

Effect of Plyometric Training on Smash Performance in Extracurricular Volleyball Students at SMP Negeri 3 Sembawa

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ABSTRACT

This research examines the effect of plyometric training on smash performance improvement in extracurricular volleyball students at SMP Negeri 3 Sembawa. Low smash ability marked by insufficient hitting power, directional inaccuracy, and attack ineffectiveness is the main problem in school extracurricular coaching. The research method used a quantitative experiment with a pre-experimental one-group pretest-posttest design. The sample consisted of 10 male students selected through purposive sampling with criteria of age 11–15 years and active participation in volleyball extracurricular activities for a minimum of six months. The treatment was a plyometric training program consisting of basic box jump, burpee, and depth jump for 16 sessions with a frequency of four times per week. Measurement instruments used a volleyball smash skill test with scoring technique toward target areas. Data analysis included Shapiro-Wilk normality test and paired sample t-test hypothesis testing using IBM SPSS 26. The results showed an increase in the average value from 9.80 (pretest) to 14.00 (posttest) with a percentage increase of 42.85%. The paired sample t-test obtained a value of $t = -31.500$, $p = 0.000$ (< 0.05), with Cohen's $d = 2.91$ effect size classified as very large. The conclusion indicates that plyometric training has a significant effect on improving smash performance in extracurricular volleyball students at SMP Negeri 3 Sembawa. This finding provides a recommendation for coaches and physical education teachers to integrate plyometric training programs systematically into smash technique training design.

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1. INTRODUCTION

Volleyball is a team sport that demands explosive physical components and high neuromuscular coordination in every phase of play. Biomechanically, the smash movement in volleyball involves a complex sequence of the stretch-shortening cycle (SSC) that requires simultaneous contribution of leg muscle strength, arm swing speed, and precise timing of ball contact at the highest point of the jump [1]. This skill is a primary determinant of attack success in modern volleyball, considering that each match requires execution of 200–400 jumps with high anaerobic intensity. In the context of school-age development, smash skill training becomes a strategic priority because it correlates directly with point productivity and game dominance above the net.

However, empirical observations in various extracurricular activities at junior high schools indicate that student smash ability is still relatively low. This condition is reflected in low jump height, weak hitting power, and high error rates in ball direction that make attacks easily anticipated by opponents. The main suspected cause is the suboptimal explosive power of leg muscles and the lack of specific and structured physical training programs to improve biomotor components supporting the smash [2]. This condition is exacerbated by the fact that extracurricular coaching in schools is generally conducted by physical education teachers without specific volleyball coaching backgrounds, so training programs tend to be general and do not adequately consider overload and specificity principles in explosive strength development.

Various studies in the last five years have confirmed the effectiveness of plyometric training in

improving physical components and technical skills in volleyball. Ramirez-Campillo et al. (2020) through a systematic meta-analysis showed that structured plyometric programs significantly improved vertical jump ability and agility in young volleyball athletes [1]. Similar findings were obtained by Raiola et al. (2025) who reported a 6.9% increase in vertical jump height ($p = 0.00$) in young non-elite athletes after undergoing an eight-week plyometric program, while the control group that only performed basic technical training showed no significant changes [2]. In the local context, Exmal and Candra (2025) reported a 51.14% improvement in smash ability in high school students after being given a plyometric training model for six weeks with $t = 7.404$ ($p < 0.05$) [3]. Another study by Qusyaeri and Rochman (2025) also verified that plyometric leg muscle training was able to improve vertical jump ability in SMK volleyball athletes from 24.53 cm to 29.27 cm [4].

From a biomechanical perspective, plyometric training works through the mechanism of stretch-shortening cycle optimization involving storage and release of elastic energy in tendons, increased contribution of stretch reflex, and more efficient motor unit recruitment [5]. This mechanism is specifically relevant to the smash movement which requires a rapid transition from the eccentric phase (body lowering before jumping) to the concentric phase (vertical push and arm swing). Recent studies using inertial measurement units (IMU) in athletes aged 13–14 years showed that an eight-week plyometric program not only increased countermovement jump (CMJ) height but also significantly improved take-off force, maximum concentric power, and peak speed compared to the control group [2]. This indicates neuromuscular adaptation and favorable force-velocity curve reorganization for explosive movement execution in volleyball.

Although literature has widely documented the benefits of plyometric training, there is a significant research gap in the context of implementation for junior high school students in rural areas with limited training facilities. Most existing studies were conducted on elite athletes, high school students, or used randomized controlled trial designs with control groups, which in practice are difficult to apply in school extracurricular settings with limited student numbers [3, 6, 7]. Furthermore, the specific combination of basic box jump, burpee, and depth jump as an integrated training program to improve smash results in junior high school students has rarely been systematically explored in national literature. The limitation of pre-experimental studies with a single group at the junior high school level also causes a lack of longitudinal data describing neuromuscular adaptation responses during late puberty.

The novelty of this research lies in the application of a plyometric training program designed specifically for junior high school students considering biological maturation levels and limited field infrastructure. This study tests the effectiveness of a combination of three types of plyometric training—each targeting different dimensions of explosive power (box jump for vertical strength, burpee for coordination and endurance, and depth jump for neuromuscular reactivity)—in one integrated program to improve smash results. This approach contributes to the development of a feasible and practical training model for physical education teachers in school extracurricular settings.

Based on the above description, the purpose of this research is to examine and analyze the effect of plyometric training on the improvement of smash performance in extracurricular volleyball students at SMP Negeri 3 Sembawa. This research is expected to provide empirical evidence for the development of specific and sustainable physical training programs in junior high school volleyball extracurricular coaching.

2. METHOD

2.1. Research Design

This research used a quantitative approach with a pre-experimental one-group pretest-posttest design. This design was chosen considering the limited population of extracurricular students who met the inclusion criteria, so allocation of a control group was not practically feasible. This design allowed measurement of changes in the dependent variable (smash performance) before and after the plyometric training intervention on the same group of subjects [8].

2.2. Participants

The research population was all extracurricular volleyball students at SMP Negeri 3 Sembawa totaling 20 students (10 males and 10 females). The sampling technique used purposive sampling with inclusion criteria: (a) male students aged 11–15 years, (b) actively participating in volleyball extracurricular activities for a minimum of six months, (c) not experiencing musculoskeletal injuries to the legs and lower back in the last three months, and (d) willing to follow all training sessions and measurement procedures. Based on these criteria, a sample of 10 male students was obtained. The consideration for selecting male students was based on the homogeneity of biomotor components and relatively uniform maturation levels, as well as the availability of samples meeting all inclusion criteria [9].

2.3. Instruments

The measurement instrument in this research was a volleyball smash skill test referring to a modification of the spike test from Bobby Agustan (2021) [5]. The test procedure was as follows: (a) the subject

stood in the attack area or free zone in the playing field; (b) the ball was tossed or passed near the net toward the subject; (c) the subject jumped and hit the ball over the net to the court area across the net that had been determined as targets with different scores. Scoring was based on the target area successfully touched by the ball with the highest score. Each subject was given four hitting opportunities, and the total score was calculated from the sum of the scores of the four opportunities. This test has been validated to measure smash accuracy and power simultaneously in the context of volleyball play [5].

In addition to the smash test, anthropometric component and basic physical condition measurements were conducted as descriptive data. However, the main variable measured in pretest and posttest was the total score of the smash test.

2.4. Procedures

The plyometric training program was conducted for four weeks with a total of 16 sessions (frequency four times per week: Tuesday, Thursday, Saturday, and Sunday, at 15.00–16.30 WIB). Each training session was structured in three phases: (a) warm-up for 10–15 minutes including jogging, dynamic stretching, and neuromuscular activation; (b) core plyometric training for 30–40 minutes; and (c) cool-down for 5–10 minutes with static stretching and relaxation [10].

The core training program consisted of three types of plyometric exercises that were rotated progressively:

Basic Box Jump: The subject stood behind a box with feet shoulder-width apart, knees slightly bent, then jumped onto the box with both feet simultaneously. This exercise aimed to increase explosive power of the gluteus, quadriceps, and hamstring muscles [11].

Burpee: A sequence of movements starting from a standing position, squatting with hands on the floor then throwing feet back to a push-up position, returning to a squat position, and jumping vertically with both hands swung upward. This exercise trained total body coordination, endurance, and explosive strength [12].

Depth Jump: The subject stood on a box or platform at a height of 30–40 cm, stepped down (not jumped), and immediately after both feet touched the floor, jumped vertically as high as possible. This exercise was designed to improve stretch-shortening cycle reactivity and explosive leg muscle strength [13].

Volume and intensity were increased progressively every week. The first week started with 2 sets $\times$ 8 repetitions for each type of exercise, increasing to 3 sets $\times$ 10–12 repetitions in the fourth week. Rest between sets was set at 60–90 seconds to ensure partial recovery and maintain movement execution quality [9].

2.5. Data Analysis

Data analysis was conducted using IBM SPSS Statistics version 26. Normality tests of pretest and posttest data were performed using the Shapiro-Wilk test considering the sample size was less than 50. The normality criterion was set if the significance value (p) $>$ 0.05 [8]. After data were proven normally distributed, hypothesis testing was conducted using paired sample t-test at a significance level of $\alpha = 0.05$. The testing criterion was: if the p -value $<$ 0.05 then the alternative hypothesis (H_a) was accepted and the null hypothesis (H_0) was rejected, meaning there was a significant effect of plyometric training on smash performance [12].

In addition, effect size was calculated using Cohen's d with the formula $d = (M_2 - M_1) / SD_{\text{pooled}}$, where SD_{pooled} is the pooled standard deviation of pretest and posttest. Effect size classification referred to Cohen's criteria: small (0.20–0.49), medium (0.50–0.79), large (0.80–1.19), and very large ($>$ 1.20) [8].

3. RESULTS AND DISCUSSION

3.1. Descriptive Statistics

The research results showed an increase in smash test scores in all samples after undergoing the plyometric training program for 16 sessions. A summary of descriptive statistics is presented in Table 1.

Table 1. Descriptive Statistics of Smash Test Pretest and Posttest Results (N = 10)

Statistic	Pretest	Posttest
Mean	9.80	14.00
Median	10.00	14.00
Mode	10	14
Standard Deviation	1.398	1.491
Minimum	8	12
Maximum	12	17

Based on Table 1, the average smash test score increased by 4.20 points (42.85%) from pretest ($M = 9.80$; $SD = 1.398$) to posttest ($M = 14.00$; $SD = 1.491$). This increase indicates that all subjects experienced consistent smash ability improvement after the intervention. The score distribution in the pretest showed that most subjects were in the range of 8–11, while in the posttest all subjects were in the range of 12–17, indicating a shift in ability from beginner level to intermediate level [3].

3.2. Assumption Test

Normality testing using Shapiro-Wilk was conducted to ensure the normality assumption of data before proceeding with parametric tests. The normality test results are presented in Table 2.

Table 2. Shapiro-Wilk Normality Test Results

Variable	Statistic	df	Significance	Description
Pretest	0.875	10	0.115	Normal
Posttest	0.918	10	0.338	Normal

The test results showed that the significance value for pretest data was 0.115 and posttest was 0.338, where both values were greater than $\alpha = 0.05$. Thus, the null hypothesis in the normality test was accepted, and pretest and posttest data were declared normally distributed. This finding met the assumption to proceed with paired sample t-test analysis [8].

3.3. Hypothesis Testing

Hypothesis testing was conducted using paired sample t-test to test significant differences between pretest and posttest smash scores. The hypothesis testing results are presented in Table 3 and Table 4.

Table 3. Paired Samples Descriptive Statistics

Variable	Mean	N	Standard Deviation	Standard Error Mean
Pretest	9.80	10	1.398	0.442
Posttest	14.00	10	1.491	0.471

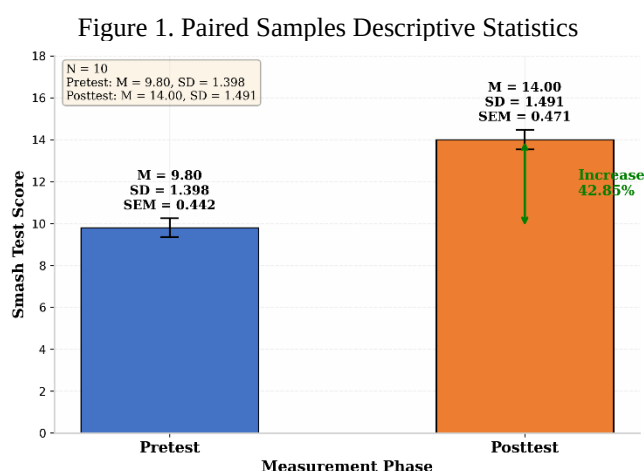


Table 4. Paired Samples t-test Results

Variable	Mean Difference	Std. Deviation Difference	t	df	Sig. (2-tailed)	Cohen's d
Pretest – Posttest	-4.200	0.422	-31.500	9	0.000	2.91

The analysis results showed a t-value = -31.500 with degrees of freedom (df) = 9 and significance value (2-tailed) = 0.000. Because the p-value < 0.05 , the null hypothesis (H_0) was rejected and the alternative hypothesis (H_a) was accepted. This means there is a significant effect of plyometric training on the improvement of smash performance in extracurricular volleyball students at SMP Negeri 3 Sembawa [12].

From the effect size perspective, the Cohen's d value = 2.91 indicates a very large effect size, which indicates that the plyometric training program given had a substantial and practically meaningful impact on improving student smash ability beyond statistical significance [8].

3.4. Discussion of Findings

This research verifies that a structured plyometric training program for four weeks (16 sessions) provides a significant increase in smash performance of extracurricular volleyball students at SMP Negeri 3 Sembawa. The average increase of 42.85% with a very large effect size (Cohen's d = 2.91) indicates that the intervention is not only statistically significant but also has high practical relevance in the context of volleyball technical skill development. This finding is in line with the principle of specificity in sports training, where specific physical

stimulation given to explosive leg movement patterns was successfully transferred into improved smash performance [9, 10].

The improvement in smash results can be explained through stretch-shortening cycle (SSC) theory and neuromuscular adaptation due to plyometric training. Physiologically, box jump, burpee, and depth jump demand rapid eccentric contraction followed by explosive concentric contraction with minimal amortization phase. This mechanism stimulates muscle spindles and Golgi tendon organs to increase rate of force development (RFD) and type II motor unit recruitment [5]. Recent studies show that horizontal and vertical plyometric training is able to increase leg stiffness and optimize elastic energy storage in tendons, contributing to increased vertical propulsion speed and jump height [1]. In the context of the smash, increased leg muscle explosive power allows players to reach a higher ball contact point, resulting in a sharper attack angle and higher ball speed [13].

Furthermore, depth jump integrated in the training program facilitates neuromuscular reactivity adaptation through the reactive strength index (RSI) mechanism. Decreased ground contact time followed by maximum vertical jump reflects increased efficiency of agonist-antagonist leg muscle coordination. This adaptation specifically supports the approach and push-off phases in the smash movement, where players must convert horizontal momentum from the approach into vertical momentum in a short time [2, 11].

3.5. Comparison with Previous Studies

The findings of this research support and expand previous research results both in national and international contexts. In the national research context, Kurniawan and Ramaddan (2025) reported that plyometric training had a significant effect on smash performance in extracurricular volleyball at SMA Negeri 1 Luragung with $t = 3.89$ ($p < 0.05$) [6]. Rahayu and Mardiana (2022) also found significant increases in smash accuracy (6.00%) and smash movement (22.0%) after plyometric intervention in high school students [7]. Widodo and Junianto (2023) reported that plyometric training was more effective than hurdle jumping in improving jumping smash ability in junior high school students [8]. Research by Exmal and Candra (2025) at SMA Negeri 18 Pekanbaru showed a 51.14% improvement in smash ability with $t = 7.404$ [3]. The findings of this research are consistent with these studies but provide contribution to a younger population (junior high school) with a more feasible pre-experimental design for application in school extracurricular settings.

In the international context, Ramirez-Campillo et al. (2020) through systematic review and meta-analysis showed that plyometric jump training significantly improved jump and agility abilities in young volleyball players [1]. Raiola et al. (2025) reported that the experimental group undergoing plyometric training showed a 2.08 cm (6.9%) increase in vertical jump in young non-elite volleyball athletes, while the control group showed no significant changes ($p = 0.47$) [2]. Recent biomechanical studies on athletes aged 13–14 years using the G-Walk inertial system showed an increase in CMJ height of 3.88 cm, take-off force of 0.12 kN, and maximum concentric power of 5.82 kW after eight weeks of plyometric training [2]. Another study by Ikadarny and Hanafi (2024) also confirmed the significant contribution of plyometric training to jumping ability in volleyball [14]. The findings of this research are relevant to these international studies, with strength in the effectiveness of a short program (four weeks) that is able to produce a very large effect size in a junior high school population.

3.6. Practical and Theoretical Implications

The results of this study have several important implications, both practically and theoretically:

Theoretical Implications: This research strengthens literature on the effectiveness of stretch-shortening cycle training during late puberty (age 11–15 years), where the neuromuscular system shows high plasticity to explosive training stimulation [1, 5]. This study confirms that the stretch-shortening cycle mechanism is the main physiological pathway in improving explosive leg muscle power that supports volleyball smash technical skills.

Practical Implications: This research develops a feasible plyometric training model with short duration (16 sessions) and minimal equipment (a simple box or bench) that can be implemented by physical education teachers in schools with limited facilities [10]. This model proves that improvement in smash technical skills does not always require sophisticated equipment, but rather consistency and progressivity in neuromuscular stimulation. For coaches and physical education teachers, this program can be integrated into volleyball extracurricular training sessions as a specific physical conditioning component. The significant improvement in smash results in a short time (four weeks) shows that plyometric training is an efficient intervention for inter-school competition preparation [3, 6].

Psychosocial Implications: The increase in student self-confidence observed during the intervention—seen from the courage to jump higher and hit harder—indicates that plyometric training also provides psychosocial benefits in the form of increased self-efficacy in technical skill execution [9].

4. CONCLUSION

This research has successfully examined the effectiveness of a plyometric training program in improving smash performance in extracurricular volleyball students at SMP Negeri 3 Sembawa. The results showed that plyometric training provided a significant effect with an average increase of 42.85% and a very large effect size (Cohen's $d = 2.91$). The program consisting of basic box jump, burpee, and depth jump for 16 sessions proved to be effective in improving student smash ability. The main mechanism behind this finding is neuromuscular adaptation through stretch-shortening cycle optimization and increased leg muscle explosive power.

An important finding of this research is that a short-duration plyometric program (four weeks) with simple equipment can produce very large effect sizes in a junior high school population. Although this study used a pre-experimental design without a control group, the very large effect size and high statistical significance provide strong empirical evidence of the practical benefits of this intervention.

Overall, this research contributes significantly to the development of a more practical and feasible physical training model for school extracurricular volleyball coaching. The findings have valuable practical implications for physical education teachers, extracurricular coaches, and sports curriculum developers, particularly in decision-making regarding physical conditioning programs that require minimal facilities but provide maximum results. Future research could explore randomized controlled trial designs with control groups, larger sample sizes, longer intervention durations (8–12 weeks) with follow-up measurements, and integration of biomechanical measurements such as force platforms or motion capture to analyze adaptation mechanisms more deeply.

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