

The Effect of Adding Lower-Body Plyometric Exercises to the Routine Training of TNI Soldier Trainees on Vertical Jump Height

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HOW TO CITE:

Handia, Ditaruni Asrina Utami, Inggar Narasinta, Soenarnatalina Melaniani (2026). The Effect of Adding Lower-Body Plyometric Exercises to the Routine Training of TNI Soldier Trainees on Vertical Jump Height. International Journal of Special Education, 41(25s), 54 - 61

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ABSTRACT:

Background: Military training requires optimal lower-extremity muscle power, which can be reflected in vertical jump height. However, routine training does not always specifically target explosive muscle strength. Plyometric training, utilizing the stretch-shortening cycle, is known to enhance muscle power and jumping performance.

Objective: To determine the effect of additional lower extremity plyometric training on vertical jump height in military trainees.

Methods: This study was a randomized controlled experimental trial with a pre- and post-test design. The study was conducted at Kodiklatal Surabaya from June to August 2025. We randomly assigned 24 male military trainees aged 18–24 years to two groups: an intervention group (n=12), which received additional plyometric training twice per week for six weeks, and a control group (n=12), which received routine training only (waitlist control). The primary outcome was vertical jump height. We analyzed data using paired t-tests and independent t-tests.

Results: The intervention group showed a significant increase in vertical jump height from 39.88 ± 7.71 cm to 45.97 ± 4.40 cm ($p=0.002$). Post-intervention comparison between groups revealed a statistically significant difference with a moderate effect size ($ES=1.15$).

Conclusion: Additional plyometric training performed twice weekly for six weeks significantly improves lower extremity muscle power, as reflected by vertical jump height, in male military trainees. This training is safe, practical, and requires no specialized equipment, making it suitable for military training programs.

Keywords: plyometric training, vertical jump, muscle power, military training, lower extremity

1. Introduction

TNI military training demands various physical capabilities, such as carrying heavy loads over long distances and across rugged terrain, running on uneven ground or in zig-zag patterns, navigating obstacles, climbing, jumping, and conducting military operations under diverse conditions. The speed and precision with which soldiers perform these activities can influence their effectiveness and combat endurance. Optimal physical performance in these environments requires strength, speed, and agility.^{1,2,3}

Soldier capabilities comprise several key physical components, including strength, power, and muscular endurance. Aerobic and anaerobic capacities, along with body composition, also support performance. Power—or explosive strength—receives particular attention, as it is a target in various soldier training protocols designed to enhance specific performance in the ACFT.^{3,4} Power is defined as the ability of a muscle or muscle group to generate force within a short period. In physiological terms, power is the product of force and movement velocity. In military and athletic activities, the ability to perform tasks rapidly and explosively—such as jumping, sprinting, dragging, or sudden lifting—relies heavily on power.⁵ The vertical jump, as an explosive movement, can serve as an indicator of maximal lower-limb muscle strength, providing valuable information regarding functional capacity.⁶ Furthermore, lower-limb strength is crucial for running, striding, sprinting, rapid changing of direction, and jumping. Frequency, duration, volume, follow-up periods, exercise order, and rest intervals are considered essential elements of lower-limb strength training.⁷

Various studies have assessed the effectiveness of military training, particularly in developed nations. A study by Cannon et al. (2024) on the physical training of Army Reserve Officers' Training Corps (ROTC) cadets—aimed at

preparing them for the Army Combat Fitness Test (ACFT)—demonstrated positive results, especially regarding the 2-Mile Run (2-MR) performance. Other studies indicate that mandatory military basic training in Singapore effectively enhances cardiopulmonary function and physical performance among conscripts.^{3,8} In Indonesia, however, there is currently no data regarding the effectiveness of the physical training undertaken by TNI soldiers.

The United States (US) Army's Joint Physical Training Injury Prevention Working Group (JPTIPWG) recommends including multi-axial, neuromuscular, proprioceptive, and agility exercises as routine components of military physical training programs. The JPTIPWG indicates that increasing the proportion of physical training time dedicated to exercises that vary musculoskeletal stress across different planes—such as agility training—can reduce the risk of injury.⁹

Military physical training encompasses running, calisthenics, obstacle courses, strength training, military martial arts, and wall and rope climbing techniques. As a result, peak performance requires strength, speed, and agility. Plyometric training—a mode of exercise designed to enhance explosive power—was first introduced by Verkhoshansky. These exercises involve rapid, explosive movements that improve speed, agility, balance, and coordination. They utilize powerful movements characterized by an eccentric contraction immediately followed by a rapid, explosive concentric contraction—a process achieved through the stretch-shortening cycle (SSC) or the eccentric-concentric coupling phase. These movements enhance agility by leveraging SSC-related neuromuscular adaptations to increase lower-limb muscle power. By strengthening muscles and connective tissues, plyometric training improves strength, stability, and resilience, thereby minimizing injury risk. Various studies show that plyometric training significantly enhances muscle strength and

physical performance, particularly in the lower limbs, which are used in explosive movements like jumping and running that involve rapid stretching and contraction. Research by Markovic (2007) found that plyometric training significantly increases vertical jump height (an SSC-based movement) by enhancing the subject's ability to utilize the elastic and neural benefits of the SSC.

In military training, plyometric exercises have proven beneficial for enhancing soldiers' physical capabilities by accelerating reaction times and increasing the explosive power of the leg muscles.¹⁴ Both plyometric and strength training are recognized as essential components of fitness programs and serve as safe methods for improving explosive performance.¹⁵ Beyond their proven positive impact on maximal power, sprint speed, and agility, plyometric exercises also aid in injury prevention by improving landing mechanics and optimizing the quadriceps-to-hamstring strength ratio.¹⁶ Consequently, plyometric training can be integrated with other military physical training programs to enhance physical endurance and optimize overall body strength. Therefore, plyometric training is highly relevant for implementation in TNI soldier physical training, particularly for developing the leg strength required to support physical activities in demanding and challenging terrain.

2. Methodology

This study uses a true experimental design with a Randomized Controlled Group Design—specifically, a two-group pre- and post-test design—to compare the treatment group with the control group. Before the study, researchers assessed subjects' maximum vertical jump height (pre-test) and measured it again (post-test) in the sixth week after the intervention. The study was conducted from June 2025 to August 2025 at Kodiklat (Naval Education and Training Command) in Surabaya.

The study subjects were male TNI soldiers aged 18–24 years undergoing initial training who met the inclusion criteria and did not meet the exclusion criteria. The inclusion criteria were:

male gender, age 18–24 years, and willingness to participate, as indicated by signing the informed consent form. Meanwhile, the exclusion criteria were: a history of or current treatment for musculoskeletal conditions (e.g., fractures, tendon ruptures, ligament ruptures, muscle ruptures, and knee joint hypermobility); a history of or current treatment for neurological disorders (e.g., epilepsy, vertigo, movement disorders, spinal cord trauma, and brain trauma); a history of or current treatment for cardiovascular and respiratory diseases (e.g., asthma, heart disease, and vascular disease); and a history of or current therapy for other conditions that could be affected by the intervention, such as psychiatric disorders.

This study used an ABN sphygmomanometer, a Littmann stethoscope, a OneMed pulse oximeter, a metronome, a wall-mounted measuring tape, a chair, a OneMed body weight scale, a Krisbow measuring tape, adhesive tape, writing instruments, a stopwatch, and a goniometer. The research procedure involved the following steps: subjects were divided into a treatment group and a control group; maximum vertical jump height was measured for both groups prior to the exercise intervention; the treatment group underwent a 6-week plyometric exercise intervention, while the control group received no intervention; and maximum vertical jump height was measured again for both groups.

Data analysis for statistical testing was performed using SPSS. We used descriptive analysis to characterize the study subjects. We tested normality with $\alpha < 0.05$ for ratio-scale data; we used parametric tests if the data were normally distributed ($p \geq 0.05$) and non-parametric tests if they were not ($p \leq 0.05$). We used paired t-tests to compare vertical jump heights before and after the intervention within each group, or the Wilcoxon Signed-Rank Test if parametric assumptions were not met. We also compared vertical jump heights before and after the intervention between the two groups, using the independent t-test if parametric assumptions were met, or the Mann-Whitney U test if they were not.

3. Results

A descriptive analysis of participant characteristics—including age, body weight,

height, and BMI—was conducted on the 24 study samples. The 24 participants were divided into two groups: 12 in the control group and 12 in the treatment group.

Table 1. Descriptive Analysis of Research Subject Characteristics

	n	Control Group (Mean $\pm$ 2SD)		Treatment Group (Mean $\pm$ 2SD)	
		Mean	<i>p value</i>	Mean	<i>p value</i>
Age	12	20.08 $\pm$ 0,83	0,056	20.83 $\pm$ 0, 90	0,30
Weight	12	64.75 $\pm$ 6,41	0,671	64.63 $\pm$ 6,41	0,018 ^a
Height	12	170.17 $\pm$ 3,71	0,652	171.25 $\pm$ 2,99	0,597
Body Mass Index	12	22.32 $\pm$ 1,60	0,814	22.02 $\pm$ 1,05	0,123
Total Leg Length Dextra	12	90.00 $\pm$ 3,46	0,724	90.00 $\pm$ 3,33	0,465
Total Leg Length Sinistra	12	90.00 $\pm$ 3,46	0,734	90.00 $\pm$ 3,33	0,465

*Data are presented in the form of mean $\pm$ standard deviation (SD). The value of *p* is significant if $p < 0.05$

In the control group, the mean age was 20.08 $\pm$ 0.83 years (range: 19–22 years), whereas in the treatment group, the mean age was 20.83 $\pm$ 0.90 years (same range). Mean body weight was 64.75 $\pm$ 6.41 kg in the control group and 64.63 $\pm$ 6.41 kg in the treatment group. Mean height was 170.17 $\pm$ 3.71 cm in the control group and 171.25 $\pm$ 2.99 cm in the treatment group. Mean BMI was 22.32 $\pm$ 1.60 kg/m² in the control group and 22.02 $\pm$ 1.05 kg/m² in the treatment group; both values generally fall within the normal BMI category.

The mean values for right and left lower limb length (Total Leg Length/TLL) were relatively similar across both groups. In the control group, the mean right and left TLL were 90.00 $\pm$ 3.46 cm, while in the treatment group, they were 90.00 $\pm$ 3.33 cm; this indicates symmetry in lower limb length between sides and similarity in anthropometric characteristics between the groups.

Table 2. Comparison of vertical jump height before (pretest) and after (posttest) in the intervention group.

Group	Lowest score	Highest score	Mean ($\pm$ SD)	Pair <i>t</i> -test	Effect size
Pretest	25.8	50.5	39,88 $\pm$ 7,71	0,002	1,15
Posttest	39.0	54.0	45,97 $\pm$ 4,40		

*nilai signifikan *P-value* <0.05

Vertical jump height in the intervention group increased from 39.88 $\pm$ 7.71 at pretest to 45.97 $\pm$ 4.40 at posttest. This mean increase of 6.09 indicates improved performance following the intervention. Paired *t*-test results demonstrated that the difference was statistically significant ($p = 0.002$; $p < 0.05$).

Table 3. Comparison of vertical jump height before (pretest) and after (posttest) in the control group.

Group	Lowest score	Highest score	Mean ($\pm$ SD)	Pair <i>t</i> -test	Effect size
<i>Pretest</i>	33.2	55.0	41,79 $\pm$ 6,91	0,421	0,24
<i>Posttest</i>	34.1	52.2	42,750 $\pm$ 5,80		

The mean vertical jump height for the pretest group was 41.79 ± 6.91 , whereas in the posttest, it increased to 42.75 ± 5.80 . Although the mean increased by 0.96, the paired *t*-test showed the difference was not statistically significant ($p = 0.421$; $p > 0.05$).

Table 4. Comparison of Vertical Jump Height Between the Intervention and the Control Group

Group	Pretest	Posttest	Pair <i>t</i> -test
Intervention	39,88 $\pm$ 7,71	45,97 $\pm$ 4,40	0,002 ^a
Control	41,79 $\pm$ 6,91	42,750 $\pm$ 5,80	0,421

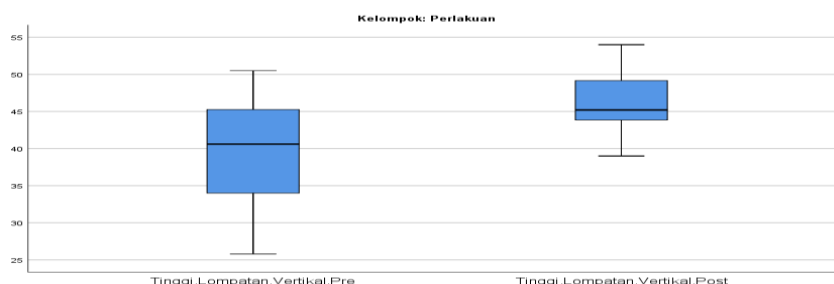
*Data are presented in the form of mean $\pm$ standard deviation (SD). The value of *p* is significant if $p < 0.05$

Vertical jump height was measured twice: before the intervention (week 0) and after six weeks of training (week 7). Table 5.4 shows that the control group had no significant change in vertical jump height between week 0 and week 7; the mean $\pm$ SD was 41.79 ± 6.91 at week 0 and 42.75 ± 5.80 at week 7 ($p = 0.421$). In contrast, the treatment group showed an increase in vertical jump height, with mean $\pm$ SD values of 39.88 ± 7.71 at week 0 and 45.97 ± 4.40 at week 7, indicating a significant difference ($p = 0.002$).

Table 5. Comparison Between Groups After 6 Weeks of Plyometric Training

	Intervention Group	Control Group	Independent <i>t</i> -test	Effect Size
Tinggi lompatan Vertikal	45.9 $\pm$ 4.40	42.75 $\pm$ 5.80	0.011 ^a	0.625 ^c

*Data are presented as mean $\pm$ standard deviation (SD). ^aThe *p*-value is significant if $p < 0.05$. Effect size values of b0.2–0.49 are considered small, c0.5–0.79 are considered medium, and d>0.8 are considered large.

Figure 1. Boxplot of vertical jump height for the control and intervention groups at pre-test and post-test.

The mean vertical jump height in the treatment group was higher (45.9 ± 4.40) than in the control group (42.75 ± 5.80). An independent *t*-test comparing the treatment and control groups

revealed a significant difference ($p = 0.011$; $p < 0.05$). The effect size of 0.625 indicates a moderate effect of plyometric training, suggesting that the intervention meaningfully

increased vertical jump height compared to the control group.

Based on the boxplot in Figure 5.1, values increased following the intervention. The median vertical jump height was approximately 40 cm at pre-test and rose to around 45 cm at post-test. These findings indicate that the intervention can improve vertical jump performance and increase performance consistency among the research subjects.

4. Discussion

Equivalence in these baseline characteristics is crucial in experimental research to ensure subjects start from comparable conditions; this increases the likelihood that any changes observed after the intervention result from the treatment itself rather than pre-existing differences between groups.¹⁷ However, a statistically significant difference in body weight was observed in the treatment group. Theoretically, body weight can influence vertical jump performance, as jumping ability depends on the ratio of leg muscle strength to body mass. Greater body mass increases the load lifted during the propulsion phase, requiring greater force to achieve optimal jump height. If an increase in body weight is not matched by a corresponding increase in muscle strength, jump performance may decline.¹⁸ The stretch-shortening cycle (SSC) is a crucial physiological mechanism supporting explosive performance in sports such as running and jumping. The SSC comprises three phases: active muscle stretching (eccentric), a brief transition with no change in muscle length (amortization), and active muscle contraction (concentric). Efficient SSC activation increases propulsive force, power, and metabolic efficiency during movement, making it vital for complex motor skills.¹⁹

Physiologically, increased jump height after an intervention can be attributed to neuromuscular adaptations, enhanced motor unit activation, improved intermuscular coordination, and an optimized stretch-shortening cycle. These adaptations enable muscles to generate greater force in less time, thereby increasing velocity and propulsive capability during the jump. Current

literature indicates that training targeting strength and power—including plyometric and resistance training—consistently improves vertical jump performance.²⁰ These findings align with a meta-analysis by Ramirez-Campillo et al. involving volleyball athletes, which demonstrated that plyometric jump training has a moderate effect on vertical jump height (effect size 0.82; $p < 0.001$). These results indicate that systematic explosive training can yield measurable adaptations in jumping ability.^{21,22}

The control group's lack of significant change may also reflect the absence of specific exercise stimuli aimed at enhancing lower-limb strength and power. Evidence from various meta-analyses indicates that improvements in jump height are generally associated with training interventions that specifically target strength and power capabilities—such as plyometric training, resistance training, or a combination of both. For instance, a meta-analysis by Ramirez-Campillo et al. showed that plyometric jump training increased jump height compared with a control group.²³ One factor requiring consideration is the familiarization or learning effect. Participants may become more accustomed to the vertical jump technique by the time of the second measurement, potentially leading to post-test results that differ slightly from pre-test results, even in the absence of substantial physiological changes. However, research on vertical jump reliability indicates that jump height measurements can be reliable, with some protocols showing no significant systematic learning effect.²⁰ More recent studies on the countermovement vertical jump have also specifically evaluated the potential for a short-term learning effect; thus, the aspect of familiarization warrants attention when interpreting pre-test to post-test changes.²¹

These findings are reinforced by a more recent meta-analysis. Ma et al. (2025) reported that, compared with routine training, plyometric training increased vertical jump height by about 5.2 cm, whereas weight-resistance exercise increased it by about 9.9 cm. For the countermovement jump, plyometric, weight-

resistance, and complex training also improved performance compared with routine training.²⁴ These results indicate that training stimuli specifically targeting strength and power can yield greater performance gains than routine activities performed without a specific training program.

The literature also indicates that the magnitude of the training response can be influenced by exercise type. A meta-analysis by Moran et al. showed that both vertically and horizontally oriented plyometric training can improve vertical performance, with no significant difference between the two orientations in vertical jump outcomes.²⁵ Other research

involving active individuals showed that resisted plyometric training resulted in greater improvements in jump height compared to an active control under certain conditions (ES = 1.06).²⁶

5. Conclusion

Vertical jump height did not increase before and after routine training in TNI student soldiers. Vertical jump height increased before and after plyometric training in TNI student soldiers. Vertical jump height increased after plyometric training compared with those who did not receive plyometric training in TNI student soldiers.

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