Optimizing Lower Limb Muscle Strength in Non-Athlete University Students Through Plyometric Training

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Abstract

This paper aims to contribute to the improvement of the physical training process for students who are part of the representative football team of the National University of Science and Technology Politehnica of Bucharest. The main objective of the study is to promote and implement a set of methods and means focused on developing the lower limb muscle strength, as well as to experimentally validate their effectiveness.

The experiment was conducted on a sample of 24 students aged between 19 and 24. The study took place between October 2024 and March 2025, during which the subjects participated in a structured training program including operational sequences focused on developing lower limb strength.

The results obtained in the final testing, compared to the initial testing, revealed significant progress, thus confirming the effectiveness of the applied methodology. The set of methods and means used represents a valuable contribution to enhancing the instructional-educational process within the physical training of non-athlete university students.

Keywords: *football, lower limb strength, students, plyometric*

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1. Introduction

Lower limb muscle strength has been extensively investigated in sports science, particularly in relation to football performance. Most existing studies focus on elite athletes—both junior and senior, male and female—while others examine sedentary individuals or those engaged only in physical education classes. However, there remains a gap in the literature regarding intermediate-level students whose

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physical condition falls between that of occasional exercisers and professional athletes. This study addresses that gap by exploring strength development in non-sports-specialized university students participating in structured physical training programs.

Football performance is influenced by a complex interplay of technical, tactical, psychological, and physiological factors [1]. Among these, lower limb muscle strength and anaerobic power are critical neuromuscular components that directly affect speed, agility, and explosive movement. The development of these qualities can lead to improved game performance through enhanced motor coordination and physical execution [2]. From a physiological standpoint, physical effort involves the conversion of chemical energy into mechanical energy, triggering systemic adaptations that depend on the nature and intensity of the exertion [3]. Strength limitations in football include general strength, starting power, strength endurance, acceleration and deceleration capacity, and reaction power—all of which vary depending on the player's position and role on the field [4].

Given the importance of these components, plyometric training (PT) was selected as the primary method for developing lower limb strength in this study. PT is widely recognized as an effective and accessible training modality that utilizes explosive movements—such as jumps, bounds, and skips—to enhance muscle power and neuromuscular efficiency [5, 6]. Compared with other conditioning methods such as resistance training, fartlek, interval training, or circuits, PT uniquely combines speed and force to elicit rapid adaptations in strength and agility [7]. Moreover, recent research has highlighted PT's potential to positively influence cognitive and psychological functions, including attention and mental states [8].

From a biomechanical perspective, athletic movements often require integrating strength and speed to produce power—a fundamental attribute in football, where players must perform high-speed runs, powerful throws, and rapid directional changes [7, 9]. Plyometric contractions generate increased tension during the stretch phase, thereby reducing energy expenditure during the subsequent shortening phase and improving performance [10]. However, such training demands careful volume and intensity management to avoid overloading the central nervous system and risking fatigue or injury [11].

In this context, general physical preparation must provide athletes with the morphological, functional, and motor development necessary to meet the demands of the game [12]. Physical training should be understood as a comprehensive system aimed at enhancing functional capacity, motor skills, and morpho-functional indicators, all grounded in optimal health [13].

Based on data analysis and practical experience with the representative football team of the National University of Science and Technology Politehnica of Bucharest (UNSTPB), a clear need was identified to improve lower limb strength among non-athlete students. This observation forms the basis of the present study, which is directed toward sports educators seeking effective strategies to enhance muscle strength—a fundamental component of physical performance. While we recognize that this paper cannot address every aspect of strength development, our

focus is on the practical application of training methods that can be readily implemented in educational settings.

The main objective of this research is to identify, apply, and promote a set of efficient training techniques specifically designed to improve lower limb muscle strength among non-athlete university students. At the same time, the study aims to experimentally validate the effectiveness of these methods through structured training programs, aiming to achieve measurable improvements in motor capacity in this young, active, but non-specialized population.

Research Hypothesis

We believe that the development and integration of a standardized training program, specifically designed for use in practical training sessions and incorporating targeted methods for muscle strength development, can serve as an efficient tool for optimizing the muscular development of the lower limbs. This approach is particularly important for students in non-sports-focused academic programs who, although not engaged in performance-level activities, can benefit significantly from well-structured physical interventions that improve their overall physical condition and motor capacity.

2. Materials and Methods

Participants

The study included a sample of 24 students, all members of the UNSTPB's representative football team. The participants were divided into two distinct groups:

- Experimental Group (G1) – which benefited from the proposed intervention through a specific physical training program.
- Control Group (G2) – which continued with their regular training regimen, without the application of the experimental method.

The age range was 19 to 24 years, and all experimental activities were conducted at the UNSTPB sports facility.

Methods

In conducting this study, we employed a range of research methods intended to ensure both a solid theoretical foundation and a rigorous analysis of the collected data. These included a review of the specialized scientific literature to define the theoretical framework of the topic, followed by a controlled experimental investigation. Furthermore, objective analysis of the collected data was carried out using statistical and mathematical processing methods, complemented by graphical representation to allow a clear visualization of the evolution of the analyzed parameters.

The statistical indicators used in this research included: arithmetic mean, standard deviation, coefficient of variation, and the independent samples t-test.

These tools enabled us to assess the significance of differences between the initial and final test results and to determine the homogeneity of the subject group.

The significance for all statistical tests was set at $p<0.05$.

Instruments

Muscular performance was assessed using the Plyometric Jump Test with the Myotest device, a modern evaluation tool that provides accurate measurements of strength and explosive power parameters in a short time frame [14]. We analyzed the following parameters:

- Jump Height – expressed in centimeters; reflects the ability to generate explosive force
- Strength Force – expressed in Newtons; shows the intensity of the muscle impulse.

Myotest is not only a measurement tool but also a performance improvement device, thanks to its integrated computer analysis software. It facilitates the optimization of training time and allows for the storage and comparison of data for one or multiple athletes and has been employed in other research studies as well.

Procedure

The experimental period lasted from October 2024 to April 2025, and was structured into three main phases:

- initial Testing – conducted between October 15–20, 2024, aimed to establish the baseline level of motor performance for both groups.
- intervention Phase – from November 25, 2024, to April 25, 2025, during which the experimental group (G1) followed a specially designed training program, including a series of operational structures targeting the development of lower limb muscular strength.
- final Evaluation – carried out between April 25–30, 2025, focused on measuring the progress made by both groups to determine the effectiveness of the applied intervention.

The research was conducted in full compliance with all ethical and medical standards required by current legislation governing studies involving human participants. All subjects were fully informed in advance of the research's purpose, the nature of the assessments, the tools used, and the procedures involved. Each participant provided written consent to take part in the study. Furthermore, at the beginning of the experiment, all subjects were clinically healthy, with no pre-existing conditions or injuries that could be aggravated by physical testing. Measurements were carried out in accordance with the ethical standards of the Declaration of Helsinki.

Training program

The muscle strength development program was built upon the plyometric training method, applied only after a prior stage of anatomical adaptation had been

completed and the fundamental elements of general physical preparation had been consolidated.

The training program, which included specific operational structures aimed at improving motor qualities, particularly muscular strength, was developed following the initial testing phase. This program was implemented during the students' training sessions in the experimental group. Each training session lasted 25-30 minutes and was conducted over 6 months.

Below is an example of training tools used within lesson sequences, integrated into the overall training sessions, aimed at stimulating lower limb muscle strength development:

- Short-distance sprints (10 and 20 meters) from a standing start. This exercise is designed to stimulate start reaction, short-distance acceleration, and rapid force production. It is a fundamental method in physical preparation for sports that require changes in rhythm and pace, such as football.
- Downhill. These runs aim to increase step frequency and enhance movement coordination during acceleration. Descending sprints improve execution speed and neuromuscular control in situations of sport-specific demand.
- Running with alternating jumps over sticks fixed to the ground. This exercise develops explosive strength, coordination, and dynamic balance. Alternating legs with each jump ensures balanced muscular engagement of both lower limbs and contributes to improved mobility and impact stability.
- Alternating jumps over 20 cm mini hurdles. This exercise falls into the medium-intensity plyometric category and is effective for improving explosive strength and reaction time. The sustained rhythm during execution leads to positive neuromuscular adaptations, essential for fast, powerful actions during gameplay.
- General Strength Circuit – 6 Functional Stations

As part of the physical training program, a general strength circuit consisting of six functional stations was implemented. Each station targets the development of key muscle groups to improve overall physical performance, with a focus on strengthening the trunk, lower limbs, and upper limbs. The circuit is structured to allow for balanced stimulation of the body, combining bodyweight exercises with dynamic movements to enhance functional strength, muscular endurance, and tone.

Circuit composition:

- Push-ups: A classic upper body strength exercise (targeting the pectorals, triceps, and shoulders), also engaging the core stabilizer muscles. Proper technique is essential, avoiding excessive arching of the lower back.
- Squats: Target the major muscle groups of the lower limbs—quadriceps, glutes, and hamstrings. This fundamental exercise contributes to both strength and stability and is essential in sports involving jumping and directional changes.

- Sit-ups: Aim to strengthen the abdominal muscles, especially the rectus abdominis. A well-conditioned core supports proper posture and efficient movement during physical effort.
- Dynamic plyometric exercise (e.g., high-knees or jump squats): Focused on developing explosive power and coordination. It intensely activates the thigh, calf, and abdominal muscles while also stimulating the cardiorespiratory system.

Each exercise is performed for 30-45 seconds, followed by an active rest period of 20 seconds. The full circuit can be repeated 2 to 3 times, depending on the participants' fitness level and the training session's objectives.

3. Results

The main objective of the study was to identify significant differences between the results obtained by the students at the conclusion of the experimental intervention, through the application of a targeted training system designed to develop lower limb muscular strength in non-sport-specialized university students.

The progression of the results obtained during the initial phase of the experiment is shown in Table 1 and presents the parameter values measured through muscular strength evaluation tests, comparing the two groups: G1 (experimental group) and G2 (control group), using the calculated statistical indicators.

Comparative Results of the Experimental Group (G1) and Control Group (G2) in the Initial Testing

Table 1

Test Plyometric Jump	n	STATISTICAL INDICATORS						
		G1	G2	G1-G2	G1	G2		
		Mean/± SD	**Mean/± SD**	**Dif. mean**	**Cv %**	**Cv %**	**t-TEST independent**	**p**
Strength / Force (N)	12	33.7/1.05	32.49/1.05	1.21	3.21	3.33	2.56	>0,05
Jump Height (cm)	12	33.57/1.05	32.78/1.05	0.79	3.4	3.41	0.19	>0,05

By comparing the results obtained (Table 1) from the two groups (experimental and control) during the initial phase of the experiment, we observe the following:

- **Strength / Force (N), (Table 1):** The mean value at the initial testing was 33.7 N for the experimental group (G1) and 32.49 N for the control group (G2). The difference between the mean values of G1 and G2 is 1.21 N. The coefficient of variation (Cv) was 3.21% for G1 and 3.33% for G2, indicating moderate dispersion and homogeneity of the samples. The calculated Student's t-test value between G1 and G2 was 2.56, which exceeds the critical value of 2.101 (at $p < 0.05$). This indicates a

statistically significant difference between the meanings of the two groups.

- **Jump Height (cm), (Table 1):** The mean value at the initial testing was 33.57 cm for G1 and 32.78 cm for G2. The coefficient of variation (Cv) was 3.4% for G1 and 3.41% for G2, indicating homogeneity of the samples. The student's t-test value for G1 vs. G2 was 0.19, which is below the critical value of 2.101 ($p < 0.05$). Therefore, no statistically significant difference exists between the meanings of the two groups.

From the perspective of lower limb strength and plyometric jump ability at the manifestation level, participants in both samples show similar initial results (Figure 1). The tests used in this research assess components of lower-limb strength essential to football performance. Based on these initial outcomes, we consider that both groups should focus on improving these capacities to enhance their overall performance.

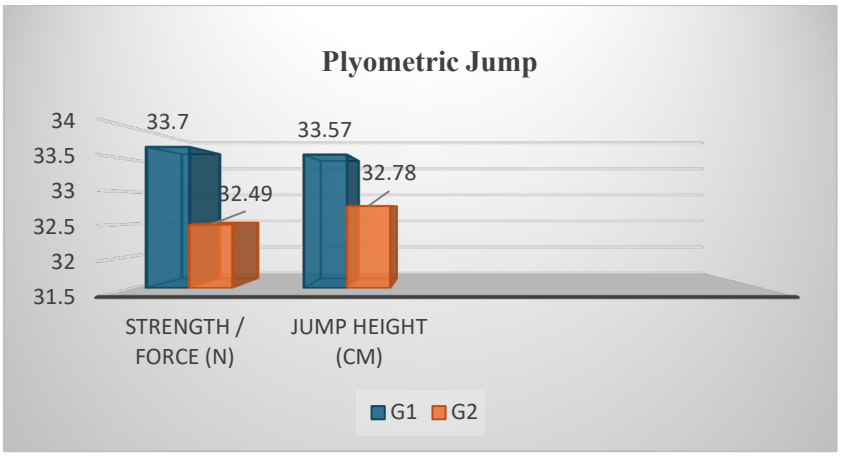

Figure 1. Comparative results of the experimental group (G1) and the control group (G2) in the initial assessment of the plyometric jump test

Comparative Results of the Experimental Group (G1) And the Control Group (G2) In the Final Testing

Table 2

Tests Plyometric Jump	n	STATISTICAL INDICATORS						
		G1	G2	G1-G2	G1	G2		
		Mean/± SD	Mean/± SD	Dif. mean	Cv %	Cv %	t-TEST independent	p
Strength / Force (N)	12	35.79/1.05	33.78/1.05	2.01	3.2	3.01	4.28	>0,05
Jump Height (cm)	12	34.49/1.05	31.91/1.05	2.58	3.39	3.13	5.47	>0,05

Following the statistical processing of the final test results of the students from the two groups (experimental group – G1 and control group – G2), the following observations were made (Table 2):

- **Strength / Force (N)**, (Table 2), the arithmetic mean for G1 was 35.79 N, while for G2 it was 33.78 N, resulting in a mean difference between G1 and G2 of 2.01 N. The calculated Student's t-test value between G1 and G2 was 4.28, which exceeds the critical value of 2.101 (at $p < 0.05$), indicating a statistically significant difference between the means of the two groups.
- **Jump Height (CM)**, (Table 2), the arithmetic mean was 34.49 cm for G1 and 31.91 cm for G2, with a mean difference of 2.58 cm between the groups. The calculated Student's t-test value was 5.47, which is also greater than 2.101 (at $p < 0.05$), confirming statistically significant differences between the groups' mean values.

Based on these results, it can be concluded that, at the final testing phase, there are statistically significant differences between the experimental and control groups across all parameters assessed using the Plyometric Jump applied test (Figure 2).

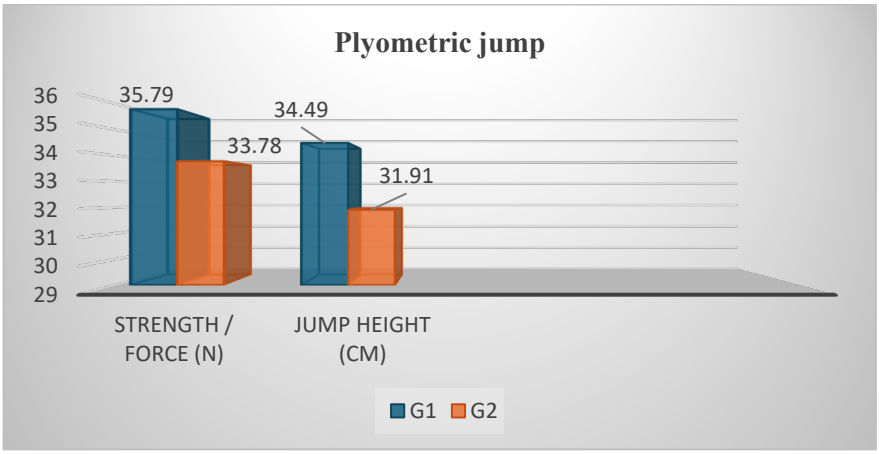

Figure 2. Comparative results of the experimental group (G1) and the control group (G2) in the final assessment of the plyometric jump test

4. Conclusions

The superior results achieved by the experimental group compared to the control group in the final testing clearly demonstrate the effectiveness of the specific methods and tools introduced and applied to improve the muscular strength of the investigated students. This significant performance difference can be attributed to

the distinct training programs followed by the two groups, confirming that the methods and exercises used to develop lower-limb muscular strength produced consistent, measurable improvements. In this way, the experiment's hypothesis is validated, highlighting the importance of applying well-designed strategies to optimize motor capacity.

The conclusions drawn from the initial assessment of the students' motor potential allowed us to develop an adapted and personalized strategy for muscular strength development, considering age-related characteristics and the physical fitness level of each participant. Therefore, the training for motor capacity – strength – was based on a rigorous methodology, including the standardization and progressive application of the selected training means. The exercises chosen were characterized by a high level of difficulty, contributing to the improvement of motor quality – strength – and the physiological adaptations required to enhance performance.

The systematic application of specific strength development methods within the context of football, carried out with non-sport-specialized university students, produced significant positive effects on the overall level of motor capacity. Thus, muscular strength, as a fundamental component of general motor ability, was considerably enhanced, demonstrating that with an appropriate program, even young individuals without specialized sports training can achieve notable progress in this regard.

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