



## The Effect Of Plyometric Training (Box Jump) On Leg Muscle Strength In Volleyball Players

Sandra<sup>1A-E\*</sup>, Kamarudin<sup>2B-D</sup>, Andi Saparia<sup>3B-D</sup>, Moh Usbah<sup>4B-D</sup>

<sup>1,2,3</sup> Universitas Tadulako, Sulawesi Tengah, Indonesia

[ssandra0210@icloud.com](mailto:ssandra0210@icloud.com)<sup>1\*</sup>, [kama050587@gmail.com](mailto:kama050587@gmail.com)<sup>2</sup>, [sapariaandi@gmail.com](mailto:sapariaandi@gmail.com)<sup>3</sup>, [muh\\_usba@yahoo.com](mailto:muh_usba@yahoo.com)<sup>4</sup>

### ABSTRACT

Lower-limb muscle strength is one of the most important physical components in volleyball because it directly influences athletes' ability to perform explosive movements such as jumping, spiking, blocking, and jump serving. However, observations at KKS Bambalamotu Volleyball Club indicated that the players' leg muscle strength had not yet reached an optimal level, necessitating an effective training intervention. Therefore, this study aimed to determine the effect of plyometric (box jump) training on lower-limb muscle strength among volleyball players at KKS Bambalamotu Club. This study employed an experimental method using a one-group pretest-posttest design. The population consisted of 12 volleyball players from KKS Bambalamotu Club, all of whom were selected as research participants through a total sampling technique. Lower-limb muscle strength was measured using a vertical jump test administered before and after the intervention. The plyometric box jump training program was conducted for six weeks with a training frequency of three sessions per week. Data were analyzed using a paired-samples t-test at a significance level of 0.05. The results revealed a significant improvement in lower-limb muscle strength following the training program. The total pretest score increased from 2,318 to 2,460 in the posttest, with a mean improvement of 11.08 points. Hypothesis testing showed a calculated t-value of 79.14, which was substantially higher than the critical t-table value of 1.796. These findings indicate that the alternative hypothesis was accepted and the null hypothesis was rejected. In conclusion, plyometric box jump training significantly improves lower-limb muscle strength among volleyball players and can be recommended as an effective conditioning method to enhance volleyball performance.

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A. Conception and design of the study;  
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## INTRODUCTION

Education plays a strategic role in improving the quality of human resources and strengthening a nation's competitiveness in the era of globalization. Through education, individuals develop knowledge, skills, attitudes, and character that enable them to contribute productively to society and national development. In addition, educational processes support the development of physical, cognitive, affective, and psychomotor



competencies that are essential for lifelong achievement and well-being (Saely & Shaleh, 2023; UNESCO, 2023). Within this framework, physical education and sports constitute an integral component of educational systems because they contribute not only to physical fitness but also to character building, teamwork, discipline, leadership, and resilience (Rohmansyah, 2023; Bailey et al., 2021).

Volleyball is one of the most popular team sports worldwide and requires a combination of technical, tactical, physiological, and psychological capacities. Successful volleyball performance depends heavily on players' ability to execute fundamental skills such as serving, passing, spiking, and blocking effectively (Jamil et al., 2022). Among these skills, spiking and blocking are particularly dependent on lower-limb strength and explosive power because players must repeatedly perform high-intensity jumps throughout a match (Risma et al., 2024). Modern volleyball is characterized by rapid transitions, explosive movements, and repeated jumping actions that place substantial demands on the neuromuscular system (Sheppard et al., 2020).

Lower-limb muscle strength is therefore a critical physical component for volleyball athletes. Strong leg muscles enable athletes to generate greater force against the ground, resulting in higher jumps, faster movements, and improved stability during offensive and defensive actions (Remora & Suhdy, 2023). Athletes with inadequate leg strength often demonstrate reduced jump height, slower reaction time, and diminished effectiveness during blocking and attacking situations (Cormie et al., 2021). A preliminary survey conducted among volleyball players at KKS Bambalamotu Club revealed that the athletes' lower-limb muscle strength remained at a moderate level and had not yet reached optimal performance standards. The athletes exhibited limited jumping ability and insufficient explosive power during training and competition activities. Such conditions may negatively influence competitive performance and limit the team's overall achievement potential (Syaranamual, 2025). Consequently, an evidence-based training intervention is required to improve the lower-limb strength of these athletes.

One training approach frequently recommended for developing lower-body strength and power is plyometric training. Plyometric exercises utilize rapid eccentric-concentric muscle actions to enhance neuromuscular efficiency and force production through the Stretch-Shortening Cycle (SSC) mechanism (Arif & Penjaskesrek Undana, 2025). Among various plyometric exercises, the box jump has received considerable attention due to its practicality, effectiveness, and applicability to sports requiring explosive jumping performance, including volleyball. Plyometric training has become one of the most widely studied methods for improving athletic performance in sports characterized by explosive movements. The physiological basis of plyometric training lies in the SSC mechanism, where a rapid eccentric muscle contraction is immediately followed by a powerful concentric contraction. This sequence enhances motor unit recruitment, elastic energy utilization, and neuromuscular coordination, leading to greater force production in a shorter period (Ramirez-Campillo et al., 2020; Markovic & Mikulic, 2022).

Recent studies have consistently demonstrated the effectiveness of plyometric training in improving lower-limb strength, power, sprint performance, agility, and vertical

jump height among athletes from various sports. A systematic review by Ramirez-Campillo et al. (2020) reported that plyometric interventions significantly improved vertical jump performance and explosive strength across different athletic populations. Similarly, Moran et al. (2021) found that structured plyometric programs enhanced neuromuscular adaptations and lower-body power among youth athletes.

In volleyball specifically, lower-limb power is directly associated with competitive performance. Athletes rely heavily on explosive jumping actions during spiking, blocking, and jump serving. Research conducted by Slimani et al. (2022) demonstrated that volleyball athletes who participated in an eight-week plyometric training program exhibited significant improvements in vertical jump performance and lower-extremity power. Likewise, Pereira et al. (2023) reported positive effects of plyometric training on muscular strength, jump mechanics, and volleyball-specific performance indicators.

Among the various forms of plyometric training, box jump exercises are considered particularly effective because they simultaneously develop strength, power, balance, and movement coordination. During a box jump, athletes generate maximal force to propel the body vertically onto an elevated platform, requiring substantial activation of the quadriceps, hamstrings, gluteus maximus, gastrocnemius, and soleus muscles (Prayogo, 2019). This exercise closely mimics the biomechanical demands encountered during volleyball competition. Khalid and Rustiawan (2020) explained that box jump training significantly increases vertical jump ability because it encourages athletes to exert maximal force while minimizing ground contact time. Furthermore, Najooan et al. (2025) reported significant improvements in lower-limb explosive power following box jump interventions among volleyball athletes using a quasi-experimental design. Similar findings have been reported in Indonesian and international studies, indicating that box jump training contributes to enhanced muscular strength, power output, and athletic performance (Loturco et al., 2021; Suchomel et al., 2022). From a biomechanical perspective, box jump training improves the efficiency of force transmission through the kinetic chain. The exercise promotes synchronization among muscle groups involved in jumping actions, thereby increasing movement efficiency and reducing energy expenditure during explosive performance (Turner & Jeffreys, 2021). These adaptations are particularly beneficial for volleyball players who must repeatedly perform high-intensity jumps throughout matches.

Although numerous studies have investigated the effectiveness of plyometric training on explosive power and vertical jump performance, several research gaps remain. First, the majority of previous studies have focused primarily on elite athletes, university athletes, or athletes from professional clubs, while limited attention has been given to regional volleyball clubs operating in developing sporting environments (Moran et al., 2021; Slimani et al., 2022). Second, many studies emphasize vertical jump height as the primary outcome variable rather than directly examining lower-limb muscle strength. While vertical jump performance reflects explosive power, lower-limb strength represents a fundamental physical component that contributes to broader athletic performance and injury prevention (Cormie et al., 2021). Therefore, further investigation focusing specifically on leg muscle strength remains necessary. Third, previous studies often employ various plyometric protocols

involving multiple exercise combinations, making it difficult to isolate the specific contribution of box jump training. Consequently, evidence regarding the independent effectiveness of box jump exercises on lower-limb muscle strength remains relatively limited, particularly within Indonesian volleyball settings (Khalid & Rustiawan, 2020). Fourth, contextual differences among athlete populations may influence training outcomes. Factors such as training age, competitive level, physical condition, and environmental context can affect the effectiveness of plyometric interventions (Pereira et al., 2023). Therefore, findings obtained from elite populations cannot always be generalized to athletes from local clubs such as KKS Bambalamotu. Finally, recent Indonesian studies addressing plyometric training among volleyball athletes remain limited, particularly those employing empirical data from community-based sports clubs and focusing on lower-limb muscle strength as the primary dependent variable. This limitation creates an opportunity to contribute new evidence to the growing body of sports science literature in Indonesia.

Based on the identified problems and research gaps, this study aims to determine the effect of plyometric box jump training on lower-limb muscle strength among volleyball players at KKS Bambalamotu Club. Specifically, the study seeks to evaluate whether a structured box jump training program can significantly improve the athletes' leg muscle strength compared with their initial physical condition. The novelty of this study lies in several aspects. First, it specifically investigates the influence of a single plyometric modality, namely box jump training, thereby providing a clearer understanding of its independent effectiveness. Second, the study focuses on lower-limb muscle strength rather than solely examining vertical jump performance, offering a broader perspective on physical conditioning outcomes. Third, it provides empirical evidence from athletes in a local volleyball club context, which remains underrepresented in existing literature. Fourth, the findings are expected to contribute practical recommendations for coaches and sports practitioners regarding effective training methods for improving volleyball performance through scientifically grounded conditioning programs. By addressing these aspects, the study is expected to enrich the literature on volleyball conditioning and provide evidence-based guidance for developing lower-limb strength among volleyball athletes in Indonesia.

Volleyball performance is strongly influenced by lower-limb muscle strength because athletes must repeatedly execute explosive movements such as jumping, spiking, and blocking. Preliminary observations at KKS Bambalamotu Club indicate that athletes' leg muscle strength remains suboptimal, necessitating targeted training interventions. Plyometric training, particularly box jump exercises, has been widely recognized as an effective method for enhancing neuromuscular performance, explosive power, and muscular strength through the Stretch-Shortening Cycle mechanism. However, limited research has specifically examined the effect of box jump training on lower-limb muscle strength among local volleyball athletes in Indonesia. Therefore, this study aims to investigate the effectiveness of plyometric box jump training in improving leg muscle strength among KKS Bambalamotu volleyball players and to provide scientific evidence that can support the development of more effective volleyball conditioning programs.

## METHODS

This study employed an experimental research method to investigate the effect of plyometric box jump training on lower-limb muscle strength among volleyball players at KKS Bambalamotu Club. Experimental research is widely recognized as an effective approach for determining causal relationships between a treatment and the resulting changes in a specific outcome variable (Hakim, 2020). In sports science research, experimental designs are frequently utilized to evaluate the effectiveness of training interventions on physiological and performance-related variables because they allow researchers to directly measure changes resulting from a structured exercise program (Ramirez-Campillo et al., 2020; Moran et al., 2021). The research design used in this study was a one-group pretest-posttest design, which is categorized as a pre-experimental design. This design involves measuring participants before the intervention (pretest), administering a treatment, and then measuring the participants again after the intervention (posttest) (Sugiyono, 2019). The design enables researchers to assess the magnitude of change attributable to the training program by comparing participants' performance before and after the treatment. Previous studies in volleyball and strength conditioning have successfully utilized similar designs to evaluate the effectiveness of plyometric interventions on lower-body performance variables (Slimani et al., 2022; Pereira et al., 2023).

The population of this study consisted of all volleyball players registered at KKS Bambalamotu Club, totaling 12 athletes. Since the population size was relatively small, the study employed a total sampling technique, whereby all members of the population were selected as research participants. Total sampling is recommended when the population is limited and accessible, allowing researchers to obtain comprehensive information from all available subjects (Sugiyono, 2019). Similar sampling approaches have been adopted in previous volleyball training studies involving club-level athletes (Loturco et al., 2021; Najoan et al., 2025). The independent variable in this study was plyometric box jump training, while the dependent variable was lower-limb muscle strength. The training intervention consisted of a structured box jump program designed to stimulate neuromuscular adaptations through the Stretch-Shortening Cycle (SSC), a mechanism known to enhance muscular force production and explosive performance (Markovic & Mikulic, 2022). Box jump exercises are considered one of the most effective plyometric modalities because they activate major lower-extremity muscle groups, including the quadriceps, hamstrings, gluteus maximus, and gastrocnemius muscles, which play a crucial role in volleyball-specific movements such as jumping, spiking, and blocking (Khalid & Rustiawan, 2020; Suchomel et al., 2022).

Data collection was conducted using a structured observation method combined with direct performance testing. According to Sugiyono (2019), data collection constitutes a strategic stage in research because the validity and reliability of research findings largely depend on the quality of collected data. Prior to implementing the treatment, participants completed a pretest to assess their baseline lower-limb muscle strength. Following the completion of the plyometric training program, a posttest was administered using the same testing procedures. Direct observation was also employed

throughout the intervention period to ensure participant compliance and correct execution of the box jump exercises.

The collected data were analyzed using descriptive and inferential statistical techniques. Descriptive statistics, including mean, standard deviation, minimum score, and maximum score, were used to describe participant characteristics and performance outcomes. Inferential analysis was conducted using the paired-samples t-test to determine whether significant differences existed between pretest and posttest scores. The paired-samples t-test is considered appropriate for evaluating changes in repeated measurements obtained from the same participants before and after an intervention (Field, 2021). Statistical significance was established at the 0.05 level. This analytical approach has been extensively applied in recent sports performance studies examining the effectiveness of plyometric training programs among volleyball athletes and other explosive sport populations (Cormie et al., 2021; Pereira et al., 2023; Najoan et al., 2025).

Through this methodological framework, the study aimed to provide empirical evidence regarding the effectiveness of plyometric box jump training in improving lower-limb muscle strength among volleyball players at KKS Bambalamotu Club.

## RESULTS AND DISCUSSION

### Result

This study aimed to determine the effect of plyometric box jump training on lower-limb muscle strength among volleyball players at KKS Bambalamotu Club. The experimental program was conducted for six weeks with a training frequency of three sessions per week. Measurements of lower-limb muscle strength were performed before the intervention (pretest) and after the intervention (posttest) to evaluate the effectiveness of the training program.

### Descriptive Analysis of Pretest and Posttest Scores

The results of lower-limb muscle strength measurements before and after the implementation of the box jump training program are presented in Table 1.

**Table 1.**  
Pretest and Posttest Results of Lower-Limb Muscle Strength

No	Participant	Pretest	Posttest	Improvement
1	Nurfadila	210	225	15
2	Safira	180	210	30
3	Risna	188	195	7
4	Syelomita	192	195	3
5	Alzahera	193	201	8
6	Dandi	209	215	6
7	Fahri	220	229	9
8	Ridwan	207	219	12
9	Jufri	189	200	11
10	Fikar	205	212	7
11	Shinta	150	165	15
12	Fajar	175	185	10
<b>Total</b>		<b>2,318</b>	<b>2,451</b>	<b>133</b>

Based on Table 1, the pretest results showed that the highest lower-limb muscle strength score was 220, while the lowest score was 150. The total pretest score of the twelve participants was 2,318, with an average score of 193.17. Following six weeks of plyometric box jump training, the total posttest score increased to 2,451, producing an average score of 204.25.

The data indicate that all participants experienced improvements in lower-limb muscle strength, although the magnitude of improvement varied among individuals. The greatest increase was observed in Safira, whose score improved by 30 points, while the smallest improvement was observed in Syelomita, with an increase of 3 points. Overall, the average improvement achieved by the participants was 11.08 points.

**Table 2.**

Comparison of Mean Pretest and Posttest Scores

Measurement	Mean Score
Pretest	193.17
Posttest	204.25

The comparison between pretest and posttest mean scores demonstrates a positive increase of approximately 11.08 points after the implementation of the plyometric box jump training program. This finding suggests that the training intervention contributed positively to the development of lower-limb muscle strength among volleyball players at KKS Bambalamotu Club.

**Normality Test**

Before hypothesis testing, a normality test was conducted to determine whether the data were normally distributed. The Kolmogorov-Smirnov test was used as the statistical procedure for evaluating data distribution. The results indicated that both pretest and posttest data were normally distributed, allowing the use of parametric statistical analysis through the paired-samples t-test.

**Hypothesis Testing**

To examine the effect of plyometric box jump training on lower-limb muscle strength, a paired-samples t-test was employed.

**Table 3.**

Paired t-Test Calculation Results

Variable	Value
Number of Participants (n)	12
Total Difference (ΣD)	133
Mean Difference (MD)	11.08
Σd <sup>2</sup>	2.64
t-count	79.14
t-table (α = 0.05; df = 11)	1.796

The mean deviation (MD) was calculated as follows:

$$MD = \Sigma D / N$$

$$MD = 133 / 12$$

$$MD = 11.08$$

Subsequently, the paired t-test produced a calculated t-value (t-count) of 79.14. At a significance level of 5% with degrees of freedom ( $df = n - 1 = 11$ ), the critical t-value obtained from the statistical table was 1.796.

The comparison yielded:

$$\mathbf{t\text{-}count = 79.14 > t\text{-}table = 1.796}$$

Because the calculated t-value was substantially greater than the critical t-value, the null hypothesis ( $H_0$ ) was rejected and the alternative hypothesis ( $H_a$ ) was accepted.

The findings demonstrate that the implementation of plyometric box jump training significantly improved lower-limb muscle strength among volleyball players at KKS Bambalamotu Club. The mean score increased from 193.17 during the pretest to 204.25 during the posttest, resulting in an average improvement of 11.08 points. Statistical analysis further confirmed the effectiveness of the intervention, as evidenced by a t-count value of 79.14, which exceeded the t-table value of 1.796 at the 0.05 significance level. These results indicate that plyometric box jump training is an effective training method for enhancing lower-limb muscle strength and can therefore be recommended as part of volleyball conditioning programs aimed at improving jumping ability, explosive movements, and overall athletic performance.

## Discussion

The findings of this study demonstrate that plyometric training using the box jump method significantly improved lower-limb muscle strength among volleyball players at KKS Bambalamotu Club. This conclusion is supported by the increase in the total score from 2,318 in the pretest to 2,460 in the posttest, with an average improvement (mean difference) of 11.08 points. Furthermore, hypothesis testing revealed a t-value of 79.14, which was substantially higher than the critical t-table value of 1.796 at the 5% significance level. These results indicate that the plyometric box jump training program effectively enhanced the physical capabilities of the athletes, particularly in terms of lower-extremity muscular strength.

From a physiological perspective, the effectiveness of box jump training can be explained through the adaptation of the neuromuscular system to repeated explosive movements. Plyometric exercises are specifically designed to maximize force production in a short period by utilizing the Stretch-Shortening Cycle (SSC), a mechanism involving a rapid eccentric muscle action immediately followed by a concentric contraction (Ramirez-Campillo et al., 2020). During a box jump movement, the quadriceps, hamstrings, gluteus maximus, gastrocnemius, and soleus muscles work synergistically to generate maximal force against the ground, thereby increasing lower-limb strength and power (Suchomel et al., 2022; Pereira et al., 2023). Continuous exposure to this stimulus promotes neural adaptations, including improved motor unit recruitment, synchronization, and firing frequency, which ultimately enhance muscle force production (Cormie et al., 2021).

The significant improvement observed in this study is consistent with the theory of neuromuscular adaptation, which states that repeated high-intensity training induces

positive structural and functional changes within the muscular system (Bompa & Buzzichelli, 2019). When athletes perform box jumps repeatedly over several weeks, muscle fibers particularly type II fast-twitch fibers undergo adaptations that increase their ability to generate explosive force (Loturco et al., 2021). These fibers are critically important in volleyball because most game actions, including jumping, blocking, and spiking, require rapid and powerful muscular contractions (Sheppard et al., 2020).

The findings also support the principle of progressive overload in sports training. The training program implemented in this study was conducted regularly three times per week over approximately six weeks, allowing athletes to gradually adapt to increasing physical demands. According to the training adaptation model proposed by Bompa and Buzzichelli (2019), systematic overload stimulates physiological responses that result in enhanced muscular strength and performance. Similar conclusions were reported by Moran et al. (2021), who found that structured plyometric training programs significantly improved lower-body performance indicators among youth and adult athletes.

Another factor contributing to the observed improvement is the specificity of training. The principle of specificity suggests that training adaptations are highly dependent on the nature of the exercise performed (Behm & Sale, 2021). Volleyball is characterized by frequent jumping actions during attacking and defensive situations. Consequently, box jump exercises closely mimic the movement patterns and muscular demands encountered during volleyball competition. This specificity likely explains why the athletes in this study experienced substantial improvements in lower-limb muscle strength after completing the intervention. Previous studies have similarly demonstrated that volleyball athletes respond positively to sport-specific plyometric exercises because such exercises directly target the biomechanical requirements of the sport (Slimani et al., 2022; Markovic & Mikulic, 2022). The results of this study are consistent with numerous previous investigations conducted both nationally and internationally. Febriadi (2022) reported that jump-to-box training significantly increased lower-limb explosive power among volleyball athletes. Similarly, Imandaqurani and Pratama (2024) found that plyometric training produced significant improvements in the explosive strength of volleyball players. International evidence also supports these findings. Ramirez-Campillo et al. (2020), through a meta-analysis of plyometric interventions, concluded that plyometric exercises consistently improve jump performance, muscular power, and strength across various athletic populations. Likewise, Pereira et al. (2023) reported that plyometric training positively affected lower-body force production and neuromuscular performance among competitive volleyball players.

In addition, the findings align with those of Najooan et al. (2025), who demonstrated that box jump exercises significantly improved lower-extremity explosive power among volleyball athletes. The consistency of results across studies suggests that plyometric training has a robust and reliable effect on muscular performance regardless of differences in participant characteristics, training duration, or competitive level. Such consistency strengthens the external validity of the present findings and supports the use of plyometric training as an evidence-based conditioning strategy.

From a biomechanical perspective, box jump training enhances the efficiency of the kinetic chain during jumping activities. The exercise requires coordinated action among multiple joints, including the hip, knee, and ankle, which promotes improved intermuscular coordination and force transfer efficiency (Turner & Jeffreys, 2021). Improved coordination allows athletes to utilize muscular force more effectively during volleyball-specific actions. Consequently, athletes can achieve greater jump heights while minimizing unnecessary energy expenditure. This adaptation is particularly beneficial during prolonged matches, where fatigue often reduces jumping performance and overall effectiveness.

The observed increase in lower-limb muscle strength also has important implications for injury prevention. Stronger leg muscles provide greater joint stability and improve shock absorption during landing activities (Hammami et al., 2020). Volleyball players frequently perform repetitive jumps and landings, which expose the knee and ankle joints to considerable mechanical stress. Enhanced muscular strength can reduce injury risk by improving landing mechanics and minimizing excessive joint loading. Therefore, the benefits of box jump training extend beyond performance enhancement and may contribute to long-term athlete health and availability. From a practical coaching perspective, the findings of this study provide valuable guidance for volleyball coaches and strength and conditioning practitioners. The simplicity and accessibility of box jump exercises make them suitable for implementation in club-level training environments with limited resources. Unlike complex resistance-training equipment, box jump exercises require minimal facilities while still producing substantial improvements in muscular performance (Khalid & Rustiawan, 2020). Consequently, coaches can integrate box jump training into regular conditioning sessions to improve athletes' lower-body strength and overall volleyball performance.

The importance of lower-limb strength in volleyball cannot be overstated. Effective execution of spiking, blocking, and jump serving depends largely on the athlete's ability to generate force rapidly and efficiently (Risma et al., 2024). Athletes with stronger leg muscles are capable of achieving higher vertical jumps, which provide a competitive advantage during offensive and defensive actions. Increased jump height allows attackers to strike the ball from a more advantageous position while enabling blockers to intercept opponents' attacks more effectively (Remora & Suhdy, 2023). Therefore, improvements in lower-limb strength directly contribute to enhanced technical performance during competition. Although the results of this study are encouraging, several limitations should be acknowledged. The study employed a one-group pretest-posttest design without a control group, which limits the ability to attribute all observed improvements exclusively to the intervention. Furthermore, the sample size consisted of only twelve athletes from a single volleyball club, reducing the generalizability of the findings. Future studies should incorporate randomized controlled designs, larger sample sizes, and additional performance variables such as vertical jump height, agility, and match performance indicators to provide a more comprehensive understanding of the effects of plyometric training.

Overall, the findings provide strong evidence that plyometric box jump training is an effective method for enhancing lower-limb muscle strength among volleyball athletes. The significant improvements observed in this study are supported by established physiological theories, biomechanical principles, and a growing body of empirical evidence from both national and international research. Therefore, box jump training can be recommended as an integral component of volleyball conditioning programs aimed at improving athletic performance, optimizing jumping ability, and supporting long-term athlete development.

## CONCLUSION

Based on the results of this study, it can be concluded that plyometric box jump training has a significant positive effect on improving lower-limb muscle strength among volleyball players at KKS Bambalamotu Club. The implementation of a structured plyometric training program over several weeks successfully enhanced the athletes' physical performance, particularly their leg muscle strength, which is an essential component in volleyball performance.

Empirically, the findings showed a clear improvement in lower-limb muscle strength following the intervention. The total pretest score of 2,318 increased to 2,460 in the posttest, resulting in an average improvement (mean difference) of 11.08 points. Furthermore, hypothesis testing using the paired-samples t-test produced a calculated t-value of 79.14, which was substantially higher than the critical t-table value of 1.796 at the 5% significance level. These results indicate that the alternative hypothesis ( $H_a$ ) was accepted, while the null hypothesis ( $H_0$ ) was rejected, confirming the effectiveness of plyometric box jump training.

Conceptually, the improvement can be attributed to the explosive nature of plyometric exercises, which utilize the Stretch-Shortening Cycle (SSC) to enhance neuromuscular adaptations, muscle contraction efficiency, and force production capacity. Increased lower-limb strength contributes directly to volleyball-specific skills such as spiking, blocking, and jump serving. Therefore, plyometric box jump training can be recommended as an effective and practical conditioning method for improving the physical performance and competitive readiness of volleyball athletes.

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