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Effect of Plyometric Training on Explosive Power in Speed Climbing World Record Athletes

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ABSTRACT

This study aims to determine the effect of the plyometric method on improving explosive power in athletes competing in the speed world record climbing discipline. The research employed an experimental method with a one-group pre-test post-test design. The sample consisted of 7 speed world record climbing athletes (aged 15–18 years) using total sampling over a 6-week training program. The instrument used was the vertical jump test to measure explosive power. Data analysis was carried out using a t-test with SPSS version 26. The results showed a significant improvement in lower limb explosive power after the plyometric training program. The average post-test results showed a 6% increase compared to the pre-test. This indicates that plyometric training is effective in improving the lower limb power needed in climbing, especially in the speed world record discipline, which requires explosive movements. It can be concluded that the plyometric training method contributes positively to improving explosive power in speed world record climbing athletes. This research is expected to serve as a reference for coaches in designing more specific and targeted training programs.

Keywords: plyometric, explosive power, sport climbing, lower limb, speed climbing

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INTRODUCTION

National and international competitions encompass three main disciplines: lead climbing (climbing with rope protection), bouldering (climbing at low heights with protective mats), and speed climbing (climbing as fast as possible on a standard route in a head-to-head format) (Lutter et al., 2021). In the speed category, there are three sub-events contested: speed classic, speed track, and speed record. Speed is a time-based category in which a climber must achieve the fastest time to outperform their opponents (Widyarto, dkk (2017) The speed world record category is part of competitive sport climbing that requires athletes to complete a standardized artificial climbing wall route, 15 meters in height, as quickly as possible (Ilham & Dimyati, 2021). In the speed world record category, the climbing route is standardized worldwide so that every official lane is identical in terms of hold placement, width, and route length. There is no tolerance for errors on the route, and climbers are required to complete it flawlessly without mistakes.

The main characteristics of the speed world record event, which was also featured in the Tokyo 2020 Olympic Games, have been established by the International Federation of Sport Climbing (IFSC). The wall consists of two parallel lanes approximately 15 meters long. Each lane has 20 square panels measuring 1.5 meters on each side, arranged in two

vertical columns of ten panels each. The wall has a consistent 5° overhang and a light grey quartz resin surface. The holds used are of two types: 20 large handholds and 11 small footholds, all based on the official IFSC master hold models. In competitions, the holds are painted bright red; however, in the most recent Olympics, each lane had three black handholds used for split-time measurement, provided by Luxov, France (Askari Hosseini & Wolf, 2023a).

The timing system uses a combination of mechanical and electronic components, including a start pad that records the moment the athlete lifts their foot off the ground and a stop device that must be hit at the top of the wall. This system has an accuracy of up to 1/1000 of a second and can also detect false starts, which occur when the athlete leaves the start pad within 0.1 seconds before the final beep. Safety in this climbing discipline is ensured through an automatic belay system anchored at the top, which must have official certification for any world record achieved in competition to be recognized Askari Hosseini & Wolf, 2023a).

In the speed world record category, athletes require optimal physical conditioning to facilitate the climbing process, as well as strong technical skills to place their feet and hands precisely and stably on the holds. Performance in sport climbing is assessed based on the "time speed" achieved by the climber (Pratama et al., 2024). Speed climbing is a form of indoor climbing where athletes compete for the fastest time to reach the top of the climbing wall (Widyarto dkk., 2017).

Muscle strength is widely recognized as a fundamental capacity that serves as the foundation for the development of muscle power, rate of force development, starting strength, and acceleration strength (Krzysztofik et al., 2019). *Muscle explosive power* is defined as the ability of a muscle or group of muscles to contract explosively in a very short period of time. Explosive power is influenced by both speed and the velocity of muscle contraction (Manda Mely Garitny dkk., 2023). Lower-limb explosive power plays an important role in speed climbing due to its dynamic and explosive movements, making it essential to train optimally in order to support jumping and height gain during ascents (Irawan & Hidayah, 2017).

Based on the author's experience as a speed climbing athlete, it has been observed that many athletes still possess relatively low levels of explosive power. This condition becomes a barrier in performing the explosive jumps that are essential for reaching the next foothold quickly and efficiently. In the speed world record category, time is the primary determinant of achieving peak performance and securing victory in competition. Therefore, explosive power—particularly in the lower limbs—should be a primary focus in the training process, as it plays a crucial role in generating fast, strong, and dynamic movements during vertical climbing in the shortest possible time.

Training programs for speed climbing athletes should prioritize the development of physical qualities that support sport-specific performance in the speed world record event. These include improvements in regional muscle hypertrophy, maximal strength, and explosive strength, tailored to the stages and needs of the athlete. In the annual training program of a speed climbing athlete, muscular strength serves as a key component that underpins the development of other physical qualities. Several studies in various sports have demonstrated significant improvements in lower-limb muscle force through training blocks lasting between 4 and 12 weeks (Giles et al., 2006).

According to (Markovic & Mikulic, 2010), one method proven effective in enhancing explosive power is plyometric training. Plyometric exercises can significantly increase

lower-limb power through neuromuscular mechanisms and improved stretch reflex efficiency. In the context of sport climbing, explosive power plays a vital role in performing rapid movements and vertical jumps to reach the next hold or point along the climbing route. Physical condition, which includes body health, physical fitness, and environmental factors such as a regularly implemented training program, can help enhance the desire to move more extensively and achieve optimal results in a sport that emphasizes lower-limb explosive power (Suantika et al., 2016). Explosive power is the ability of the muscles to exert maximum strength in a short period of time (Yasa dkk., 2022). According to Widyarto et al. (2017), explosive power, or power, is the ability of the muscles to generate maximum strength in a very short time. According to Sajato, muscle power is the same as explosive power, which depends on two interrelated factors: the interaction between muscle strength and speed (Widiastuti, 2015).

Plyometric training is one of the techniques used to improve power and is widely implemented by renowned coaches across various sports. It is a common component in many athletic disciplines, with a wide range of applications and variations, including two-foot and single-leg exercises, static drills performed in place, and other dynamic variations (Irawan & Hidayah, 2017). This training method can also be applied to the *Training to Train* age group, namely boys aged 12–16 years and girls aged 11–15 years, taking into account factors such as age, ability, skill level, and injury history (Aprtianto et al., 2024). Plyometric exercises involve the rapid acceleration of mass, which may consist of external loads, such as equipment, or the athlete's own body weight. Lower-body plyometric training generally includes jumping and various single-leg or double-leg hopping variations (Booth & Orr, 2016). Compared to strength training alone, plyometric exercises have been shown to yield greater improvements in dynamic performance measures (Jaya & Rohmat, 2019).

METHOD

This study employed an experimental method. Only one group was given the treatment; therefore, the research design used was a One-Group Pre-test and Post-test Design. This experimental design involves administering a pre-test to a single group of subjects, followed by the treatment, and then a post-test. The purpose of this design is to determine whether changes or improvements occur after the treatment is given. According to (Arisetiawan dkk, 2020), the one-group pre-test and post-test design is a common form of quantitative experiment used when researchers aim to identify changes in behavior or performance after an intervention, without employing a control group. This design was chosen because it aligns with the research conditions, which involved only one group of athletes and aimed to evaluate changes occurring after a plyometric training program over 12 sessions. Through this design, comparisons of vertical jump test results before and after training can be used to assess the treatment's effect on explosive power.

Table 1. One-Group Pretest-Post-tests Design

Pre-test	Treatment	Post-test
O1	X	O2

The sample used in this study was representative of the target population. A total of seven participants were selected. Referring to the previous study by (Nonnato et al.,

2022), the sample consisted of seven speed climbing athletes from FPTI Kota Bandung. The sampling technique employed was total sampling, in which the number of samples is equal to the population when the population size is fewer than 100; thus, the entire population was included in the study(Nurhayati & , Langlang Handayani, 2020).

The primary research instrument was the Vertical Jump Test based on the jump-and-reach method, conducted manually using chalk and a measuring tape. The procedure involved marking the standing reach and the jump reach with chalk against a wall, and then calculating the difference between the two as the jump height. Previous research has shown that this manual method provides good reliability in measuring lower-limb explosive power(Oncen dkk., 2018).

RESULTS AND DISCUSSION

Findings

The results of the study indicate an improvement in the athletes' explosive power following the implementation of the plyometric training method. The pre-test and post-test results using the vertical jump test are presented in Table 2.

Table 2. Ilustration

Data	N	Min	Maks	Avarage	%
Pretest	7	30,48	68,58	46,91	76%
Posttest	7	34,8	73,66	50,12	83%

Source: Processed data (2025)

The tests were conducted at the beginning (pre-test) to determine the athletes' initial abilities and at the end (post-test) to measure performance after receiving the treatment. The collected data were processed and analyzed using appropriate statistical methods, specifically the t-test, with the assistance of SPSS version 26.

The mean pre-test score was 76%, while the mean post-test score increased to 83%, reflecting a 6% improvement. This increase demonstrates that the training program implemented had a positive impact on the measured physical ability, specifically the improvement of lower-limb explosive power in speed climbing world record athletes. Based on the results of the normality test in Table 3, it can be seen that the Shapiro–Wilk significance value for the plyometric pre-test was 0.591, indicating that the data were normally distributed. For the plyometric post-test, the Shapiro–Wilk significance value was 0.252, also indicating a normal distribution. Overall, all groups demonstrated normally distributed data based on the Shapiro–Wilk test results.

Table 3. Normality Test Results

Variabel	Shapiro-Wilk		
	Statistic	Df	Sig.
Pretest	0,935	7	0,591
Postest	0,885	7	0,252

Source: Processed using SPSS 26 (2025)

Based on the results table 4 of the homogeneity test using Levene's Test on the Vertical Jump variable, the Levene's Statistic was obtained at 0.906 with a significance value (Sig.) greater than 0.05. This indicates that the data have homogeneous or equal variances across groups. In other words, there is no significant difference in variances between groups, so the assumption of homogeneity is fulfilled and the data are eligible for further analysis using parametric statistical tests.

Table 4. Homogeneity Test Results

	Lavene Statistic	df1	df2	Sig.
Pretest-Posttest	0.15	1	5	0,906

Source: Processed using SPSS 26 (2025)

Based on the results of the Paired Sample T-Test on the Vertical Jump variable, a mean difference of 3.21 was obtained with a t-value of -3.044 and a significance value (Sig. 2-tailed) of 0.023, which is less than 0.05. This indicates that there is a significant difference between the pretest and posttest scores. In other words, the intervention applied in this study had a significant effect in improving the athletes' vertical jump performance, thus confirming the effectiveness of the training program.

Table 5. Paired Sample T-Test Results

Variabel		Paired Differences					t	Df	Sig. (2-tailed)
		Mean	Std. Dev	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest - Posttest	3.20857	2.78920	1.05422	5.78815	0.62900	-3.044	6	0.023

Source: Processed using SPSS 26 (2025)

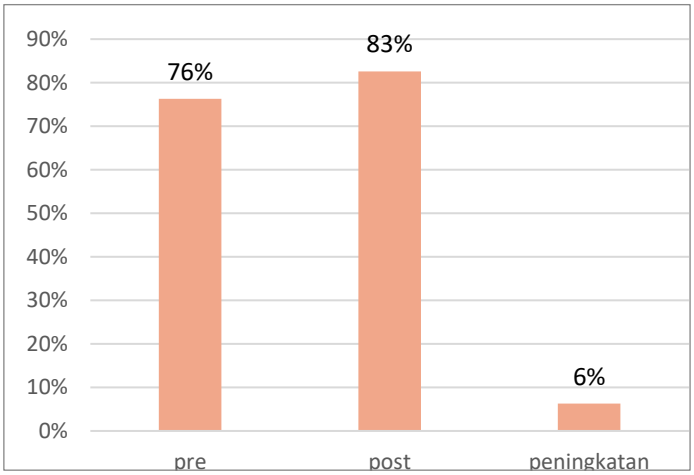

Figure 1. Percentage Results
Source: Processed using SPSS 26 (2025)

Based on the research conducted on 7 speed climbing athletes from the FPTI Bandung City, it can be concluded that the plyometric training method had a positive impact on improving lower-limb explosive power. This was evidenced by the comparison of vertical jump test results between the pre-test and post-test, which showed an increase in the mean score from 46.91 cm to 50.12 cm. This 6% improvement reflects the

effectiveness of the plyometric training program, particularly the variations focusing on single-leg–dominant exercises such as single-leg hops, single-leg box jumps, and single-leg step-ups with jumps, in stimulating the explosive strength that is crucial in the speed climbing world record discipline.

As a result, the incorporation of plyometric methods into the training program demonstrated a tangible contribution to the improvement of explosive muscle power, particularly in the lower limbs, which is crucial in rapid vertical sprinting (Shih et al., 2024). These findings align with the study by (Huang dkk, 2023) which reported significant improvements in speed, agility, and explosive strength parameters among elite athletes following eight weeks of plyometric training. Furthermore,(Askari Hosseini & Wolf, 2023) through video analysis of Olympic Games competitions, identified lower-limb power, low body mass index, efficient anaerobic glycolytic capacity, and agility as key performance indicators in speed climbing. Their analysis revealed that male speed climbing athletes, on average, executed 13 take-off jumps from footholds and 4 jumps directly from the climbing wall.

Plyometric training designed with a dominance of unilateral (single-leg) exercises holds high relevance in the context of the speed climbing world record event. Exercises such as single-leg hops, single-leg box jumps, and single-leg step-ups with jumps specifically target the lower-limb muscles in an isolated yet functional manner. This approach aligns with the biomechanical characteristics of rapid climbing movements, where athletes frequently push off and propel from one leg alternately on each foothold.

In the context of the speed climbing world record discipline, movement patterns are not symmetrical but highly dynamic, relying heavily on balance control, unilateral strength, and precise single-leg propulsion. Based on the video analysis by (Askari Hosseini & Wolf, 2023), each stride along to the speed climbing route involves an explosive jump from one leg to transition between footholds. This underscores the importance of enhancing unilateral function through single-leg–based plyometric exercises. Therefore, the integration of unilateral plyometric exercises into the training programs of climbing athletes not only enhances unilateral lower-limb muscle strength but also improves sport-specific technical performance in the speed climbing world record discipline.

CONCLUSION

The present study provides compelling evidence that plyometric training, particularly programs emphasizing unilateral explosive movements, significantly enhances lower-limb explosive power in elite speed climbing athletes. These improvements align closely with the biomechanical demands of the speed climbing world record discipline, in which athletes must generate rapid and forceful propulsion from a single foothold to the next. The observed performance gains were both statistically significant and functionally meaningful, indicating improved efficiency in route completion times.

Given the sport-specific requirements of asymmetrical and dynamic climbing movements, integrating unilateral plyometric exercises—such as single-leg hops, single-leg box jumps, and single-leg step-ups with jumps—into training regimens offers dual benefits: strengthening unilateral lower-limb musculature and refining sport-specific technical execution. These findings support the inclusion of targeted plyometric protocols as an evidence-based strategy to optimize performance in speed climbing events.

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