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The Effectiveness of Plyometric and Tabata on Leg Muscle Power and Anaerobic Endurance of Junior Volleyball Players of Panji Laras Club Nganjuk Regency

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Abstract

This study aimed to examine the effects of plyometric and Tabata training on leg power and anaerobic endurance in junior volleyball athletes from the Panji Laras Club, taking into account differences in leg length. A quasi-experimental design with a pretest–posttest structure was used, involving four groups: Plyometric A (long legs), Plyometric B (short legs), Tabata A (long legs), and Tabata B (short legs), each consisting of four athletes. Leg power was assessed using the vertical jump test, while anaerobic endurance was measured through the fatigue index. Both training programs were applied over the intervention period. The results showed that all groups experienced an increase in leg power, with improvements ranging from +2.25 to +3.50, and a decrease in fatigue index values, indicating better anaerobic endurance. Repeated-measures ANOVA revealed a significant main effect of time for both leg power ($p < 0.001$) and anaerobic endurance ($p < 0.001$), while no significant interaction effects were found between training type and leg length. These findings indicate that both plyometric and Tabata training effectively improved performance outcomes, and leg-length differences did not significantly influence adaptation. In conclusion, plyometric and Tabata training can be used as alternative methods to enhance leg power and anaerobic endurance in junior volleyball athletes.

How to Cite

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INTRODUCTION

Volleyball is a highly popular and growing sport in Nganjuk Regency, supported by the presence of various development clubs that actively participate in regional competitions such as POPDA and PROPROV. One of the prominent clubs, Panji Laras, located in Cengkok Village, Ngronggot District, has consistently taken part in regional tournaments and conducted structured training for junior athletes. Despite the existence of such developmental programs and regular local competitions aimed at talent identification, the physical potential of many athletes is still considered underdeveloped. Interviews with Panji Laras coaches revealed two major concerns: the limited endurance of athletes and their unstable performance during long matches. Observations conducted by the researcher in several age-group tournaments confirmed that players tend to experience fatigue during extended games, which reduces their effectiveness in executing explosive movements such as spiking and blocking.

Pretest results also showed that many junior athletes demonstrated only average or below-average levels of leg power and anaerobic endurance, indicating the need for specific training interventions. The physical demands of volleyball require athletes to perform frequent explosive actions, including rapid transitions, jumps, and directional changes. Thus, leg muscle power and anaerobic endurance are fundamental components for optimal performance (Ramirez-Campillo et al., 2020). Plyometric training is commonly used in volleyball due to its effectiveness in enhancing explosive strength, neuromuscular responsiveness, jump height, agility, and overall physical conditioning. Through the Stretch-Shortening Cycle (SSC), plyometric exercises such as tuck jumps and high hurdle jumps train the muscles to produce maximal force in minimal time, making them highly relevant for volleyball-specific actions. Plyometric exercises are commonly used in volleyball because the sport demands fast, powerful actions (Silva et al., 2019). Previous studies have reported that plyometric training can improve isokinetic strength, explosive power, and jump performance in volleyball players (Iranpour et al., 2025). Volleyball performance requires technical, tactical, and physical competence (Gonçalves et al., 2021), and plyometric training has been shown to enhance muscle strength, jumping ability, running performance, agility, and endurance (Grgic et al., 2021). It also contributes to improving the effectiveness of volleyball smashes. Previous studies have demonstrated that plyometric training improves isokinetic strength, explosive power, and vertical jump performance among volleyball athletes, while also contributing to better speed, agility, and VO_2Max (Kons et al., 2023; Silva et al., 2019). Similarly, anaerobic endurance plays a critical role in sustaining performance during long sets and rallies, making it essential for volleyball athletes to maintain energy output throughout the match (Ramirez-Campillo et al., 2021).

In addition to plyometrics, tabata training, categorized as High-Intensity Interval Training (HIIT) is known for its efficiency in improving anaerobic fitness, muscular endurance, and metabolic function (Murawska-Cialowicz et al., 2020). The Tabata protocol has been found to significantly improve body composition, increase irisin concentration, and enhance physical performance. Previous research has also shown that HIIT-based programs improve speed, agility, and anaerobic endurance, making tabata training a relevant complementary method for volleyball conditioning programs (Lu et al., 2023). Considering the theoretical and empirical support for both training methods, combining them presents a promising strategy for addressing the physical limitations observed in Panji Laras junior athletes. Based on these considerations, the present study aims to analyze how leg muscle power and anaerobic endurance of junior volleyball athletes change after undergoing plyometric and tabata training, particularly when taking into account differences in leg length. The study also seeks to compare the effectiveness of the two training methods in improving leg muscle power and anaerobic endurance. Accordingly, the research tests the hypotheses that plyometric and tabata training produce different effects on leg muscle power and anaerobic endurance, and that training type interacts with leg length in influencing both variables. The novelty of this study lies in its simultaneous comparison of plyometric and Tabata training within a 2×2 factorial design that includes leg-length categories, providing new evidence on whether anthropometric differences moderate improvements in leg power and anaerobic endurance among junior volleyball athletes.

METHOD

This study employed a quantitative approach using a 2×2 factorial experimental design. The treatments consisted of two training methods, namely plyometric training using tuck jump and high hurdle jump (A1), and Tabata training with a 2:1 interval (A2). The attribute variable used in the study was leg length, categorized into good leg length (B1) and sufficient leg length (B2). A pretest–posttest model was applied in which all subjects completed initial tests prior to the intervention and final tests after the intervention period.

The research instruments included the Vertical Jump Test to measure lower-limb explosive power and the Running-Based Anaerobic Sprint Test (RAST) to measure anaerobic endurance. The Vertical Jump Test was carried out by recording the initial reach height, followed by three maximum jumps, with the highest result recorded as the final score. The RAST consisted of six sprints over a distance of 35 meters with 10 seconds of rest between each sprint, and the results were used to calculate the fatigue index. The equipment used in the study included a measuring tape, chalk or powder, a measuring board or wall at least 300 cm high, 30–50 cm hurdles for plyometric training, and a 35-meter running track for the RAST.

Figure 1. Running-Based Anaerobic Sprint Test RAST) (Source: www.scienceforsport.com)

The subjects of this research were members of the Panji Laras volleyball club in Cengkong Village, Ngronggot District, Nganjuk Regency. The sample was selected using purposive sampling with criteria including male athletes aged 14–17 years, physically and mentally healthy, and consistently participating in training. Based on these criteria, 16 athletes were selected and divided into two groups according to leg length, which were then further divided into four groups according to the factorial design. The data collected were quantitative, consisting of measurements of lower-limb explosive power obtained through the Vertical Jump Test and anaerobic endurance obtained through the RAST. Leg-length data were also collected to determine group classification. All data were obtained through direct testing before and after the treatment period. Data collection began with measuring leg length using a tape measure from the malleolus to the iliac crest, after which the subjects were ranked and grouped into B1 and B2. All subjects then completed the pretest consisting of the Vertical Jump Test and the RAST. Following this, the subjects received treatment according to their respective groups. The plyometric training included high hurdle jumps and tuck jumps performed for eight repetitions in three sets, while the Tabata training used intervals of 20 seconds of work and 10 seconds of rest for eight repetitions, employing movements that resemble volleyball-specific actions. The intervention lasted eight weeks with a frequency of three sessions per week.

After the intervention period, all subjects completed the posttest using the same procedures as the pretest. Data analysis began with prerequisite tests, including normality testing using the Shapiro–Wilk test and homogeneity testing to determine group variance similarity. If the data were normally distributed and homogeneous, further analysis was conducted using t-tests and two-way ANOVA. If the data were not normally distributed, the nonparametric Kruskal–Wallis test was used. All analyses were performed using SPSS.

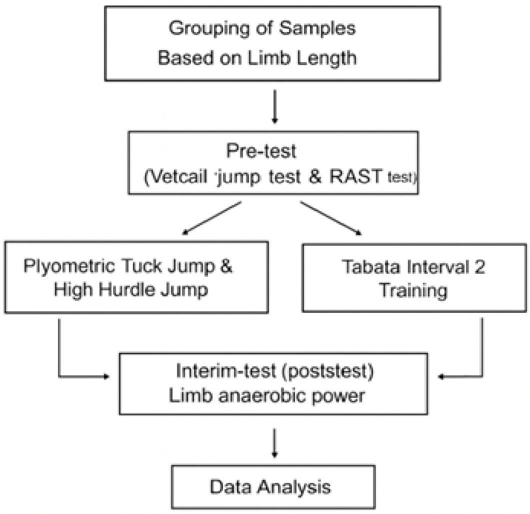

Figure 2. research procedure

RESULTS AND DISCUSSION

This study involved 16 junior volleyball players of the Panji Laras Nganjuk Club who were divided into two main intervention groups, namely the plyometric exercise group and the

2:1 interval tabata training group. Each group was then divided based on the category of leg length into good leg length and sufficient leg length. Measurements were taken through pretest and posttest to measure leg muscle power and anaerobic endurance, with an eight-week exercise program. This study involved 16 junior volleyball players of the Panji Laras Nganjuk Club who were divided into two main intervention groups, namely the plyometric exercise group and the 2:1 interval tabata training group. Each group was then divided based on the category of leg length into good leg length and sufficient leg length. Measurements were taken through pretest and posttest to measure leg muscle power and anaerobic endurance, with an eight-week exercise program. Participants from all four groups (Plyometric A, Plyometric B, Tabata A, and Tabata B) showed relatively homogeneous baseline physical characteristics. The mean age ranged from 14.75 to 16.25 years. Mean height varied between 1.660 ± 0.022 m and 1.738 ± 0.048 m, while body weight ranged from 50.75 ± 4.27 kg to 63.25 ± 9.07 kg. The BMI distribution indicated that all groups were within a normal range (17.98–20.90 kg/m²). These values confirm that the four groups possessed comparable anthropometric profiles before treatment (table 1).

Tabel 1. Summary of Subject Characteristics, Lower-Limb Power, and Anaerobic Endurance (Mean ± CHG.)

Variable	Pylometric A (N=4)	Pylometric B (N=4)	Tabata A (N=4)	Tabata B (N=4)	Description
Age (years)	16.25 ± 0.50	14.75 ± 0.96	15.25 ± 0.96	15.25 ± 1.50	accepted
Height (m)	1.738 ± 0.048	1.660 ± 0.022	1.713 ± 0.043	1.680 ± 0.008	Normal
Body Weight (kg)	63.25 ± 9.07	54.25 ± 3.78	59.50 ± 8.43	50.75 ± 4.27	Normal
BMI	20.90 ± 2.43	19.72 ± 1.83	20.27 ± 2.66	17.98 ± 1.39	Normal
Leg Power (Pretest)	51.00 ± 4.24	48.75 ± 9.98	50.00 ± 6.27	46.50 ± 10.08	baseline
Leg Power (Posttest)	54.00 ± 3.83	52.25 ± 9.74	52.25 ± 5.56	49.50 ± 9.98	Improved
Anaerobic Endurance (Pretest)	1.89 ± 0.39	1.72 ± 0.61	1.90 ± 0.51	1.47 ± 0.42	Baseline
Anaerobic Endurance (Posttest)	1.44 ± 0.09	1.48 ± 0.50	1.49 ± 0.16	1.16 ± 0.25	Improved

The results **Tabel 1** showed consistent improvements across all groups following the training interventions. In terms of leg power, every group demonstrated positive progress from pretest to posttest. The Plyometric A group increased from 51.00 ± 4.24 to 54.00 ± 3.83 (chg. = +3.00), while Plyometric B improved from 48.75 ± 9.98 to 52.25 ± 9.74 (chg. = +3.50). Similar improvements were also observed in the Tabata groups, with Tabata A showing a gain of +2.25 and Tabata B increasing by +3.00. These outcomes indicate that both plyometric and Tabata training were effective in enhancing lower-limb explosive strength, with slightly greater improvements appearing in the plyometric groups, particularly Plyometric B. In addition, anaerobic endurance also improved across all groups, as reflected in the reductions of the fatigue index values. Plyometric A recorded the most notable improvement, decreasing from 1.89 ± 0.39 to 1.44 ± 0.09 (chg. = −0.45), followed by Tabata A with chg. = −0.41, Tabata B with chg. = −0.31, and Plyometric B with chg. = −0.24. Because lower fatigue index values indicate better anaerobic endurance, these results suggest that all training protocols led to meaningful enhancements in the athletes' ability to sustain high-intensity efforts. Overall, the combined findings demonstrate that both training methods contributed to improvements in leg power and anaerobic endurance, though plyometric training showed a slightly stronger influence on explosive performance.

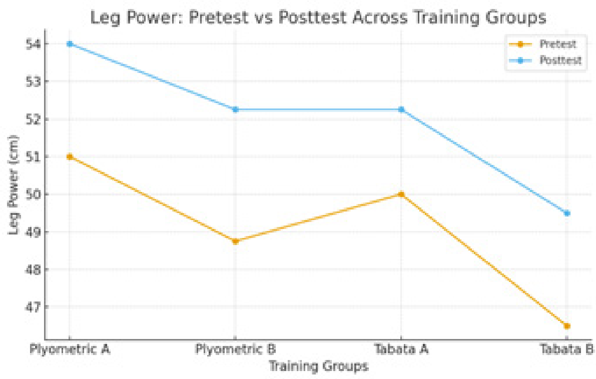

Figure 3. Pretest–Posttest Leg Power Across Plyometric and Tabata Training Groups.

In **Figure 3**, it can be seen that leg power before and after the test showed that all four groups experienced an increase after the treatment. The Plyometric A group improved from 51.00 to 54.00, while Plyometric B increased from 48.75 to 52.25. Similarly, the Tabata A group went up from 50.00 to 52.25, and Tabata B increased from 46.50 to 49.50. Plyometric movements rely on the stretch-shortening cycle to produce faster and more powerful contractions (Ramírez-Campillo et al., 2016). These results indicate that both exercise methods produced positive changes in leg power, with a slightly greater increase seen in the plyometric groups.

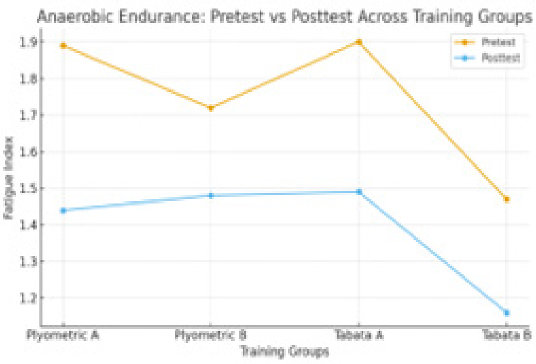

Figure 4. Changes in Anaerobic Endurance (Fatigue Index) Before and After Treatment.

Figure 4 shows that anaerobic endurance, indicated by the fatigue index, improved across all four groups following the treatment, as reflected by lower posttest values. Hypothesis testing results showed a significant difference in leg power between pre- and post-training measurements for both methods (Kons et al., 2023). The Plyometric A group decreased from 1.89 to 1.44, while Plyometric B declined from 1.72 to 1.48. The Tabata A group showed a reduction from 1.90 to 1.49, and the Tabata B group decreased from 1.47 to 1.16. These results demonstrate that both training methods contributed to better anaerobic endurance, with the greatest improvement observed in the Plyometric A group, followed by Tabata A and Tabata B. Plyometric training is widely recognized for its ability to enhance neuromuscular performance through the stretch–shortening cycle (SSC). In this study, both Plyometric A and Plyometric B showed meaningful increases in leg power, with the highest improvement recorded in Plyometric B (chg. = +3.50). This supports previous literature stating that plyometric exercises such as tuck jumps and high hurdle jumps stimulate rapid eccentric–concentric muscle actions, improving rate of force development and explosive strength(Grgic et al., 2021; Silva et al., 2019). Additionally, plyometric training also contributed to improvements in anaerobic endurance, as reflected by reductions in fatigue index values. Plyometric A demonstrated the best enhancement (chg. = −0.45), which aligns with studies showing that plyometric work can increase metabolic efficiency, buffering capacity, and the ability to sustain high-intensity bouts. These outcomes suggest that plyometric training not only develops power but can indirectly support anaerobic performance by improving muscular resilience during intense repeated actions such as jumping, blocking, and spiking an integral component of volleyball. Although Tabata training is primarily known for improving aerobic and anaerobic conditioning, this study found that the method also contributed to increases in leg power. The improvements observed in Tabata A and B (chg. = +2.25 and +3.00) indicate that high-intensity intervals performed at maximal effort can stimulate neuromuscular adaptations similar to explosive training. This is consistent with previous findings that HIIT-based protocols can enhance muscle recruitment, anaerobic capacity, and overall fitness (Azizah et al., 2023; Murawska-Cialowicz et al., 2020).

Regarding anaerobic endurance, Tabata training showed strong effects. Tabata A and B achieved notable reductions in fatigue index (chg. = −0.41 and −0.31), which aligns with research demonstrating that HIIT protocols, particularly the Tabata method, effectively improve anaerobic glycolytic system efficiency and lactate tolerance (Wibowo, 2020). These adaptations are crucial for volleyball athletes, who must maintain high-intensity performance during multi-set matches.

This similarity suggests that plyometric and Tabata training stimulate overlapping physiological responses related to anaerobic performance. Previous findings highlight that HIIT-type protocols, including Tabata, can enhance anaerobic energy production and overall conditioning (Domaradzki et al., 2020). The results also align with volleyball-specific demands, where anaerobic capacity is essential for sustaining repeated high-intensity actions such as jumping and attacking (Bora & Dağlıoğlu, 2022; Weldon et al., 2021).

Tabel 2. Results of Repeated-Measures ANOVA on Leg Power and Anaerobic Endurance Across Training Groups

Variable	Source of Variance	df	F	p-value	ηp^2	Description
Leg Power	Time (Pre–Post)	1	206.173	<0.001	0.936	Significant effect
	Time × Training Method	1	2.333	0.149	0.143	Not significant
	Between-Group Effects (Training Type & Leg Length)	3	0.272	0.844	0.019	Not significant
Anaerobic Endurance	Time (Pre–Post)	1	26.766	<0.001	0.69	Significant effect
	Time × Group	1	0.005	0.943	4.45×10^{-4}	Not significant
	Time × Leg Length	1	1.124	0.31	0.086	Not significant
	Time × Group × Leg Length	1	0.147	0.708	0.012	Not significant
	Between-Group Effects (Group)	1	0.474	0.504	0.038	Not significant
	Between-Subjects – Leg Length	1	1.379	0.263	0.103	Not significant
	Group × Leg Length	1	0.662	0.432	0.052	Not significant

The results of this study demonstrate that both training methods plyometric and Tabata produced significant improvements in performance among junior volleyball players, specifically in leg power and anaerobic endurance. The repeated-measures ANOVA revealed a strong and statistically significant main effect of time on leg power ($F = 206.173$, $p < .001$, $\eta p^2 = .936$), indicating that the players experienced meaningful increases from pretest to posttest regardless of the training method or leg-length category. A similar pattern was observed in anaerobic endurance, which also showed a significant improvement over time ($F = 26.766$, $p < .001$, $\eta p^2 = .690$). These findings confirm that the training interventions applied in this study were effective in enhancing both muscular power and anaerobic capacity. This effect aligns with the principle that plyometric training trains muscles to produce maximal force output in a short duration (Narayanan et al., 2025). Previous research has also confirmed that plyometric training increases rapid power production through efficient use of the stretch-shortening cycle (Wang et al., 2023).

However, the analysis also showed that there were no significant differences between the training groups. For leg power, the between-subjects effect for group was non-significant ($p = .844$), and the interaction between time and training method was also non-significant ($p = .149$). Likewise, for anaerobic endurance, the interaction between time and training group was not significant ($p = .943$), and the between-subjects effect for group also showed no significant differences ($p = .504$). These results indicate that the improvements observed were not dependent on whether participants performed plyometric or Tabata training. Instead, both methods contributed similarly to performance enhancement.

CONCLUSION

Overall, the findings indicate that while both plyometric and Tabata training effectively improve leg power and anaerobic endurance, neither method was statistically superior within the sample and conditions of this study. The substantial improvements across time reflect that the athletes responded positively to structured training stimuli, whereas the absence of differences between groups suggests that both methods are similarly applicable for junior volleyball athletes in improving these physical capacities. Leg length also did not produce any meaningful effects, either as a main factor or in interaction with training type, for both variables measured. This suggests that the response to the training programs was relatively consistent across athletes with different leg-length categories.

Future studies may consider several directions based on the findings of this research. Since both training methods produced meaningful improvements over time but did not differ meaningfully from one another, subsequent research could employ a larger sample size to increase statistical power and better detect potential group differences. In addition, extending the duration of the training intervention may provide clearer insight into whether longer exposure to plyometric or Tabata training leads to divergent effects on leg power or anaerobic endurance. Researchers may also explore additional moderating variables that did not show meaningful effects in this study, such as leg length, by incorporating more detailed anthropometric or biomechanical measurements. Examining other performance components relevant to volleyball such as agility, vertical jump mechanics, or reactive strength could offer a more comprehensive understanding of how different training modalities influence athletic development. Furthermore, comparing these training methods across different age categories, competitive levels, or female athletes may broaden the applicability of the findings. Finally, incorporating physiological markers, such as lactate response or neuromuscular activation patterns, may provide deeper insights into the mechanisms underlying performance improvements.

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