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Applied Research on the Impact of a Neuromotor Development Program on the Lower Limb Strength of Young Junior Athletes in Greco-Roman Wrestling

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Abstract

This study aims to investigate the impact of a structured and specific motor intervention program on the development of lower limb strength in young junior athletes practicing Greco-Roman wrestling. Given the importance of explosive strength in executing techniques and decisive actions during combat, this research adds value by implementing a progressive applied protocol adapted to the neuromotor development level of children aged 10 to 12 years. The study was conducted over 17 months and involved two groups of athletes (experimental and control), each comprising 14 registered wrestlers from School Sports Club No. 5 in Bucharest. The experimental group followed a complementary motor training program focused on plyometric exercises, body-weight strength applications, and specific wrestling exercises, while the control group followed the standard training regimen. The intervention's impact was assessed using the OptoJump Next system, a biomechanical analysis tool that measured key explosive strength parameters: jump height, ground contact time, flight time, and reactive strength index (RSI). The applied tests included the counter-movement jump (CMJ). Comparative analysis of initial and final tests revealed a significant improvement in neuromotor performance among athletes in the experimental group, confirming the effectiveness of the proposed methodology. Thus, this research offers a reproducible intervention model, based on objective evidence, with direct applicability in training young Greco-Roman wrestlers.

Keywords: explosive strength; young juniors; Greco-Roman wrestling; intervention program; OptoJump

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1. Introduction

In the sport of Olympic wrestling, particularly in the Greco-Roman style, motor qualities such as explosive strength, reaction speed, and postural stability are essential components of technical and tactical performance. These attributes depend heavily on lower body efficiency, which is key to balance, attack initiation, counters, and quick phase transitions in combat. [1,2].

The period of middle childhood and preadolescence (ages 10–12) is considered optimal for neuromotor development interventions, primarily due to the heightened plasticity of the central nervous system and the muscular adaptability to training stimuli [3,4]. This stage builds a foundation for reactive and explosive strength using functional, age-appropriate methods without excessive loads.

Recent studies have demonstrated that well-structured and supervised plyometric training programs can lead to significant improvements in young athletes' neuromotor performance, directly impacting sport-specific abilities [5,6]. In Greco-Roman wrestling, lower limb explosive strength is vital for performing rapid lifts, disengagements, blocks, and pivots from unstable positions. Therefore, developing this quality during formative years has a major impact on long-term performance and helps prevent neuromuscular imbalances or injuries [7].

The evaluation of these motor qualities is no longer limited to subjective or empirical methods but is increasingly supported by advanced technologies capable of providing precise and reproducible data. One of the most widely used instruments in sports performance laboratories is the OptoJump Next system. This is based on optical sensors that allow biomechanical analysis of vertical jumps and other forms of reactive movement. Measured parameters, such as jump height, flight time, contact time, and the reactive strength index (RSI), serve as valuable indicators for assessing the explosive strength of the lower limbs [2,8].

Furthermore, recent literature highlights the importance of tailoring motor interventions to young athletes based on their individual profiles, physical development level, and the wrestling style they practice. Recent experimental studies support combining plyometrics, bodyweight strength training, and sport-specific drills within a safe, controlled, and progressively structured framework. [1,9].

This study aligns with contemporary trends, proposing an applied neuromotor development program focused on enhancing lower limb explosive strength in junior Greco-Roman wrestlers. The 17-month intervention was objectively assessed through repeated OptoJump testing, offering a solid quantitative basis for evaluating the effectiveness of the applied methodology. This research aims to strengthen the scientific basis of effective training for young athletes, providing coaches with a validated, reproducible model for practical application. At the same time, it presents an integrated perspective on how explosive strength development can be safely stimulated and effectively monitored, without compromising the health or natural development of young wrestlers.

The research is driven by two central questions: What is the influence of a specific intervention program on the development of lower limb explosive strength in young junior Greco-Roman wrestlers, as measured by the OptoJump system? And, what are the most effective training methods (exercises and techniques) for optimizing lower limb explosive strength in young junior wrestlers, tailored to their age and the demands of the Greco-Roman style?

To address these questions, the study is guided by the hypothesis that the implementation of a specific neuromotor development program, structured around plyometric exercises, functional strength training, and applications tailored to the Greco-Roman wrestling style, will lead to a significant improvement in the explosive strength parameters of the lower limbs in young junior athletes compared to those following a standard training program. The effectiveness of this program is expected to be demonstrated through the analysis of objective data obtained from the OptoJump testing system, revealing statistically significant improvements in the experimental group relative to the control group.

Through its objectives and methodology, this research seeks to contribute to the scientific foundation of effective training practices for young athletes, offering coaches a reproducible and validated model for practical intervention. At the same time, it presents an integrated perspective on how explosive strength development can be safely stimulated and effectively monitored, without compromising the health or natural development of young wrestlers.

2. Materials and Methods

2.1. Participants

2.1.1. Research Conditions

The participants included in this experimental research were organized into two distinct groups of young junior athletes: an experimental group (EG) and a control group (CG), each composed of 14 subjects (n = 14). These athletes, aged between 10 and 12 years, were registered and actively training in the Greco-Roman wrestling section of School Sports Club No. 5 in Bucharest (Table 1). The two groups were carefully balanced in terms of initial morphological, functional, and motor

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characteristics to ensure optimal homogeneity. This homogeneity was essential for objectively conducting the experimental intervention and created favorable conditions for comparing the effects of the specific intervention program applied to the experimental group with those of the standard training program followed by the control group. Additionally, age, height, weight, and body mass index (BMI) indicators of the children in both research groups were analyzed.

All subjects were declared medically fit for specific physical effort, according to their sports medical records. Their participation in the study was conducted in strict compliance with current ethical standards regarding research involving minors. The experimental protocol was approved by the Ethics Committee of School Sports Club No. 5 Bucharest (499/11.06.2025), and informed consent was obtained in writing from the athletes' parents or legal guardians before the commencement of any research procedures.

Table 1. Subjects of the Research Groups (Control and Experimental) – Anthropometric Parameters in the Initial Phase of the Study.

No	Control Group	Age	Weight (kg)	Height (cm)	BMI (kg/m²)	Experimental Group	Age	Weight (kg)	Height (cm)	BMI (kg/m²)
1	M.N.	12	57	167	0.34	T.V.	12	38	146	0.26
2	C.D.	11	50	160	0.31	R.L.	11	28	135	0.21
3	G.S.	12	60	169	0.36	E.F.	12	43	161	0.27
4	L.I.	11	58	157	0.37	P.C.	10	53	164	0.32
5	A.T.	12	48	157	0.31	N.D.	12	50	152	0.33
6	D.C.	9	40	136	0.29	I.M.	11	70	172	0.41
7	V.B.	10	34	135	0.25	K.S.	12	69	160	0.44
8	H.P.	11	47	153	0.31	M.E.	10	104	180	0.61
9	R.A.	11	61	148	0.41	Z.M.	12	61	172	0.35
10	E.T.	12	67	173	0.39	B.C.	11	67	138	0.49
11	S.O.	9	40	133	0.3	C.I.	10	42	162	0.26
12	T.R.	12	75	161	0.47	A.G.	11	49	160	0.31
13	I.F.	12	38	147	0.26	O.N.	10	41	136	0.3
14	P.M.	12	78	168	0.46	U.S.	11	50	158	0.32

2.2. Study Design

The research was conducted at School Sports Club No. 5 in Bucharest, in a controlled environment adapted to the specific training requirements of young junior Greco-Roman wrestlers. The experimental activities were implemented under real sports training conditions, adhering to the methodological rigor of a systematically planned intervention process.

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The independent variable (specific intervention program) was applied to the experimental group over approximately 17 calendar months, from March 2023 to September 2024 (Table 2). During this period, the athletes in the experimental group followed a structured training program, complementary to the classical method, specifically aimed at developing lower limb explosive strength. Meanwhile, the control group continued with the club's standard training regimen, without additional interventions related to the research objective.

The working conditions, sports infrastructure (mats, strength equipment), general training schedule, and involved personnel (wrestling coaches) remained constant throughout the study for both groups to minimize the influence of external factors. The initial and final evaluations were conducted under the same conditions, in the same training hall, using the same technological equipment (OptoJump system) to ensure the comparability and validity of the obtained results.

Table 2. Research Stages**.**

Period	Activity
March 2023	Initial Testing
April 2023 – August 2024	Implementation of the Intervention Program
September 2024	Final Testing

2.3. Research Content

The content of our research was built around an applied experimental approach, focusing on evaluating the influence of a specific neuromotor development program on lower limb strength in two groups of young junior athletes practicing Greco-Roman wrestling. The intervention program was designed to stimulate explosive strength and motor control through plyometric exercises and wrestling-specific techniques.

The research was structured into four main stages:

1. Documentation and research design stage, in which recent specialized studies were analyzed, the hypothesis and objectives were formulated, intervention methods were defined, and relevant biomechanical indicators were selected for evaluating lower limb strength.
2. Initial evaluation stage (pretesting) took place at the beginning of the experimental period (March 2023) at the training facility of School Sports Club No. 5 in Bucharest. All participating athletes were tested using the OptoJump Next system, performing the countermovement vertical jump (CMJ) to determine baseline parameters such as jump height, ground contact time, and reactive strength index (RSI).
3. Applied intervention stage, conducted over approximately 17 months (March 2023 – September 2024), included a progressive neuromotor development program applied exclusively to the experimental group. This program consisted of plyometric exercises, wrestling movements adapted to lower limb strength development, and functional activities emphasizing the specifics of the Greco-Roman style. The control group followed a standard sports training program in parallel, without additional interventions. Training sessions took place in the facilities and laboratories of School Sports Club No. 5 in Bucharest, under continuous monitoring.
4. Final evaluation stage (posttesting) was conducted at the end of the intervention period (September 2024), applying the same tests and evaluation methods as in the pretest. The obtained results were statistically analyzed to determine the effectiveness of the applied program and the progress differences between the two groups.

Through this structure, the research aims to provide scientific validation of the effectiveness of a specific intervention program for developing lower limb strength in young junior wrestlers, utilizing objective, technology-assisted testing methods. The results will contribute to the methodological foundation of physical training in Greco-Roman wrestling at this age category.

2.3.1. Training Methods Used in the Research

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In the applied experimental research conducted at School Sports Club No. 5 in Bucharest, the two groups of young junior athletes were trained according to a differentiated training plan, designed based on the methodological intervention objectives. Both groups followed programs specific to the Greco-Roman style but with distinct methodological focuses: the experimental group benefited from a comprehensive program aimed at developing lower limb strength and integrating it into standing wrestling techniques, while the control group followed a traditional training program without the application of modern methods or advanced biomechanical structures.

Experimental Group – Intervention Focused on Lower Limb Strength Development and Standing Wrestling Techniques

The program designed for the experimental group targeted specific neuromotor development, directly enhancing lower limb explosiveness, reactivity, and stability through a functional integration of strength components into wrestling techniques performed in a standing position. Accordingly, the program included advanced plyometric exercises, functional partner training, tactical and technical applications, and specialized thematic sequences for Greco-Roman wrestling.

Specific Plyometric Exercises were aimed at increasing reactive capacity and explosive strength, including:

• Jumps on a mat from a guard position
• Drop jumps with immediate takeoff and repositioning for engagement
• Lateral jumps over a partner, followed by rapid penetration into attack position
• Squat jumps combined with partner lifting exercises

Functional Strength Training Included:

• Squats with a partner on the back, for posterior chain development and stability
• Pulls and pushes from a clinch position
• Repeated mannequin lifts using a belt grip
• Circuit exercises incorporating "sumo walks," lunges with grip, and balance drills simulating wrestling movements

Technical-Tactical Elements Specific to Greco-Roman Wrestling:

• Takedowns via belt grip, lifting, and swinging, emphasizing force impulse synchronization
• Rotations from torso grasp, placing opponents in disadvantageous positions
• Low-guard penetrations, adjusting center of gravity and efficient lower limb positioning
• Thematic applications where athletes executed techniques immediately after securing a grip

Reactive and Stability Components Were Developed Through:

• Tandem exercises (pushes, resistance, holding)
• Repetitions of low-guard throws using mannequins
• Medicine ball drills (e.g., vertical and lateral throws from strength positions)
• Video feedback and biomechanical corrections regarding lower limb positioning and technique execution

This set of methods aimed to optimize physical qualities and wrestling-specific motor skills simultaneously, ensuring a real transfer between neuromotor development and competitive performance in Greco-Roman wrestling.

Control Group – Standard Training Program for the Greco-Roman Style

The control group was trained using a traditional program commonly applied in beginner or intermediate-level athlete preparation, without biomechanical analysis or technology-assisted interventions. The training focused on learning and reinforcing fundamental techniques of the Greco-Roman style using conventional general and specific training methods.

General Physical Component Included:

• Linear runs and obstacle runs, push-ups, sit-ups, pull-ups• Basic squats, stationary or dynamic jumps, mobility drills

Technical Exercises Focused On:

• Learning and repeating takedown techniques such as basic belt grip and balanced throws• Controlled projections with a partner, without explosive or reactive elements• Mannequin drills to reinforce fundamental techniques in takedowns and lifts

Tactical Applications Were Conducted Through:

• Thematic training fights (engagements without ground transition, responses to slow attacks)• Attack/counterattack simulations from fixed guard positions or in restricted spaces• Paired drills in repeated series, without progressive difficulty increments

Motor Skill Games Targeted:

• Balance maintenance, controlled opposition, gripping and postural stability exercises• Wrestling-themed games adapted to the athletes' age

This program ensured a standard training framework without additional optimization elements, making it ideal for comparing the effectiveness of the intervention applied to the experimental group.

2.3.2. Research Variables

In the experimental research conducted at School Sports Club No. 5 in Bucharest, the two groups of young junior athletes underwent differentiated training programs to investigate the impact of neuromotor development on lower limb strength parameters. The methodological design involved applying an independent variable to the experimental group while maintaining a standard training program for the control group to highlight potential functional and motor modifications.

The independent variable was represented by the neuromotor intervention program applied to the experimental group, which included plyometric exercises, functional strength development methods, and the application of specific standing wrestling techniques from the Greco-Roman style. This program was designed to stimulate explosive strength development and the specific reactive capacity of the lower limbs, being adapted to the age characteristics and training level of the subjects.

The dependent variable consisted of the level of lower limb strength development, objectively measured using the OptoJump system through countermovement vertical jump (CMJ) tests. The analyzed indicators included jump height, flight time, ground contact time, and the Reactive Strength Index (RSI), which reflects neuromuscular efficiency and the ability to rapidly generate force.

By analyzing these variables, the research aims to provide an objective basis for assessing the effectiveness of a training program focused on strength development in a specific wrestling context, with the goal of scientifically substantiating methodological decisions in the training of young performance athletes.

2.3.3. Statistical Analysis

The data were analyzed using the statistical package SPSS. In our research, the data collected through various measurements and tests were subjected to statistical analysis, utilizing the following indicators:

Maximum (Upper Limit): Represents the highest recorded value within the data set.

Minimum (Lower Limit): Indicates the lowest value observed in the data series.

Arithmetic Mean: Reflects the central tendency of the group under study, calculated by dividing the total sum of all values by the number of cases (n).

Variance: Expresses the relative degree of variability in the data, helping to assess the importance and stability of the results.

Dependent t-test: This statistical method is used when the same participants are measured more than once (a repeated-measures or within-subjects design). In our study, we adopted a significance level of $p = 0.05$, indicating a 5% risk of error. This means we can be 95% confident that the true population mean lies within the determined confidence interval. A higher t-value suggests a more substantial difference between means and lower variability within the compared series.

The correlation coefficient is a measure of the strength and direction of the association between two variables measured on an ordinal or nominal scale. This statistical indicator ranges from -1 to +1 and provides information about the correlation between two variables. Specifically:

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- 0.3 < r < 0.5 or -0.5 < r < -0.3 – Low positive or negative correlation
- 0.5 < r < 0.7 or -0.7 < r < -0.5 – Moderate positive or negative correlation
- r > 0.7 or r < -0.7 – High positive or negative correlation

Correlation attempts to construct an optimal line of fit through the data for two variables, and the correlation coefficient, r, indicates how far the data points are from this line of fit—that is, how well the points conform to the model or line.

Test Assumptions

- Assumption 1: The two variables must be measured on ordinal or nominal scales. This assumption is fulfilled.
- Assumption 2: There exists a linear relationship between the two variables. This assumption is met, particularly for the variables in the experimental group.
- Assumption 3: There should not be any extreme values. This assumption is fulfilled since no extreme values are present.
- Assumption 4: The variables should be approximately normally distributed. This assumption is met, especially for the experimental sample, as the Skewness and Kurtosis values indicate a distribution similar to the Gaussian curve.

3. Results

During testing with the OptoJump analysis system, vertical jumps (5JS2D) were performed, with five repetitions for each leg (right and left). These measurements provided conclusive data for our research (Figure 1).

Figure 1. Images of OptoJump Next Testing.

Five vertical jumps were performed for each lower limb, with the OptoJump computerized program objectively measuring the following indicators:

- T Cont – ground contact time with the force plate, measured in fractions of a second
- T Flight – flight time (time spent in the air), measured in fractions of a second
- Height – jump height (calculated in cm)
- RSI - Reactive Strength Index – "The reactive strength index (RSI) is an effective marker of reactive force due to the rapid shortening caused by prior activation in the DJ - Drop Jump, also known as the stretch-shortening cycle" [10].
- Pace – jump cadence
- Power – strength (watts/kg)

We considered vertical jump performance to be the most relevant indicator for Greco-Roman wrestling, given the specificity of techniques in this discipline. For this reason, we conducted all comparative analyses between the subjects of the two research groups based on this parameter.

3.1. Descriptive Statistics

Control Group vs. Experimental Group

From Table 3 and Figure 2, it is observed that:

- The average value of the Height indicator is much higher in the experimental group (11.63 cm) compared to the control group (7.48 cm) in the final test, even though the initial test values were reversed—2.61 cm for the experimental group versus 3.37 cm for the control group. This indicates that the athletes in the experimental group evolved much better, obtaining higher individual outcomes and average values as a result of the adaptations to the loads and dosing of the training means employed as the independent variable.
- Power per body weight is much higher in the experimental group (13.52 W) compared to the control group (10.33 W) in the final test, even though the initial test values were reversed—4.66 W for the experimental group and 5.32 W for the control group. This suggests that the athletes in the experimental group evolved much better due to the type of training practiced. Although the control group athletes initially recorded slightly higher average values, their level of preparation was similar.

Table 3. Comparison of the Mean Values Between the Control Group and the Experimental Group in the Initial and Final Testing.

OptoJump Variables	Height	Power	Pace	RSI	T Cont.	T Flight
Initial Testing Control Group	3.37	5.32	1.62	0.07	0.54	0.16
Initial Testing Experimental Group	2.61	4.66	1.76	0.06	0.48	0.14
Final Testig Control Group	7.48	10.33	1.57	0.26	0.56	0.21
Final Testig Experimental Group	11.63	13.52	1.57	0.33	0.37	0.3

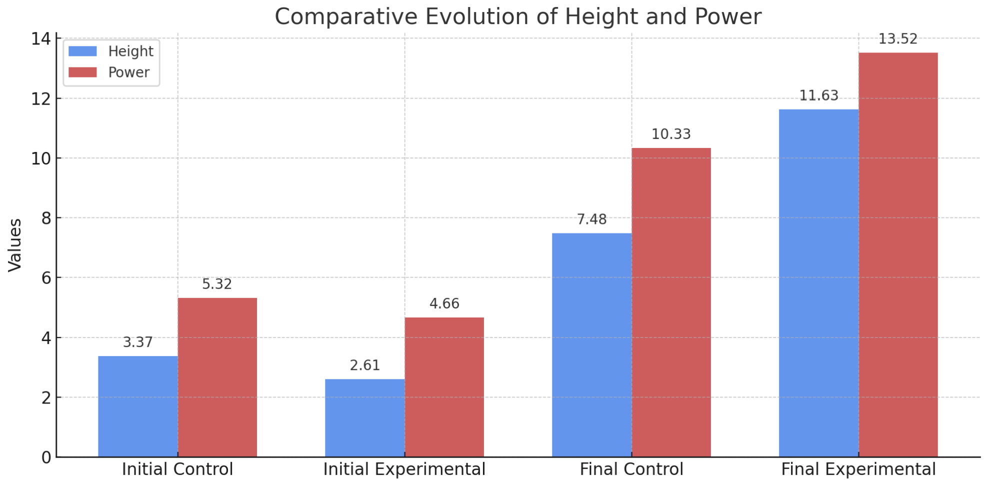

Figure 2. Mean Values for Height and Power: Control Group vs. Experimental Group.

From Figure 3, it is observed that:

- Jump Cadence: The jump cadence is identical in the experimental group (1.57 jumps/sec) and the control group (1.57 jumps/sec) at the final test. However, during the initial test, the experimental group exhibited higher average values (1.76 jumps/sec) compared to the control group (1.62 jumps/sec).

- Reactive Strength Index (RSI): The RSI is significantly higher in the experimental group (0.33) than in the control group (0.26) at the final test, even though both groups had approximately equal values in the initial test (0.06 for the experimental group versus 0.07 for the control group). This increase in both individual and mean values among the experimental subjects represents progress, as the RSI is an effective indicator of reactive strength.
- Ground Contact Time (T Cont): Ground contact time is considerably lower in the experimental group (0.37 sec) compared to the control group (0.56 sec) at the final test. Although in the initial test the experimental group (0.48 sec) also showed lower values than the control group (0.54 sec), the difference was smaller and not significant. Given the young age and corresponding exertion capacity of the subjects, the contact duration is notably high; thus, the reduction in ground contact time indicates an improvement in impulse, resulting in increased power, longer flight phase, and higher jump height.
- Flight Time (T Flight): Flight time is substantially higher in the experimental group (0.30 sec) compared to the control group (0.21 sec) at the final test, while in the initial test both groups recorded approximately equal values (0.14 sec for the experimental group and 0.16 sec for the control group). The increase in flight time reflects an enhancement in the athletes' capacity for effort, which may also contribute to improved combat performance, as observed.

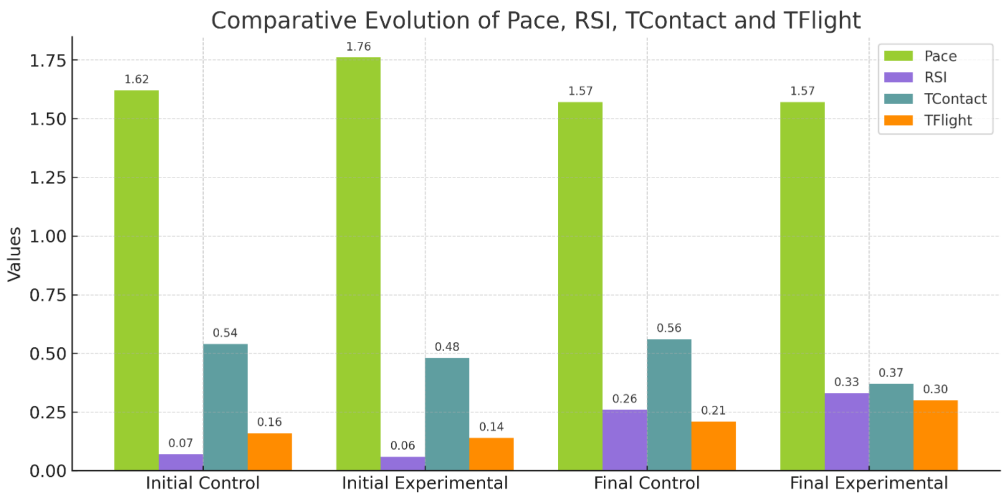

Figure 3. Mean Values for Cadence (Pace), Reactive Strength Index (RSI), Ground Contact Time (T Cont), and Flight Time (T Flight): Comparison Between the Control Group and the Experimental Group.

3.1.1. Inferential Statistics

T-Test – Control Group versus Experimental Group (Final Testing)

In order to find out whether there is a statistically significant difference between the initial and the final t-test, we apply the Paired Two Sample for Means (t-Test).

- For Ground Contact Time: The t-statistic for the test is $t = 2.71$, which is greater than the minimum accepted two-tailed critical t-value (1.67), with a very high level of significance ($p = 0.01 < 0.05$) and a 95% confidence level. We conclude that the mean value for Ground Contact Time in the control group (0.55 sec) is higher than that in the experimental group (0.37 sec). The differences between the individual results and the mean values are statistically significant.
- For Flight Time: The t-statistic for the test is $t = 3.69$, which is greater than the minimum accepted two-tailed critical t-value (1.67), with a very high level of significance ($p = 0.00 < 0.05$) and a 95% confidence level. We conclude that the mean value for Flight Time in the control group (0.21 sec) is lower than that in the experimental group (0.29 sec). This difference is statistically significant, further confirming the research hypothesis.

- For the control group, the SD shows more homogeneous results (0.12) compared to the experimental group (0.01), and the CV is very small (0.01) for the experimental group, confirming the high consistency.

The inferential statistical test allows us to generalize our conclusions to the entire statistical population, since t Stat > t Critical and p < 0.05. In other words, if the test were repeated under similar conditions, we would obtain similar results (Table 4).

Table 4. Statistical indicators –Ground Contact Time and Flight Time (CG vs. EG).

Indicators		Mean	SD	CV	t Stat	P(T<=t) one-tail	t Critical one-tail	P(T<=t) two-tail	t Critical two-tail
Ground Contact Time	CG*	0.55	0.34	0.12	2.71	0.00	1.67	**0.01**	2.01
	EG**	0.37	0.09	0.01					
Flight Time	CG	0.21	0.09	0.01	-3.69	0.00	1.67	**0.00**	2.01
	EG	0.29	0.07	0.01					

* CG – control group. **EG – experimental group.

According to SD (8.30, 11.56) and CV (68.95, 133.7), the results of the control group are dispersed, with subjects performing extremely differently for both indicators (height and power) The experimental group performed much better and much more homogeneous.

For Jump Height: The t-statistic for the test is t = 2.10, which is greater than the minimum accepted two-tailed critical t-value (1.67), with a very high level of significance (p = 0.01 < 0.05) and a 95% confidence level. We conclude that the mean jump height in the control group (7.61 cm) is lower than that in the experimental group (11.60 cm). This difference is statistically significant, thereby confirming the research hypothesis.

For Power per kg Body Weight: The t-statistic for the test is t = 1.21, which is lower than the minimum accepted two-tailed critical t-value (1.67), with a very low level of significance (p = 0.15 > 0.05) and a 95% confidence level. We conclude that the mean power for the control group (10.52 W) is lower than the mean power for the experimental group (13.50 W); however, this difference is not statistically significant. The inferential statistical test does not allow us to generalize our conclusion to the entire statistical population, as t Stat < t Critical and p > 0.05. In other words, if the test is repeated under similar conditions, similar results would not be obtained. Nonetheless, we maintain that even insignificant differences in applying specific techniques in Greco-Roman wrestling can, in many cases, make the difference during competitive matches (Table 5).

Table 5. Statistical indicators – Height and Power (CG vs. EG).

Indicators		Mean	SD	CV	t Stat	P(T<=t) one-tail	t Critical one-tail	P(T<=t) two-tail	t Critical two-tail
Height	CG	7.61	8.30	68.95	-2.10	0.02	1.67	**0.04**	2.01
	EG	11.60	1.50	2.24					
Power	CG	10.52	11.56	133.70	-1.21	0.11	1.67	0.23	2.01
	EG	13.50	1.76	3.09					

For Jump Frequency: The t-statistic for the test is 0.10, which is lower than the minimum accepted two-tailed critical t-value (1.67), with a very low level of significance (p = 0.15 > 0.05) and a 95% confidence level. We conclude that the mean cadence for the control group (1.56 jumps/sec) is nearly equal to the mean cadence for the experimental group (1.57 jumps/sec). This difference is not statistically significant.

For Reactive Strength Index (RSI): The t-statistic for this test is 0.56, which is lower than the minimum accepted two-tailed critical t-value (1.68), with a very low level of significance (p = 0.15 >

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0.05) and a 95% confidence level. We conclude that the mean RSI for the control group (0.27) is lower than that for the experimental group (0.32). However, this difference is not statistically significant.

The inferential statistical test does not allow us to generalize our conclusion to the entire statistical population, because t Stat < t Critical and p > 0.05. In other words, if the test were repeated under similar conditions, similar results would not be obtained.

Two-Sample t-Test Assuming Equal Variances: When comparing the control group to the experimental group, the two-sample t-test assuming equal variances is statistically significant for Ground Contact Time, Flight Time, and Height. In contrast, the t-test is not statistically significant for Power, Cadence, or the Reactive Strength Index. This suggests that the training applied was much more effective in the experimental group regarding Ground Contact Time, Flight Time, and Height. Although large differences were observed between the control and experimental groups in Power, Cadence, and RSI, these differences are not statistically significant, implying that further research should be pursued in these areas (Table 6).

Table 6. Statistical indicators –Cadence and Reactive Strength Index - RSI (CG vs. EG).

Indicators		Mean	SD	CV	t Stat	P(T<=t) one-tail	t Critical one-tail	P(T<=t) two-tail	t Critical two-tail
Cadence	CG	1.56	0.37	0.14	-0.10	0.46	1.67	0.92	2.01
	EG	1.57	0.18	0.03					
Reactive Strength Index (RSI)	CG	0.27	0.50	0.24	-0.56	0.29	1.68	0.58	2.01
	EG	0.32	0.16	0.03					

3.2. Statistical Association

Correlation Coefficient – Control Group

A strong positive correlation is observed among the following indicators: Flight Time, Jump Height, Power per kg body weight, and Reactive Strength Index. (Table 7). All these indicators represent different manifestations of force. Specifically:

- Flight Time & Jump Height: A very strong positive correlation is observed (r = 0.9). Additionally, strong correlations exist between Flight Time and Power per kg body weight (r = 0.81) and between Flight Time and Reactive Strength Index (r = 0.72). In practical terms, high values of Flight Time are associated with high values for Jump Height (r = 0.90) as well as with high values of both Power per kg body weight and Reactive Strength Index (r = 0.88).
- Jump Height & Power per kg Body Weight / Reactive Strength Index: A very strong correlation is observed between Jump Height and Power per kg body weight (r = 0.92) and between Jump Height and Reactive Strength Index (r = 0.88). This indicates that high jump heights are associated with high power output and a strong reactive strength index.
- Power per kg Body Weight & Reactive Strength Index: An almost perfect positive correlation is recorded (r = 0.99), meaning that high power values are closely associated with high values of the Reactive Strength Index (as reflected in Table 37).

Table 7. Correlation between Variables – Control Group.

Control	Test	T Cont.	T Flight	Height	Power	Pace	RSI
Test	1.00						
T Cont.	0.04	1.00					
T Flight	0.37	-0.03	1.00				
Height	0.33	-0.08	0.90	1.00			

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Power	0.29	-0.16	0.81	0.92	1.00		
Pace	-0.08	-0.67	-0.42	-0.31	-0.20	1.00	
RSI	0.26	-0.19	0.72	0.88	0.99	-0.13	1.00

In contrast, a moderate negative correlation is noted between Jump Frequency and Ground Contact Time (r = -0.67). This implies that higher jump frequencies tend to be associated with a reduction in Ground Contact Time.

Additionally, a small negative correlation is found between Jump Frequency and both Flight Time (r = -0.42) and Jump Height (r = -0.42). This is logical since, as the values for Flight Time and Jump Height increase (indicating greater power output), the Jump Frequency tends to decrease—or conversely, higher jump frequencies are associated with lower values of Flight Time and Jump Height due to the reduced power expression (Table 7).

Correlation Coefficient – Experimental Group

In Table 8 is observed a strong positive correlation between:

- Flight Time and Height (r = 0.98), Flight Time and Power (r = 0.98), and Flight Time and Reactive Strength Index (r = 0.96): This indicates that high values of Flight Time are associated with high values of Height, Power, and the Reactive Strength Index.
- Height and Power (r = 0.98) and Height and Reactive Strength Index (r = 0.97): In other words, high jump heights are associated with high power output and high values of the reactive strength index (with a correlation of r = 0.99 reported in one instance).
- Power and Reactive Strength Index (r = 0.99): Very high power values are, therefore, almost perfectly associated with very high Reactive Strength Index values.

Table 8. Correlation between Variables – Experimental Group.

Experiment	Test	T Cont.	T Flight	Height	Power	Pace	RSI
Test	1.00						
T Cont.	-0.37	1.00					
T Flight	0.81	-0.32	1.00				
Height	0.78	-0.30	0.98	1.00			
Power	0.78	-0.37	0.98	0.98	1.00		
Pace	-0.35	-0.37	-0.63	-0.58	-0.57	1.00	
RSI	0.76	-0.40	0.96	0.97	0.99	-0.50	1.00

A moderate positive correlation is observed between:

- Jump Cadence and Reactive Strength Index (r = 0.50): This means that higher jump cadence values tend to be associated with moderate increases in the Reactive Strength Index.

On the other hand, there is a small negative correlation—without statistical significance—between:

- Ground Contact Time and Flight Time (r = -0.32)
- Ground Contact Time and Height (r = -0.30)
- Ground Contact Time and Power (r = -0.37)
- Ground Contact Time and Jump Cadence (r = -0.37)
- Ground Contact Time and Reactive Strength Index (r = -0.40)

These negative correlations indicate that longer Ground Contact Times are associated with lower values of Flight Time, Height, Power, Jump Cadence, and the Reactive Strength Index. In practical terms, when the expression of force (in the form of power) is lower, Ground Contact Time tends to be higher.

4. Discussion

This study contributes to the specialized literature on optimizing the physical and technical-tactical training of junior Greco-Roman wrestlers by introducing an intervention program focused on developing lower-body strength and executing techniques in a standing position. A distinctive feature of this research is the use of the OptoJump system for precise quantification of neuromotor performance, providing an objective evaluation framework [11, 12, 13].

According to recent studies, the performance of Greco-Roman wrestlers is closely linked to explosive strength and reaction ability, particularly in executing offensive maneuvers initiated from a standing position. These components are essential in an acyclic sport characterized by rapid alternation between maximum-intensity efforts and phases of control or energy conservation [14–17]. The findings of our research, which revealed a significant increase in jump height and the Reactive Strength Index (RSI) in the experimental group, confirm the relevance of these characteristics for success in competition.

The specific effort required in Greco-Roman wrestling places continuous demands on the neuromuscular system under conditions of constant contact with the opponent, where reaction speed and motor coordination are decisive factors [18,19]. Therefore, the selection of training methods such as plyometric jumps, dummy lifts, and clinch-position exercises facilitated a direct transfer between physical development and the application of sport-specific techniques.

Aquino et al. (2023) emphasize that junior competitive performance is determined not only by general physical preparation but also by its integration into tactical contexts similar to competition scenarios. The experimental group's results—significant improvements in repeated jumps and countermovement jumps (CMJ), as well as a reduction in fatigue index—support the hypothesis of the effectiveness of such integration. Furthermore, the homogeneity of performance within this group, observed in statistical analysis, aligns observations on the positive effects of sport-specific adapted programs in standardizing performance [20,21].

An additional explanation for the observed progress lies in the differentiated methodological approach. While the control group followed a conventional training regimen focused on general exercises and fundamental techniques, the experimental group benefited from functional stimuli tailored to competition demands. This methodological distinction also explains the more modest progress recorded by the control group, a finding supported by Nagovitsyn et al.'s (2019) [22] research on the necessity of adapting training programs to the neuromotor profile of young wrestlers.

Moreover, recent studies indicate that applying visual feedback and utilizing technological measurement systems such as OptoJump not only ensure objectivity but also enhance athletes' motivation and engagement in the learning process [23–26]. This observation is indirectly validated by the behavior of athletes in the experimental group, who demonstrated active participation and more rapid adaptation to the technical and physical demands of training.

Plyometric exercises combined with wrestling techniques, along with the inclusion of tactical sequences under opposition conditions, have facilitated a genuine transfer between the development of neuromotor qualities and their applicability in actual combat. The effectiveness of this training approach is supported by recent literature, which advocates for aligning physical preparation with the biomechanical and tactical demands of combat sports [27–30]. Additionally, integrated training methods that incorporate complex motor tasks within decision-making contexts have been shown to contribute to the development of advanced neuromotor control and the execution efficiency of techniques under competitive conditions [31–33]

In this context, it is essential to highlight that neuromotor development is not merely a consequence of increased exercise volume but, more importantly, of the quality of these stimuli and how they are integrated into the technical-tactical content specific to Greco-Roman wrestling [34–37].

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5. Conclusions

The research carried out at the Sports School Club No. 5 in Bucharest primarily aimed to analyze the effects of an intervention program focused on developing lower-limb strength, combined with the application of technical-tactical procedures specific to upright combat, on young junior athletes in Greco-Roman wrestling.

Based on the values obtained from the initial and final tests, the following conclusions—grounded in both statistical and methodological analyses—can be formulated:

Pretest Phase Homogeneity: During the pretest phase, no statistically significant differences were observed between the two research groups (control and experimental). This confirms the initial homogeneity of the groups in terms of morpho-functional and motor characteristics, thereby constituting a valid premise for the objective application of the independent variable.

Significant Improvements in the Experimental Group: The application of the intervention program in the experimental group over a period of 17 months led to statistically significant increases in parameters related to explosive and reactive lower-limb strength, as measured by the OptoJump system (including CMJ, DJ, RSI, fatigue index, repeated jump height, etc.). These results support the validity of the formulated hypothesis and underscore the relevance of the methodological content applied.

Transfer of Neuromotor Qualities to Specific Combat Techniques: Comparative Progress Between Groups: The control group, which followed a standard program without the integration of advanced neuromotor development components, demonstrated significantly smaller improvements. This finding confirms the superiority of the differentiated approach implemented in the experimental group.

Validation of Integrative Training Strategy: The data validate the efficiency of an integrative training strategy in which the development of reactive strength and muscular explosiveness is coupled with the repetitive application of specific combat maneuvers—such as takedowns, lifts, and balancing drills performed in controlled opposition.

Reduced Performance Dispersion: The analysis of variation coefficients revealed a decrease in performance dispersion within the experimental group, indicating a higher standardization of motor levels among young athletes.

Objective Evaluation with OptoJump: The use of the OptoJump system has proven to be a valuable resource in the objective assessment of progress, and it is recommended for systematic integration into neuromotor testing of young athletes.

Overall, the results clearly support the idea that differentiated training—centered on stimulating lower-limb strength through functional exercises and specific application in the technical context of combat—is a decisive factor in optimizing performance among young junior athletes. Structuring training in accordance with the physiological, motor, and tactical requirements of the sport leads to increased efficiency and a superior developmental potential in subsequent performance stages.

The originality of this research lies in its integrative approach, which combines neuromotor development with sport-specific applications in Greco-Roman wrestling for young junior athletes. Unlike traditional training programs, the experimental intervention was meticulously designed to enhance lower limb explosiveness, reactivity, and stability through advanced plyometric drills, functional strength training, and biomechanically-informed technical execution. This study stands out by embedding these physical qualities directly into standing wrestling techniques, promoting a real and immediate transfer between training adaptations and competitive performance. Furthermore, the research employs objective biomechanical monitoring tools, such as the OptoJump system and video feedback, to quantify performance changes and correct technical execution. By contrasting this with a control group following conventional methods, the study not only highlights the efficacy of the intervention but also offers a practical and replicable methodological framework for coaches aiming to optimize youth athletic development in wrestling. This constitutes both the scientific innovation and applied know-how of the research.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of NAME OF INSTITUTE (protocol code 499/11.06.2025)." for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: We encourage all authors of articles published in MDPI journals to share their research data. In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Where no new data were created, or where data is unavailable due to privacy or ethical restrictions, a statement is still required. Suggested Data Availability Statements are available in section "MDPI Research Data Policies" at https://www.mdpi.com/ethics.

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Abbreviations

The following abbreviations are used in this manuscript:

CG	Control group
EG	Experimental group

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