

Article

Effect of 12 Weeks of the Plyometric Training Program Model on Speed and Explosive Strength Abilities in Adolescents

Artan R. Kryeziu ^{1,2}, Astrit Iseni ^{2,3,*}, Dragos Florin Teodor ⁴, Horia Croitoru ⁵ and Dana Badau ^{6,7,*} 

- ¹ Department of Sport and Movement Science, University for Business and Technology, Astrit Rrushi, 10000 Pristina, Kosovo
- ² Center of Research, Studies in Physical Education, Sport and Health-CRSPES, 10000 Pristina, Kosovo
- ³ Faculty of Physical Education, University of Tetovo, 1300 Tetovo, North Macedonia
- ⁴ Faculty of Physical Education and Sport, Ovidius University of Constanta, 900470 Constanta, Romania
- ⁵ Naval Tactics and Armament Department, “Mircea cel Batran” Naval Academy, 900218 Constanta, Romania
- ⁶ Petru Maior Faculty of Sciences and Letters, “George Emil Palade” University of Medicine, Pharmacy, Sciences and Technology, 540142 Targu Mures, Romania
- ⁷ Interdisciplinary Doctoral School, Transilvania University, 500068 Brasov, Romania
- * Correspondence: astrit.iseni@unite.edu.mk (A.I.); dana.badau@umfst.ro (D.B.)

Abstract: This study examined the effect of two different follow-ups of a plyometric program on improving speed and explosive strength. Thus, the purpose of this study is to identify the 12-week effect of the plyometric program on the development of speed and explosive strength in adolescents. The research was conducted on a sample of 195 male adolescent participants aged 15 years \pm 6 months, who were divided into two groups, the first group of the plyometric group (PG) 90 adolescents participated in plyometric training sessions three times a week for 12 weeks, while the control group (CG) 105 adolescents only attended their regular lessons in Physical Education. Tests of study: sprint (S) 30 m speed; S80 m speed; S100 m speed; Standing long jump; Standing triple jump; Vertical Jump. The results presented between the measurement pre- and post-plyometric program in the group (PG) have resulted in favor of this group over the control group (CG), and it has also been identified that there are significant differences in the indicators of speed and explosive strength at the level ($p < 0.05$). In conclusion, a 12-week plyometric program has shown significant increases in speed and explosive strength indicators in teenagers, and the same model can be used in elite athletes.

Keywords: plyometric program; speed; explosive strength; teenagers; model of plyometric exercises



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1. Introduction

Plyometrics is a type of exercise that uses the speed and strength of various movements to build muscle strength. Plyometric training can improve your physical performance and ability to do different activities. Plyometric training has been shown to improve the following physical qualities in both youth and adults: strength [1,2], speed [3–5], the speed with a change of direction [6–9] etc. Several research studies have confirmed that plyometric training can increase muscle power, strength [10], and speed [5,9]. Training adaptations in the development of sprinting and jumping skills are more variable, showing an initial increase during ages 5–9 years, which is followed by a second period of rapid improvement during puberty [11].

A plyometric exercise is a popular form of training used to improve athletic performance [12]. It involves a stretch of the muscle-tendon unit immediately followed by a shortening of the muscle unit. This process of muscle lengthening, followed by rapid shortening during the stretch-shortening cycle (SSC), is integral to plyometric exercise [13]. The SSC consists of (a) a rapid eccentric muscle action followed by (b) an isometric amortization phase and (c) a concentric muscle action [14–17]. The rational use of plyometric training can effectively improve muscle strength and explosive strength [18,19], and the

generation of explosive strength can be well-explained by mechanical and neurophysiological models [9]. In the mechanical model, the rapid elongation of the tendon increases its elastic potential energy, which is then stored [20–22], and when followed by a rapid centripetal contraction, the previously stored elastic potential energy is rapidly released, thus increasing the force output [20–22]. The neurological model involves the detrusor reflex to enhance the force of the centripetal contraction [23–25]. A popular plyometric exercise used to increase vertical jump height is called “drop jump”. It involves a vertical jump that is performed immediately after dropping down from an elevated surface. A few weeks of plyometric training can increase vertical jump height when tested by performing drop jumps [26–30], which translates to improvements in such athletic events as sprinting and jumping [31]. Plyometric exercise is effective in improving jump performance [32], but the average relative improvement ranged between 14% to 29% in the vertical jump, given the specific nature of the plyometric method. However, plyometric is a method that helps develop strength, explosive and speed [32].

Plyometric training is effective in increasing athletic performance in sprinting and jumping in prepubescent athletes [33]. Plyometric exercises and well-designed programs for the development of explosive strength have positive effects on increasing and improving morphological characteristics [34,35] and motor skills such as speed and explosive strength in students and athletes [36,37]. Recently, [38] reported that plyometric training produced small effects ($d = 0.57$) on jump performance in young girls (8–18 years), while there is limited evidence on the extent to which prepubescent girls adapt to training plyometric.

In the study, we determined to see how the effect of the plyometric program had an impact on speed and explosive strength in adolescents, but we have before that in previous studies, many researchers have systematically addressed these issues during the pre-puberty phase and in adolescence, developing different programs aimed at developing speed and explosive strength [39]. In particular, plyometric exercises represent an effective method to improve a number of physical qualities [40], such as short-distance running speed in adolescent girls [41].

However, according to some previous studies which have been carried out with children and adolescents, according to our knowledge they have not addressed plyometric training models in improving running speed in the distance of 30 m, 80 m and 100 m in adolescents, but studies in the space of speed have been treated [42] by many researchers in specific sports. However, with a bunch of studies, data has been presented that only plyometric training can increase running speed [43]. If we look at the segment of explosive strength on the effects of plyometric exercise training in adolescents, there are more studies that deal with this problem. However, one study has addressed this aspect [43,44]. Moreover, a program of plyometric training sessions has been conducted in which it would be important to demonstrate a positive relationship [40–45] between the duration of the program and the number of sessions with the effect of PT on jump performance.

Although generally accepted as an effective training method, previous studies have not established the optimal model of plyometric training, including volume and explosive strength increase [45,46], but the three jumps standing long jump, standing triple jump, and vertical jump, have not been treated in such a publication, even against numerous scientific arguments and evidence that the effect of plyometric training on explosive strength has not been addressed, that the indicators we obtained for study. Many previous studies related to the effects of the plyometric program on adolescents focused on participants from different sports [47], but in our study, the focus will be on adolescents without following any training program in addition to the physical education class they attended.

Therefore, we have selected a group of adolescents to follow the plyometric training program in order to see the effect of this program, taking as a basis that these adolescents [48] should follow a specific program in plyometrics. The novel aspects of the present study aimed to analyze the impact that plyometric training has on the development of speed and explosive strength in teenagers who perform these pieces of training in physical education lessons without having previously experienced plyometric training. We have

had the training to see how important it is to investigate further the effect of the plyometric program on speed and explosive strength in adolescents. However, the results of our study will be able to provide physical educators, physical education teachers, sports science specialists and researchers with a plan to see the effects of plyometric exercises in improving speed and explosive strength performance at age and adolescence.

The main purpose of this study was to investigate the 12-week effect of the plyometric program on speed and explosive strength performance in adolescents; the secondary purpose of this study was to present a model of plyometric exercises that have an effect based on a designed program for adolescents. First, it is hypothesized that plyometric model training affects the development of speed indicators. Secondly, it is hypothesized that there would be a higher load effect of the plyometric program on explosive strength training in adolescents.

2. Materials and Methods

2.1. Research Design

In this research, we aim to influence the effect of a 12-week plyometric program on speed and explosive strength performance in adolescents. A between-group design was applied to examine the effect of the plyometric training program on groups of adolescents. Participants were placed into an experimental group that followed a plyometric program (PG) and a control group (CG). The plyometric group (PG) participated in plyometric training sessions three times a week for 12 weeks, while the control group (CG) only attended their regular lessons in Physical Education classes. Both groups (PG) and (CG) were tested at the same time in both speed and explosive strength, both in the pre-measurements and in the post-measurements.

Ethical approval was obtained from the Institutional Scientific Ethical Committee of the University of Tetovo dated (20 February 2021 under protocol number 0129/12), and all procedures were under the Code of Ethics for Biomedicine with Humans based on the Declaration of Helsinki (WHADH, 2000).

2.2. Participants

The sample of participants includes adolescents who followed the plyometric program model. The study sample consisted of 195 male adolescent participants aged 15 years \pm 6 months, who were divided into two groups, the first group of 105 adolescents was described as the control (CG), and the second group of 90 adolescents as the plyometric group (PG). The data collection was carried out while following the learning process of the students at school, all the adolescents did not even have an experience in training or additional educational programs, and all of them only attended the physical education class at school. The participants were also informed about the procedures and the main purpose of this study. Before giving consent, they signed a statement in which they would continue the plyometric training program until the end of the twelfth week, and they were also free to withdraw from the consent given to carry out the study. During the entire time that the study has been carried out, no one has dropped out of the study. All participants were fully informed about the study procedures and were thoroughly assessed on their medical history (chronic diseases, recent injuries, or surgeries). Characteristics of the participants (mean \pm SD) in Table 1.

2.3. Test Protocol

For research, we selected the test protocol in which only indicators of speed and explosive force were included. The testing protocol is selected according to the type of program and the requirements of the designed plyometric program. The number of test subjects was large, but they were carried out based on the design of the planning of this planned study; the first measurements were carried out at the beginning of March on the dates 01, 02, and 03 of 2021 in the gymnasiums of the elementary schools involved in this study and the second measurements at the beginning of May on the 10th, 11th and 12th

of 2021 were carried out after following the 12-week program. The measurements were performed in the morning when all the adolescents had physical education lessons, and they were also performed under the same conditions and at the same time for three days. For each test, an evaluation protocol was applied. Each test was evaluated three times, and the highest evaluation was taken as the basis, and the other two results were canceled during the testing of teenagers. During the performance of the jumping tests, three jumps were tried, but the highest jumping result was recorded in the register.

Table 1. Characteristics of the participants (mean \pm SD).

Groups Tests	Control Group-CG		Plyometric Group-PG	
	Pre-Test	Post-Test	Pre-Test	Post-Test
Number of Subjects	105		90	
Parameters	Mean \pm St. Dev.	Mean \pm St. Dev.	Mean \pm St. Dev.	Mean \pm St. Dev.
Age (years)	15.6 \pm 2.3	15.9 \pm 2.1	15.9 \pm 2.6	15.12 \pm 2.1
Height (cm)	168.8 \pm 7.4	168.8 \pm 7.4	169.3 \pm 6.8	169.3 \pm 6.8
Body mass (kg)	56.8 \pm 10.3	56.8 \pm 10.3	60.4 \pm 8.5	59.9 \pm 7.9
BMI (kg/m ²)	20.8 \pm 3.2	20.8 \pm 3.2	21.1 \pm 3.6	20.9 \pm 3.2
Age and PHV	13.9 \pm 0.40	13.9 \pm 0.41	14.2 \pm 0.52	14.4 \pm 0.54
Maturity Offset (Years)	1.0 \pm 0.43	1.0 \pm 0.44	1.3 \pm 0.54	1.4 \pm 0.54
Training experience (y)	Physical education programs		12-week programs	

CG: Control group; PG: Plyometric group; Mean—Arithmetic Mean; St. Dev.—Standard Deviation, PHV—Peak Height Velocity.

2.3.1. Predicted Maturity Offset Calculate

Maturity offset, defined as the time before PHV, was predicted at each observation for the 58 players with the original equation for boys [49]:

$$\text{Maturity offset (years)} = -9.236 + (0.0002708 \times (\text{Leg Length} \times \text{Sitting Height})) + (-0.001663 \times (\text{CA} \times \text{Leg Length})) + (0.007216 \times (\text{Ca} \times \text{Sitting Height})) + (0.02292 \times (\text{Weight by Height Ratio} \times 100)). \quad (1)$$

Leg length was estimated at each observation as standing height minus sitting height. The need to multiply the weight by height ratio by 100 was overlooked in the original report [1]; in some publications using the equation, it is not clear if the adjustment was applied. Maturity offset was also predicted at each observation with a modified equation for boys that incorporated age and height [50]:

$$\text{Maturity offset (years)} = -7.999994 + (0.0036124 \times (\text{CA} \times \text{Height})) \quad (2)$$

The equation with age and height was selected for evaluation as it is increasingly used [51–53]. Standard errors for the original [49] and modified [50] equations were, respectively, 0.592 and 0.542 years. Predicted maturity offset and predicted age at PHV with the respective equations are subsequently labeled in the text, tables and figures as Mirwald and Moore, respectively.

The predicted age at PHV was estimated as CA minus the predicted maturity offset at each observation for individual players with the respective equations.

Observed or actual maturity offset at each observation was estimated as CA at prediction minus observed age at PHV based on the SITAR model [53].

2.3.2. Speed Assessment

Speed assessment was performed using running tests for S30, S80, and S100 m (30, 80, and 100 m) sprints, according to the protocol described [54,55]. Running 30, 80, and 100 m (30, 80, and 100 m) was measured with the Microgate Witty SEM system, which was placed in four

gates to measure the running distance at the same time. In this case, the child starts running from the start with a rush and reaches the destination at maximum speed. All participants underwent the test three times, with repetitions and breaks in between for statistical analysis to obtain the best result. The test included running at maximum speed for a distance of 30, 80, and 100 m. The result is recorded on the child's record sheet in 0.1 s [54,55].

2.3.3. Assessment of Explosive Strength

We chose three tests for the assessment of explosive strength, they were: standing long jump (SBJ), standing triple jump (STJ), and vertical jump (VJT), following the described protocols [56]. These three tests evaluate the explosive strength of the lower limbs. The measurement of the standing long jump (SBJ) is that from a starting line, feet shoulder-width apart, the child is asked to jump over a metric tape as far as possible from the starting line, then must place both feet without falling back (it is not allowed to put hands on the floor). In this case, the best result measured in centimeters is noted, and it is recorded in the child's registration sheet in centimeters [54,55]. In the three-step measurement from the seat, the test starts the jump with feet together; the first jumping step starts with one foot, then with the other foot, always on the rubber mat, and finally, jumps with feet together on the mat. Three jumps are performed. Jumps that are performed incorrectly are repeated. The length of the jump is measured perpendicular to the vertical line. The measurement accuracy is shown in cm. The longest jump out of three attempts is scored. No double steps allowed. The test taker must smear the soles of the feet with magnesium. He jumps barefoot or with sneakers [57]. Measuring the vertical jump (VJT) from the place is to put metric tape on the wall or a table. First, the child should raise his hand up and then make a vertical jump with both feet with a touch of the metric tape. The result is recorded between the touch and the touched site in centimeters and recorded on the child's record sheet in centimeters [54,55]. The measuring instruments were implemented based on several studies carried out by the authors [48,58,59].

The application of the plyometric model was carried out with the aim of seeing the effect of the explosive strength tests, with particular emphasis on dances such as the Standing Long Jump. It was carried out according to the test protocol of this test and the first authors [60–62], and the test was carried out according to reliability and validity with the author [63]. Likewise, the Standing Triple jump test [64] was performed according to the protocol of the previous test [60]. Therefore, this test has reliability and validity since it performs according to the protocol [65–67]. In the application of the Vertical Jump test, the same protocol has been designed and tested with different age groups, athletes and non-athletes [68,69], as well as its procedure and the way the test is performed has its reliability and validity [70–72] on the basis of which we have carried out the research. All test protocols for the segment of explosive strength are arguments that show that the participants in our studies have followed the procedure of the same study and others in time, the same conditions and the identical methodology. Likewise, the model selected to see the effect of the plyometric program on the explosive strength tests has come as a result of the orientation and improvement of the skills of 15-year-old school teenagers.

2.3.4. Plyometric Training Programs

The investigation of the effect of 12 weeks of plyometric training on the efficiency of the results in the measurements of speed and explosive strength in adolescents aged 15 years was carried out in two groups of participants, the control group (CG) and the plyometric group (PG). The 12-week program of plyometric training was carried out only in the experimental group, who, in addition to the regular 2-h weekly exercises in the subject of physical education (Tuesday, Thursday), organized a training system with three additional hours per week (Monday, Wednesday, Friday), a total of 36 h (3 additional hours for 1 week, 3×12 weeks = 36 h) training in 12 weeks. The participants of the control group did not attend any special training apart from regular physical education classes. In both groups of participants, in the same period, the measurements before the experiment

(before the start of the plyometric program), and the measurements after the experiment (after the end of the plyometric program), were performed in the researched segments: the measurements in the speed and explosive strength tests. We have divided each hour of the experimental program into four parts, as well: the introductory part (5–10 min) to prepare the organism for further work, the preparatory part (10–15 min) to warm up the locomotor system, mainly the muscles, tendons and ligaments of the lower extremities, the main part (25–30 min) the implementation of the experimental program plan which contains various plyometric exercises, such as: jumps with one leg, jumps with two legs, jumps deep, dances in the Swedish box, etc., and the final part (8–15 min) calming the body and emotions with forms of relaxing dances and muscle stretching. The number of sets of each exercise was a minimum of 3 sets, with a maximum of 10 repetitions, with a pause between exercises of 45–90 s, and with a load intensity of 60–75%. Each participant in all testing and plyometric training was closely monitored by physical education teachers and experts in the implementation of this scientific research. The plyometric program applied in this research is composed of different movements, such as: running, sprinting, one and two-legged jumps, extensions, deep jumps, deep Swedish mass jumps, and deep station jumps. This training model was applied based on the authors' publications [48]. Design of the plyometric training program model in Table 2.

Table 2. Design of the plyometric training program model.

Exercises	Week 0	Week 1–3	Week 4–6	Week 7–9	Week 10–12	Week 10–12	Week 13
Sprint 10 m- two-legged jumps 10 m		×3					
Sprint 10 m- jumps with one leg 10 m		×3					
Progressive sprint 30 m		×3					
Progressive sprint 40 m		×3					
Deep jumps with two feet 30 m		×3					
Jumps with one and the other leg zig-zag 30 m		×3					
Two-legged plyometric box jumps 20 (50 cm)			3 × 10				
Two-legged plyometric box jumps 25 (63 cm)			3 × 10				
Double leg jumps on plyometric box 30 (76 cm)	Pre-test		3 × 10				Post-test
One-legged plyometric box jumps 20 (50 cm)			4 × 10				
Deep jumps on the Swedish box 60 cm				4 × 10			
Deep jumps on the Swedish box 80 cm				4 × 10			
Deep jumps on the Swedish box 100 cm				4 × 10			
Jumps with the right leg 10 m—jump with the left leg 10 m—sprint 10 m					×4	×4	
Jumps on two feet left-right zig-zag 30 m					×4	×4	
Jumps with two legs between hurdles 30 m					×4	×4	

2.4. Statistical Analysis

Descriptive data were calculated for all tests and presented as the mean (Mean) and standard deviation (St. Dev.) of the control group (CG) and plyometric group (PG). In an analysis applied to the differences between the groups in the measurements pre and post-experiment, analysis of variance (ANOVA) was used to detect the differences between the study groups in all the basic variables practiced in this study in the initial measurements, while to determine the differences between the groups in the finale measurements with the division of the differences to test the main effects between the pre and post-experiment testing, between the groups (CG and PG). Significant values were set at probability $p < 0.05$, and a

confidence interval was set at 95%. Effect sizes (ES) were determined by converting the partial eta squared to Cohen's *d* [73,74] to determine the magnitude of differences. The magnitude of effect size was classified as trivial (<0.20), small (0.20–0.49), medium (0.50–0.79), and large (0.80 and greater) [73,74]. The correlations among the analyzed variables were determined using Pearson's correlation analysis. Correlations were evaluated as follows: Trivial (0.0–0.09), Small (0.10–0.29), moderation (0.30–0.49), Large (0.50–0.69), Very Large (0.70–0.89), Nearly Perfect (0.90–0.99), and Perfect (1.0) [73,74]. The results of this study were processed with the statistical program SPSS version 26.0.

3. Results

In Tables 3 and 4, we present the main results of our study and the main statistical parameters of pre and post-tests.

Table 3. Descriptive statistics of the tests for both groups of study.

Test	Group	Test	Mean ± St. Dev	Cohen's <i>d</i> (Pre vs. Post-Training)	Effect-Size	<i>p</i> Value (Pre vs. Post-Training)																																																																																														
S30 m speed	CG	Pre	4.94 ± 0.446	−1.166	−0.53	0.014																																																																																														
		Post	5.66 ± 0.750				S30 m speed	PG	Pre	4.77 ± 0.528	0.367	0.180	0.000	Post	4.59 ± 0.449	S80 m speed	CG	Pre	11.81 ± 1.38	−0.351	−0.173	0.070	Post	12.31 ± 1.46	S80 m speed	PG	Pre	11.55 ± 1.36	0.273	0.135	0.028	Post	11.20 ± 1.19	S100 m speed	CG	Pre	15.48 ± 1.82	−0.201	−0.100	0.019	Post	15.82 ± 1.54	S100 m speed	PG	Pre	14.99 ± 1.71	0.356	0.175	0.194	Post	14.44 ± 1.36	SBJ	CG	Pre	194.81 ± 28.14	−1.112	−0.486	0.000	Post	225.33 ± 27.41	SBJ	PG	Pre	196.44 ± 27.47	0.892	0.407	0.020	Post	266.53 ± 26.74	SLJ	CG	Pre	498.74 ± 56.45	−0.919	−0.417	0.000	Post	548.65 ± 51.98	SLJ	PG	Pre	502.64 ± 56.38	−2.200	−0.739	0.035	Post	621.54 ± 51.59	VJT	CG	Pre	32.01 ± 5.76	−0.935	−0.423	0.000	Post	37.03 ± 4.94	VJT	PG	Pre	32.05 ± 5.59
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		Post	15.82 ± 1.54				S100 m speed	PG	Pre	14.99 ± 1.71	0.356	0.175	0.194	Post	14.44 ± 1.36	SBJ	CG	Pre	194.81 ± 28.14	−1.112	−0.486	0.000	Post	225.33 ± 27.41	SBJ	PG	Pre	196.44 ± 27.47	0.892	0.407	0.020	Post	266.53 ± 26.74	SLJ	CG	Pre	498.74 ± 56.45	−0.919	−0.417	0.000	Post	548.65 ± 51.98	SLJ	PG	Pre	502.64 ± 56.38	−2.200	−0.739	0.035	Post	621.54 ± 51.59	VJT	CG	Pre	32.01 ± 5.76	−0.935	−0.423	0.000	Post	37.03 ± 4.94	VJT	PG	Pre	32.05 ± 5.59	−3.421	−0.863	0.000	Post	49.94 ± 4.84																															
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		Post	14.44 ± 1.36				SBJ	CG	Pre	194.81 ± 28.14	−1.112	−0.486	0.000	Post	225.33 ± 27.41	SBJ	PG	Pre	196.44 ± 27.47	0.892	0.407	0.020	Post	266.53 ± 26.74	SLJ	CG	Pre	498.74 ± 56.45	−0.919	−0.417	0.000	Post	548.65 ± 51.98	SLJ	PG	Pre	502.64 ± 56.38	−2.200	−0.739	0.035	Post	621.54 ± 51.59	VJT	CG	Pre	32.01 ± 5.76	−0.935	−0.423	0.000	Post	37.03 ± 4.94	VJT	PG	Pre	32.05 ± 5.59	−3.421	−0.863	0.000	Post	49.94 ± 4.84																																								
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		Post	225.33 ± 27.41				SBJ	PG	Pre	196.44 ± 27.47	0.892	0.407	0.020	Post	266.53 ± 26.74	SLJ	CG	Pre	498.74 ± 56.45	−0.919	−0.417	0.000	Post	548.65 ± 51.98	SLJ	PG	Pre	502.64 ± 56.38	−2.200	−0.739	0.035	Post	621.54 ± 51.59	VJT	CG	Pre	32.01 ± 5.76	−0.935	−0.423	0.000	Post	37.03 ± 4.94	VJT	PG	Pre	32.05 ± 5.59	−3.421	−0.863	0.000	Post	49.94 ± 4.84																																																	
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		Post	266.53 ± 26.74				SLJ	CG	Pre	498.74 ± 56.45	−0.919	−0.417	0.000	Post	548.65 ± 51.98	SLJ	PG	Pre	502.64 ± 56.38	−2.200	−0.739	0.035	Post	621.54 ± 51.59	VJT	CG	Pre	32.01 ± 5.76	−0.935	−0.423	0.000	Post	37.03 ± 4.94	VJT	PG	Pre	32.05 ± 5.59	−3.421	−0.863	0.000	Post	49.94 ± 4.84																																																										
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Legenda: CG—control group; PG—plyometric group; S—sprint run; SBJ—Standing long jump; (STJ)- Standing triple jump; (VJT)—Vertical Jump; Mean—Arithmetic mean; Std. Dev.—Standard deviation; Significant differences *p*-value < 0.05.

In Table 3, we have shown the results achieved for the tests of sprinting and jumping. In this reflection of the results, the speed of 30 m showed an improvement in time in the group that followed the plyometric program (PG). The test result pre-experiment in the pre-measurements was (4.94 ± 0.446), while the test result post the experiment in the post-measurements was (4.59 ± 0.449), which means that we have a value difference (Cohen's *d* = −1.166, Effect-size = 0.53, *p* < 0.014), also the speed 80 m showed time improvement in the plyometric group (PG), the test result pre the experiment in the pre measurements was (11.55 ± 1.38) while the test result post the experiment in the post measurements

was (11.20 ± 1.19) , which means that we have a significant difference (Cohen’s $d = 0.273$, Effect-size = 0.135 , $p < 0.028$). Even the speed 100 m test showed an improvement in time in the group that followed the control group (CG); the test result prior to the experiment in the premeasurements was (15.48 ± 1.82) , while the test result, post the experiment, in the post-measurements was (15.82 ± 1.54) , which means that we have a significant difference (Cohen’s $d = -0.201$, Effect-size = -0.100 , $p < 0.019$). However, it should be noted that in the standing long jump test, there was a marked difference between the CG group and the PG group, but the greatest effect was in the PG group, with the result in the pre-experiment test $(196.44 \text{ cm} \pm 27.47)$ and in the test post the experiment $(266.53 \text{ cm} \pm 26.74)$ with a significant statistical difference (Cohen’s $d = 0.892$, Effect-size = 0.407 , $p < 0.020$), the triple jump test from the place showed learning in the jump distance in particular in the PG group in the test pre the experiment $(502.6 \text{ cm} \pm 56.38)$ and post-experiment testing $(621.5 \text{ cm} \pm 51.59)$ with a significant statistical difference (Cohen’s $d = 2.200$, Effect-size = 0.407 , $p < 0.020$). If we take for comparison the indicator of the height jump from the place, the difference between the CG and PG groups shows that the PG group has the highest performance with the result in the test pre the experiment $(32.0 \text{ cm} \pm 5.59)$ and the test post the experiment $(49.9 \text{ cm} \pm 4.84)$ with a significant statistical difference (Cohen’s $d = -3.421$, Effect-size = -0.863 , $p = 0.000$).

Table 4. Pearson’s correlation between speed and explosive strength abilities according to pre and post-tests.

Tests		VJT	SBJ	SJL	S30	S80	S100
VJT	Pearson Correlation	1.000	0.733	0.712	-0.483	-0.545	-0.563
	Sig. (2-tailed)	.	0.000	0.000	0.000	0.000	0.000
SBJ	Pearson Correlation	0.733	1.000	0.811	-0.604	-0.682	-0.697
	Sig. (2-tailed)	0.000	.	0.000	0.000	0.000	0.000
SJL	Pearson Correlation	0.712	0.811	1.000	-0.541	-0.609	-0.630
	Sig. (2-tailed)	0.000	0.000	.	0.000	0.000	0.000
S30 m speed	Pearson Correlation	-0.483	-0.604	-0.541	1.000	0.797	0.770
	Sig. (2-tailed)	0.000	0.000	0.000	.	0.000	0.000
S80 m speed	Pearson Correlation	-0.545	-0.682	-0.609	0.797	1.000	0.917
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	.	0.000
S100 m speed	Pearson Correlation	-0.563	-0.697	-0.630	0.770	0.917	1.000
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	.

S—sprint run; SBJ—Standing long jump; SJL—Standing triple jump; VJT—Vertical Jump.

Analysis of Data Processing in Graphs

The graphs are processed according to groups separately in pre and post-measurements of the Error Bar model.

According to the data presented in Figure 1, we see a difference between the two groups and between the pre and post-measurement. In the presented figure, it can be seen that the post-measurement in (PG) showed the best results in relation to the pre-measurement and also showed significant differences in value ($p < 0.05$), while in (CG), we have a decrease in the result of speed 30 m, we also have no significant differences between the pre and post measurement. The statistical indicators are presented in Table 3, while the performance of the test is presented in Figure 1.

At the speed of 80 m, PG showed the best performance in favor of the post-measurement; significant differences between the value measurements were presented ($p < 0.05$). While the CG has shown a drop in the result in the post-measurement in relation to the pre-measurement, in this case, we have no significant differences between the measurements in the CG. The statistical indicators are presented in Table 3, while the performance of the test is presented in Figure 2.

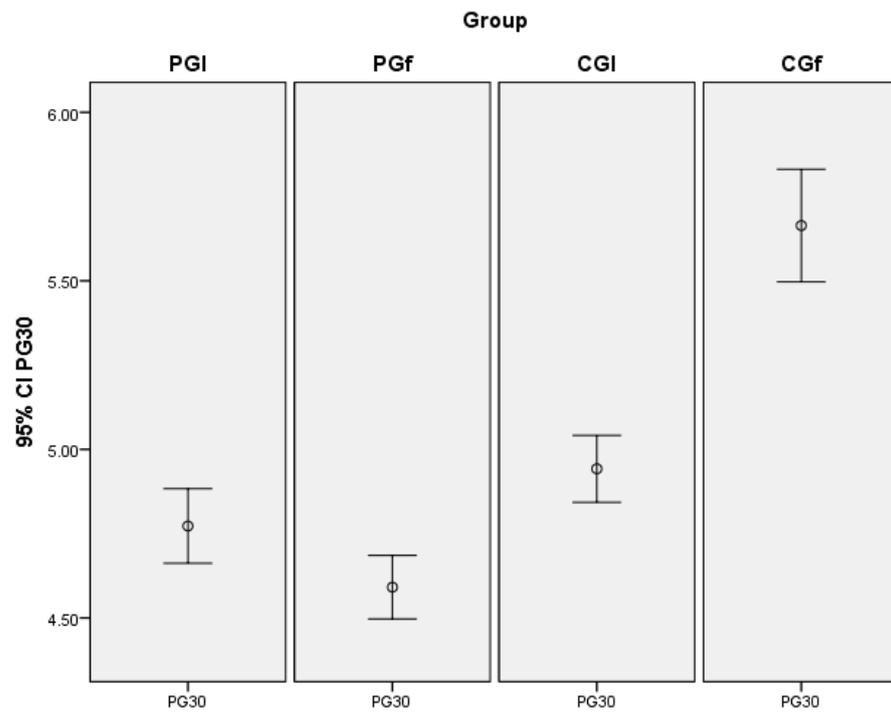


Figure 1. Speed 30 m means between the PG and CG group.

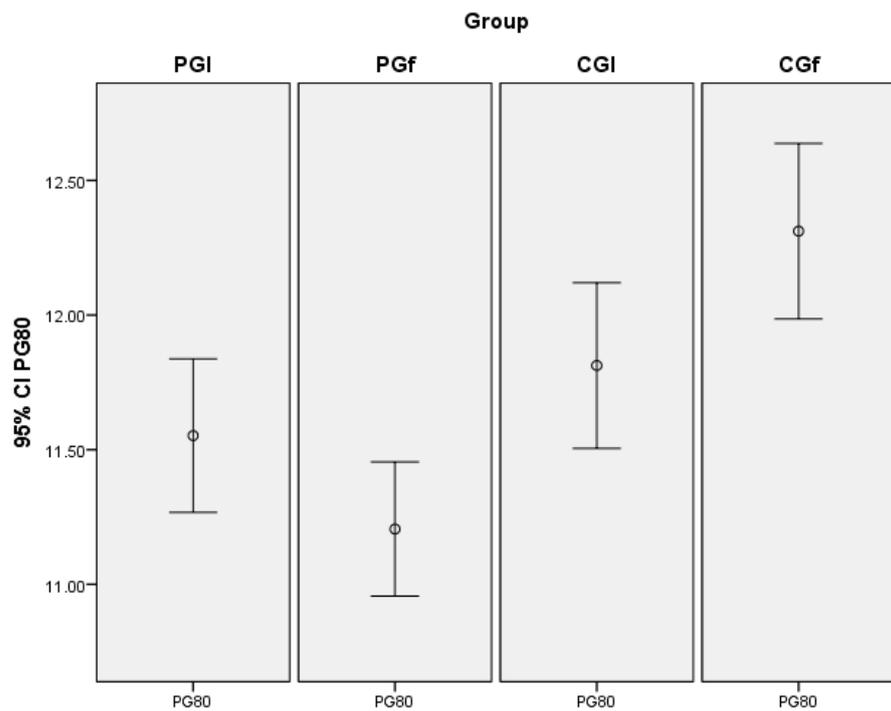


Figure 2. Speed 80 m means between the PG and CG groups.

In the speed 100-m test, we also have the highlighted results between PG and CG, especially in the post-measurement. PG scored a better result in the post-measurement, but the differences between the pre and post-measurements were not presented. Whereas in CG, we have a significant difference between pre and post-measurement ($p < 0.05$). The statistical indicators are presented in Table 3, while the performance of the test is presented in Figure 3.

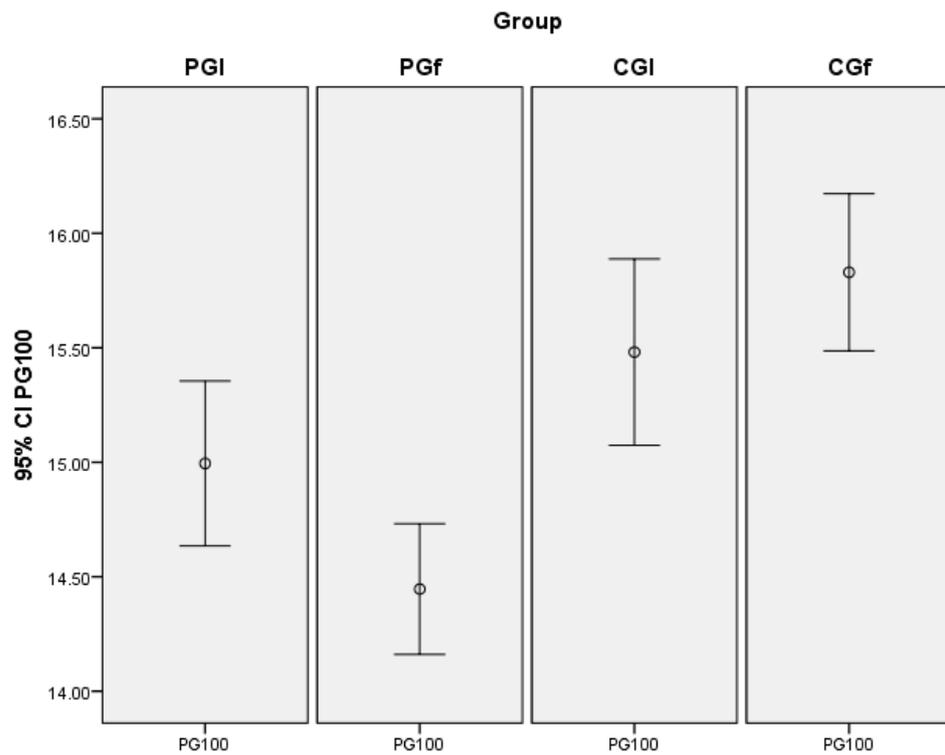


Figure 3. Speed 100 m means between the PG and CG group.

In Figure 4, we present the standing long jump test. Post-measurement in PG has a significant result in relation to prey and also in relation to CG in both measurements. If we look at the significant differences, CG has shown significant differences between the pre and post-measurement with a value ($p < 0.05$), while PG with value ($p < 0.05$).

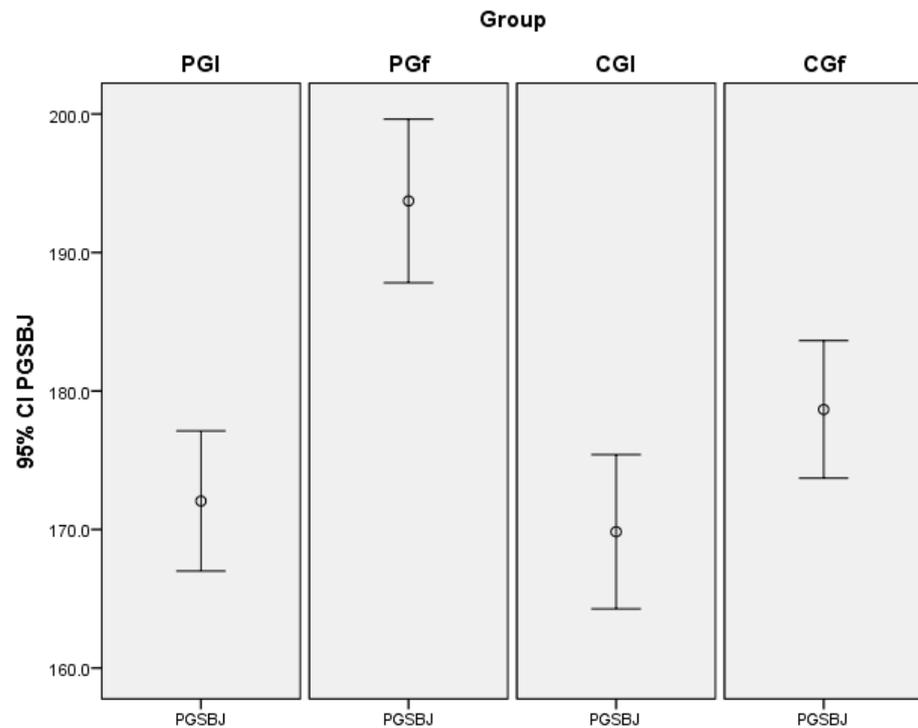


Figure 4. Standing long jump means between the PG and CG groups.

In Figure 5, we have presented the standing triple jump test. In this case, we see that PG has better results in the post-measurement in relation to the pre-measurement. Likewise, CG has a better result in the post in relation to the pre-measurement, and if we take it as a whole, we see that the plyometric group has shown more favorable results in both measurements, both in the pre and the post. In CG, significant differences were presented between pre and post-measurement ($p < 0.05$), while in PG, no significant differences were shown between pre and post. The statistical indicators are presented in Table 3, while the performance of the test is presented in Figure 5.

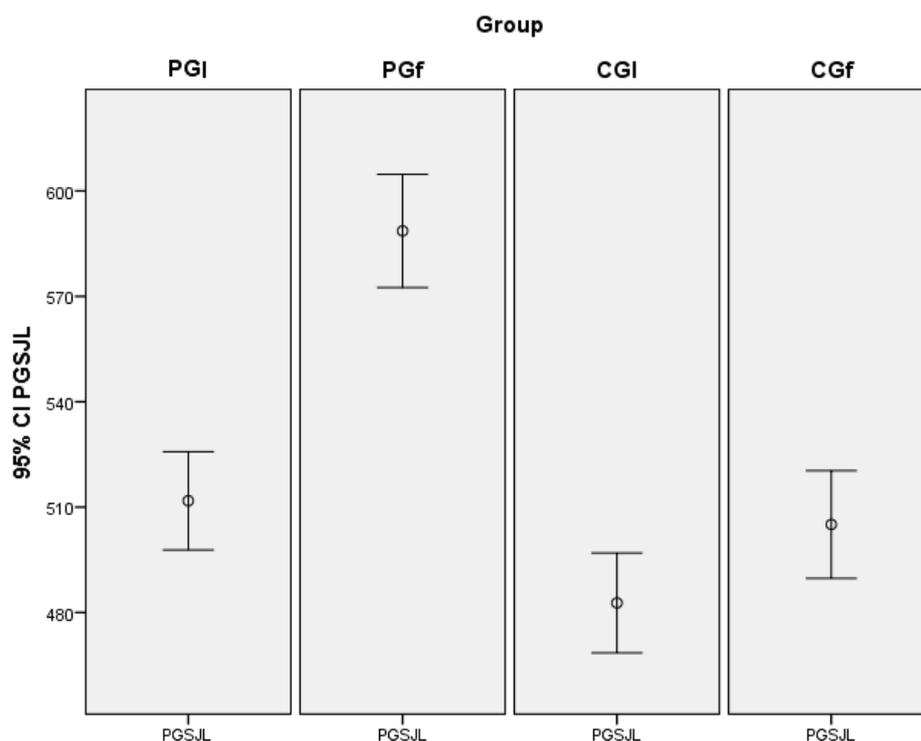


Figure 5. Standing triple jump means between the PG and CG group.

In Figure 6, we have presented the vertical jump test; in this case, we see that PG has better results in the post-measurement in relation to the pre-measurement. If we take the ratio between the PG and CG group, we see that the post-measurement has a significant difference between the measurements in the two groups. In CG, significant differences were presented between pre and post with a value ($p < 0.05$), and differences were also presented in the pre and post-measurement in PG. The statistical indicators are presented in Table 3, while the performance of the test is presented in Figure 6.

Table 4 shows the correlation analysis between the speed and explosive strength tests and the subjects studied. It should be emphasized that in the entire system of the correlation table, statistically significant positive and negative correlations between the tests have been presented. The results obtained in this way show a statistically significant positive correlation between speed and explosive strength tests. VJT has shown positive correlations with SBJ ($r = 0.733; p = 0.000$), SJL ($r = 0.712; p = 0.000$), the SBJ test has correlations with SJL ($r = 0.811; p = 0.000$), S30 has positive correlations with S80 ($r = 0.797; p = 0.000$), S100 ($r = 0.770; p = 0.000$), S80 has correlations with S100 ($r = 0.917; p = 0.000$). Furthermore, a statistically significant negative correlation was achieved between the following VJT tests with S30 ($r = -0.483; p = 0.000$), S80 ($r = -0.545; p = 0.000$), S100 ($r = -0.563; p = 0.000$). SBJ has correlations with S30 ($r = -0.604; p = 0.000$), S80 ($r = -0.682; p = 0.000$), S100 ($r = -0.697; p = 0.000$), then the test with S30 ($r = -0.541; p = 0.000$), S80 ($r = -0.609; p = 0.000$), S100 ($r = -0.630; p = 0.000$). The results obtained in this way show that a statistically significant positive correlation in the plyometric group is quite high between the tests, while statistically negative correlations are

lower correlation values. Moreover, in this situation, differences between the left and the pre and post were presented in all tests with values of $p = 0.000$.

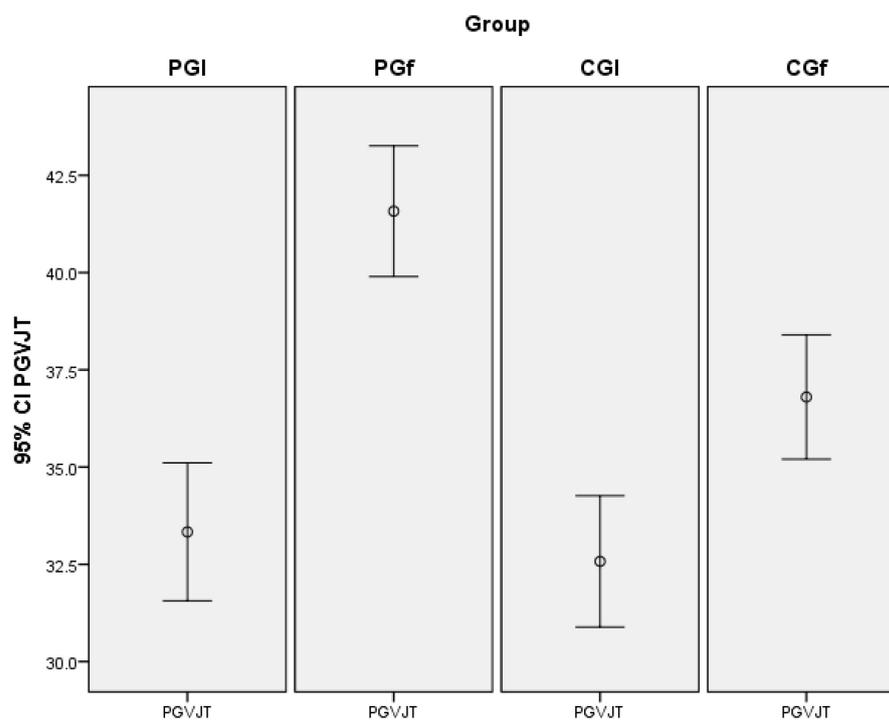


Figure 6. Vertical Jump means between the PG and CG group.

4. Discussion

In this study, the main goal is to identify the effectiveness of the plyometric program for the development of speed and explosive strength in adolescents. From the examination of the results in the initial measurements in both research subjects, the control (CG) and plyometric (PG), it was shown that in the speed and explosive strength abilities of the adolescents, significant statistical differences were identified while through the univariate analysis of variance (ANOVA). After the implementation of the plyometric program (PG) for the development of speed and strength explosives, which training model lasted for 12 weeks and only the plyometric group (PG) underwent, from the examination of the post measurements, it was identified that in the abilities of speed and strength explosives have significant differences in all investigated tests, where the obtained results were in favor of the plyometric group (PG) compared to the control group (CG). Below we will present the two main findings of this study: first, the first finding of the effects of the plyometric program on speed and second, the effects of the plyometric program on explosive strength.

4.1. Effects of the Plyometric Program on Speed Ability

The 12-week training program model significantly improved speed performance. Learning to run 30 m was mainly shown in the group that followed the plyometric program (PG) after the test, and significant differences were also confirmed between the groups. The same model of the program followed, which improved the results after the final test [75]; significant differences between the initial and final measurements were also presented in this study that we took for comparison after 12 weeks of the plyometric training model. Furthermore, in the 80 m running the test, we also have statistically significant differences in favor of the plyometric group (PG) in the final measurements, in this case, these results show that different plyometric training programs affect speed runs [76], also according to in the measurement tests before and after the experiment, significant differences between the groups are presented at the $p < 0.05$ level. It should be noted that the 100-m run had a noticeable improvement in speed between the measurement before and after the

experiment in the plyometric group (PG); it was evident that the result in favor of the PG group came as a result of following the plyometric training program, it should be noted that the control group (CG) in the post measurements have shown weaker results with the pre-measurement, some authors have also found the same improvements in their results in their published studies [35,75].

Likewise, in these 100-m running tests, differences between the measurements before and after the experiment between the groups at the $p < 0.05$ level has been proven. If we take the plyometric group (PG) for comparison, those who ran 100 m turned out to have better performance results than those who ran 80 m and then those who ran 30 m between the pre and post-measurements. In the experiment, if we compare the control group (CG), we see that those who ran 80 m performed better than those who ran 100 m and, finally, 30 m. Therefore, the plyometric training program carried out in this study consists mainly of repetitive jumps, sprints at short distances, then combined sprints and jumps. Our results align with the most relevant results identified by previous studies that highlighted the impact of plyometric training on the development of speed parameters [76–79].

4.2. Effects of the Plyometric Program on Explosive Strength Ability

A 12-week plyometric training program significantly improved explosive strength in adolescents. Our other finding in this study was the effect of the plyometric program in favor of those who have followed the plyometric program with special emphasis on the indicators of explosive strength. It has also been proven again in our study that the long jump indicator from the place had changed between the measurements in the control group (CG) and the plyometric group (PG), but the results are in favor of the plyometric group (PG), the same results were consistent with previous findings made by several other authors [80–83]; where an increasing trend of lower muscle strength in the horizontal jump was also detected in this study.

However, in our study, significant low differences were expressed between the measurements before and after the experiment between the CG and PG groups at the $p > 0.05$ level. The indicators of the triple jump variable from the place showed an improvement in the jump distance in favor of the plyometric group (PG) in the final measurements; the same results during the plyometric training program were also achieved through the application of the same training program in favor of the plyometric group (PG) improving the results of good performance [84]. In our study, differences between groups with a value of $p < 0.05$ were presented. In some results of the three-step jump test from the place, opposite data have been observed [85–87]. There were no significant differences between the groups.

The results are in agreement with other studies that have followed the plyometric program [88]. In this case, there are differences between the control group (CG) and plyometric (PG) in the high jump from the place; significant changes were seen in the plyometric group (PG), who showed better performance between the measurement pre- and post-implementation of the plyometric program. Also, through the analysis of covariance (ANCOVA), differences between the groups were reflected at the $p > 0.05$ level. Taking into account the current study and the review of previous research, vertical jump performance can be expected to improve as a result of training, and the degree of improvement is related to the mode, frequency and intensity of training, as well as the training experience of the subjects [89–91].

Finally, the strength of the study is the large involvement of adolescents in this research in a 12-week plyometric training program. Another strong point is the use of sophisticated speed evaluation equipment. All these can affect the results from three perspectives. First of all, none of the participants reported injuries or damage while participating in plyometric programs, and the participants in this research were included only from one school. Secondly, the study, developed across 12 weeks, was followed by the researchers of this research in all the sessions of following the plyometric training program. Thirdly, the development of motor abilities, as in this study, speed and explosive strength in all participants, changes were observed in these two skills that we had for treatment. The

contribution of this study lies in the fact that a large number of subjects participated in this study through the 12-week plyometric training program.

The findings of our study suggest that a supplemental plyometric program can significantly improve explosive speed and strength in school-aged adolescents. From this study, we can confirm that this type of plyometric program should be a model for all pedagogues, trainers, and sports researchers who want to increase the performance of speed and explosive strength in the disciplines of running and jumping in adolescents; this type of program is applicable to elite athletes as well. The results of the study are in agreement with previous studies that highlighted the importance of plyometric training on the development of explosive strength in junior teenagers practicing athletic sports [92–95].

Therefore, further research of this nature would be useful to investigate the selected sample in the selected sport, as this type of plyometric training should include specific exercises in terms of speed and explosive strength of the lower limbs. In future studies, the inclusion of women should be expanded, in specific sports, depending on the level of competition changes, as well as the impact of the plyometric program on other motor abilities by changing the models of the programs with different intensities as well as the application and other plyometric training programs. In future studies, the inclusion of physiological and biomechanical analysis related to explosive speed and strength, as well as other indicators of motor abilities under the influence of the plyometric program, will be carried out.

5. Conclusions

The 12-week plyometric training program for learning the performance of speed and explosive strength has positively influenced the improvement of the results in all the tests presented in this study among adolescents, more concretely it has improved the results of the plyometric group (PG) in all the tests in the measurements post. More specifically, if we look at our findings first, the CG group in speed performance showed a decrease in the results during the initial measurement compared to the post-measurements, while the jump indicators showed a normal increase in the result. Secondly, the PG showed a significant increase in the result of running speed, while the results of the jump showed a marked increase in relation to pre- and post-testing. Moreover, as another conclusion, it has been seen that the tests between PG and CG have shown distinct values among themselves. Significant differences were of significant value in both groups at the level of significance ($p < 0.05$). If we look separately at PG, we have the data in favor of this group in the 30 m running segment with significant differences of 0.000, then comes 80 m run with significant differences of less than 0.028, while in the 100 m run, we have no significant differences between the pre and post measurements. In the standing long jump test, we have a difference between the pre and post-measurements with a value of 0.020. Moreover, in the standing triple jump test, we have the same value of differences with a result of 0.035, but it should be noted that in the vertical jump test, we have a difference, i.e., worth 0.000. These findings show us that the plyometric training model of 12 weeks affects improving indicators of speed and explosive strength in adolescents. The effectiveness of a program of plyometric exercises model is conditioned by the way in which the content of the exercises, their dosage and organization are adapted to the particularities of age and the level of physical fitness.

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Institutional Review Board Statement: The study was approved by the Institutional Scientific Ethical Committee of the University of Tetovo dated (20 February 2021 under protocol number 0129/12) and all procedures were under the Code of Ethics for Biomedicine with Humans based on the Declaration of Helsinki (WHADH, 2000).

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

Conflicts of Interest: The authors declare no conflict of interest.

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