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Effects of the Use of Plyometric Exercises on the Development of Explosive Strength in High School Students During Physical Education Lessons

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ABSTRACT. *Introduction*: Explosive strength represents a fundamental component of motor capacity, playing a decisive role in achieving motor performance both in sports activities and in physical education lessons. In the current context, plyometric training is recognized as one of the most effective methods for developing this motor quality, especially among adolescents. The aim of the study was to analyse the effects of a plyometric exercise program on the development of explosive strength in 10th grade students during physical education lessons. *Materials and methods*: The research was conducted on a sample of students aged 15–16 years, divided into an experimental group and a control group. The experimental group followed a structured plyometric exercise program integrated into physical education lessons, while the control group followed activities according to the regular school curriculum. Evaluation was carried out in two stages (initial and final testing), using specific tests for assessing explosive strength. Statistical analysis included the calculation of arithmetic mean and comparative analysis of results. *Results:* Results highlighted meaningful improvements in explosive strength parameters in the experimental group compared to the control group. *Conclusions:* Integrating plyometric exercises into physical education lessons represents an effective and accessible method for developing explosive strength and increasing the attractiveness of the educational process.

Keywords: *plyometric training, explosive strength, physical education, high school students, motor performance.*

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INTRODUCTION

Physical education and sport represent essential components in the harmonious development of children and adolescents, generating benefits at the somatic, functional, psychological, cognitive, and social levels. In the context of contemporary society, characterized by decreasing levels of physical activity and increasing sedentary behaviours among young people, physical education lessons play a crucial role in promoting active lifestyles and supporting health-related fitness (World Health Organization, 2020; Donnelly et al., 2016).

Among the motor qualities developed through physical education, muscular strength occupies a central position due to its contribution to the execution of motor skills and sports-specific movements. Explosive strength, understood as the ability of the neuromuscular system to generate maximal force in the shortest possible time, is particularly important during adolescence, when significant physiological and neuromuscular adaptations occur (Suchomel et al., 2016; Lloyd et al., 2011).

The development of explosive strength is closely related to the efficiency of the stretch-shortening cycle (SSC), a neuromuscular mechanism that enables the storage and subsequent release of elastic energy during movement. This mechanism contributes to improved jumping, sprinting, and change-of-direction performance and represents the physiological basis of plyometric training methods (Komi, 2000; Markovic & Mikulic, 2010).

Plyometric exercises consist of rapid eccentric-concentric muscle actions designed to enhance power production and neuromuscular efficiency. Numerous studies have demonstrated that appropriately designed plyometric programs can significantly improve strength, power, speed, and overall athletic performance in children and adolescents without negatively affecting their development when properly supervised (Faigenbaum et al., 2007; Behm et al., 2017; Ramírez-Campillo et al., 2020).

Considering the educational value of plyometric exercises and their applicability within school settings, investigating their effectiveness during physical education lessons may provide valuable information for optimizing teaching strategies aimed at improving students' motor performance and physical fitness.

Research Objectives

- Determining the initial level of explosive strength in high school students.
- Designing and implementing a plyometric exercise program adapted to the students' age and level.

- Comparing the evolution of explosive strength parameters between the experimental and control groups.
- Evaluating the effectiveness of plyometric exercises in physical education lessons.
- Analysing the impact of these exercises on student motivation and involvement.

Research Hypothesis

It is assumed that the systematic use of plyometric exercises during physical education lessons leads to a statistically significant increase in explosive strength parameters among high school students compared to traditional methods included in the school curriculum.

MATERIALS AND METHODS

Participants

The study was designed as a pedagogical experiment aimed at investigating the effects of plyometric exercises on the development of explosive strength in high school students. The research sample consisted of 40 students from the Agricultural High School of Beclean, Romania, divided into two groups: an experimental group (n = 20) and a control group (n = 20).

Table 1. Structure of the Research Groups

Variables	Experimental Group	Control Group	Total
Participants	20	20	40
Boys	14	13	27
Girls	6	7	13
Urban area	3	7	10
Rural area	17	13	30
Intervention duration	8 months	8 months	8 months

Participants were enrolled in grades X–XII and had a mean age ranging between 16 and 17 years. Prior to the intervention, the two groups were assessed and found to be comparable in terms of age, gender distribution, physical development, and initial motor performance, ensuring similar baseline conditions for the experiment.

The inclusion criteria were: (a) regular attendance in physical education classes; (b) absence of musculoskeletal injuries, chronic diseases, or medical contraindications to physical exercise; (c) participation throughout the entire duration of the study; and (d) submission of informed consent forms signed by both the students and their legal guardians.

The exclusion criteria included: (a) medical restrictions preventing participation in physical activity; (b) absence from more than 20% of the intervention sessions; (c) injuries occurring during the research period that limited participation in training or testing procedures; and (d) incomplete participation in the assessment protocol.

The participants were not involved in specialized strength or plyometric training programs outside the school curriculum and presented a relatively homogeneous level of physical preparation corresponding to their age and educational level. All students followed the standard physical education curriculum prescribed by the national educational framework.

The experimental group participated in a structured plyometric exercise program integrated into physical education lessons, while the control group continued to follow the traditional physical education program. The intervention was implemented over a period of eight months.

The study was approved by the management of the Agricultural High School of Beclean; All participants and their legal caretakers were informed about the objectives, procedures, benefits, and potential risks associated with the study. Written informed consent was obtained prior to participation.

The research was conducted in accordance with the ethical principles of the Declaration of Helsinki and respected the standards regarding voluntary participation, confidentiality, anonymity, and the protection of personal data. Meantime, the groups were formed using a quasi-experimental design based on existing class structures, while maintaining comparable baseline characteristics.”

The distribution of participants according to gender and area of residence is presented in Table 1.

Procedure

The research was conducted during the 2024–2025 school year and was structured over five instructional intervals according to the official organization of the school year.

The didactic intervention consisted of the systematic integration of plyometric exercises into physical education lessons, particularly within the stages dedicated to the development of motor abilities.

• Level 0 – intended for beginners, focusing on the consolidation of general motor skills and neuromuscular coordination.

• Level 1 – intended for subjects with good general strength but low explosive strength.

• Level 2 – involved increased intensity and complexity, introducing variations of execution angles and auxiliary materials.

• Level 3 – integrated work with external weights and different contact surfaces.

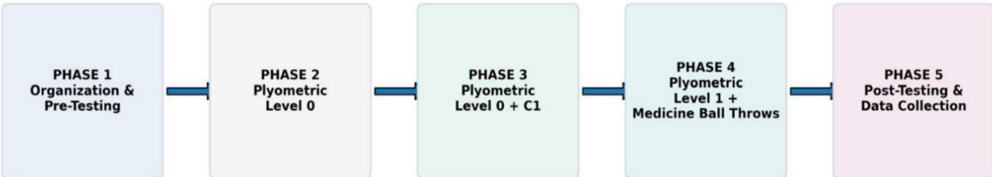

Fig. 1. Experimental design and progression of the plyometric intervention program implemented during the intervention period.

This hierarchy allowed not only a logical progression of the effort, but also a differentiated approach, adapted to the individual pace of development of the students.

Plyometric exercises were the core of the intervention, being represented by jumps on the spot and from the move, oriented towards the development of muscle reactivity and intersegmental coordination.

The scientific foundation of the intervention is based on the mechanism of the stretch-shortening cycle, considered essential in the manifestation of explosive force. This mechanism involves a rapid and efficient succession of three distinct but interdependent phases:

- The eccentric phase, in which the muscles are subjected to rapid stretching, causing the accumulation of elastic energy at the level of the musculotendinous components.

- The transition phase (damping), characterized by an extremely short interval, in which the accumulated energy is transferred, and the myotatic reflex contributes to facilitating the muscle response.

- The concentric phase, in which the muscles are rapidly shortened, and the momentum is generated, expressed by the manifestation of explosive force.

The effectiveness of this mechanism depends essentially on reducing the duration of the transition phase and on the ability of the neuromuscular system to harness the accumulated elastic energy.

The intervention program was progressively organized from simple exercises to more complex motor structures, focusing on the efficient development of the neuromuscular mechanisms involved in explosive strength production. The training protocol was implemented over a period of 8 weeks, with a frequency of two sessions per week, integrated into the regular physical education lessons. Each session lasted approximately 20–25 minutes and was performed following the warm-up phase.

The program included the following exercises:

- Multiple one-leg jumps over short distances (2–3 sets × 8–10 repetitions per leg), designed to improve unilateral lower-limb power, dynamic balance, and neuromuscular coordination.
- Two-leg jumps on coordination ladders (3 sets × 10–12 repetitions), emphasizing rapid ground contact, lower-limb reactivity, and movement rhythm.
- Lateral and zig-zag jumps over floor markings (3 sets × 8–10 repetitions), aimed at enhancing multidirectional explosive force, agility, and spatial orientation.
- Forward-backward jumps over a line (3 sets × 15–20 seconds), focusing on stretch-shortening cycle efficiency and quick force production.
- Explosive medicine ball throws from the chest and overhead (2–3 sets × 8–10 repetitions using 1–2 kg medicine balls), targeting upper-body explosive strength and whole-body force transfer.

Training volume and exercise complexity were progressively increased throughout the intervention period by manipulating the number of repetitions, sets, movement speed, and task difficulty. Recovery intervals ranged between 60 and 90 seconds between sets to ensure adequate performance quality and minimize fatigue accumulation.

The exercises were selected according to the age-specific characteristics of the participants and respected the principles of progressive overload, exercise variability, and safety. Particular attention was paid to correct landing mechanics, body alignment, and movement execution to reduce injury risk and maximize training adaptations.

The plyometric exercises were incorporated into the main part of the physical education lesson following a standardized warm-up. The training load was progressively increased throughout the intervention period by manipulating exercise complexity, number of repetitions, and movement intensity. Particular attention was paid to proper landing mechanics, postural control, and injury prevention.

Table 2. Structure of the Plyometric training program implemented during the intervention period

Training Phase	Duration	Frequency	Session Duration	Main Exercises	Sets × Repetitions	Rest Between Sets	Main Objective
Level 0	Weeks 1–8	2 sessions/ week	15–20 min	Forward-backward jumps; ladder drills; two-leg jumps; low-amplitude jumps	2–3 × 8–10	60–90 s	Neuromuscular adaptation, movement technique, and coordination development
Level 0 + C1	Weeks 9–16	2 sessions/ week	15–20 min	Single-leg jumps; lateral jumps; zig-zag jumps; multidirectional jumps	3 × 8–12	60–90 s	Improvement of reactive strength and SSC efficiency
Level 1 + Medicine Ball Throws	Weeks 17–32	2 sessions/ week	15–20 min	Multiple jumps; advanced plyometric drills; chest passes; overhead medicine-ball throws	3–4 × 10–12	90–120 s	Development of explosive strength, power output, and neuromuscular efficiency

Table 3. General characteristics of the intervention program

Variable	Description
Total intervention duration	8 months
Weekly frequency	2 physical education lessons per week
Estimated total sessions	Approximately 64 sessions
Plyometric work per lesson	15–20 minutes
Training progression	Gradual increase in complexity, volume and intensity
Recovery strategy	Active recovery through walking and mobility exercises
Safety procedures	Teacher supervision and emphasis on proper landing mechanics
Training environment	School gymnasium and outdoor sports facilities

Materials: The selected assessment battery targeted three complementary manifestations of explosive strength.

1. Standing long jump, evaluated horizontal propulsion, capacity and the ability to generate force in the direction of movement.
2. Vertical jump, assessed vertical propulsion and lower-limb power production, reflecting the participants' ability to rapidly overcome body weight.
3. One-hand distance throw; measured explosive force transfer through the upper body and the efficiency of force generation and transmission along the kinetic chain.

Together, these tests provided a comprehensive assessment of explosive strength by examining its expression in horizontal, vertical, and throwing movements. This multidimensional approach allowed for a more accurate evaluation of the adaptations induced by the plyometric training program.

Data analysis

To provide a comprehensive overview of the intervention effects, the mean values obtained in the three performance tests (standing long jump, vertical jump, and medicine ball throw) were analyzed for both the experimental and control groups, separately for boys and girls. Overall, all groups demonstrated positive progress between the initial and final assessments; however, the magnitude of improvement was consistently greater in the experimental groups.

In order to compare the data obtained in the two tests, statistical-mathematical calculations were used, for processing the data using the arithmetic mean (which represents the average value of performances)

RESULTS

Table 4. Mean values recorded in the experimental and control groups (boys)

Group	Standing Long Jump (m) Initial	Standing Long Jump (m) Final	Vertical Jump (m) Initial	Vertical Jump (m) Final	Medicine Ball Throw (m) Initial	Medicine Ball Throw (m) Final
Experimental	1.934	2.126	0.315	0.395	6.692	6.829
Control	1.908	2.033	0.394	0.433	6.150	6.225

Note: All values are expressed as arithmetic means.

Table 5. Mean values recorded in the experimental and control groups (girls)

Group	Standing Long Jump (m) Initial	Standing Long Jump (m) Final	Vertical Jump (m) Initial	Vertical Jump (m) Final	Medicine Ball Throw (m) Initial	Medicine Ball Throw (m) Final
Experimental	1.718	1.815	0.295	0.356	4.700	4.838
Control	1.652	1.715	0.275	0.305	4.578	4.635

Note: All values are expressed as arithmetic means.

Table 6. Progress rates in boys following the intervention

Test	Experimental Group (%)	Control Group (%)	Difference Between Groups (%)
Standing Long Jump	9.93	6.55	3.38
Vertical Jump	25.39	9.89	15.50
Medicine Ball Throw	2.04	1.21	0.83

Note: All values are expressed as arithmetic means.

Table 7. Progress rates in girls following the intervention

Test	Experimental Group (%)	Control Group (%)	Difference Between Groups (%)
Standing Long Jump	5.64	3.81	1.83
Vertical Jump	20.67	10.90	9.77
Medicine Ball Throw	2.93	1.24	1.69

Note: All values are expressed as arithmetic means

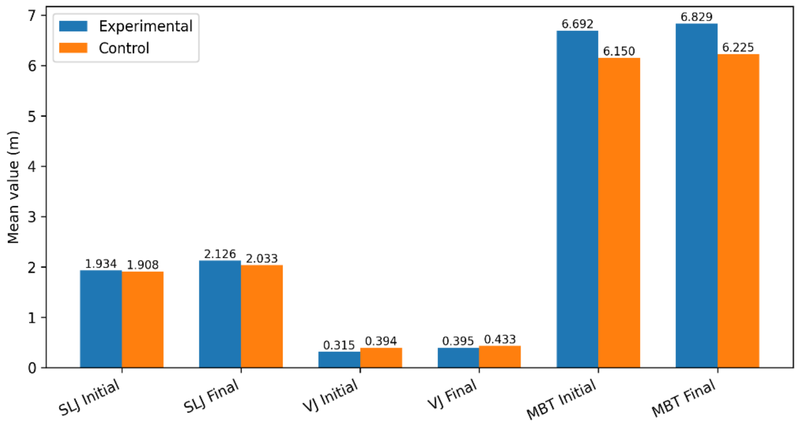

Fig. 1. Boys- mean values

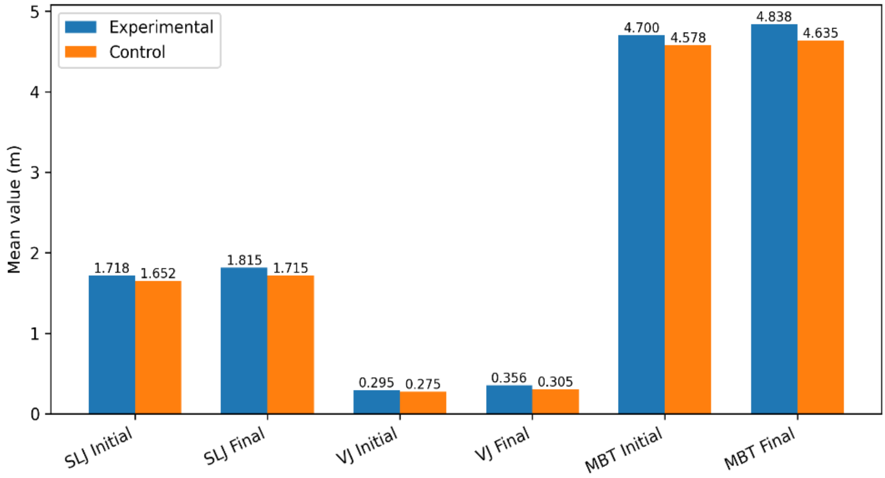

Fig. 2. Girls- mean values

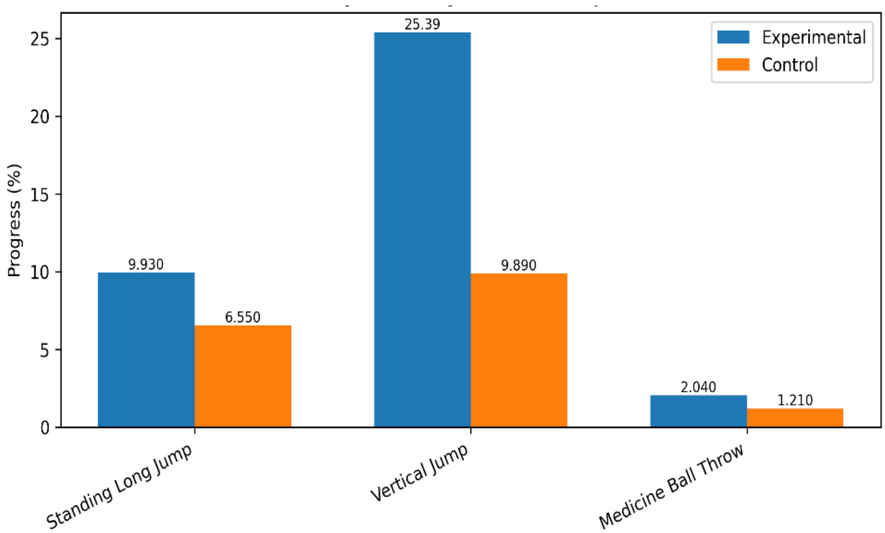

Fig. 3. Progress Rates- boys
Abbreviations: SLJ = Standing Long Jump; VJ=Vertical Jump; MBT = Medicine Ball Throw.

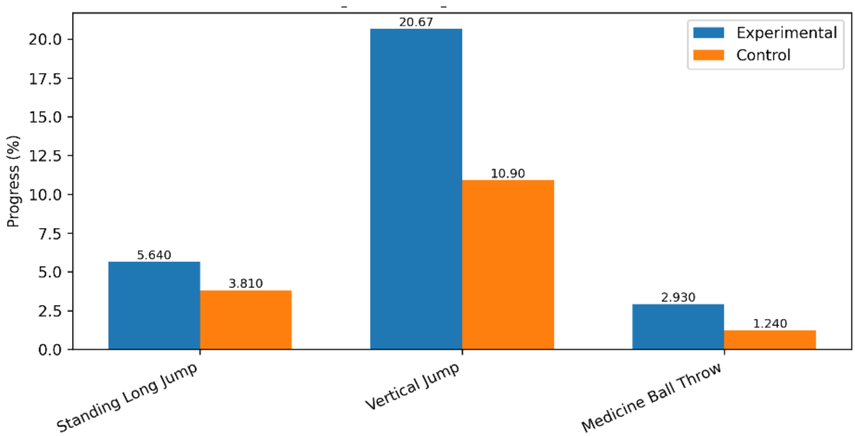

Fig. 4. Progress Rates- girls

At the long jump from the spot, the assessment of the results presented in the previous figures is presented as follows: BOYS – experimental group (X1 = 1.934 m, X2 = 2.126 m), control group (X1 = 1.908 m, X2 = 2.082 m), GIRLS – experimental group (X1 = 1.756 m, X2 = 1.806 m), control group (X1 = 1.652 m, X2 = 1.735 m).

The vertical jump reveals the following averages performed by the subjects of the two groups: BOYS – experimental group (X1 = 0.315 cm, X2 = 0.379), control group (X1 = 0.375 cm, X2 = 0.442), GIRLS – experimental group (X1 = 0.295 cm, X2 = 0.356), control group (X1 = 0.275 cm, X2 = 0.305 cm).

The results of the weight throw show the following averages: BOYS – experimental group (X1 = 6.692 cm, X2 = 6.829 cm), control group (X1 = 6.150 cm, X2 = 6.225 cm), GIRLS – experimental group (X1 = 4.700 cm, X2 = 4.838 cm), control group (X1 = 4.578 cm, X2 = 4.635 cm).

The experimental groups demonstrated superior improvements across all performance tests compared with the control groups. The largest gains were observed in the vertical jump test, indicating a substantial enhancement of explosive lower-limb power following the plyometric intervention.

For the male participants, the experimental group improved from 1.934 m to 2.126 m in the standing long jump, representing a progress rate of 9.93%, compared with 6.55% in the control group. Similar trends were observed in the vertical jump test, where the experimental group increased from 0.315 m to 0.395 m, corresponding to a 25.39% improvement, while the control group recorded only a 9.89% increase. In the medicine ball throw, the experimental group improved by 2.04%, compared with 1.21% in the control group.

The largest difference between groups was observed in the vertical jump test (15.5%), suggesting that the implemented plyometric program had a particularly strong effect on the development of explosive lower-limb power in the vertical direction.

Among female participants, the experimental group increased performance in the standing long jump from 1.718 m to 1.815 m, corresponding to a 5.64% improvement, whereas the control group achieved a 3.81% increase. In the vertical jump test, the experimental group improved by 20.67%, almost double the gain observed in the control group (10.90%). Similarly, the medicine ball throw performance increased by 2.93% in the experimental group compared with 1.24% in the control group.

The greatest superiority of the experimental group was again observed in the vertical jump test, with a between-group difference of 9.77%, confirming the effectiveness of the intervention in enhancing explosive strength capacities in female participants.

The results indicate that the plyometric training program produced superior adaptations compared with the traditional training approach. The most substantial improvements were observed in tests requiring rapid force production and neuromuscular coordination, particularly the vertical jump assessment. These findings are consistent with previous research demonstrating that plyometric exercises enhance the efficiency of the stretch-shortening cycle, improve motor unit recruitment, and increase the rate of force development.

Although improvements in medicine ball throw performance were more modest, the experimental groups still achieved greater gains than the control groups, suggesting that the training stimulus positively influenced explosive power transfer to the upper body as well. Overall, the experimental groups maintained their performance advantage across all tests at the final assessment, highlighting the effectiveness of the intervention program in developing explosive strength among cadet athletes.

From a practical perspective, the differences in progress rates between the experimental and control groups suggest a meaningful training effect. The markedly higher improvements observed in the experimental groups, particularly in vertical jump performance, indicate that the intervention generated adaptations beyond those attributable to regular training and natural growth processes. If confirmed by inferential statistical analysis ($p < 0.05$), these findings would support the hypothesis that the plyometric training program significantly enhances explosive strength development in cadet athletes.

DISCUSSION

The present study aimed to examine the practical effects of a plyometric training program on selected indicators of explosive strength in young school students. Although all groups recorded improvements between the initial and final assessments, the experimental groups consistently demonstrated greater progress than the control groups across all three performance tests. The most substantial improvements were observed in the vertical jump test, followed by the standing long jump, while more moderate gains were found in the medicine ball throw assessment.

These findings are consistent with recent evidence highlighting the effectiveness of plyometric training for enhancing explosive power and jumping performance in youth athletes. Several systematic reviews and meta-analyses have demonstrated that plyometric interventions significantly improve vertical jump height, sprint performance, change-of-direction ability, and lower-limb power in children and adolescents (Ramírez-Campillo et al., 2020; Moran et al., 2018; Behm et al., 2017; Chaabene et al., 2019).

The superiority of the experimental groups in the vertical jump test is particularly noteworthy. The rate of improvement observed in the experimental groups exceeded that of the control groups by a considerable margin, suggesting that the intervention provided an additional neuromuscular stimulus beyond that achieved through regular physical education alone. Similar conclusions have been reported by Ramírez-Campillo et al. (2020), who identified vertical jump performance as one of the physical capacities most responsive to plyometric training. Likewise, Markovic and Mikulic (2010) concluded that stretch-shortening cycle adaptations substantially contribute to improvements in explosive jumping performance.

The positive changes observed in the standing long jump test further support the effectiveness of the program in developing horizontal force production. Previous investigations have shown that multidirectional plyometric drills, bounding exercises, and horizontal jump training improve horizontal power production and sport-specific explosive performance (Moran et al., 2018; Asadi et al., 2016; Slimani et al., 2016).

Although the improvements in medicine ball throw performance were smaller than those observed in the jumping tests, the experimental groups still demonstrated greater progress than the control groups. This finding may indicate that the intervention contributed not only to lower-limb explosiveness but also to improved force transmission through the kinetic chain (Behm et al., 2017).

The present findings are also consistent with the recommendations of the National Strength and Conditioning Association (Lloyd et al., 2014), which emphasize that appropriately supervised plyometric training is both safe and effective for youth populations.

However, caution is warranted when interpreting these results because inferential statistical analyses were not performed. Consequently, the findings provide practical evidence suggesting a potentially beneficial effect of the intervention that should be verified through future studies employing appropriate statistical procedures and effect-size calculations (Lakens, 2013).

Overall, the present findings suggest that the implementation of a structured plyometric training program may contribute to the development of explosive strength in high school students. Future studies including inferential statistical analyses and larger samples are recommended to further validate these findings.

CONCLUSIONS

The present study examined the practical effects of an eight-month plyometric training program implemented during physical education lessons on selected indicators of explosive strength in high school students.

The results showed consistent improvements in all assessed performance variables in both the experimental and control groups. However, participants who followed the structured plyometric program demonstrated greater percentage improvements in vertical jump, standing long jump, and medicine ball throw performance than those who participated only in the regular physical education curriculum. The greatest relative gains were observed in vertical jump performance, suggesting that lower-limb explosive power may be particularly responsive to long-term plyometric training during adolescence.

From a practical perspective, the findings indicate that a progressively designed plyometric program can be successfully integrated into school-based physical education without disrupting the regular curriculum. Such interventions may represent a feasible strategy for enhancing explosive strength, improving neuromuscular function, and supporting the physical development of adolescents. Nevertheless, the findings should be interpreted with caution. Since inferential statistical analyses were not performed, it cannot be concluded that the observed differences between groups were statistically significant. Consequently, the present results should be regarded as practical observations indicating a favourable tendency rather than definitive proof of the superiority of the intervention.

Future research should include larger and more heterogeneous samples, randomized controlled designs, comprehensive statistical analyses, and additional performance indicators such as sprint speed, agility, reactive strength, and change-of-direction ability. Furthermore, controlling biological maturation, training history, and extracurricular physical activity would improve the internal validity of future investigations.

Overall, the present study provides practical evidence supporting the inclusion of structured plyometric exercises in secondary school physical education. While additional statistically validated research is required, the observed improvements suggest that plyometric training has the potential to contribute meaningfully to the developmen of explosive strength during adolescence.

AUTHOR CONTRIBUTIONS

Horea Ștefănescu (Babeș-Bolyai University, Faculty of Physical Education and Sport) contributed to the study conception and design, research methodology, data analysis and interpretation, statistical processing, manuscript writing, discussion and conclusions, and critical revision of the final manuscript.

Marcel Bondor (Agricultural High School, Beclean, Romania) coordinated and implemented the experimental intervention, organized the data collection process, supervised the participants throughout the intervention period, and contributed to the acquisition and validation of the research data.

Cosmin Prodea (Babeș-Bolyai University, Faculty of Physical Education and Sport) contributed to the research design, statistical analysis, interpretation of the findings, preparation of the discussion and conclusions, manuscript editing, and critical review of the final version.

All authors contributed to the interpretation of the results, reviewed the manuscript critically for important intellectual content, approved the final version of the manuscript, and agreed to be accountable for all aspects of the work. This research received no external funding.

INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. The research was carried out within the regular physical education curriculum at the Agricultural High School in Beclean, Romania, using standard educational activities and non-invasive physical performance tests. Participation was voluntary, and the study complied with the ethical and educational regulations applicable at the institution.

INFORMED CONSENT STATEMENT

Written informed consent was obtained from all participants and, where required, from their parents or legal guardians prior to participation in the study. Participants were informed about the objectives and procedures of the research and were free to withdraw from the study at any time without consequences.

DATA AVAILABILITY STATEMENT

The data sets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

ACKNOWLEDGMENTS

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Conflicts of Interest

The authors declare no conflict of interest. The research was conducted independently and received no external funding. The authors declare that they have no financial, commercial, institutional, or personal relationships that could have influenced the design, implementation, analysis, interpretation, or reporting of the study.

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