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Original Article

Development of Lower Limb Muscle Strength through the Implementation of a Plyometric Program for 7th Grade Students

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Abstract

The aim of this research is to investigate the effect of plyometrics on the development of explosive strength in the lower limb muscles of 7th-grade students (13-14 years old). Two classes were selected for the study: one experimental group with 24 students (8 female and 16 male) and one control group with 24 students (12 female and 12 male). A plyometrics program was implemented for 12 weeks. From the initial test to final test, both groups showed improvements to all tests applied, except for the drop jump test for the control group. Analysis of data between the groups shows improvement in favor of experimental group to the 10m and 20m sprint tests, standing long jump, counter-movement jump and drop jump. In conclusion, the implementation of the program significantly influenced the development of explosive strength.

1. Introduction

A third of the global population aged 15 years and older engages in insufficient physical activity, which has detrimental effects on health. The risks associated with sedentary lifestyles are well-known, including the onset of obesity, cardiovascular diseases, diabetes, and other health issues. Studies have shown that the average daily duration of sedentary behaviour is 8.3 hours among the Korean population and 7.7 hours among the American adult population (Park, Moon, Kim, Kong, & Oh, 2020). Consequently, physical education teachers must encourage students to engage in physical activity by promoting diversity, creativity, and attractiveness in lessons, thereby enhancing students' physical performance.

Several studies (Kryzeiu et al., 2023) demonstrate the beneficial effects of plyometric exercise programs in physical education settings. These programs have been shown to enhance strength, as evidenced by improved performance in sprint tests over 30m, 80m, and 100m, as well as in long jump, high jump, and triple jump events for 15-year-old students. Additionally, similar programs have been applied successfully to improve strength in 10m sprint tests, counter-movement jumps, and 4x10-meter sprints for students aged 8-12 years (Marzouki et al., 2022).

Strength, as defined by Manno (1992), is the motor capacity that allows an individual to overcome resistance or exert force through intense muscular effort. This can manifest in various forms, including dynamic (which can be further classified into maximum strength, speed-strength, or strength-endurance), static, or mixed strength. Muscular strength can also be categorised based on changes at the muscular fibre level, including isometric, plyometric, and miometric strength (Dragnea et al., 2006).

The key distinction between force and power lies in the duration over which the movement occurs. Force (F) refers to the ability to exert a movement that overcomes resistance or maintains it against an external load, measured in Newtons (N). It is mathematically expressed as the product of mass (m) and acceleration (a) ($F = m \times a$). In contrast, power (P) is the ability to exert force in the shortest possible time, measured in Watts (W). Power is expressed either as the product of force (F) and velocity (v) ($P = F \times v$) or as the ratio of work (W) to time (t) ($P = W/t$) (Bosse, 2018).

Plyometrics is widely regarded as a method for bridging the gap between speed and power (Hansen & Kennelly, 2017). This form of exercise involves muscular loading through eccentric contraction followed by concentric contraction (Bompa, 2001), combining strength and movement speed through rapid and explosive execution (Chu, Faigenbaum, & Falkel, 2006). Plyometric exercises utilise the body's kinetic energy generated during the fall phase, which is then harnessed for explosive movement (A.N.S. & I.N.C.S., 2005).

Most plyometric movements in sports focus on the lower body and include jumps that help develop power and explosiveness (Anderst, Eksten, & Koceja, 1994). The methods of practising these exercises are determined by factors such as the number of lower limbs involved (single leg, both legs, or alternating), the amplitude of movement (small or large), the direction of movement (horizontal, vertical, lateral, or mixed), the number of repetitions, the intensity of the exercises (maximum, very high, submaximal, moderate, or low), and the level of impact (low or high) (Bompa, 2001).

Plyometric exercises typically occur through the stretch-shortening cycle (SSC), which involves two main phases: the eccentric phase (rapid stretching of the muscle) and the concentric phase (rapid shortening of the muscle) (Komi, & Bosco, 1978). Between these two phases, there exists a cushioning phase, an isometric action that occurs during the transition from the eccentric to the concentric phase (Davies, Riemann, & Manske, 2015).

From a physiological perspective, the contractile components of the sarcomere, particularly the actin and myosin cross-bridges, play a crucial role in adapting movement and producing force during the plyometric phase. By following the length-tension curve, pre-stretching helps muscle fibres generate maximal tension, leading to the production of maximum force (Davies & Matheson, 2001).

The effectiveness of plyometric training has been well-researched in both adults and pubertal children, particularly in enhancing running speed and jump capacity (Markovic, 2007), as well as developing strength (Sáez-Sáez de Villarreal, Requena, & Newton, 2009). However, it is important to note that strength development may be less pronounced in some children due to varying growth mechanisms and individual differences in strength development. Prepubertal children, in particular, lack the circulating androgens responsible for muscle hypertrophy, making intrinsic muscle and neural adaptations essential for strength development (Guy, 2001).

2. Materials and methods

The objective of this research is to examine the extent to which specific plyometric exercises enhance the development of explosive strength in the lower limb muscles of 7th-grade students.

The hypothesis posits that incorporating a tailored plyometric and speed-running program into physical education lessons for 12 weeks, featuring courses that include specific jumping exercises and speed, will lead to a significant improvement in the explosive strength of the lower limbs in 7th-grade students.

The study involved 48 participants aged 13–14 years, divided into two groups: an experimental group comprising 24 students (16 male and 8 female) and a control group also consisting of 24 students (12 male and 12 female). The experimental group, while implementing the proposed program, was organised into six teams: four male teams and two female teams, each comprising four members. All teams performed exercises simultaneously to optimise lesson density. Each student completed the course twice, with active rest achieved by walking to the back of the line and waiting for their next turn.

The program spanned 12 weeks, with sessions conducted twice per week. A total of 360 minutes were allocated to the plyometric program, with 90 minutes dedicated to each subprogram. During each physical education class, students practised the designated subprogram for 15 minutes.

The assessment included the following tests: the standing long jump (SLJ), the drop jump (DJ) from a gymnastics box of 30 cm, and the countermovement jump (CMJ) to evaluate explosive strength expressed through plyometric performance. Additionally, speed running over 10m and 20m was measured to assess explosive strength expressed in running performance.

- Standing Long Jump (SLJ): Participants stood with their feet shoulder-width apart behind a marked line. Using an arm swing for momentum, they performed the longest horizontal jump possible, landing with both feet simultaneously. The distance was measured from the starting line to the heel of the rear foot.
- Drop Jump (DJ): Participants began on a gymnastics box and, after dropping to the ground, executed the highest vertical jump possible upon contact with the ground, assisted by an arm swing. The height of the jump was measured from the ground to the highest point reached.

- Countermovement Jump (CMJ): Participants began in an upright position with hands on their hips, performed a rapid downward movement by flexing their knees and hips, and then executed a maximum vertical jump. The jump height was measured in the same way as the DJ test.
- Sprint Runs: Participants started in a standing split-stance position behind a fixed line. At a signal, they performed a speed run over distances of 10m and 20m, with the time to complete each distance recorded.

All participants were evaluated under identical conditions during the same sessions. Parental and student consent was obtained for participation, and the study was approved by the school board and physical education staff.

The plyometric program was divided into four subprograms, each lasting three weeks. The experimental group followed these subprograms, while the control group engaged in standard physical education exercises, including classical jumps, height jumps, tuck jumps, and regular running.

Subprogram 1: Starting from a standing position, the participant performs jumps over the first two 20 cm hurdles. They then execute a jump into the first circle, positioned diagonally to the left, landing on the left foot. This is followed by a jump into the circle on the right, landing on the right foot. Subsequently, the participant performs another jump into the final circle, landing on both feet, and then jumps onto a gymnastics bench. From the bench, they perform a drop jump, and upon landing, they sprint 10m to a designated cone.

Subprogram 2: Beginning in a standing position, the participant jumps onto a gymnastics bench, landing on both feet, followed by a drop jump. After landing, they proceed to jump over three consecutive 20 cm hurdles. At the end of the hurdles, the participant leaps over a stick positioned 1m away and transitions into a 10m sprint to a cone.

Subprogram 3: From a standing start, the participant performs single-leg hops, alternating between circles arranged in a zig-zag pattern. Following this, they leap towards the first row of two 10 cm cones, over which they jump on the same leg. The same procedure is repeated for the subsequent set of cones, with the opposite leg used for the leap and jumps over the hurdles. The sequence concludes with a 10m sprint to the cone.

Subprogram 4: Starting in a standing position, the participant jumps over the first set of hurdles using the left foot and lands in a circle. They then perform a lateral jump into a circle on the right, followed by a second series of hurdles executed with the opposite foot. At the end of this sequence, they perform another lateral jump into the circle on the left, landing on both feet. The participant then jumps onto a gymnastics bench and descends from it. The final exercise involves a reactive jump over a 20 cm hurdle, transitioning into a 10m sprint to the cone.

Statistical Analyses

Statistical analyses were conducted using IBM SPSS Statistics 25. All data are presented as means (m) and standard deviations (s). Both dependent and independent t-tests were applied to identify any systematic bias. The coefficient of variation (CV%) was utilised as a measure of reliability, representing the standard error of measurement. Cohen's *d* effect size (ES) was calculated to assess the extent to which the program influenced the results. The coefficient of asymmetry Beta (Coef. β), reflecting positive or negative differences between the mean and the median, was also computed. Finally, omega-squared (Ш²) was calculated to estimate the significance of the program's effect on the outcomes between the experimental and control groups, as observed in the final tests.

3. Results and discussions

Table 1. *Speed 10m and 20m for Experimental Group*

Speed running	*No.*	*Testing*	*m±s (sec)*	*Coef. β*	*CV%*	*t-dep/p*
10m	24	Initial	2.26±0.24	0.322[1]	10.72	3.782[3/]p<0.0005
		Final	2.13±0.27	0.136[2]	12.44	
20m	24	Initial	3.94±0.48	0.269[2]	12.19	3.845[3/]p<0.0005
		Final	3.72±0.40	0.025[2]	10.73	

Notes: [1] notable skewness; [2] normal skewness; [3] significant p<0.0005;

Table 1 demonstrates that, in the 10m test, the experimental group achieved an improvement of 0.13 seconds between the initial and final tests**.** Similarly, an improvement of 0.22 seconds was observed in the 20m test. The dependent *t*-test indicated a statistically significant difference, with $p < 0.0005$.

Table 2. *Speed 10m and 20m for Control Group*

Speed running	*No.*	*Testing*	*m±s (sec)*	*Coef. β*	*CV%*	*t-dep/p*
10m	24	Initial	2.33±0.24	0.16[1]	10.48[3]	0.861 (p>0.05)
		Final	2.37±0.33	0.55[2]	13.75[3]	
20m	24	Initial	4.25±0.52	0.498[4]	12.28[5]	0.797 (p>0.05)
		Final	4.23±0.55	0.217[1]	12.89[5]	

Notes: [1] notable skewness; [2] pronounced skewness; [3] population of values with high homogeneity; [4] notable skewness; [5] population of values with medium homogeneity;

Table 2 shows that the control group experienced a decrease of 0.04 seconds in the 10m speed running test between the initial and final results. In contrast, the 20m test recorded an increase of 0.02 seconds between the initial and final tests. The differences observed in both the 10m and 20m tests for the control group were not statistically significant, with $p > 0.05$.

Table 3 indicates that the experimental group improved the differences between the initial and final test results by 13.6 cm, 1.47 cm, and 3.7 cm in the standing long jump, drop jump, and counter-movement jump, respectively. The dependent *t*-test revealed statistically significant results in all tests, with $p < 0.0005$.

Table 3. *Explosive Strength: SLJ, DJ and CMJ for the Experimental Group*

Test	*No.*	*Testing*	*m±s (cm)*	*Coef. β*	*CV%*	*t-dep/p*
SLL	24	Initial	165.31±27.10	0.011[1]	16.39[3]	4.915 (p<0.0005)
		Final	178.91±23.72	-0.383[2]	13.26[3]	
DJ	24	Initial	26.27±3.68	0.062[1]	14.009[3]	5.333 (p<0.0005)
		Final	27.74±4.09	0.187[1]	14.724[3]	
CMJ	24	Testing	25.36±3.35	-0.012[1]	13.19[3]	4.898 (p<0.0005)
		Initial	29.06±3.46	0.034[1]	11.91[3]	

Notes: [1] normal skewness; [2] notable skewness; [3] population of values with medium homogeneity;

Table 4. *Explosive Strength: SLJ, DJ, and CMJ for the Control Group*

Test	*No.*	*Testing*	*m±s (cm)*	*Coef. β*	*CV%*	*t-dep/p*
SLL	24	Initial	165.08±19.90	0.457[1]	12.05[2]	0.804 (p>0.05)
		Final	166.25±20.41	0.184[1]	12.27[2]	
DJ	24	Initial	22.80±2.44	-0.187[1]	10.70[2]	0.09 (p>0.05)
		Final	22.80±2.34	-0.218[1]	10.24[2]	
CMJ	24	Testing	20.92±1.75	0.418[3]	8.346[4]	0.339 (p>0.05)
		Initial	20.94±1.76	0.376[3]	8.411[4]	

Notes: [1] normal skewness; [2] population of values with medium homogeneity; [3] notable skewness; [4] population with homogenous values;

In contrast, Table 4 shows that the control group recorded minor differences of 1.17 cm, 0 cm, and 0.02 cm in the standing long jump, drop jump, and counter-movement jump, respectively. These results did not achieve statistical significance, as indicated by the dependent *t*-test, with $p > 0.05$.

Table 5. *Speed for Experimental and Control Group Final Testing*

Speed running	*No.*	*Group*	*m±s (sec)*	ω^2	*ES*	*CV%*	*t-ind/p*
10m	24	Exp	2.13±0.27	0.132	-0.83[2]	12.65[1]	2.857 p<0.005
	24	Ctrl	2.38±0.33	13.2%		13.67[1]	
20m	24	Exp	3.73±0.41	0.216	-1.083[2]	10.83[1]	3.735 p<0.0005
	24	Ctrl	4.25±0.54	21.6%		12.77[1]	

Notes: [1] population of values with medium homogeneity; [2] the effect size is large; Exp = Experimental; Ctrl = Control;

Table 5 shows that, in the 10m final test, there was a difference of 0.25 seconds in favour of the experimental group, which resulted in a statistically significant outcome in the independent *t*-test, with $p < 0.005$. In contrast, in the 20m test, the difference of 0.52 seconds between the experimental and control groups led to a statistically significant result in the independent *t*-test, with $p < 0.0005$.

Table 6. *Explosive Strength: Experimental and Control Group Final Testing*

Test	*No.*	*Gr.*	*m±s (cm)*	*Coef. β*	Ш^2	*ES*	*CV%*	*t-ind/p*
SLL	24	Exp	178.91±23.72	-0.383[1]	0.057 5.7%	0.573[6]	13.26[3]	1.958/ p<0.05
	24	Ctrl	166.25±20.41	0.184[2]			12.28[3]	
DJ	24	Exp	27.74±4.09	0.187[2]	0.344 34.4%	1.494[5]	14.72[3]	5.063/ p<0.0005
	24	Ctrl	22.80±2.34	-0.218[2]			10.24[3]	
CMJ	24	Exp	29.06±3.46	0.034[2]	0.681 68.1%	2.977[5]	11.91[3]	10.073/ p<0.0005
	24	Ctrl	20.94±1.76	0.376[1]			8.41[4]	

Notes: [1] notable skewness; [2] normal skewness; [3] population of values with medium homogeneity; [4] population with homogeneous values; [5] the effect size is large; Exp = Experimental; Ctrl = Control;

Table 6 shows that in the standing long jump final test, there was a significant difference of 13.66 cm, which resulted in a statistically significant outcome in the independent *t*-test, with $p < 0.05$. In the drop jump test, the experimental group demonstrated a difference of 4.94 cm, with the independent *t*-test yielding a statistically significant result, with $p < 0.0005$. Similarly, in the counter-movement jump, the experimental group achieved a difference of 8.12 cm compared to the control group, which also resulted in a statistically significant outcome in the independent *t*-test, with $p < 0.0005$.

Discussions

The recorded results highlight the potential of plyometric exercises, when adapted for physical education lessons, to improve explosive strength in the lower limbs and, by extension, optimise students' motor performance. Furthermore, the findings align with the hypotheses put forward in similar research. The effectiveness of plyometric programs in enhancing speed running and standing long jump performance is emphasised, consistent with the study by Kryeziu, Iseni, Teodor, Croitoru, & Bădău (2023). Additionally, the optimisation of counter-movement jump (CMJ) performance supports the findings of Marzouki et al. (2022).

Another study by Meylan and Malaesta (2009) demonstrated the development of CMJ results (p=0.004) in 13-year-old early-puberal male football players following 8 weeks of plyometric training. Sáez de Villarreal, Suarez-Arrones, Requena, Haff, & Ferrete (2015) conducted a study that demonstrated the significant effects of a 9-week plyometric and sprint training program on CMJ increases (3 cm, 9.4%, $p \leq 0.05$) and 10m sprint times (-0.07 seconds, 8.7%, $p \leq 0.05$) in 14-15-year-old football players. These improvements resulted in significant differences ($p \leq 0.01$) compared to the control group, which showed no improvements.

In a study by Mirzaei, Norasteh, Sáez de Villarreal, and Asadi (2014), a 6-week CMJ training program conducted on sand led to statistically significant improvements ($p = 0.004$) in the standing long jump test, with pre- to post-training results showing marked improvement in a group of 10 untrained, healthy men without regular strength training or sports experience.

Assadi and Arazi (2012) also conducted a study in which a high-intensity plyometric training program was applied to an experimental group of 8 semi-professional male basketball players, leading to statistically significant improvements in the standing long jump test and 20m sprint test ($p < 0.05$). Assadi (2013) extended this research by implementing a plyometric training program over six weeks, with sessions held twice a week for 10 basketball players aged 20, competing in a Division I provincial team. The experimental group recorded statistically significant improvements in the final standing long jump test compared to the control group ($p < 0.05$).

Ethiraj and Dr (2017) examined the effects of incorporating plyometrics into a maximal power training program (MPTWP) on acceleration speed (20m test) and multiple speed (6x40m test) in college-level male team handball players. After practising the program on three non-consecutive days per week for 12 weeks, the experimental group demonstrated increases of 1.44% in acceleration speed and 0.13% in multiple speed.

Finally, it is important to emphasise the need to promote diversity and authenticity in physical education lessons, as these elements are crucial for stimulating student engagement and increasing participation, which in turn enhances the overall effectiveness of the lessons.

4. Conclusions

In conclusion, research across various studies demonstrates that plyometric programs, when applied to both athletes and non-athletes, can significantly enhance explosive strength and power. In the present study, the implementation of a plyometric program, divided into four subprograms over a 12-week period in physical education lessons for seventh-grade students, yielded optimal results in the development of both explosive strength and lower limb muscle speed. These improvements were particularly evident in the 10m and 20m sprint tests, as well as the standing long jump, drop jump from a gymnastics box, and counter-movement jump. These outcomes were achieved by aligning the program with the physiological characteristics of the group, ensuring optimal and gradual dosage of effort, facilitating efficient content assimilation by the students, and maintaining engagement through diversified methods to ensure active participation of the experimental group.

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