



The Effect of Plyometric Training on Enhancing Ball Speed in the Flying Shoot Technique During Training to Compete Phase

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ABSTRACT

This study aimed to evaluate the effectiveness of plyometric training in enhancing ball speed during the execution of the flying shoot technique among male handball athletes in Bojonegoro District during the training-to-competition phase. The research employed a one-group pretest-posttest design using a quantitative descriptive approach within a pre-experimental framework. The total sample consisted of 13 male handball athletes selected through total sampling. Ball speed was assessed using a radar gun test. Data normality was tested using the Shapiro-Wilk test, which showed that the ball speed data for both pretest ($p = 0.151$) and posttest ($p = 0.323$) were normally distributed ($p > 0.05$). Homogeneity testing using Levene's Test revealed a significance value of 0.320 ($p > 0.05$), indicating homogeneous variance. Hypothesis testing using a paired sample t-test yielded a significance value of 0.000 ($p < 0.05$), confirming a statistically significant effect of the intervention. The findings indicate that plyometric training has a significant impact on improving ball speed in the flying shoot technique for male handball players during the training-to-compete phase.

Keywords: Handball, Ball Speed, Plyometric Training, Flying Shoot, Performance Enhancement.

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Article info

Received : 11 June 2025

Accepted : 24 June 2025

Published : 30 June 2025

P-ISSN 2613-9421

E-ISSN 2654-8003

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INTRODUCTION

Handball is characterized by an intermittent tempo involving rapid transitions between offensive and defensive phases, with performance heavily influenced by endurance, explosive power, and muscular strength (Saavedra et al., 2017). Success in handball requires a high level of physical conditioning to meet the game's physiological demands. The sport is characterized by intense physical activities, including running, sprinting, jumping, throwing, shooting, blocking, and physical contact between players (Karcher & Buchheit, 2014).

It is undeniable that shooting is one of the most frequently utilized technical elements in handball. As the final attacking action, shooting plays a

decisive role in determining a team's ability to score. The primary objective of handball is to score as many goals as possible against the opposing team, making shooting a critical skill in achieving this aim. Consequently, shooting speed is a crucial factor in the success of offensive performance in handball (Clanton & Dwight, 1997, p. 42). The effectiveness of a shot is primarily influenced by two key components: ball velocity and throwing accuracy (Raeder et al., 2015).

Ball speed significantly affects the overall efficiency of a shot, as it can ultimately determine the outcome of a handball match. High-speed, accurate shooting is a fundamental performance factor in handball (Shalfawi et al., 2014). The faster the ball is released, the less reaction time defenders and goalkeepers have to respond. A combination of speed and precision determines shooting efficiency. Several factors can contribute to reduced shot effectiveness, including poor upper-limb strength and inadequate explosive power, which may result in low ball velocity and decreased shooting efficiency.

Upper-body explosive power is a primary contributor to performance in handball (Hammami et al., 2020). Handball is a sport that demands complex motor actions and repeated explosive muscular contractions. According to Wagner Hinz (2023), explosive movements constitute approximately 25% of all physical actions performed during a match. A high level of muscular strength and upper-limb power is required to execute effective shooting techniques in competitive handball. Belcic et al. (2023) emphasized that upper-extremity explosive skills play a crucial role in achieving optimal performance among handball athletes.

Specific physical conditioning, including strength and power training, has a significant influence on throwing performance and physical confrontations in team handball (Wagner et al., 2017). As noted by Karcher Buchheit (2014), these physical components can be enhanced and optimized through structured training sessions, ensuring that players are physically prepared for the demands of competition. Improving physical fitness should begin early in an athlete's development, particularly during the training-to-compete phase. This developmental stage typically occurs between the ages of 16 and 23 for males and 15 and 21 for females. During this phase, individual training programs are

designed with progressively higher volumes and intensities, maintaining a recommended competition-to-training ratio of 40:60. According to Anton (2006), the primary objective of training during this phase is to develop position-specific technical and tactical skills that support peak athletic performance. Therefore, appropriate training methods aligned with the developmental goals of this phase are essential.

To develop the required physical condition, particularly the component of upper-limb explosive power, implementing an appropriate and targeted training method is essential. Selecting the right training approach can optimize an athlete's potential and help them reach peak performance. Among the various methods available to enhance upper-body explosiveness, plyometric training is widely recognized for its effectiveness in improving upper-body explosiveness. Plyometric training is designed to enable muscles to generate maximal force in the shortest possible time. The application of an 8-week plyometric training program has been shown to significantly increase ball-throwing velocity in handball athletes, as has a study by Chelly et al. (2014). In a study by Gjinovci et al. (2017), upper-body plyometric training performed twice a week over 12 weeks was demonstrated to improve throwing performance in volleyball players. Building on the findings of previous research, this study aims to investigate whether plyometric training has a significant impact on increasing ball speed in the flying shoot technique during the training-to-competition phase in handball.

METHODS

This study employed a one-group pretest-posttest design within a pre-experimental research framework, using a quantitative descriptive approach. The research design involved administering a pretest, followed by an intervention in the form of plyometric training and concluded with a posttest evaluation. The intervention was applied to male handball athletes from Bojonegoro District.

The population of this study consisted of all male handball athletes in Bojonegoro District. The sampling technique used was total sampling, resulting in a sample of 13 male athletes aged between 20 and 21 years. The research instruments included both test and non-test methods. The test instrument consisted of a ball speed test conducted using a Bushnell 10911 radar speed gun to measure

the velocity of the ball during the flying shoot technique. The radar speed gun is a handheld point-and-shoot device used to detect and record the speed of moving objects. The procedure for conducting the ball speed test was as follows: 1) The radar speed gun operator stood behind the participant at a distance of 3 to 6 meters, 2) The participant executed a flying shoot toward the goalpost, with the take-off point marked at 9 meters from the goal, 3) As the participant released the ball, the operator aimed the device at the ball and pressed the trigger beneath the screen to capture the speed measurement. The ball speed test demonstrated strong psychometric properties, with a validity coefficient of 0.85 and a reliability coefficient of 0.77. The non-test instrument involved research documentation in the form of photographs and video recordings. The study was conducted over 9 weeks, from July to September 2023. The plyometric training intervention was administered twice per week for a total of 18 training sessions. Following the collection of pretest and posttest data, both assumption testing and hypothesis testing were conducted. The assumption tests included two procedures: a normality test and a homogeneity test. The normality test was conducted using the Shapiro–Wilk test to determine whether the data distribution conformed to a standard curve (Sukestiyarno, 2013). The homogeneity test employed Levene’s Test to assess whether the data exhibited homogeneous variance across the sample groups. Once the assumption tests were completed, hypothesis testing was performed using a paired sample t-test. This statistical test aimed to determine whether plyometric training had a significant effect on increasing ball speed in the flying shoot technique among male handball athletes from Bojonegoro District during the training-to-compete phase. All data analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 23.

RESULTS AND DISCUSSION

Results

The results of the pretest and posttest ball speed tests conducted by male handball athletes from Bojonegoro District are presented as follows:

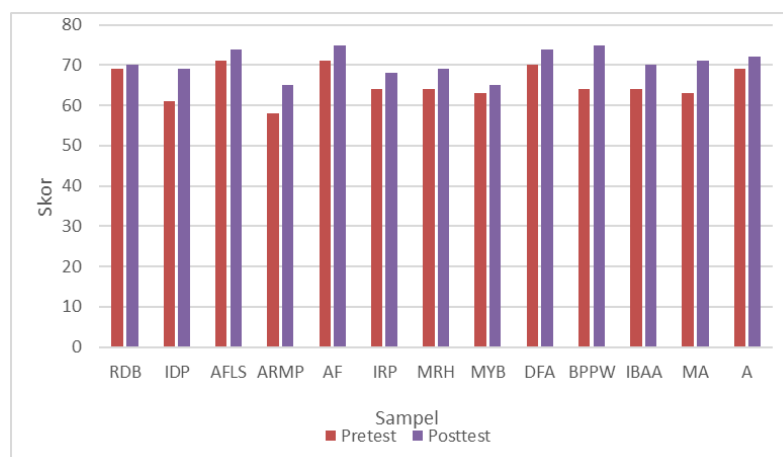


Figure 1. Pretest–Posttest Graph of Ball Speed Test Results for Male Handball Athletes in Bojonegoro District

Based on the graph in Figure 1, the highest pretest ball speed was recorded by participants AFLS and AF, both with a speed of 71 km/h. The lowest pretest result was recorded by participant ARMP, with a ball speed of 58 km/h. In the posttest, participants AF and BPPW achieved the highest ball speed, scoring 75 km/h, while the lowest posttest result was recorded by participant MYB, with a speed of 65 km/h. From the comparison of pretest and posttest scores, it can be observed that all participants experienced an increase in ball speed following the plyometric training intervention. This improvement is evident from the higher posttest scores compared to the pretest scores.

Table 1. Descriptive Statistics of Pretest and Posttest Ball Speed for Male Handball Athletes in Bojonegoro District

Data Description	Ball Speed Test	
	Pretest	Posttest
Mean	65,5	70,5
Median	64,0	70,0
Range	13,0	10,0
Minimum	58,0	65,0
Maximum	71,0	75,0
Standard Deviation	4,11	3,40

The descriptive analysis of the pretest results indicated a mean ball speed of 65.5 km/h, a median of 64.0 km/h, a range of 13.0 km/h, a minimum value of 58.0 km/h, a maximum value of 71.0 km/h, and a standard deviation of 4.11. For the posttest, the mean ball speed increased to 70.5 km/h, with a median of 70.0 km/h, a range of 10.0 km/h, a minimum value of 65.0 km/h, a maximum value of 75.0 km/h, and a standard deviation of 3.40 (see Table 1).

Normality Test Results

In this study, the Shapiro–Wilk test was used to assess data normality, with analysis performed using the SPSS Statistics 23 software. According to Sukestiyarno (2013), if the significance value of the Shapiro–Wilk test exceeds $\alpha = 0.05$, the null hypothesis (H_0) is rejected, indicating that the data are not normally distributed.

Table 2. Shapiro–Wilk Normality Test Results for Pretest and Posttest Ball Speed of Male Handball Athletes in Bojonegoro District

	Variable	Sig.
Ball Speed Test	Pretest	0,151
	Posttest	0,323

As shown in Table 2, the normality test results for both the pretest and posttest data indicate a normal distribution. The significance value for the pretest was 0.151 ($p > 0.05$), and for the posttest, it was 0.323 ($p > 0.05$). These values confirm that the data meet the assumption of normality.

Homogeneity Test Results

In this study, Levene’s test was used to assess data homogeneity. According to Arifin (2017:98), data are considered homogeneous if the significance value obtained from both *the pretest* and *posttest* is greater than 0.05.

Table 3. Levene’s Test Results for Homogeneity of Pretest and Posttest Ball Speed in Male Handball Athletes of Bojonegoro District

Variable	Levene-test	df1	df2	Sig.
Ball Speed Test	1,030	1	24	0,320

As shown in Table 3, the homogeneity test results indicate that the pretest and posttest data exhibit homogeneous variance. The significance value for the ball speed test was 0.320, which is greater than 0.05, indicating that the data meet the assumption of homogeneity.

Hypothesis Test Results

Hypothesis testing was conducted after confirming that the data were normally distributed and exhibited homogeneous variance. This hypothesis testing aimed to determine whether plyometric training had a significant effect on increasing ball speed during the flying shoot technique among male handball athletes in Bojonegoro District during the training-to-competition phase. The hypothesis was tested using a paired sample t-test. If the result of the significance value (*2-tailed*) $< 0,05$, the null hypothesis (h_0) is rejected, and the alternative hypothesis (h_a) is accepted, indicating a significant effect of plyometric training on ball speed. Athletes from Bojonegoro District are in the training-to-competition phase. Conversely, if the significance value. (*2-tailed*) $> 0,05$ hypothesis null (h_0) is accepted, and the alternative hypothesis (h_a) is rejected, indicating that plyometric training does not have a significant effect on increasing ball speed in the flying shoot technique among male handball athletes from Bojonegoro District in the training to compete phase.

Table 4. Paired Sample t-Test Results for Pretest–Posttest Ball Speed of Male Handball Athletes in Bojonegoro District

Variabel	Df	Sig. (2-tailed)
Ball Speed Test	12	0,000

Based on the hypothesis test results in Table 4, the significance value. (*2-tailed*) was $0,000 < 0,05$, indicating a statistically significant effect of plyometric training on ball speed. Therefore, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_a) is accepted. This confirms that plyometric training significantly improved ball speed in the flying shoot technique among male handball athletes during the training-to-compete phase.

Discussion

The findings of this study demonstrate that upper-extremity plyometric training, implemented over 9 weeks with high volume and intensity, significantly improved ball speed in the flying shoot technique among male handball athletes from Bojonegoro District during the training-to-competition phase. This conclusion is supported by the results of the hypothesis test, in which the paired sample t-test produced a significance value of $p < 0,05$. The results of the pretest and posttest ball speed tests were categorized using normative standards: 0-58

km/h = poor, 59-62 km/h = fair, 63-66 km/h = good, 67-70 km/h = very good, dan 71-100 km/h = excellent. Based on these criteria, the pretest scores revealed that 1 participant was categorized as poor, one as fair, six as good, three as very good, and two as excellent. In the posttest, improvements were evident, with 2 participants categorized as fair, eight as good, and three as very good. These results indicate a notable improvement in ball speed among the research participants, confirming that upper-body plyometric training is an effective method for enhancing the performance of the flying shot technique in handball athletes during the training-to-compete phase.

Plyometric training is a method that combines speed and strength to develop muscular power and reactive ability (Selcuk et al., 2018). Egan-Shuttler et al. (2017:2) further describe plyometric training as a practical approach to enhancing strength and speed within a short period. Moreover, plyometrics involve rapid and dynamic muscle contractions followed by a concentric shortening of the same muscle and connective tissues (Wang & Zhang, 2016). Traditionally, plyometric training has been more commonly applied to lower-body conditioning, as it comprises a variety of explosive movements that are well-suited for enhancing lower-limb power. However, in the present study, plyometric training was adapted to target upper-body muscles, specifically to enhance arm strength to increase ball speed in the flying shot technique. Given the statistically significant results of this study, plyometric training is also practical as an upper-body training method, especially in enhancing arm muscle strength. The effectiveness of this method in improving ball speed during the flying shoot lies in the core characteristics of plyometric exercises—rapid and forceful movements—which align well with the demands of handball, a sport characterized by robust and high-speed actions in both offensive and defensive phases (Karcher & Buchheit, 2014). Additionally, the dynamic and rapid nature of plyometric movements contributes to the improvement of upper-limb explosive power. This enhancement plays a vital role in increasing muscle strength, which is crucial for generating higher ball velocity in handball throwing performance (Cüre et al., 2020).

To achieve optimal training outcomes, a well-structured training program or periodization is essential. In alignment with Bompa and Haff (2009), periodization serves as a fundamental framework in planning both individual and team training programs. It outlines training targets and competition schedules, which are used to determine the appropriate methods and frequency of training required to achieve specific performance goals. According to this principle, the plyometric training implemented in this study was conducted over 9 weeks. This aligns with the findings of Chelly et al. (2014), who reported that an 8-week upper-body plyometric training program effectively improved throwing performance and upper-limb explosive power in handball athletes. The plyometric exercises incorporated in this study included ballistic six drills, elastic band resistance, and structured plyometric workouts, as described in the studies of Aloui et al. (2020), Dhauta & Bura (2014); Turgut et al. (2019) and training manual by Bompa & Haff (2009) '*Periodization: Theory and Methodology of Training*.' The training was conducted twice per week. From a methodological standpoint, strength and power training are recommended to be performed once to three times per week, depending on the training objectives, the athlete's schedule, and the competition calendar. A twice-per-week training frequency is considered ideal for plyometric training in well-conditioned athletes aiming to enhance muscular strength and power (Carter et al., 2007; Iacono et al., 2017).

The success of plyometric training in improving ball speed in this study can be attributed to its progressive volume and high intensity, which ranged from 80% to 90%. Plyometric training, which demands explosive power, typically involves 4 to 5 sets per session with short rest intervals of less than one minute (Bompa, 1999). This approach aligns with the recommendations of Balyi et al. (2016), who stated that the training-to-compete phase emphasizes individualized training with increased volume and intensity, maintaining a 40:60 training-to-competition ratio, provided that the training is implemented consistently. The effectiveness of the training program in this study highlights the importance of tailoring training interventions to the specific needs and conditions of the athletes. However, it is essential to acknowledge the study's limitations. One such limitation was the relatively small sample size, which posed logistical challenges

during the implementation phase of training. A critical issue arose from the application of plyometric methods within a team training setting, even though plyometric exercises are fundamentally designed for individual training (Michele, 2014). This mismatch in application may increase the risk of injury—particularly to the joints, muscles, and tendons—if exercises are performed improperly or without adequate preparation. Moreover, it may result in overtraining, fatigue, and, ultimately, a decline in physical performance if the athletes are not closely supervised during plyometric sessions (Booth & Orr, 2016).

In a study conducted by Cüre et al. (2020), upper-extremity plyometric training utilizing the ballistic six method—comprising the two-handed overhead throw, two-handed chest pass/diamond push-up, and 90/90 shoulder internal rotation—was found to be highly effective in enhancing throwing performance. Most movements in handball, particularly ball throwing, involve a combination of eccentric and concentric muscle contractions known as the stretch-shortening cycle (SSC). Consistent with these findings, Porter (2008) emphasized that, functionally, muscles are pre-stretched before a maximal concentric contraction. This is followed by a rapid transition from the eccentric to concentric phase, which helps stimulate proprioceptors and facilitates increased muscle recruitment within a short time frame. The application of plyometric training, which utilizes the stretch-shortening cycle, is crucial for developing explosive power in athletes. This is due to its ability to generate greater force output and promote enhanced power adaptations, making it particularly beneficial for improving performance in high-intensity sports such as handball.

CONCLUSIONS

Based on the results of this study, it can be concluded that plyometric training has a significant effect on increasing ball speed in the flying shoot technique among male handball athletes from Bojonegoro District during the training-to-compete phase. The statistical analysis yielded a significance value of $p < 0,05$, indicating that the null hypothesis (H_0) was rejected and the alternative hypothesis (H_a) was accepted. Therefore, plyometric training is an effective method for enhancing key physical performance elements in male handball

athletes from Bojonegoro District. This training approach may serve as a novel and beneficial strategy to improve explosive power and throwing velocity in handball performance.

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