.47	0.04	9.3	0.13	0.43	0.56
Reactive force index based on flight time	EG	1.37	1.30	0.20	15.3	0.50	1.02	1.52
Reactive force index based on flight time	EG BEFORE	1.23	1.16	0.18	15.3	0.44	0.91	1.35

Reactive force index based on force impulse	EG	1.31	1.27	0.25	19.6	0.71	0.86	1.57
Reactive force index based on force impulse	EG BEFORE	1.17	1.13	0.23	19.9	0.64	0.76	1.40
Peak power, Watt	EG	6975.70	6910.92	1523.44	22	4628.81	5465.11	10093.92
Peak power, Watt	EG BEFORE	6215.85	6154.35	1349.27	21.9	4080.47	4876.78	8957.25
Stabilization time, s	EG	1.21	1.15	0.31	27	0.80	0.70	1.50
Stabilization time, s	EG BEFORE	1.08	1.02	0.28	27	0.71	0.62	1.33

From the presented table, an increase is observed in the average, maximum, and minimum values while maintaining the coefficient of variation. There is no change in the normality of the groups. The positive evaluation indicates an improvement in the physical data of the examined individuals.

Table 11. Variation Analysis of Data After the Completion of the Pedagogical Experiment for the Control Group on the Exercise "Jump After Acceleration from Two Steps"“

Parameter	Group	Me	X	S	V	R
Jump height based on flight time, cm	KG	44.95	36.01	22.81	63.3	54.60
Jump height based on flight time, cm	KG BEFORE	44.28	35.34	22.38	63.3	53.38
Jump height based on force impulse, cm	KG	45.35	37.81	24.45	64.7	59.90
Jump height based on force impulse, cm	KG BEFORE	44.67	37.11	23.98	64.6	58.60
Peak force, N	KG	2314.16	1825.93	1150.26	63	2909.70
Peak force, N	KG BEFORE	2275.97	1791.79	1128.06	63	2844.43
Force impulse, N*s	KG	225.57	189.58	121.06	63.9	297.79
Force impulse, N*s	KG BEFORE	222.16	186.02	118.72	63.8	291.11
Vertical take-off velocity, m/s	KG	2.98	2.35	1.47	62.5	3.43
Vertical take-off velocity, m/s	KG BEFORE	2.94	2.31	1.44	62.5	3.36
Force gradient, N/s	KG	41651.97	34454.16	22793.57	66.2	59188.54
Force gradient, N/s	KG BEFORE	40970.63	33813.77	22366.65	66.1	58196.18
Support time, s	KG	0.39	0.31	0.19	62.6	0.48
Support time, s	KG BEFORE	0.40	0.32	0.20	62.7	0.49
Reactive force index based on flight time	KG	1.13	0.87	0.55	63.3	1.38
Reactive force index based on flight time	KG BEFORE	1.11	0.86	0.54	63.3	1.35
Reactive force index based on force impulse	KG	1.14	0.92	0.59	64.6	1.52
Reactive force index based on force impulse	KG BEFORE	1.13	0.90	0.58	64.6	1.49
Peak power, Watt	KG	5073.21	4201.16	2681.45	63.8	6875.37
Peak power, Watt	KG BEFORE	4998.52	4122.68	2629.70	63.8	6721.13
Stabilization time, s	KG	1.30	1.13	0.79	70.2	2.38
Stabilization time, s	KG BEFORE	1.27	1.11	0.78	70.1	2.33

From the presented table, it is evident that the average, maximum, and minimum values are higher while maintaining the coefficient of variation. The positive evaluation indicates an improvement in the physical performance of the examined individuals.

2.2. Correlation Analysis of Data After the Completion of the Pedagogical Experiment.

We used correlation analysis to identify the most strongly correlated indicators among the examined variables. This would guide our attention toward the more significant variables in our study.

The Spearman correlation method was employed because, upon data verification, it provides more reliable results, and some of the indicators do not have a normal distribution.

2.2.1. Correlation Analysis of Data After the Completion of the Pedagogical Experiment for the Exercise "Standing Jump Without Arm Assistance"

Table 12. Correlation Dependence Between Jump Height and Other Variables in the Exercise "Standing Jump Without Arm Assistance" After the Pedagogical Experiment.

Spearman's correlation			Spearman's rho		p
Jump Height based on flight time, sm	-	Jump height based on force impulse, cm	0.737	**	0.001
	-	Peak force, N	0.209		0.436
	-	Force impulse, N*s	0.298		0.262
	-	Peak power, Watt	0.395		0.130
	-	Stabilization time, s	0.109		0.687
	-	Maximum take-off force, N	0.209		0.436
	-	Vertical take-off velocity based on force impulse, m/s	0.731	**	0.001
	-	Take-off time, s	-0.166		0.539

Spearman's correlation					
			Spearman's rho		p
	-	Take-off effort impulse, N*s	0.118		0.663
	-	Average take-off force, N	0.263		0.326
	-	Force gradient, N/s	0.136		0.616
	-	Reactive force index based on force impulse	-0.151		0.578
	-	Reactive force index based on flight time	-0.121		0.655
	-	Average take-off power, Watt	0.381		0.146
Jump height based on force impulse, cm	-	Peak force, N	0.306		0.249
	-	Force impulse, N*s	0.447		0.084
	-	Peak power, Watt	0.576	*	0.022
	-	Stabilization time, s	-0.174		0.519
	-	Maximum take-off force, N	0.306		0.249
	-	Vertical take-off velocity based on force impulse, m/s	0.999	***	< .001
	-	Take-off time, s	0.103		0.703
	-	Concentric effort impulse, N*s	0.282		0.288
	-	Average take-off force, N	0.103		0.705
	-	Force gradient, N/s	0.082		0.763
	-	Reactive force index based on force impulse	0.240		0.370
	-	Reactive force index based on flight time	0.088		0.745
	-	Average take-off power, Watt	0.271		0.310

* p < .05, ** p < .01, *** p < .001

From the correlation table between the variables, a significant relationship is observed between the Vertical take-off velocity based on force impulse, m/s and the Jump height based on force impulse. The correlation after conducting the pedagogical experiment is stronger. The same applies to other correlated indicators, where their relationships with the dependent variable are also stronger.

2.2.2. Correlation analysis of the data after the completion of the pedagogical experiment for the experimental group in the exercise "Jump After Depth Jump"

Table 13. Correlation dependence between jump height and other variables in the exercise "Jump After Depth Jump" after conducting the pedagogical experiment

Spearman's correlation					
			Spearman's rho		p
Jump height based on flight time, sm	-	Jump height based on force impulse, cm	0.997	***	< .001
	-	Peak force, N	0.547	*	0.031
	-	Force impulse, N*s	0.638	**	0.009
	-	Vertical take-off velocity based on force impulse, m/s	0.996	***	< .001
	-	Force gradient, N/s	0.638	**	0.009
	-	Reactive force index based on flight time	0.534	*	0.033
	-	Reactive force index based on force impulse	0.515	*	0.041
	-	Peak power, Watt	0.735	**	0.002
	-	Eccentric phase, s	-0.409		0.115
	-	Time to change direction, s	-0.031		0.910
	-	Maximum force during eccentric effort, N	0.285		0.283
	-	Average force during eccentric effort, N	0.150		0.579
	-	Impulse of eccentric effort, N*s	-0.126		0.641
	-	Average velocity during eccentric effort, m/s	-0.032		0.908
	-	Maximum take-off force, N	0.547	*	0.031
	-	Average take-off force, N	0.541	*	0.033
	-	Average take-off power, Watt	0.659	**	0.007
	-	Take-off time, s	-0.328		0.215
	-	Take-off impulse, N*s	0.035		0.900
Jump height based on force impulse, cm	-	Peak force, N	0.576	*	0.022
	-	Force impulse, N*s	0.650	**	0.008

Spearman's correlation						
				Spearman's rho		p
		-	Vertical take-off velocity based on force impulse, m/s	0.999	***	< .001
		-	Force gradient, N/s	0.641	**	0.009
		-	Reactive force index based on flight time	0.528	*	0.036
		-	Reactive force index based on force impulse	0.509	*	0.044
		-	Peak power, Watt	0.759	***	< .001
		-	Eccentric phase, s	-0.409		0.115
		-	Time to change direction, s	-0.019		0.944
		-	Maximum force during eccentric effort, N	0.288		0.278
		-	Average force during eccentric effort, N	0.156		0.564
		-	Impulse of eccentric effort, N*s	-0.124		0.648
		-	Average velocity during eccentric effort, m/s	-0.041		0.882
		-	Maximum take-off force, N	0.576	*	0.022
		-	Average take-off force, N	0.559	*	0.027
		-	Average take-off power, Watt	0.668	**	0.006
		-	Take-off time, s	-0.336		0.204
		-	Take-off impulse, N*s	0.047		0.865
* p < .05, ** p < .01, *** p < .001						

After conducting the pedagogical experiment, Vertical take-off velocity, Force gradient, and Peak power, Watt exhibit a statistically significant correlation with jump height, measured both by flight time and by force impulse.

A strong correlation is observed between explosive parameters and eccentric parameters. This justifies our focus on the eccentric phase before the jump.

2.2.3. Correlation analysis of the data after the completion of the pedagogical experiment for the experimental group in the exercise "Jump After Acceleration from Two Steps".

Table 14. Correlation dependence between jump height and other variables in the exercise "Jump After Acceleration from Two Steps" after conducting a pedagogical experiment with the experimental group.

Spearman's correlation					
			Spearman's rho		p
Jump Height based on flight time,sm	-	Jump height based on force impulse	0.647	**	0.007
	-	Peak force, N	0.735	**	0.001
	-	Force impulse, N*s	0.732	**	0.001
	-	Vertical take-off velocity, m/s	0.647	**	0.007
	-	Force gradient, N/s	0.797	***	< .001
	-	Support time, s	0.307		0.248
	-	Reactive force index based on flight time	0.894	***	< .001
	-	Reactive force index based on force impulse	0.587	*	0.017
	-	Peak power, Watt	0.965	***	< .001
	-	Stabilization time, s	0.140		0.605
Jump height based on force impulse	-	Peak force, N	0.549	*	0.028
	-	Force impulse, N*s	0.850	***	< .001
	-	Vertical take-off velocity, m/s	1.000	***	< .001
	-	Force gradient, N/s	0.700	**	0.003
	-	Support time, s	0.280		0.294
	-	Reactive force index based on flight time	0.637	**	0.008
	-	Reactive force index based on force impulse	0.912	***	< .001
	-	Peak power, Watt	0.652	**	0.006
	-	Stabilization time, s	0.398		0.127

* p < .05, ** p < .01, *** p < .001

From the dependencies in this table, two uncorrelated variables are evident: stabilization time and support time. All force indicators show a strong correlation with jump height. The athletes' strength data are crucial for achieving a high jump. The speed at which force values are reached plays a significant role in achieving height. Two factors stand out that require attention in the training process, and in our case, the result appears positive.

2.3. Analysis of Result Growth During the Pedagogical Experiment

The analysis utilized the Mann–Whitney test and Rank-Biserial Correlation. The Mann–Whitney test is a nonparametric method that evaluates whether the distributions of two independent samples differ. When using the Mann–Whitney test, it is often useful to determine the strength of the effect of the difference between the groups. The rank-biserial correlation addresses this need by showing the strength of the relationship between the category (two groups) and the results, converting them into ranks.

Once the U-test indicates a significant difference between the two groups, the rank-biserial correlation provides a numerical measure of this difference. It helps interpret the effect in a more familiar context (similar to correlation).

Since the Mann–Whitney test works with ranks, the rank-biserial correlation also uses ranks instead of actual values. This makes the method robust to deviations and compatible with the nonparametric nature of the test.

The rank-biserial correlation can calculate the extent to which the results in one group are higher or lower than those in the other. The correlation value indicates the strength of this relationship, approaching the familiar values of the correlation coefficient (from -1 to 1), where a value close to 1 or -1 shows a strong relationship between the groups and their ranks.

2.3.1. Analysis of Result Growth for the Exercise "Standing Jump Without Arm Assistance"

Table 27. Estimated Growth

Estimated growth	Rank-biserial correlation	
	CG	EG
Jump height based on flight time, cm	0.188	0.688
Jump height based on force impulse, cm	0.219	0.188
Peak force, N	0.219	0.563
Force impulse, N*s	0.156	0.438
Vertical take-off velocity based on force impulse, m/s	0.297	0.781
Force gradient, N/s	0.188	0.375
Reactive force index based on flight time	0.125	0.031
Reactive force index based on force impulse	0.094	0.047
Peak power, Watt	0.156	0.469
Stabilization time, s	-0.125	-0.156
Maximum take-off force, N	0.219	0.563
Average take-off force, N	0.188	0.406
Average take-off power, Watt	0.156	0.281
Take-off time, s	-0.172	-0.297
Take-off effort impulse, N*s	0.188	0.313

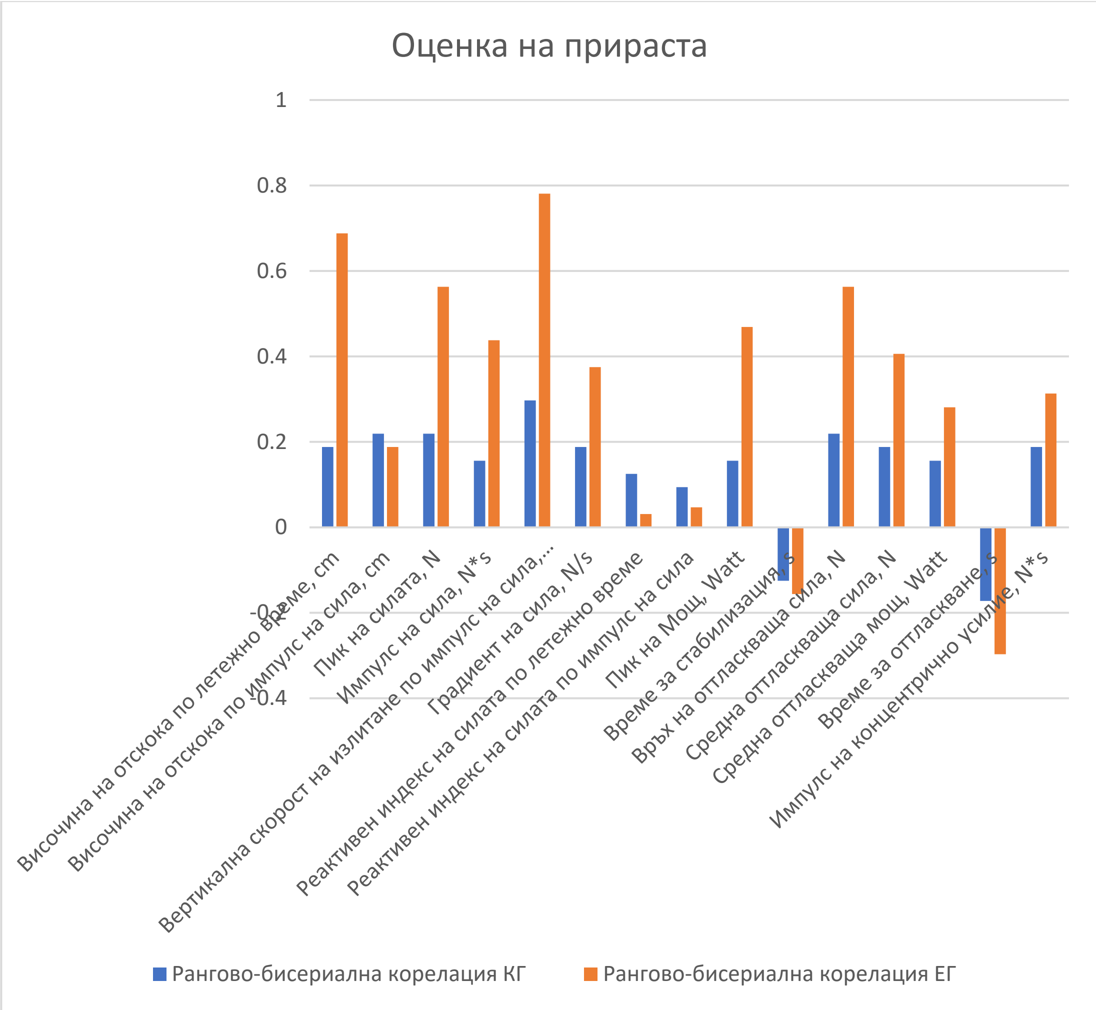


Fig 10. Estimated growth.

Fig. (13) visually illustrates the increase in indicators for the experimental group and the control group. The significant rise in values is noteworthy. The reactive force indices are an exception compared to the other variables.

The evaluation of the growth in the jump height parameter is presented using Student's t-test, as the data follows a normal distribution.

Table 28. Student's T-Test for Standing Jump Without Arm Assistance.

T - тест					
	t	**df**	**p**	**Cohen's d**	**SE Cohen's d**
Jump height based on flight time, cm	3.422	14	0.004	1.711	0.658
Jump height based on force impulse, cm	1.404	14	0.182	0.702	0.530

T - тест					
	t	**df**	**p**	**Cohen's d**	**SE Cohen's d**
Note. Student's T test					

For the parameter jump height based on flight time, the t-value (3.422) indicates the degree of difference between the groups. The high t-value suggests a significant difference. The p-value of 0.004 is below the conventional threshold of 0.05, meaning there is a statistically significant difference in jump height based on flight time between the two groups.

Cohen's d(1.711) is a measure of effect size, and here the value is high. Typically, a value above 0.8 is considered a large effect, so 1.711 indicates a very strong effect. This demonstrates that the difference is not only statistically significant but also practically important.

SE Cohen's d (0.658) is the standard error of the effect size and reflects the precision of the calculation. The low value (0.658) suggests a relatively stable estimate of the effect.

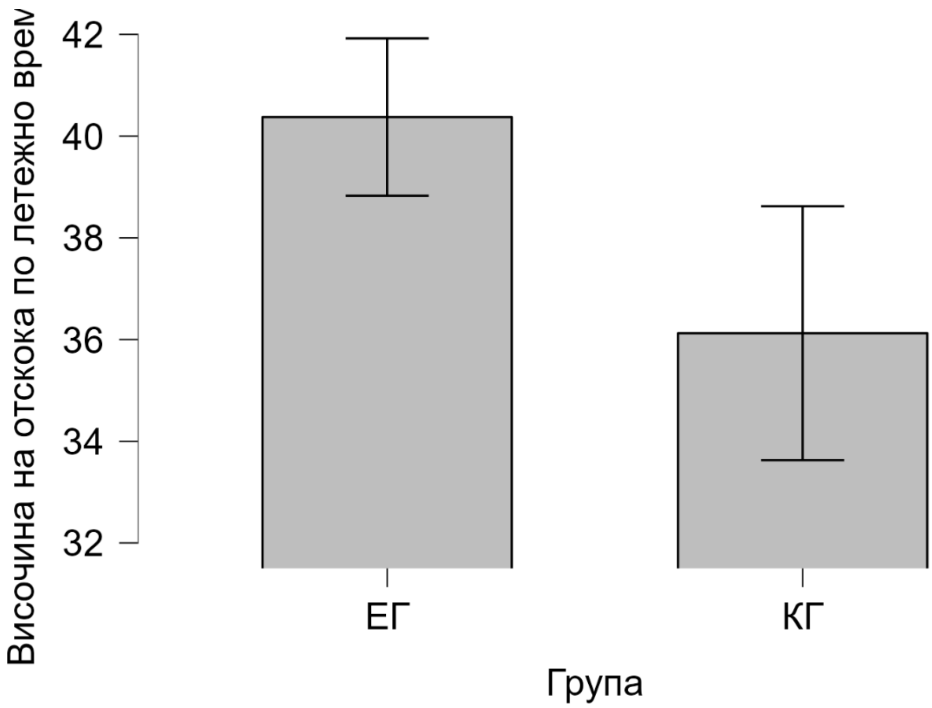


Fig 11. Jump height based on flight time. T - test

2.3.2. Analysis of Result Growth for the Exercise "Jump After Depth Jump"

Table 29. Estimated growth

Estimated growth	Rank-biserial correlation	
	CG	EG
Jump height based on flight time, cm	0.25	0.781
Jump height based on force impulse, cm	0.219	0.781
Peak force, N	0.219	0.563
Force impulse, N*s	0.188	0.5
Vertical take-off velocity based on net impulse, m/s	0.328	0.953
Force gradient, N/s	0.156	0.219
Reactive force index based on flight time	0.141	0.219
Reactive force index based on force impulse	0.125	0.188
Peak power, Watt	0.156	0.594
Eccentric phase, s	0.063	-0.219
Time to change direction, s	-0.156	-0.281
Maximum force during eccentric effort, N	0.25	0.313
Average force during eccentric effort, N	0.156	0.344
Impulse of eccentric effort, N*s	0.156	0.281
Average velocity during eccentric effort, m/s	0.141	0.25
Maximum take-off force, N	0.219	0.563

Average take-off force, N	0.219	0.563
Average take-off power, Watt	0.125	0.438
Take-off time, s	-0.156	-0.578
Take-off impulse, N*s	0.219	0.469

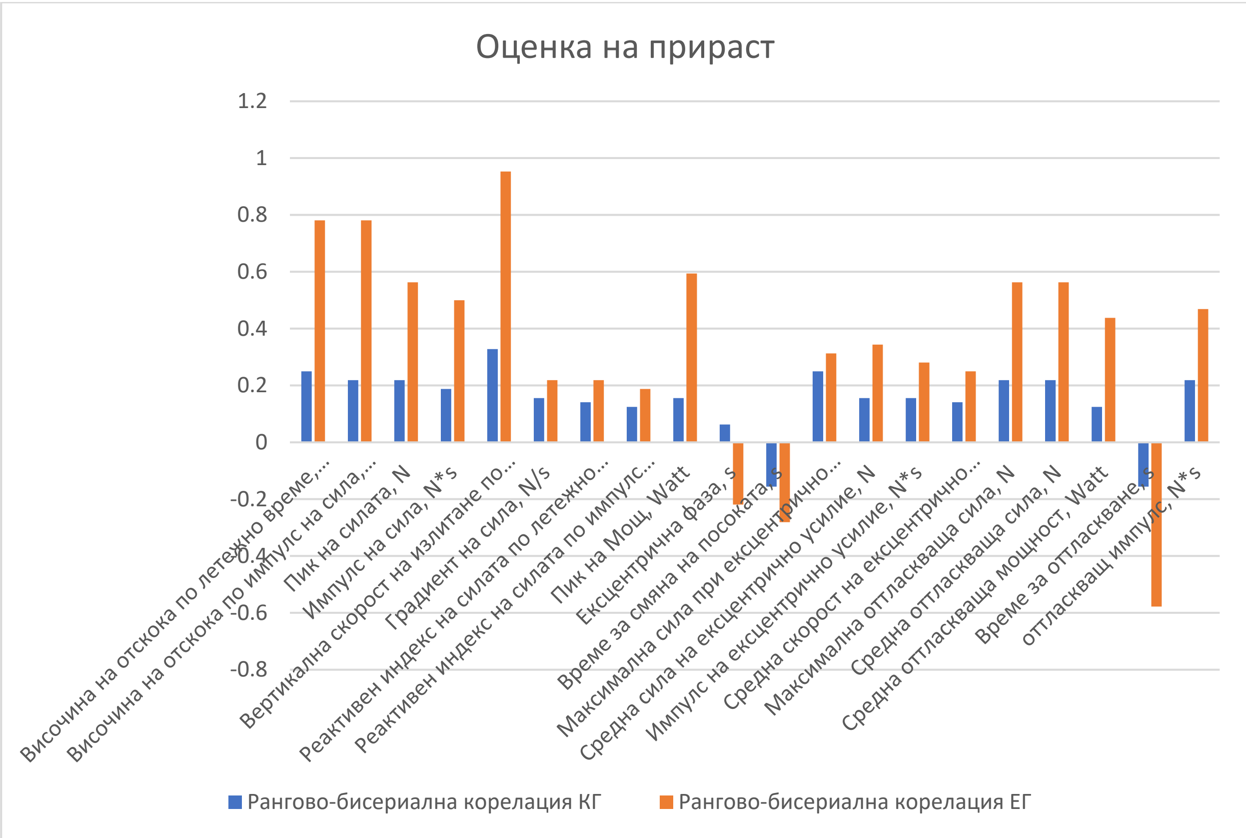


Fig 12. Estimated growth.

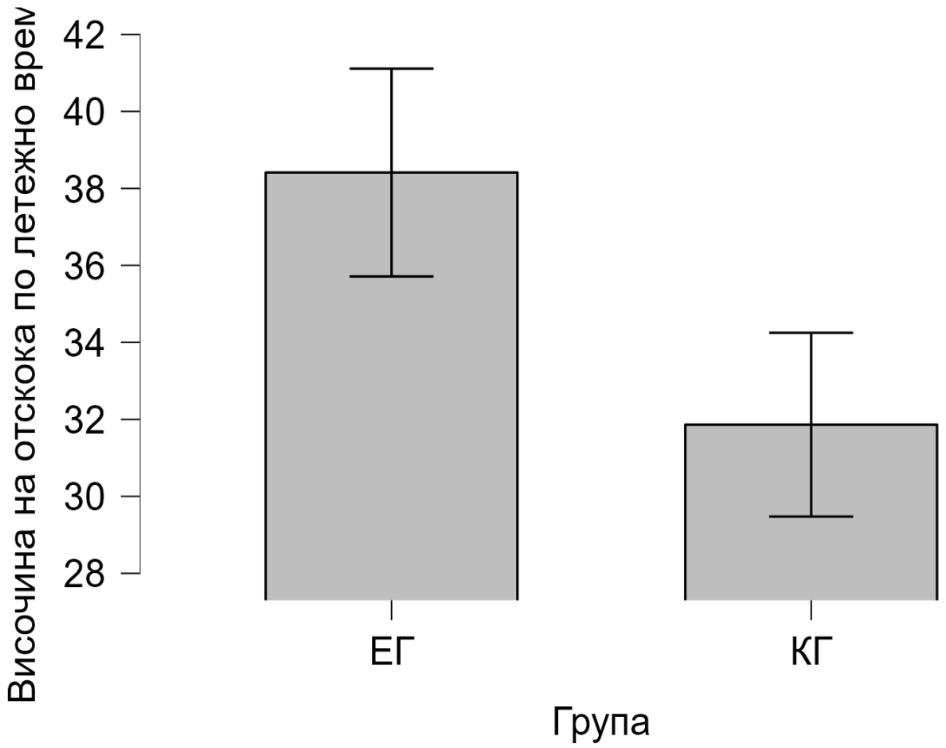
The greatest increase is observed in the indicators related to explosive efforts. The significant differences in the growth of these variables are the basis for the increased jump height.

The evaluation of the growth in the jump height parameter is presented using Student's T-test, as the data follows a normal distribution.

Таблица 30. Student's T-test

T - Тест					
	t	**df**	**p**	**Cohen's d**	**SE Cohen's d**
Jump height based on flight time, cm	4.298	14	0.000	2.149	0.734
Jump height based on force impulse, cm	4.288	14	0.000	2.144	0.733
Student's T-test					

Both methods for measuring jump height in the depth jump test on a force plate show highly significant differences between the groups, both statistically ($p < 0.001$) and practically (Cohen's $d > 2$).



2.3.3. Analysis of Result Growth for the Exercise "Jump After Acceleration from Two Steps"

Table 31. Estimated Growth.

Estimated Growth	Rank-biserial correlation	
	CG	EG
Jump height based on flight time	0.125	0.625
Jump height based on force impulse	0.125	0.563
Peak force, N	0.125	0.563
Force impulse, N*s	0.094	0.469
Vertical take-off velocity, m/s	0.125	0.75
Force gradient, N/s	0.094	0.344
Support time, s	-0.109	-0.688
Reactive force index based on flight time	0.094	0.484
Reactive force index based on force impulse	0.109	0.359
Peak power, Watt	0.125	0.406
Stabilization time, s	0.109	0.219

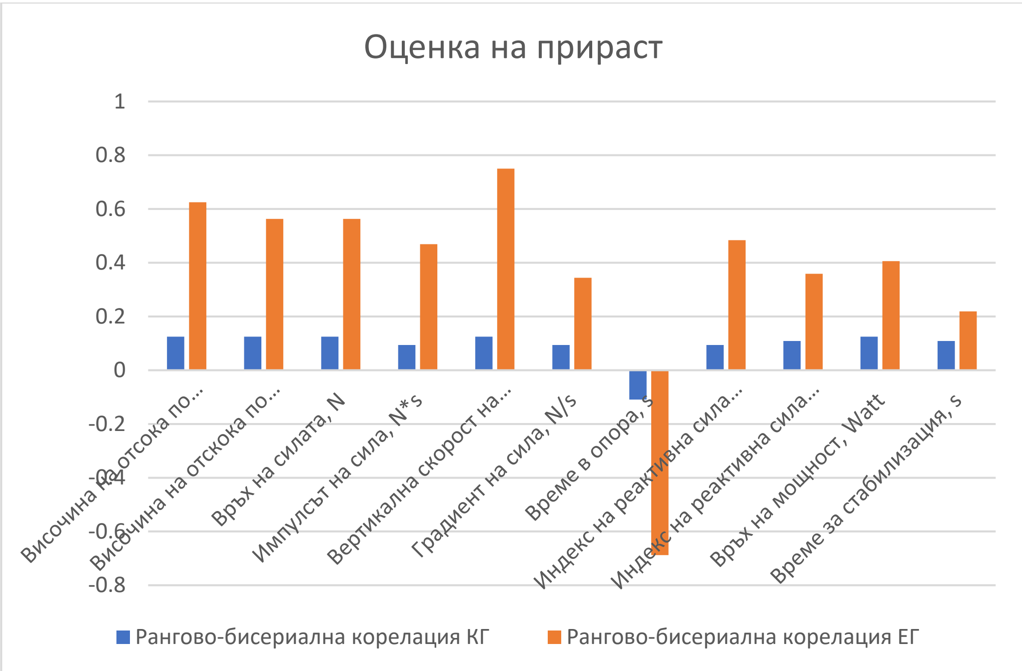


Fig 13. Estimated Growth.

The evaluation of growth shows a significant advantage for the experimental group. These values indicate that the respondents who followed the experimental methodological guidelines improved their indicators more than the control group.

The evaluation of the growth in the jump height parameter is presented using Student's T-test, as the data follows a normal distribution.

Table 32. Student’s T-test.

T-Test					
	t	**df**	**p**	**Cohen's d**	**SE Cohen's d**
Jump height based on flight time	2.187	14	0.046	1.093	0.570
Jump height based on force impulse	1.682	14	0.115	0.841	0.542
Student’s T -test					

For jump height based on flight time, the t-value is 2.187, which is a moderately high value, indicating a difference between the groups. The p-value of 0.046 is right at the conventional threshold of 0.05, meaning that the difference is statistically significant, though not very pronounced. This allows the rejection of the null hypothesis and suggests that jump height based on flight time differs significantly.

Cohen's d (1.093) indicates a large effect, exceeding the threshold for a significant effect (0.8). This means that the difference is both practical and important, demonstrating a strong impact of the method. The standard error of Cohen's d (0.570) shows some variation around the mean value but is not too high, making the result reliable.

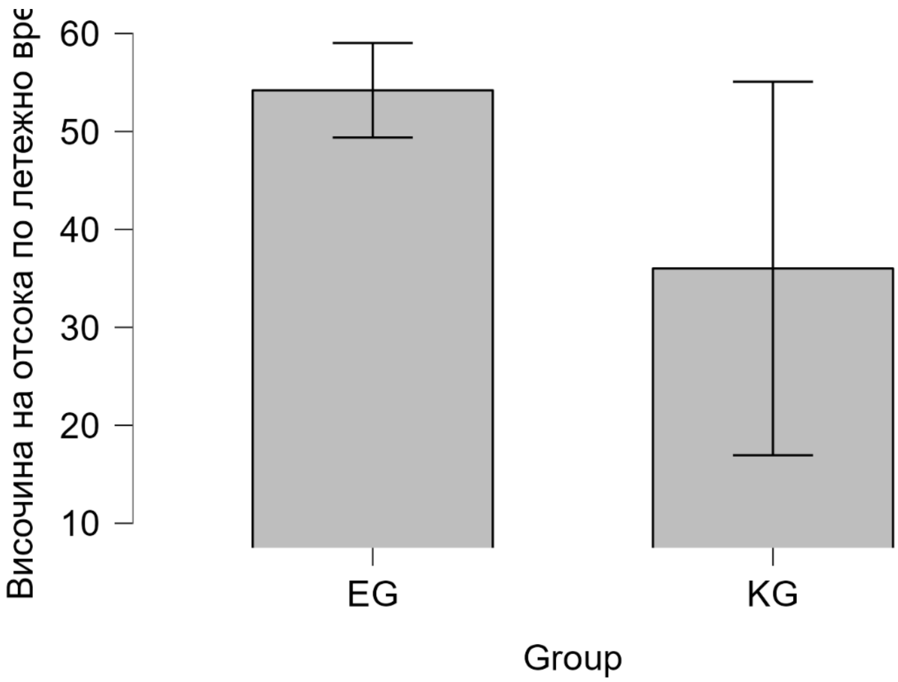


Fig 14. Jump Height Based On Flight Time

2.3.4. Analysis of Result Growth for the Exercise "Jump After Acceleration"

Table 33. T-test after conducting the pedagogical experiment for the experimental group for the exercise "Jump After Acceleration".

	Before	*After*
Arithmetic Mean	347.875	352.5
Variance	94.41071429	89.42857143
Observations	8	8
Correlation	0.995800422	
df	7	

The table shows an increase in the mean value and a decrease in variance. This confirms the development of the capabilities of the experimental group.

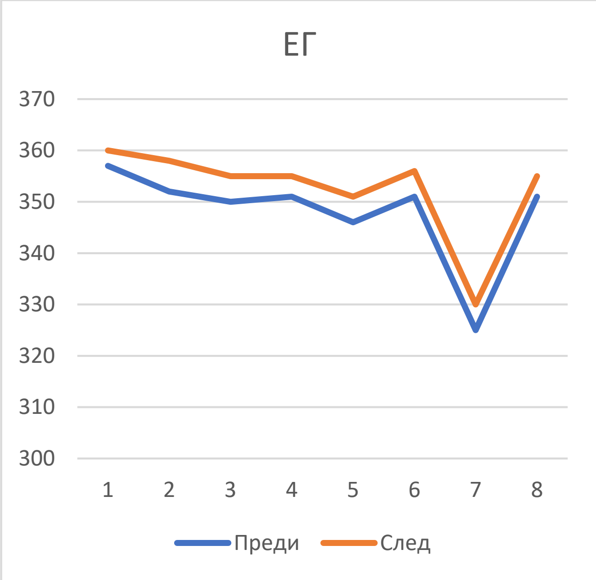


Fig 15. Graph of the development of jump height for individual subjects in the experimental group.

The graph shows an improvement in the results of the respondents who participated in the study as the experimental group.

Table 34. T-test after conducting the pedagogical experiment for the control group for jump height after acceleration.

	Before	After
Arithmetic Mean	333.625	333.5
Variance	285.4107	295.1429
Observations	8	8
Correlation	0.996972	
df	7	

It is notable that the mean value has not changed, while the variation has slightly increased. We could hypothesize that some respondents in the control group did not achieve a sufficient training effect, while others improved their abilities insignificantly, which could be the reason for the greater dispersion.

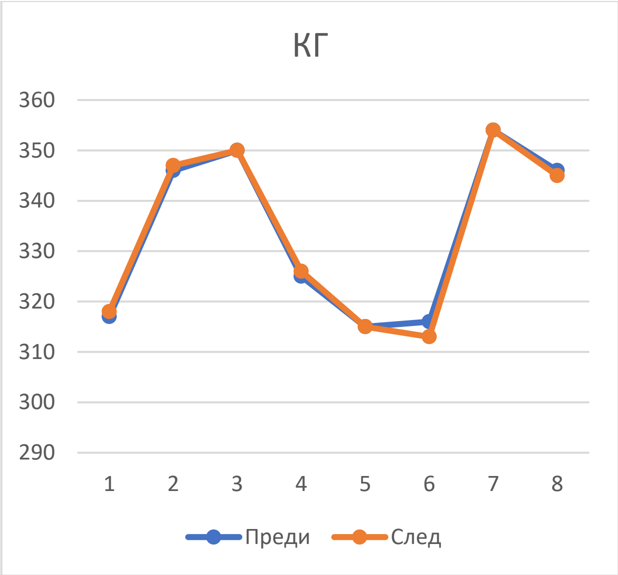


Fig 16. Graph of the development of jump height for individual subjects in the control group.

The graph shows that some respondents have lower indicators compared to the beginning of the study, while others have higher ones. The differences are insufficient to significantly affect the statistical values and demonstrate development in physical capabilities.

3. Regression Analysis of the Research Data

After comparing the groups, to discover how the variables influence jump height, we conducted a regression analysis. We found that we were able to develop the physical qualities of the experimental group to statistically significant values compared to the control group. We will now deepen the analysis of the data to establish and test our thesis on the significant indicators that require more attention in the training process.

To identify the factors influencing jump height, we will use the data from both groups before and after the study.

3.1. Regression Analysis of Data for the Exercise "Standing Jump Without Arms"

From the conducted regression analysis, we noticed that the statistically significant indicators that influence jump height are: Vertical take-off velocity, m/s; Force impulse, N*s; Peak power, Watt; Average take-off power, Watt. Other highly significant indicators are: Stabilization time, s; Reactive force index based on force impulse, These indicators are negatively correlated.

Table 35. Part and partial correlation in the standing jump without arm assistance after the regression model.

Part and partial correlation				
Model			Part	Partial
H_1	Peak force, N		0.09	0.031
	Force impulse, N*s		-0.43	-0.156
	Vertical take-off velocity, m/s		0.56	0.225
	Force gradient, N/s		-0.13	-0.043
	Reactive force index based on flight time		0.79	0.427
	Reactive force index based on force impulse		-0.79	-0.431
	Peak power, Watt		0.65	0.282
	Stabilization time, s		-0.43	-0.159
	Average concentric force, N		-0.34	-0.121
	Average concentric power, Watt		0.41	0.15
	Concentric effort time, s		0.13	0.045
	Concentric effort impulse, N*s		0.08	0.028

When examining partial and partial correlations, we can observe that some indicators show a strong correlation when the other indicators are present (force impulse, N*s; vertical take-off velocity, m/s; peak power, Watt; average take-off power, Watt), while their individual influence is nearly half as strong. This suggests that in order to identify the most accurate factors determining jump height, we should focus our attention on more than one indicator.

3.2. Regression analysis of the data for the exercise "Jump After Depth Jump"

According to the regression analysis, it is evident that some of the indicators have a strong negative correlation for this type of jump, while others have a strong positive correlation. The remaining significant independents have a negative correlation and would negatively impact the jump. Notably, the average eccentric force stands out, and its effect can be explained by the generation of high tension and its use to generate concentric efforts during the change of movement direction, where the elastic properties of the tissues play a significant role.

Table 36. Partial and partial correlation in the exercise "Jump After Depth Jump".

Part and partial correlation				
Model			Part	Partial
H_1		Peak force, N	0.543	0.027
		Force impulse, N*s	-0.251	-0.011
		Vertical take-off velocity, m/s	0.94	0.116
		Force gradient, N/s	-0.768	-0.05
		Reactive force index based on flight time	0.521	0.026
		Reactive force index based on force impulse	-0.49	-0.024
		Peak power, Watt	0.144	0.006
		Eccentric phase, s	0.052	0.002
		Time to change direction, s	-0.255	-0.011
		Maximum force during eccentric effort, N	-0.737	-0.046
		Average force during eccentric effort, N	0.731	0.045
		Impulse of eccentric effort, N*s	-0.205	-0.009
		Average velocity during eccentric effort, m/s	-0.609	-0.032
		Average concentric force, N	-0.748	-0.047
		Average concentric power, Watt	0.786	0.053
		Concentric effort time, s	-0.19	-0.008
		Take-off impulse, N*s	0.011	0

When examining the partial and partial correlations, we can observe that some indicators have a strong correlation when the other indicators are present

(Peak Force, N; Vertical Take-Off Velocity by Net Impulse, m/s; Average Braking Force, N; Average Propulsive Power, Watt), while their individual influence is much lower, and for some of them, the correlation is negligible. On the other hand, we notice parameters with a strong negative correlation, which, when examined individually, are also negligible.

This suggests that, in order to identify the most accurate factors determining jump height, we need to focus our attention on more than one indicator.

3.3. Regression analysis of the data for the exercise "Jump After Acceleration from 2 Steps".

From the conducted regression analysis, we can observe that the statistically significant variables also have a strong influence on jump height.

Table 37. Partial and partial correlation after the regression model in the exercise "Jump After Acceleration from Two Steps".

Part and partial correlation				
Model			Part	Partial
H_1		Peak force, N	-0.18	0
		Force impulse, N*s	0.501	0
		Vertical take-off velocity, m/s	0.91	0
		Force gradient, N/s	-0.547	0
		Support time, s	-0.88	0
		Reactive force index based on flight time	-0.522	0
		Reactive force index based on force impulse	0.827	0
		Peak power, Watt	0.135	0
		Stabilization time, s	0.634	0
		Jump height based on force impulse, cm	-0.03	0

The correlation table of the independent variables with the dependent one shows that none of the indicators have a correlation when considered individually. However, when considered together, several indicators stand out: Vertical take-off velocity, m/s (r = 0.91), Support time, s (r = -0.88), Reactive force index based on force impulse (r = 0.827). Further analysis is needed to group the variables and identify fewer factors.

4. Factor analysis of the research data.

After conducting the previous statistical analyses, we chose to proceed with factor analysis of the collected data in order to minimize the factors influencing jump height and to contribute to the development of training systems for physical abilities.

At its core, factor analysis aims to find linear combinations of variables that explain the most variation in the data. These combinations are called factors, with each factor being a linear combination of all the variables in the data set. The factors are selected in such a way that they explain as much of the variation in the data as possible while minimizing the number of factors required for that explanation.

We used the data from both groups before and after the study to have a larger sample and to more accurately determine the factors of our research.

4.1. Factor analysis of the data for the exercise "Standing Jump Without Arm Assistance".

Table 38. Chi-square of the factor analysis model for the exercise "Standing Jump Without Arm Assistance".

Chi-square			
	Value	df	p
Model	1014.598	63	< .001

The chi-square table of our model shows that due to a very low p-value (< 0.001), we conclude that the factor analysis model is statistically significant. This means that the factors are important and significantly explain the variation in the observed data.

Table 39. Factor loadings in the exercise "Standing Jump Without Arm Assistance".

Factor Loading				
	Factor 1	Factor 2	Factor 3	Uniqness
Peak Force, N	0.974			0.05
Peak Propulsive Force, N	0.974			0.05
Reactive Strength Index by Flight Time	0.767			0.433
Max Rate of Force Development, N/s	0.682			0.59
Reactive Strength Index by Net Impulse	0.674			0.43
Jump Height by Net Impulse, cm		0.995		0.127
Vertical Take-Off Velocity by Net Impulse, m/s		0.977		0.099
Net Impulse, N*s		0.786		0.152
Peak Power, Watt		0.629		0.002
Propulsive Duration, s			-0.99	0.003
Average Propulsive Power, Watt			0.882	0.003
Propulsive Impulse, N*s			-0.876	0.119
Average Propulsive Force, N			0.786	0.221
Jump Height by Flight Time, cm				0.832
Time to Stabilization, s				0.589
Rotation model - Promax.				

To obtain the factors, we used the "Promax" rotation model, considering that the factors might be correlated. This type of rotation model provided the clearest factors and matched the requirements of the task. We set the lower bound for the loading of different variables at 0.6 to ensure maximum accuracy in obtaining the factors. Three factors were identified, which we could define as: Strength (Factor 1), Speed (Factor 2), and Concentric (Factor 3). Notable uniqueness (>0.4) is observed primarily in the strength factor for the Force Gradient. The weight of the variables is high, with the most distinctive being Peak Force and Peak Concentric Force in the first factor, Vertical Take-Off Velocity in the second, and Concentric Effort Time, which has a negative correlation. From the distribution of these factors, the relationship between concentric effort speed and the maximum efforts generated during that time is clearly evident.

After establishing the factors and their distribution of weight, it was found that the third factor has the highest strength (75.3%) and explains the largest portion of the variation.

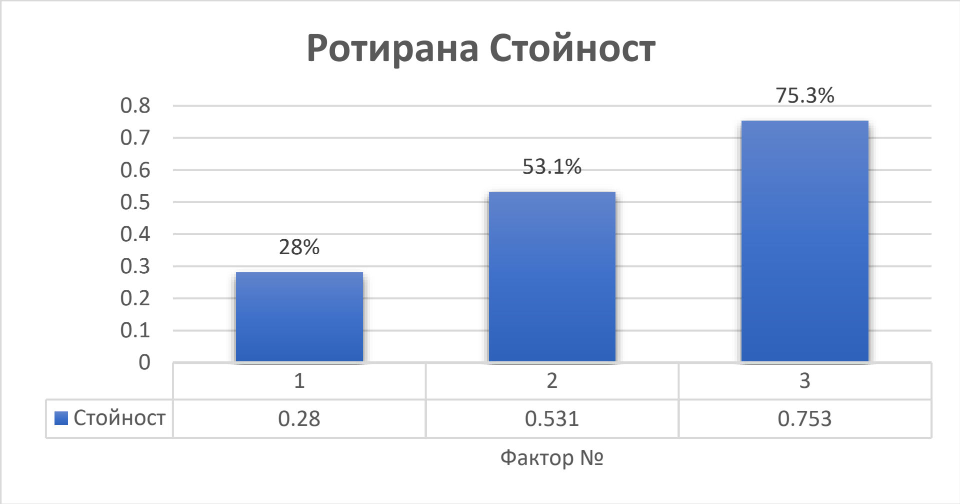


Fig 17. Factor determination

The rotated values are 28% for the first factor, 53.1% for the second, and 75.3% for the third factor.

Table 40. Correlation between the factors for the factor model in the exercise "Standing Jump Without Arm Assistance".

Factor Correlation			
	Factor 1	Factor 2	Factor 3
Factor 1	1	0.375	0.059
Factor 2	0.375	1	0.055
Factor 3	0.059	0.055	1

The correlation dependency between factor 1 and factor 2 is of moderate strength (0.375). Considering the strength and speed variables included in them, we do not find this surprising.

In this type of jump, we establish that the maximum force generated during the concentric effort and the speed at which it is realized are of utmost importance.

4.2. Factor analysis of the data for the exercise "Jump After Depth Jump".

Table 41. Chi-square of the factor analysis model for the exercise "Jump After Depth Jump".

Chi-Square			
	Value	df	p
Модел	1355.375	133	< .001

The chi-square table of our model shows that due to the very low p-value (< 0.001), we conclude that the factor analysis model is statistically significant. This means that the factors are important and significantly explain the variation in the observed data.

The factor values obtained from the rotation model show that the individual factors have relatively high importance (>50%). The most significant of them is the eccentric factor with 78%. The speed of passing through the eccentric phase plays a crucial role in this type of jump. This could also determine the directions in which training should be focused.

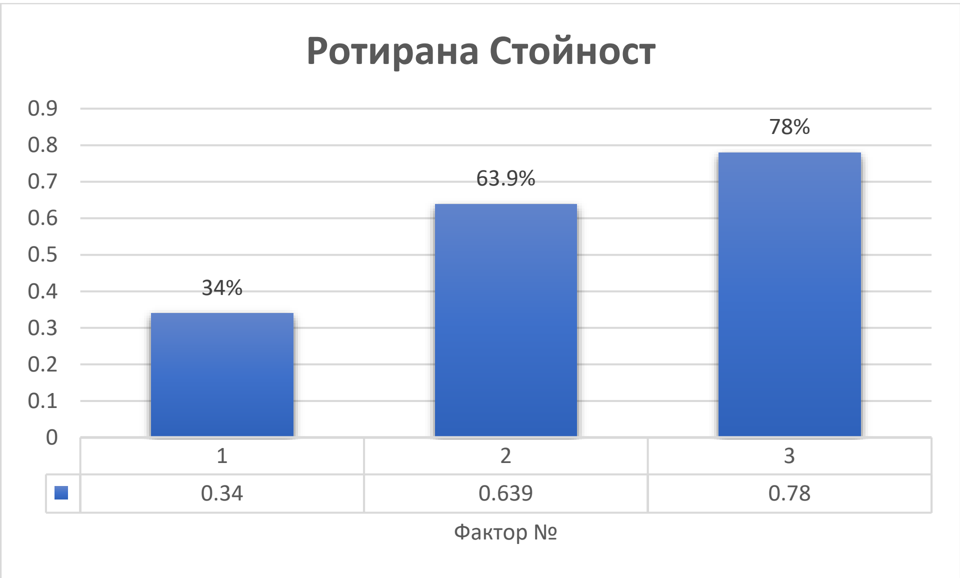


Fig 18. Factor distribution

The rotated solutions confirm the stability of the obtained factors. The strongest influence is observed in the eccentric factor. This indicates the decisive importance of effectively utilizing the generated forces during the amortization phase when transitioning to the take-off phase, leading to achieving a high jump.

Table 42. Correlation of the factors in the exercise "Jump After Depth Jump".

Factor correlation			
	Factor 1	Factor 2	Factor 3
Factor 1	1	0.557	-0.375
Factor 2	0.557	1	-0.169
Factor 3	-0.375	-0.169	1

The correlation between the identified factors is strong between the first and second factors. It is understandable that the generated force correlates with power. The third factor has a weak to moderate negative correlation with the first and a weak correlation with the second. This indicates the nature of the manifestation of different qualities. However, it seems that the interrelationship between these different qualities and abilities is crucial for achieving the jump. The weight with which the corresponding qualities influence the jump can be seen in the values of the individual factors.

4.3. Factor Analysis of the Data for the Exercise "Jump After Acceleration from Two Steps"

Table 43. Chi-square for the model in the exercise "Jump After Acceleration from Two Steps".

Chi-square			
	Value	df	p
Модел	392.255	34	< 0.001

The chi-square table of our model shows that due to the very low p-value (< 0.001), we conclude that the factor analysis model is statistically significant. This means that the factors are important and significantly explain the variation in the observed data.

When determining the strength of the two factors, we find that the unrotated solutions give us similar strength. After rotating the solutions, these values change and remain at 58.1% for the explosive factor and 92.5% for the speed factor.

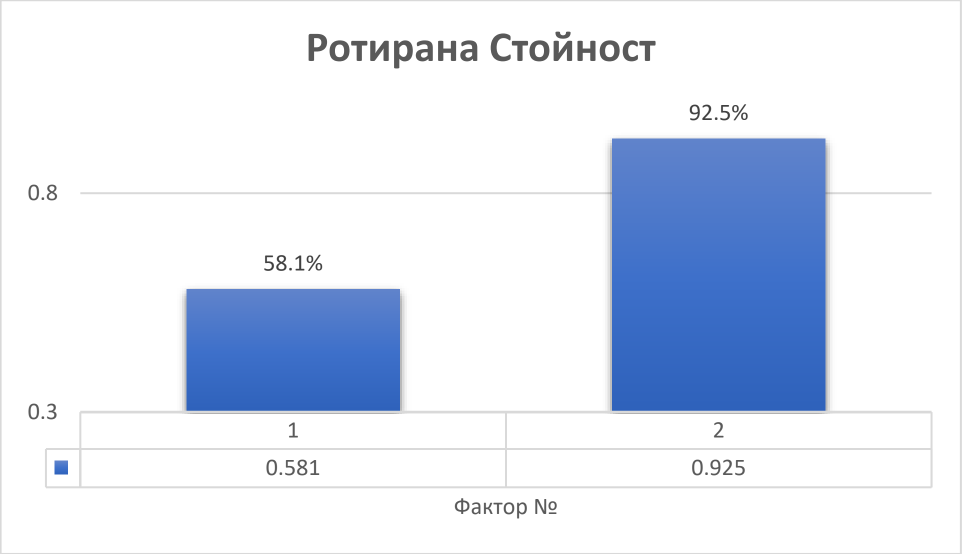


Fig 19. Distribution of the factors at rotated values.

The rotated value defines the speed factor as stronger and more significant.

Таблица 44. Factor correlation

Factor correlation		
	Factor 1	Factor 2
Factor 1	1	0.777
Factor 2	0.777	1

The correlation dependency between the factors is strong (0.78), which is an important clarification when developing a training methodology or system.

IV. Conclusions and Recommendations

The analysis shows that the training modules and methods used successfully improve the speed-strength indicators of athletes, increasing jump height and reducing the time to transition between movement phases. The conducted pedagogical experiment confirms the effect of the modules on explosive qualities and demonstrates a significant improvement in results in the experimental group compared to the control group. The main recommendation is to integrate and adapt the system and methods for various sports, with a focus on the musculoskeletal system and precise loading. The methodology provides a modern and effective framework for achieving optimal results in sports training.

Conclusions:

1. Positive effect of the used modules on jump height and execution.
2. The "Explosive Strength" module improves speed-strength qualities.
3. The physical training complex improves jump phases.
4. Landing guidelines facilitate control and amortization.
5. The methodology is well integrated into the physical development system.
6. The experiment confirms a positive influence on explosive qualities and jump height.
7. The applied methodology has been confirmed in a competitive environment.
8. The need for further research on the economical use of the muscular system.

Recommendations:

1. Application of the system for developing explosive qualities.
2. Development of new methodologies based on the proposed system.
3. Consideration of the structure of the musculoskeletal system.

4. Use of the studied principles and methods for loading.

The athletes who participated in the experiment received silver medals at the World Volleyball Championship for youth.

This research was conducted with the support of the Research Center at the National Sports Academy "Vasil Levski".

Publications related to the dissertation:

- **FACTORS AFFECTING JUMP HEIGHT IN VOLLEYBALL**; Serafim Lazov, PhD student; National Sports Academy "Vasil Levski", Department of "Athletics", 2023; 1(23) 95-103
- **Factors affecting jump height after acceleration from two steps**; Journal "Series on Biomechanics" Vol.37, No.2 (2023), 85-94