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MAXIMIZING JUMP PERFORMANCE: THE ROLE OF PLYOMETRICS IN YOUTH FOOTBALL TRAINING

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Abstract

Vertical jump training is a fundamental method for the physical conditioning of athletes. The synergy of motor skills exhibited during such movements substantially contributes to achieving motor acts and actions with higher performance indices. In football, vertical jumping, like other specific factors, is an essential element that can determine the outcome of a match. Football players need to be physically prepared to handle any complex situations that may arise during a game.
Our study aims to evaluate the impact of plyometric training on vertical jump height performance in young football players.
A total of 16 subjects, U11 football players, were randomly assigned equally into a PL group (N=8), which followed a plyometric training routine for 6 weeks, and a control group (N=8), which followed the routines set by the club team's coach. They were evaluated in two phases – an initial and a final phase – using Optojump testing equipment. The results obtained were compared using statistical and mathematical methods of descriptive analysis, the Shapiro-Wilk test for normality distribution, and the Independent Samples T-test.
Additionally, Levene's test was used to analyze the type of variances in the distributions.
Our study confirmed that a customized plyometric training routine can significantly improve vertical jump performance, considering age-specific characteristics.
Our investigations suggest that integrating this type of training into the subjects' routines can bring significant benefits to the development of motor skills, specifically to young football players, offering exciting perspectives for optimizing their performance in the long term.

Keywords: *vertical jump, football, sports performance, jump height, neuromuscular*

INTRODUCTION

Lower limb strength and vertical jump are fundamental to athletic performance (CANAVAN & VESCOVI, 2004). Improving vertical jump height performance in numerous sports can significantly indicate outcomes in elite competitions. In addition to football-specific stimuli, coaches and specialists in the field have attempted to use various conditioning programs to optimize the strength and power of athletes' lower limbs (TRECROCI ET AL., 2016).
By applying such methods, football players can perform complex tasks during the game more quickly. Without proper conditioning of football players in terms of fitness elements, coaches and specialists will not be able to develop individual training plans to achieve desired performance levels (ROMERO-CABALLERO, VARELA-OLALLA & LOËNS-GUTIÉRREZ, 2021).

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Over time, it has been demonstrated that a well-developed vertical jump is associated with success in numerous sports (BOBBERT, 1990; POTTEIGER ET AL., 1999; ARNASON ET AL., 2003; PUPO ET AL., 2021; KUMAR ET AL., 2023).

Jump training is a contemporary method for improving the physical conditioning indices of football players (RAMIREZ-CAMPILLO ET AL., 2022). From an early age, modern football requires athletes to have excellent physical abilities to meet high-performance demands (RAMIREZ-CAMPILLO ET AL., 2020). In addition to physical conditioning and technical preparation (HARASZTI ET AL., 2023), cognitive training can play a decisive role in football, regardless of age, gender, or performance level. Bucz et al. (2023) highlighted in their study that integrating cognitive training into football players' routines can enhance their motor performance.

Thus, in sports, whether in high-performance settings or mass participation (e.g., group fitness training), plyometric training is used to improve jump height. Plyometrics is recognized as a muscle training method based on the rapid alternation of eccentric and concentric contractions (HÄKKINEN, ALÉN & KOMI, 1985; ANDERSON ET AL., 2010). This form of training has become popular in physical conditioning by involving exercises composed of rapid and robust movements, such as bodyweight jumps, also known scientifically as the "stretch-shortening cycle" (MARKOVIC & MIKULIC, 2010; DE VILLARREAL ET AL., 2009; MEYLAN & MALATESTA, 2009; BOUGUEZZI ET AL., 2020).

This training method aims to optimize muscle strength relative to speed, enhancing athletic performance. Additionally, this training method is frequently integrated into athletes' routines to optimize results in specific sports disciplines or events that involve motor skills in situations requiring force, speed, agility, endurance, or sport-specific jumps.

Various studies demonstrate that plyometric training improves vertical jump height performance in children and young adults, regardless of their sports experience or training level (MILLER ET AL., 2003; MARKOVIC, 2007; DE VILLARREAL ET AL., 2009; ALMEIDA ET AL., 2021).

In football, plyometric training and other methods constitute fundamental elements of physical preparation and conditioning, significantly impacting players' performance. This method aims to develop general motor capacity and specific motor qualities essential to the sport, such as explosive strength, agility, and spatial-temporal and inter-segmental coordination, which are crucial in youth football. Educating and developing these skills early is vital for players to meet the high demands of competition (REILLY & GILBOURNE, 2003).

Due to the short transitions between muscle contractions, plyometric training contributes to the development of strength relative to speed. Plyometric exercises generally involve rapid, high-intensity contractions with an increased force-to-speed ratio, facilitating the development of significant power in the lower limbs (WANG & ZHANG, 2016).

Studies over the past decades have demonstrated increases in vertical jump height and reductions in sprint time because of this type of training (WILSON ET AL., 1993; GEHRI ET AL., 1998; DELECLUSE ET AL., 1995; KRAEMER ET AL., 2000; RIMMER & SLEIVERT, 2000).

Currently, the diversification of plyometric training methods has led to significant improvements in the motor characteristics of football players (KOKINDA ET AL., 2023; MICHAILIDIS, VENEGAS & METAXAS, 2023; SAMMOUD ET AL., 2024; SEABURIN & SRIPOKHA, 2023). Additionally, recent studies have highlighted plyometric programs'

effectiveness in optimizing football players' physical condition (TVRDÝ ET AL., 2023; OLIVER ET AL., 2023; HASAN, 2023). Various force platforms or contact mats can be used to evaluate the effects of plyometric training.
Our study aimed to integrate a customized plyometric training program into the routines of young football players to observe significant effects on jump height.

MATERIAL AND METHODS

PARTICIPANTS

A sample of sixteen eleven-year-old football players (N=16) registered at a football academy in Romania participated in this study. The participants were randomly divided into two equal groups: an experimental PL group (N=8) and a control group (n=8). All participants consistently engaged in the training sessions prescribed by the sports club and possessed motor skills necessary for performing various sport-specific and non-specific motor tasks. These skills were primarily developed through active participation in school physical education classes and performance training at the club. There were no players with medical issues among the study participants. As the study involved young participants, parents were informed of its purpose and provided written consent for their children's participation in the experiment.

PROCEDURES

The experiment was conducted over 6 weeks, specifically during April-May 2021, and included two evaluation sessions (an initial evaluation - pre- and a final assessment - Post). The control group performed their usual football training during this period, while the PL group followed a customized plyometric training program. The Pre and Post-test sessions were conducted at the Research Center of the Faculty of Physical Education and Sports at "Aurel Vlaicu" University in Arad. Before each evaluation, the subjects performed an appropriate general dynamic warm-up (e.g., moderate tempo endurance running for 5-6 minutes) and a specific warm-up targeting the primary muscles involved in plyometric training (e.g., bodyweight squats, forward and lateral lunges). The PL group was introduced to the plyometric training program 10 days before the start of the experimental procedure to familiarize them with the exercises to be performed. Additionally, the subjects involved in this research had prior experience with plyometric training routines at their club, which laid the groundwork for conducting this study.

ANTHROPOMETRIC AND BIOMETRIC ASSESSMENT

The subjects were assessed both anthropometrically (height, weight, body mass index) and biometric (vertical jump height using the CMJ test) in both the Pre (CMJ_{pre}) and Post (CMJ_{post}) tests. An Omron BF511 bioimpedance scale was used for body mass evaluation, and a stadiometer was used to measure the subjects' height. The CMJ test was also conducted to evaluate vertical jump performance using OptoJump Next equipment from Microgate. The subjects were instructed to keep their hands on their hips throughout the vertical jump test. Each subject performed three jumps with a 45-second rest between each set. The result of the best jump was recorded for analysis.

PLYOMETRIC TRAINING SESSION

A plyometric training program was implemented for 6 weeks, with two training sessions per week. Considering the age of the subjects and consulting various specialized studies, we decided not to conduct the training for the PL group on fixed days (WATHEN, 1993; FEIGENBAUM, 2006). Instead, the sessions were conducted every three days. We adapted the plyometric training program for the 6 weeks in terms of intensity and workload volume from that of Miller et al. (2006). The training volume varied between 70 and 140 ground contacts per session. The regular football training routines remained the same throughout the experiment. The intensity of the applied program was progressively modified during the training routines. To enable the subjects to perform the exercises at their maximum capacity according to their age and fitness level, they were properly instructed. Additionally, the participants in this study were continuously monitored by the research team and the team staff, and they were consistently encouraged and verbally motivated to perform the exercises with maximum effort and efficiency.

Table 1: The Plyometric Training Protocol is for six weeks (Developed by Miller et al. (2006) and adapted by us).

Training Week	Training Volume	Plyometric Drills	Sets x Repetitions	Training Intensity
1	70	Side to side ankle hops	2 x 10	Low
		Standing jump and reach	2 x 10	Low
		Front cone hops	6 x 5	Low
2	90	Side to side ankle hops	2 x 10	Low
		Standing jump and reach	2 x 10	Low
		Lateral jump over barrier	6 x 5	Low
		Double leg hops	15 x 2	Medium
3	110	Side to side ankle hops	2 x 10	Low
		Standing long jump	2 x 10	Low
		Lateral jump over barrier	6 x 5	Medium
		Double leg hops	10 x 2	Medium
		Lateral cone hops	2 x 10	Medium
4	130	Single leg bounding	2 x 10	High
		Standing long jump	3 x 10	Low
		Lateral jump over barrier	8 x 5	Medium
		Lateral cone hops	3 x 10	Medium
		Tuck jump with knees up	5 x 2	Medium
5	140	Single leg bounding	2 x 15	High
		Jump to box	2 x 15	Low
		Double leg hops	5 x 2	Medium
		Lateral cone hops	2 x 10	Medium
		Tuck jump with knees up	5 x 2	High
		Lateral jump over barrier	3 x 10	High
6	110	Jump to box	2 x 15	Low
		Depth jump to prescribed height	5 x 2	Medium
		Double leg hops	5 x 4	Medium
		Lateral cone hops	2 x 5	Medium
		Tuck jump with knees up	5 x 4	High
		Lateral jump single leg	2 x 10	High

Note: Training volume is calculated in foot contact.

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STATISTICAL ANALYSES

The statistical indicators were obtained using SPSS v.23 and included the following:

- Descriptive analysis of the distributions, highlighting the arithmetic mean and standard deviations.
- We implemented the Shapiro-Wilk test to assess the distributions of the sample.
- Independent Samples T-Test was chosen based on the interpretation of the Shapiro-Wilk test results.
- Levene's test assessed the type of variances in the distributions analyzed with the Independent Samples T-Test.

RESULTS

Table 2: Descriptive Statistics for CMJ in Pre and Post-Stages

Test	Group	N	*M*	*SD*	*Std. Error Mean*
CMJ_{pre}	PL	8	27.57	3.24	1.14
	Control	8	26.15	3.34	1.18
CMJ_{post}	PL	8	30.80	2.6	0.92
	Control	8	26.13	3.19	1.13

The measurements for the countermovement jump (CMJ) before the intervention (CMJ_{pre}) show a higher mean for the plyometric training group (PL) (27.57 cm) compared to the control group (26.15 cm). This trend persists after the intervention (CMJ_{post}), where the mean for the PL group (30.80 cm) is higher than that of the control group (26.13 cm). The standard deviations indicate some variability in individual responses, and the standard errors of the mean provide information about the precision of the group mean. The sample size is 8 for each group. These findings suggest possible significant differences between the PL and Control groups in measurement outcomes, highlighting the importance of a detailed analysis of the study results.

Table 3: Anthropometric Measurements in both Pre and Post-test stages

Group	N	Weight (kg)	Height (cm)	BMI (%)
PL_{pre}	8	33±3.00	141±6.00	15.9±2.0
$Control_{pre}$	8	35±4.00	144±5.00	16.8±1.7
PL_{post}	8	33.04±3.07	141±6.00	15.64±1.93
$Control_{post}$	8	35.80±3.44	144±5.00	16.58±1.71

In the PL_{pre} group, the average weight of the subjects is approximately 33±3.00 kg, the average height is approximately 141±6.00 cm, and the average body mass index (BMI) is

approximately 15.9±2.0%. This group shows moderate weight, height, and BMI variation, suggesting a relatively homogeneous distribution of these assessed characteristics.
In contrast, in the Control group, the average weight is higher, at approximately 35±4.00 kg, while the average height is approximately 144±5.00 cm. The average BMI in this group is approximately 16.8±1.7%. This group also demonstrates moderate variation in the evaluated characteristics.
In the PL_{post} group, following the intervention, the subjects' weight remained approximately 33.04±3.07 kg, while the BMI slightly decreased to 15.64±1.93%. In the Control group, the average weight increased somewhat to 35.80±3.44 kilograms, and the average BMI was 16.58±1.71%.
The dynamics of the recorded results suggest possible changes in body composition specific to the age of the subjects involved in the research. At this stage of life, children experience significant physiological changes (e.g., increases in height, muscle development, or accumulation of adipose tissue), impacting their body weight.

Table 4: Testing the Normality of Distributions in the Two Groups and Selection of the Statistical Comparison Test

Measurements	Shapiro-Wilk	df	Interpretation *p*	Finding the status of distributions	Appropriate statistical test
CMJ_{pre} - PL	.923	8	$p > 0.05$	normal	Independent Sample T Test
CMJ_{pre} - Control	.912	8	$p > 0.05$	normal	Independent Sample T Test

Table 5: Testing the Normality of Distributions in the Two Groups and Selection of the Statistical Comparison Test

Measurements	Shapiro-Wilk	df	Interpretation *p*	Finding the status of distributions	Appropriate statistical test
CMJ_{post} - PL	.970	8	$p > 0.05$	normal	Independent Sample T Test
CMJ_{post} - Control	.922	8	$p > 0.05$	normal	Independent Sample T Test

The values for the Shapiro-Wilk test indicate that the data for the CMJ_{pre} and CMJ_{post} measurements in the PL group (plyometric training) have p-values of 0.456 and 0.897, respectively, for a significance threshold of p = 0.05. For the Control group (standard group), the p-values are 0.368 and 0.443. These high p-values suggest insufficient evidence to reject the null hypothesis that the data come from normal distributions, indicating a potential normality of the data in both groups and measurement periods. It is important to note that this interpretation is based solely on the Shapiro-Wilk test and that other factors may influence the results.

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Table 6: The results of Levene's test and the Independent t-test for both testing phases

		F	*Sig.*	*t*	*df*	*Sig* (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
CMJ_{pre}	Equal Variances Assumed	.181	.677	0.864	14	.402	1.43	1.65	-2.11	4.96
	Equal Variances Assumed			0.864	13.98	.402	1.43	1.65	-2.11	4.96
CMJ_{post}	Equal Variances Assumed	.642	.436	3.19	14	.006	4.66	1.46	1.53	7.78
	Equal Variances Assumed			3.19	13.44	.007	4.66	1.46	1.52	7.80

Levene's test for equality of variances and the t-test for equality of means provide information about the variability and average differences between the PL (plyometric training) and Control (standard group) for the CMJ_{pre} and CMJ_{post} measurements.

For CMJ_{pre}, Levene's test indicates a nonsignificant variation between groups ($F = 0.181$, $p = 0.677$), and the independent t-test does not identify significant differences between the means of the two groups in the pre-test phase ($t = 0.864$, $df = 14$, $p = 0.402$). Thus, there is insufficient evidence to reject the null hypothesis that the means are equal.

For CMJ_{post}, Levene's test indicates a nonsignificant variation between groups ($F = 0.642$, $p = 0.436$). At the same time, the t-test identifies significant differences between the means of the two groups in the post-test phase ($t = 3.198$, $df = 14$, $p = 0.006$). This result suggests significant differences in the means of post-training measurement between the PL and Control groups. The 95% confidence interval indicates a mean difference between 1.53519 and 7.80195.

In conclusion, for CMJ_{pre}, there are no significant differences between groups, whereas, for CMJ_{post}, the differences are substantial, indicating a possible influence of plyometric training on the post-training results.

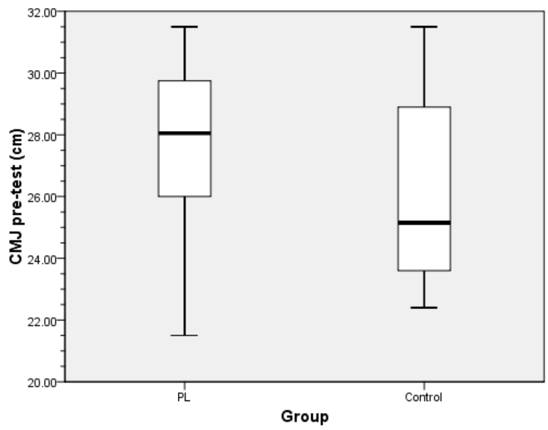

Figure 1: Jump Height in the Pre-Test Stages

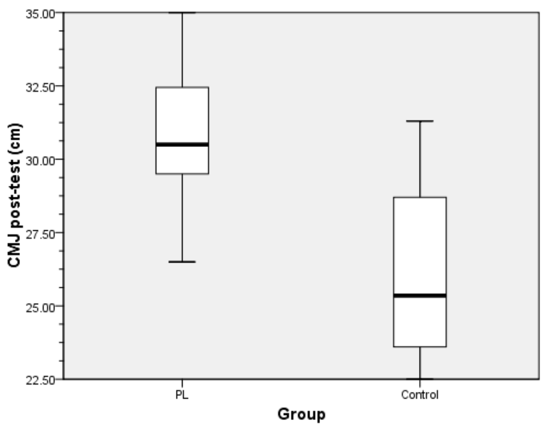

Figure 2: Jump Height in the Post-Test Stages

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DISCUSSION

Our results demonstrate that implementing a plyometric training routine can significantly improve vertical jump height. Considering the age of the subjects in our study, their lower limb strength levels were satisfactory. The six-week plyometric program yielded significant results in terms of vertical jump height. The fact that the subjects were in the middle of the competitive season, rather than in a training camp period where acute physical fatigue might occur, also contributed to the changes in jump height. Despite this, their regular training routines, led by the team coach, were based on technical-tactical exercises and general physical preparation specific to their age. Additionally, the coach occasionally included plyometric exercises, which made it easier for the subjects to understand the purpose of our study.

Although it might have been interesting to analyze the vertical jump performance of the players involved in the study based on their position on the field, the literature suggests that maximum jump height can vary depending on a football player's position (JEZDIMIROVIĆ ET AL., 2013). Moreover, behind this jump height lies many variables, including power, strength, muscular endurance, neuromuscular coordination, etc. An athlete with highly developed general and specific motor qualities is much closer to achieving optimal performance in prestigious competitions.

Currently, neuromuscular training programs for various sports are gradually gaining momentum. Brain stimulation is vital for developing concentration capacity, attention, and cognitive abilities to understand situations and make correct decisions under challenging circumstances (BUCZ ET AL., 2023) and strengthening the brain-muscle connection. It would be exciting and essential to explore the information obtained from sport-specific motor actions more deeply, considering psycho-neuro-motor qualities "through the entire motor chain from brain command to muscle and back" (GEANTĂ & DE HILLERIN, 2023).

For coaches interested in gaining knowledge, it might be advisable to direct their attention toward training that aims at muscle development and brain training. Most contemporary coaches strive to improve their athletes' performance in sports where jumping tasks are fundamental to determining results. Based on our study, which was based on a relatively accessible plyometric program, we can affirm that if routines are appropriately designed and implemented according to collective or individual peculiarities, they can be used effectively to enhance both vertical jump performance and neuromuscular components, regardless of whether we are talking about trained or untrained individuals.

Our literature review highlighted several studies that support our hypothesis. For example, Negra et al. (2020) assert that plyometric training combined with regular football practice represents safe interventions for young football players. Other studies highlight that plyometric training is helpful for young soccer players to optimize their "stretch-shortening" function (MORAN ET AL., 2017; RADNOR ET AL., 2018). Trecroci et al. (2022) study on novice young football players unfamiliar with plyometric exercises found that a training program focused on plyometric exercises combined with cognitive involvement can bring slight but significant improvements in physical and cognitive performance in just four weeks. This finding strengthens our argument that familiarizing the study sample with plyometric exercise routines was essential for obtaining significant results.

Thus, our study contributes significantly to the field by optimizing motor performance for young football players through customized plyometric routines tailored to age, sex, sport, and performance level. Future studies should propose and develop programs that can rapidly optimize vertical jump performance, considering psycho-neuro-motor aspects.
In the correct repetition and execution of a movement, psycho-neuro-motor exercises play an essential role (GABR ET AL., 2013). Various studies from numerous knowledge areas, such as physical education (CAMENIDIS ET AL., 2024) or different sports and branches of sports (BOTEZATU, ANDREI & HILLERIN, 2014; DHAROD ET AL., 2020; IORGA ET AL., 2024) use psycho-neuro-motor exercises to correct or optimize human performance abilities.

CONCLUSIONS

Plyometric training represents a valuable method for optimizing vertical jump height, as demonstrated by this study's efficacy in improving athletic performance. The age and strength level of the subjects involved in the research influence the results of plyometric training, and conducting these sessions during the competitive season is advantageous as it avoids the accumulation of acute fatigue.
Integrating a plyometric exercise routine into traditional training programs can significantly enhance athletes' awareness of the purpose and importance of these exercises, whether in football or other sports where lower limb performance is crucial. Additionally, stimulating the cortex is fundamental in developing cognitive capacity and athletic performance, making neuromuscular training increasingly useful. Psycho-neuro-motor qualities are critical for optimizing athletic performance in football. Coaches should pay particular attention to proposing and integrating such exercise programs into athletes' training routines. Integrating psycho-neuro-motor exercises can improve athletes' motor control, enhancing their motor performance in various sport-specific tasks.

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