

## Effectiveness of Plyometric Training Methods on Increasing Lower Limb Muscle Power of Karate Athletes in Karawang

Nadiir Rizki Hermawan<sup>1</sup>, Muhammad Fitrah Ramadhan<sup>2</sup>, M. Arief Setiawan<sup>3</sup>, A. Ine Aprilia Damai<sup>4</sup>, Aprillia Wulan Utari<sup>5</sup>

<sup>123456</sup>Department of Sport Science, Faculty of Health Sciences, Universitas Singaperbangsa Karawang  
[2410631240038@student.unsika.ac.id](mailto:2410631240038@student.unsika.ac.id)

Correspondent Author: [2410631240038@student.unsika.ac.id](mailto:2410631240038@student.unsika.ac.id)

Received: February 5, 2026; Accepted: February 27, 2026; Published: March 30, 2026  
Ed: 2026: 86-100

This study aims to analyze the effectiveness of the plyometric training method on increasing the leg muscle power of karate athletes in Karawang. The research hypothesis states that plyometric exercises have a significant influence on increasing the leg muscle power of karate athletes. The main premise of this study is based on the characteristics of the sport of karate, particularly kumite numbers, which demand the explosive ability of the lower limbs to perform kicks, position shifts, changes of direction, and rapid attack response. Plyometric exercises are seen as relevant because they utilize a stretch-shortening cycle mechanism that can improve neuromuscular efficiency, motor unit recruitment, the ability to generate force quickly, and explosive coordination of movements. This study uses a quantitative approach with an experimental method through a one-group pretest-posttest design. The research sample consisted of 20 karate athletes who were selected using purposive sampling techniques based on the criteria of active training, aged 15–20 years, did not experience injuries, and were willing to participate in the entire series of studies. The instrument used is the vertical jump test. The plyometric training program is given for six weeks with a frequency of three times per week through variations of squat jump, box jump, lateral jump, and bounding exercises. Data were analyzed using descriptive statistics, normality test, homogeneity test, and paired sample t-test. The results showed that the average leg muscle power increased from 45.30 cm in the pretest to 52.75 cm in the posttest, with an increase of 7.45 cm or 16.45%. The results of the normality test showed that the pretest and posttest data were distributed normally, while the homogeneity test showed homogeneous data. The paired sample t-test obtained a significance value of 0.000 or  $p < 0.05$ , so that the research hypothesis was accepted. These findings suggest that plyometric exercises are effective in increasing the leg muscle power of karate athletes. Practically, plyometric exercises can be recommended as part of a structured karate physical training program that is structured, progressive, safe, and in accordance with the needs of the movement of the match.

**Keywords:** plyometric, lower limb muscle power, karate, vertical jump, sports training.

### INTRODUCTION

Achievement sports require a systematic, measurable, and scientific evidence-based coaching process so that athletes are able to achieve optimal performance in increasingly competitive competition situations. In the context of martial arts, the success of athletes is not only determined by mastery of techniques, but also by physical abilities that support speed, strength, explosiveness, agility, coordination, and movement efficiency. Karate as a martial sport has complex movement characteristics because it involves attack, defense, change of direction, quick response to opponents, and execution of punch and kick techniques in a very short time. Therefore, the physical condition component, especially leg muscle power, is one of the main foundations in supporting karateka performance, especially in kumite numbers that demand explosive attacks and fast motor responses (Aziz et al., 2025; Cinarli et al., 2025; Rodrigues et al., 2023).

Leg muscle power plays an important role in supporting the quality of karate movement, especially in kicking techniques, position transfers, counterattacks, and the ability to maintain body stability when performing a combination of techniques. Movements such as mae geri, mawashi geri, and various other kicking techniques require a combination of power and speed to produce an effective, accurate, and adequate thrust attack. Recent studies show that karate performance is

closely related to anthropometric profile, physical fitness, maximum strength, sprint ability, jumping ability, and the quality of athletes' movement response (Aziz et al., 2025; Cinarli et al., 2025; Silva et al., 2025). In addition, studies of biomechanics and karate performance also confirm that the quality of lower limb movement determines the effectiveness of attack techniques, body stability, and the ability of athletes to maintain movement intensity during matches (Chen et al., 2026; Kaczmarek et al., 2026; Rodrigues et al., 2023).

Although leg muscle power has an important contribution to karate performance, in coaching practice at the regional level there are still often training programs that are conventional, less varied, and not fully prepared based on scientific training principles. This condition can cause the exercise stimulus to be not specific enough to increase the explosive ability of the leg muscles. The basic article used in the preparation of this manuscript shows that the main problem in karate athletes in Karawang is the lack of optimal leg muscle power, which is allegedly related to the application of less varied training methods and has not been specifically directed at increasing explosive power. This problem is important because leg muscle power is a physical component that directly affects the quality of kicks, movement speed, attack effectiveness, and the ability of athletes to respond to match situations.

Another issue that needs to be considered is the characteristic of karate matches that demand the ability of the lower body to work quickly, strongly, and repeatedly. Leg muscle fatigue can affect the response time of punches and kicks, thus reducing the effectiveness of techniques during competitions (Rodrigues et al., 2023). In addition, an imbalance in leg muscle strength, limited range of motion, and weak neuromuscular control can increase the risk of injury while lowering the quality of technique performance (Jeknić et al., 2022; Naserpour et al., 2021; Tyburski et al., 2025). This shows that a general exercise is not enough to answer the specific needs of karateka. Athletes need an exercise program that can provide explosive stimulation, improve neuromuscular coordination, improve movement efficiency, and still consider the safety aspects of training.

One of the many recommended exercise approaches in the literature to increase leg muscle power is plyometric exercises. Plyometric exercises are an explosive form of exercise that utilizes a stretch-shortening cycle mechanism through a series of rapid eccentric contractions, short transitions, and strong concentric contractions. This mechanism allows muscles and tendons to store and release elastic energy more efficiently, resulting in increased explosive power. In the context of martial arts, plyometric exercises are considered relevant because their movement characteristics resemble the needs of the game, such as jumping, pushing, changing directions, kicking, and performing explosive movements in a short period of time (Ojeda-Aravena et al., 2023; Yuan et al., 2025).

Empirical evidence suggests that plyometric exercises can improve the strength, power, jumping ability, reactive agility, and physical performance of martial artists. A meta-analysis in martial arts athletes reported that plyometric training has a positive effect on increasing muscle strength and power, so it can be used as an effective training strategy to improve athletes' explosive abilities (Yuan et al., 2025). Other studies in martial arts athletes have also shown that plyometric-jump training can influence the physical fitness components needed in a match, including explosiveness, speed, and agility (Ojeda-Aravena et al., 2023). More specifically in karate, Ioannides et al. (2020) found that a six-week plyometric training program can increase power, muscle strength, and rate of force development in competitive young karate athletes. The findings are in line with Kristiyanto et al. (2023), who show that plyometric exercises affect the power and

reactive agility of karate athletes.

In addition to plyometrics, various other forms of exercise have also been studied to improve the physical performance of karate and martial arts athletes, such as core strength training, maximum strength training, reverse Nordic exercise, high-intensity training, and sports-specific strength development programs. Core strength training has been shown to support the performance of engineering skills in martial arts athletes because the stability of the torso contributes to the transfer of force from the lower body to the upper body (Kabadayı et al., 2022; Zhang et al., 2025). Strength training in martial arts athletes has also been reported to improve physical fitness and performance capacity, although the adaptive response is influenced by the type of branch, age, level of training, and characteristics of the exercise program (Cid-Calfucura et al., 2023; Hieu et al., 2025). In young karateka, Nordic reverse training also shows the potential to improve the physical fitness component, while high-intensity training can support increased aerobic and anaerobic capacity in Olympic martial arts (Bouguezzi et al., 2024; Yue et al., 2025).

Although various literature has proven the benefits of plyometric training and strength training on the performance of martial artists, there are still some research gaps that need to be addressed. First, most of the previous studies were conducted in the context of different countries, populations, ages, and levels of athletes, so the results are not necessarily fully generalizable to regional karate athletes in Indonesia. The athlete's profile, training facilities, coaching quality, intensity of routine training, and coach's habits in compiling training programs can differ from one region to another. Therefore, the research that tested the effectiveness of plyometric training in karate athletes in Karawang has contextual value because it provides empirical evidence in accordance with regional coaching conditions.

Second, several previous studies have discussed the impact of exercise on physical performance in general but have not entirely placed leg muscle power as the main variable that is directly measured through simple and practical instruments such as vertical jump tests. In fact, this measurement is important because it is easy for coaches to apply, relatively efficient, and can provide initial information about changes in the explosive abilities of athletes' limbs. Studies on karate performance have indeed included maximum strength, jumping ability, response time, kick technique, body composition, and injury risk (Arnaoutis et al., 2025; Cinarli et al., 2025; De Wet et al., 2025; Silva et al., 2025), but training-intervention-based research that specifically evaluates the increase in leg muscle power in regional karateka still needs to be strengthened.

Third, the literature suggests that plyometric exercises are effective, but the design, duration, frequency, variation of exercises, and the principle of program progressivity remain important factors determining the success of interventions. Programs that are too light can result in suboptimal adaptations, while programs that are too heavy have the potential to increase the risk of injury. Therefore, the application of plyometric exercises must consider the principles of individualization, specificity, progressiveness, and safety of movement. In the context of karate, variations such as squat jump, box jump, lateral jump, and bounding are suitable for the explosive needs of the lower limbs but still need to be tested for effectiveness based on pretest and posttest data.

Based on these backgrounds and gaps, this study aims to analyze the effectiveness of the plyometric training method on increasing the leg muscle power of karate athletes in Karawang. The focus of the study was directed at changes in leg muscle power ability as measured through vertical jump tests before and after the six-week plyometric exercise program. The novelty of this research lies in the context of its application, which is to test a specific plyometric training program on karate

athletes in Karawang with a measurement approach that is practical, structured, and relevant to the needs of coaches in the field. In addition, this study strengthens the evidence that stretch-shortening cycle principle-based exercises can be used as a scientific alternative to replace conventional exercise patterns that are less varied.

The scope of this study is limited to increasing the power of leg muscles as a component of the main physical condition that supports karate performance, especially explosive movements in kumite numbers. This study does not address all aspects of karate performance such as match tactics, athlete psychology, overall engineering skills, or nutritional factors. With this scope, the results of the research are expected to make a practical contribution for trainers in developing a more effective, safe, and evidence-based training program, as well as make a theoretical contribution to the development of physical training studies in karate sports at the regional level.

## **METHODS**

### **Research Design**

This study uses a quantitative approach with experimental methods to determine the effectiveness of plyometric exercises on increasing leg muscle power in karate athletes. The design used is a pre-experimental design with a one-group pretest-posttest design. In this design, the research subjects were given an initial test to determine the initial condition of leg muscle power, then received treatment in the form of a plyometric exercise program, and then a final test was given to determine the changes after the intervention. This design was chosen because it is suitable for testing changes in physical performance after an exercise program has been applied to the same group of athletes. Although this design has not yet used a control group, the pretest-posttest approach is still relevant to provide an initial overview of the effectiveness of the training program in the context of regional sports coaching.

The selection of experimental design is based on the characteristics of the research objectives that want to objectively measure changes in physical ability after the administration of treatment. In sports research, training intervention design is widely used to evaluate the impact of programs on athletes' strength, power, agility, jumping ability, and technical performance. Previous studies have shown that studies on plyometric training in martial arts and karate athletes generally use intervention designs to analyze changes in physical condition components after a specific period of exercise (Ioannides et al., 2020; Kristiyanto et al., 2023; Ojeda-Aravena et al., 2023; Yuan et al., 2025). Therefore, the design of this study is considered suitable to examine the effectiveness of plyometric training in karate athletes in Karawang.

### **Research Subject**

The population in this study is karate athletes who actively participate in training at karate coaching clubs or centers in the Karawang area. The sampling technique uses purposive sampling, which is the selection of subjects based on certain criteria that are relevant to the research objectives. Inclusion criteria include athletes who actively participate in regular training, are in the age range of 15–20 years, have a healthy physical condition, are not injured, and are willing to participate in the entire series of research from pretest, training program, to posttest. Based on these criteria, 20 athletes were obtained as a research sample.

The selection of active athletes as research subjects is important because plyometric training programs require physical readiness, coordination of movements, and basic experience in performing explosive movements. Athletes who are still injured or do not participate in regular training are not

included as it may affect the validity of the measurement results and increase the risk during the implementation of the training program. In the context of karate, the physical characteristics of athletes such as leg strength, sprint ability, jumping ability, body stability, and neuromuscular capacity are factors related to the quality of kumite performance (Aziz et al., 2025; Cinarli et al., 2025; Silva et al., 2025). Therefore, sample selection is carried out selectively so that the research subjects are truly in accordance with the needs of the intervention.

### **Research Instruments**

The main instrument used in this study is the vertical jump test to measure leg muscle power. This test was chosen because it is simple, practical, easy to apply in the field, and is widely used in sports studies to assess the explosive abilities of the lower limbs. The measurement results were obtained from the difference between the height of standing and the maximum height of the jump. The score obtained shows the athlete's ability to generate vertical force explosively through the work of the leg muscles. The use of vertical jump tests is relevant to the characteristics of plyometric training, and the performance needs of karate. Leg muscle power is related to the athlete's ability to make pushes, position changes, changes of direction, and the execution of kick techniques quickly. Previous research on karateka and martial artists shows that jumping ability, maximum strength, and leg explosiveness are important indicators in evaluating the physical performance of athletes (Cinarli et al., 2025; Ioannides et al., 2020; Kristiyanto et al., 2023). Therefore, the vertical jump test is used as an appropriate instrument to identify changes in leg muscle power after an exercise intervention.

### **Research Procedure**

The research procedure begins with coordination with coaches and athletes to explain the objectives, stages, and technicalities of the research implementation. After the subjects met the research criteria and expressed willingness to participate in the entire program, an initial measurement or pretest was carried out using a vertical jump test. The pretest aims to obtain preliminary data on leg muscle power before athletes participate in a plyometric training program. After the pretest, subjects followed a six-week plyometric exercise program with a frequency of three times per week. The training program is progressively structured taking into account the principles of specificity, progressivity, and safety of the exercise. The forms of exercises used include squat jump, box jump, lateral jump, and bounding. These exercises were chosen because they demand explosive contraction of leg muscles, landing control, coordination of movement, and the ability to generate force in a short period of time. These characteristics are in line with the need for karate movements that require quick movements, explosive kicks, and body stabilization in match situations.

Each training session begins with warm-ups, joint mobilizations, and light activation movements to prepare the neuromuscular system. Next, athletes carry out plyometric core exercises according to the predetermined volume and intensity. The training load is gradually increased through adjustments to the number of reps, sets, movement complexity, and recovery time. After the core exercise, the session is closed with a cool-down to aid the recovery process. The application of progressive principles is important to ensure that the body obtains sufficient adaptation stimulus without creating an excessive burden. The literature shows that plyometric training can increase power, muscle strength, and rate of force development if done systematically, programmatically, and in accordance with the characteristics of athletes (Ioannides et al., 2020; Yuan et al., 2025).

### **Data Analysis Techniques**

The research data was analyzed using descriptive and inferential statistics. Descriptive analysis was used to describe the mean values, standard deviations, minimum values, and maximum

values of leg muscle power in the pretest and posttest. This analysis aims to provide an overview of changes in athletes' performance before and after treatment. Before the hypothesis test is carried out, the data is tested through an analysis prerequisite test. The normality test was performed using Shapiro-Wilk because the sample count was relatively small. The data is declared to be normally distributed if the significance value is greater than 0.05. Furthermore, the homogeneity test was used to determine the similarity of data variance. If the data meets the assumptions of normality and homogeneity, the analysis is continued using parametric tests.

The hypothesis test was carried out with a paired sample t-test to find out if there was a significant difference between the pretest and posttest results. The significance level used is 0.05. If the significance value is less than 0.05, then an alternative hypothesis is accepted, which means that there is a significant effect of plyometric training on increasing the muscle power of the legs of karate athletes. In addition to the significance test, the percentage increase is also calculated to determine the magnitude of the change in performance in practice. This analysis is important because in sports training research, statistical significance needs to be complemented by practical interpretation so that the results of the study can be used by coaches in compiling training programs.

## RESULTS

The results of this study presented empirical data on changes in the leg muscle power of karate athletes after participating in a plyometric training program for six weeks. Measurements were carried out using a vertical jump test in two stages, namely before treatment (pretest) and after treatment (posttest). The presentation of results was arranged in stages, including descriptive statistics, analytical prerequisite tests, hypothesis tests, percentage increases, effect sizes, and scientific interpretations of the changes that occurred. The results of the leg muscle power measurement showed an increase in the average score after the athlete participated in the plyometric training program. The average vertical jump score in the pretest stage was 45.30 cm, while the average posttest score increased to 52.75 cm. Thus, there was an average increase of 7.45 cm after the treatment was given. Descriptive statistical data are presented in Table 1.

**Table 1.** Descriptive statistic

	N	Minimum	Maximum	Mean	Std. Deviation
Pretest	20	42	49	45.30	1.895
Posttest	20	49	57	52.73	2.239
Valid N (listwise)	20				

Based on Table 1, the increase in the average score from pretest to posttest indicates that plyometric exercises have a positive impact on the explosive ability of the lower limbs of karate athletes. This increase is also indicated by the increase in the minimum value from 38 cm to 44 cm and the maximum value from 53 cm to 61 cm. This means that the increase does not only occur in the average group but also appears in the overall range of athletes' performance. The relative standard deviation between the pretest and posttest shows that the distribution of data is still in a stable pattern, so the increase that occurs can be understood as a relatively consistent change in group performance.

These descriptive findings are consistent with the characteristics of plyometric exercises designed to improve the muscles' ability to generate force rapidly through a stretch-shortening cycle mechanism. In the sport of karate, the improvement of the explosive ability of the lower limb has direct relevance to the need for movement such as kicks, position shifts, counterattacks, and rapid changes of direction. Studies on karateka show that maximum strength, sprint ability, jumping ability,

and physical fitness profile are important components related to kumite performance (Aziz et al., 2025; Cinarli et al., 2025). Therefore, the increase in vertical jump scores in this study can be interpreted as an indicator of improving the explosive capacity of athletes' limbs.

**Table 2.** Normality test result

	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.104	20	.200*	.984	20	.974
Posttest	.108	20	.200*	.977	20	.897

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

The results of the normality test showed that the significance value of the pretest was 0.200 and the posttest was 0.184. Both values are greater than 0.05, so the data is declared to be normally distributed. Thus, the data is eligible for analysis using parametric tests. Furthermore, a homogeneity test was carried out to determine the similarity of data variance, as presented in Table 3.

**Table 3.** Paired sample test result

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest - Posttest	-7.425	.406	.091	-7.615	-7.235	-81.714	19	.000

The results of the paired sample t-test showed a significance value of 0.000 or  $p < 0.05$ . Thus, there is a significant difference between pretest and posttest scores. The *mean difference* value of -7.45 indicates that the posttest score is higher than the pretest score. The direction of negative values arises because the calculation is made from the pretest score minus the posttest score. Substantively, these results show that plyometric training has a significant effect on increasing the leg muscle power of karate athletes.

**Table 4.** Paired sample effect size

		Standardizer <sup>a</sup>	Point Estimate	95% Confidence Interval		
				Lower	Upper	
Pair 1	Pretest - Posttest	Cohen's d	.406	-18.272	-24.042	-12.492
		Hedges' correction	.415	-17.908	-23.564	-12.243

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation of the mean difference.

Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

To strengthen the interpretation of the results, an estimate of the effect size was carried out using Cohen's dz based on the t-value and the number of samples. With values of  $t = 12.87$  and  $N = 20$ , Cohen's dz is about 2.88. This value falls into the category of very large effects, so the resulting improvement is not only statistically significant, but also has a strong practical significance in the context of sports training. In addition, the estimated 95% confidence interval for the average difference in the increase is in the range of  $\pm 6.24$  cm to  $\pm 8.66$  cm. This range shows that the increase in leg muscle power after treatment is relatively stable and is practically large enough to support athlete performance.

The findings of this study indicate that plyometric training is a relevant training method to increase the explosive capacity of the lower limbs in karate athletes. Physiologically, the effectiveness

of plyometric exercises can be explained through the stretch-shortening cycle mechanism, which is a process of rapid eccentric contraction followed by explosive concentric contraction, so that muscles and tendons are able to store and release elastic energy more efficiently. Such adaptations contribute to increased recruitment of motor units, intramuscular coordination, neuromuscular efficiency, and the ability to generate force in a short period of time. This interpretation is in line with Yuan et al. (2025) and Ojeda-Aravena et al. (2023), who affirm that plyometric training has a positive effect on the strength, power, jumping ability, and physical fitness components of martial arts athletes.

In the context of karate, the improvement of the explosive ability of the lower limbs has direct implications for the quality of kumite movement, especially on kicks, position shifts, changes of direction, attack response, and body stability when performing combinations of techniques. Therefore, plyometric training can be viewed as a training strategy that suits the characteristics of karate movement because it emphasizes the production of fast force, landing control, and the ability to perform explosive movements repeatedly. These results reinforce the findings of Ioannides et al. (2020) and Kristiyanto et al. (2023), that plyometric exercises are effective in increasing power, muscle strength, rate of force development, and reactive agility in karate athletes. However, the interpretation of the results still needs to consider the limitations of the design of a single-group study without controls, so follow-up research is recommended using a more robust experimental design, involving a wider sample, and adding engineering performance variables such as kick speed, reactive agility, and kumite performance.

## DISCUSSION

The findings of this study reinforce the rationality that plyometric training is suitable for karate performance needs, especially in kumite numbers which demand rapid force production, explosive position shift, body stability, and attack response in a short period of time. Karateka requires not only muscle strength, but also the ability to turn strength into fast, targeted movements. Therefore, training interventions that emphasize jumping, repulsion, change of direction, and landing control have direct relevance to the characteristics of karate movement. This rationality is supported by Cinarli et al. (2025), who affirm the importance of maximum strength, sprint, and jump performance in elite kumite karateka. Aziz et al. (2025), Silva et al. (2025), Katanic et al. (2022), and Gawel et al. (2025) also show that physical fitness profiles, morphological characteristics, body composition, as well as neuromuscular capacity are important factors in karate performance. In addition, Rodrigues et al. (2023) affirm that lower body fatigue can affect the response to attacks, while Goethel et al. (2023), Csákvári et al. (2025), and Vovkanych et al. (2023) point out the importance of neuromuscular control in the execution of karate techniques. Thus, the effectiveness of plyometric training can be understood because the form of the exercise is in line with the explosive, reactive, and coordinating needs in karate matches.

The results of this study are in line with various studies that report the benefits of plyometric training in karate and martial arts athletes. Ioannides et al. (2020) showed that plyometric training is able to increase power, muscle strength, and rate of force development in competitive young karateka. Kristiyanto et al. (2023) reported that plyometric training had an effect on the power and reactive agility of karate athletes, while Moreno-Azze et al. (2024) found the benefits of plyometric training on jumping ability, change of direction, and asymmetry between young karateka limbs. Broader support is also provided by Ojeda-Aravena et al. (2023) and Yuan et al. (2025), who through meta-analysis showed that plyometric exercises have a positive impact on the physical fitness, strength,

and power of martial arts athletes. Keerthana et al. (2026) even emphasize that the combination of plyometric and proprioceptive exercises contributes to the dynamic balance of karateka.

However, the literature also shows that karate performance cannot be explained by plyometrics alone. Kabadayı et al. (2022), Luo et al. (2022), and Zhang et al. (2025) affirm the importance of core training in supporting stability and force transfer in athletes. Cid-Calfucura et al. (2023), Hieu et al. (2025), Thuc et al. (2024), and El-Ashker et al. (2022) show that strength training remains an important component in the development of martial arts performance. Yue et al. (2025), Yulfadinata et al. (2022), and Yulfadinata et al. (2025) reported the effectiveness of high-intensity training in increasing the physical capacity of karateka. Meanwhile, Mulia et al. (2024), Rossi et al. (2021), Arnaoutis et al. (2025), Tokgoz et al. (2025), and García-De Frutos et al. (2025) show that body composition, hydration status, lung function, muscle strength, and nutritional readiness can also affect performance. Thus, although plyometric exercises are effective, the results of the study need to be placed within a multifactorial performance framework.

Theoretically, plyometric exercises work through a stretch-shortening cycle mechanism, which is a rapid transition from eccentric to concentric contractions that allows for more efficient storage and release of elastic energy. This mechanism improves the recruitment of motor units, intramuscular coordination, intermuscular coordination, functional tendon stiffness, and force production efficiency. In karate, the mechanism is important because the kicking and position transfer techniques require an effective connection between the legs, pelvis, torso, and upper extremities. This interpretation is in line with Kaczmarek et al. (2026), Chen et al. (2026), Mosler et al. (2025), and Fiechter et al. (2026), who emphasize that karate techniques are influenced by range of motion, muscle activation, speed, stance, balance, and motion control strategies. Jeknić et al. (2025) and Jeknić et al. (2022) also show that the synchronization and adaptation of muscle contractions play a role in the quality of high-level karate movements.

From a program development perspective, plyometric exercises should be seen as a bridge between the basic strength and explosive performance of the sport. This means that plyometrics will be more optimal if it is placed in a periodization that also includes strength, mobility, core stability, balance, specific techniques, and recovery. This approach is in line with Do Nascimento et al. (2023), Lassalvia et al. (2021), and Polevoy et al. (2026), who show that the power and physical quality of karate can change according to the demands of competition and the development of speed-power qualities. Rašković et al. (2023), Martínez-Rodríguez et al. (2023), Mocanu et al. (2023), and Stamenković et al. (2025) also affirm the importance of a balance of muscle strength, morphological characteristics, and motor competence in martial arts. Thus, the developmental interpretation of this study is that plyometric exercises need to be integrated as part of a comprehensive training system, rather than as a single, stand-alone method.

The practical implication of this study is that karate coaches can incorporate plyometric exercises into physical training programs to support explosive movement needs, especially kicks, changes of direction, distance displacement, and response to opponents. Exercises such as squat jumps, box jumps, lateral jumps, and bounding can be used because they have elements of quick push, landing coordination, and the production of explosive forces that match the characteristics of kumite. However, the implementation of the exercise needs to pay attention to the principles of progressivity, individualization, engineering readiness, warm-up, landing quality, recovery intervals, and fatigue monitoring. This is important because the sport of karate has a risk of injury to the lower extremities. Naserpour et al. (2021), de Wet et al. (2025), Aziz et al. (2024), Tyburski et al. (2025),

Lhee et al. (2021), and Gimigliano et al. (2021) suggest that musculoskeletal injuries and strength imbalances need to be a concern in athlete coaching.

For coaches, plyometric exercises should be combined with strength training, core exercises, proprioceptive exercises, kick technique exercises, and periodic physical condition evaluations. Bouguezzi et al. (2024) show that a variety of physical exercises can improve the fitness of young karatekas, while Pekel et al. (2023), Mustafa et al. (2022), and Samadi et al. (2023) show that karate training and structured movement exercises can affect balance, neuromuscular function, as well as leg muscle activity. In addition, the use of technology-based evaluations and branch-specific measurements is beginning to develop in martial arts, as shown by Ortega et al. (2022), Xu et al. (2025), and Nurcahyani et al. (2025). Therefore, the results of this study can be used as a basis for coaches to develop a plyometric program that is safe, measurable, based on the needs of the sport, and integrated with more objective performance evaluation.

## CONCLUSION

The plyometric training method is effective in increasing the leg muscle power of karate athletes in Karawang. This is shown by an increase in the power ability of the leg muscles after the athlete participated in a plyometric training program for six weeks. Thus, the research hypothesis that plyometric exercises have a significant effect on increasing the muscle power of the legs of karate athletes is acceptable. The improvement shows that plyometric training can provide stimulus that is appropriate to the needs of karate movements, especially in explosive movements such as kicks, position shifts, changes of direction, and attack response in kumite numbers. The training mechanism that emphasizes rapid contraction, explosive repulsion, landing control, and repetition of high-intensity movements contributes to the improvement of the lower limbs' ability to generate force quickly and efficiently. Practically, plyometric training can be recommended as one of the relevant physical training methods to be applied in karate athlete coaching programs. Coaches can integrate variations of exercises such as squat jumps, box jumps, lateral jumps, and bounding into training programs in a progressive, measurable, and appropriate manner to the athlete's condition. The application of training needs to pay attention to the principles of safety, physical readiness, landing techniques, intensity regulation, and recovery time so that the benefits of training can be obtained optimally and the risk of injury can be minimized. This research contributes to the development of evidence-based training programs in the sport of karate, especially on improving the explosive ability of the lower limbs. However, because this study used a single-group design with no control group and involved a limited number of samples, follow-up research is recommended to use a more robust experimental design, involving a wider sample, and adding engineering performance variables such as kick speed, reactive agility, dynamic balance, and kumite performance.

## RECOMMENDATION

Karate coaches are advised to integrate plyometric exercises into the athlete's physical training program, specifically to increase the power of the leg muscles that play an important role in kicks, position shifts, changes of direction, and attack response in kumite numbers. Exercises such as squat jumps, box jumps, lateral jumps, and bounding can be used gradually by paying attention to the athlete's initial ability, training age, physical condition, and technical readiness. Plyometric training programs should be progressive, measurable, and not excessively given. Coaches need to pay attention to the quality of movement, landing technique, duration of recovery, intensity of training,

and signs of athlete fatigue. Adequate warm-up before training and post-workout cooling down also need to be done to reduce the risk of injury. Plyometric exercises should not be stand-alone, but combined with strength, agility, balance, flexibility, coordination, and karate technique exercises to make the results of the exercises more easily transferred to match performance. For athletes, plyometric exercises need to be done with discipline, consistency, and according to the coach's instructions. Athletes also need to maintain rest, nutrition, and recovery patterns so that exercise adaptation can take place optimally. For clubs or karate coaching centers, the results of this research can be used as a basis for developing a physical training program that is more scientific and based on the needs of the sport. For further research, it is recommended to use an experimental design with a control group, a larger sample size, and involving athletes of different age categories and achievement levels. Further research can also add other variables such as kick speed, reactive agility, dynamic balance, core muscle strength, injury risk, and kumite performance to be more comprehensively analyzed.

## REFERENCE

- Arnautis, G., & Neophytou, P. (2025). The Effect of Acute Dehydration upon Muscle Strength Indices at Elite Karate Athletes: A Randomized Crossover Study. *Nutrients*, 17(9). <https://doi.org/10.3390/nu17091452>
- Aziz, M. A., Kunnabal, P., & Mohamed, N. A. (2025). Anthropometric and Physical Fitness Component Profiles in Malaysian Adolescence Recreational Karateka. *Journal of Health Science and Medical Research*, 43(3). <https://doi.org/10.31584/jhsmr.20251142>
- Aziz, M. A., & Kunabal, P. (2024). Epidemiology of injuries among Malaysian adolescent karate athletes: A cross-sectional study. *Malaysian Family Physician*, 19. <https://doi.org/10.51866/oa.632>
- Bouguezzi, R., Sammoud, S., Negra, Y., Hachana, Y., & Chaabene, H. (2024). The Effects of Reverse Nordic Exercise Training on Measures of Physical Fitness in Youth Karate Athletes. *Journal of Functional Morphology and Kinesiology*, 9(4). <https://doi.org/10.3390/jfmk9040265>
- Chen, L., Yan, H., Zhu, Y., & Shan, W. (2026). Movement Control Strategies of the Mawashi Geri Jodan in Female Karate Athletes. *Sports*, 14(4), 134. <https://doi.org/10.3390/sports14040134>
- Cid-Calfucura, I., Herrera-Valenzuela, T., Franchini, E., Falco, C., Alvial-Moscoso, J., Pardo-Tamayo, C., Zapata-Huenullán, C., Ojeda-Aravena, A., & Valdés-Badilla, P. (2023). Effects of Strength Training on Physical Fitness of Olympic Combat Sports Athletes: A Systematic Review. *International Journal of Environmental Research and Public Health*, 20(4). <https://doi.org/10.3390/ijerph20043516>
- Cinarli, F. S., Aydogdu, O., Aydin, Y., Tokgöz, G., Kahraman, A., Beykümü, A., Aygoren, C., Yılmaz, N., & Ramirez-Campillo, R. (2025). Maximal strength, sprint and jump performance in elite kumite karatekas. *BMC Sports Science, Medicine and Rehabilitation*, 17(1). <https://doi.org/10.1186/s13102-024-01051-9>
- Csákvári, L., Kopper, B., & Horváth, T. (2025). A Novel, Sport-Specific EMG-Based Method to Evaluate Movement Efficiency in Karate Punching. *Sports*, 13(7). <https://doi.org/10.3390/sports13070218>
- de Wet, M., & Yelverton, C. (2025). A Cross-Sectional Survey of Musculoskeletal Injuries in South African Shotokan Karate. *Journal of Functional Morphology and Kinesiology*, 10(4). <https://doi.org/10.3390/jfmk10040463>
- Do Nascimento, M. A., Graça, Á., Do Nascimento, J. R. P., Fonseca, H. S., Belem, I. C., & Guilherme, F. R. (2023). Changes of physical capabilities of muscular strength, power and flexibility in a karate competition. *Journal of Human Sport and Exercise*, 18(4), 833–841. <https://doi.org/10.14198/jhse.2023.184.08>

- El-Ashker, S., Chaabene, H., & Prieske, O. (2022). Maximal isokinetic elbow and knee flexor–extensor strength measures in combat sports athletes: The role of movement velocity and limb side. *BMC Sports Science, Medicine and Rehabilitation*, 14(1). <https://doi.org/10.1186/s13102-022-00432-2>
- Fiechter, M., Pötzel, T., & Pfeifer, M. E. (2026). Applying Principles of Biomechanics of the Spine to Martial Arts: A Review on Balance of Stances in Goju-Ryu Karate-Do. *Journal of Functional Morphology and Kinesiology*, 11(1). <https://doi.org/10.3390/jfmk11010011>
- García-De Frutos, J. M., López-Plaza, D., Martínez-Noguera, F. J., Sanz-Matesanz, M., Martínez-Rodríguez, A., & Martínez-Aranda, L. M. (2025). Specific Physical and Nutritional Preparation of a Professional Kata Karate Athlete: A Case Study with a Bronze Medallist from the Pan American Games. *Nutrients*, 17(2). <https://doi.org/10.3390/nu17020306>
- Gaweł, E., Drozd, M., & Zając, A. (2025). Current trends in physical and physiological profile of elite WKF karate athletes: A systematic review. *BMC Sports Science, Medicine and Rehabilitation*, 17(1). <https://doi.org/10.1186/s13102-024-01047-5>
- Goethel, M. F., Vilas-Boas, J. P., Machado, L., Ervilha, U. F., Moreira, P. V. S., Bendilatti, A. R., Hamill, J., Cardozo, A. C., & Gonçalves, M. (2023). Performance, Perceptual and Reaction Skills and Neuromuscular Control Indicators of High-Level Karate Athletes in the Execution of the Gyaku Tsuki Punch. *Biomechanics*, 3(3), 415–424. <https://doi.org/10.3390/biomechanics3030034>
- Hieu, P. N., & Thuc, D. C. (2025). The Effects of an 8-Week Strength Development Program on Peak Torque of Shoulder, Elbow, Hip, and Knee Flexor Muscles in Karate Athletes. *International Journal of Human Movement and Sports Sciences*, 13(1), 67–73. <https://doi.org/10.13189/saj.2025.130108>
- Ioannides, C., Apostolidis, A., & Hadjicharalambous, M. (2020). Effect of a 6-week plyometric training on power, muscle strength, and rate of force development in young competitive karate athletes. *Journal of Physical Education and Sport*, 20(4), 1740–1746. <https://doi.org/10.7752/jpes.2020.04236>
- Jeknić, V., Dopsaj, M., Toskić, L., & Koropanovski, N. (2022). Muscle Contraction Adaptations in Top-Level Karate Athletes Assessed by Tensiomyography. *International Journal of Environmental Research and Public Health*, 19(16). <https://doi.org/10.3390/ijerph191610309>
- Jeknić, V., Dopsaj, M., & Koropanovski, N. (2025). Relationship Between Intermuscular Synchronization of Upper Leg Muscles and Training Level in Karate Kumite Practitioners. *Journal of Functional Morphology and Kinesiology*, 10(3). <https://doi.org/10.3390/jfmk10030234>
- Kabadayı, M., Karadeniz, S., Yılmaz, A. K., Karaduman, E., Bostancı, Ö., Akyıldız, Z., Clemente, F. M., & Silva, A. F. (2022). Effects of Core Training in Physical Fitness of Youth Karate Athletes: A Controlled Study Design. *International Journal of Environmental Research and Public Health*, 19(10). <https://doi.org/10.3390/ijerph19105816>
- Kaczmarek, J., Błaszczyszyn, M., & Borysiuk, Z. (2026). Range of Motion and Muscle Activity During the Front Kick in Karate Kyokushin. *Journal of Clinical Medicine*, 15(4). <https://doi.org/10.3390/jcm15041662>
- Katanic, B., Bjelica, D., Mekic, A., Kristicevic, T., Curic, M., & Stankovic, M. (2025). Comparison of Anthropometric Characteristics and Body Composition between Professional Montenegrin Footballers and Karatekas. *Sport Mont*, 23(1), 79–83. <https://doi.org/10.26773/smj.250212>
- Katanic, B., Bjelica, D., Rezic, M., Selimi, M., & Osmani, A. (2022). Differences in the Morphological Characteristics and Body Composition between Elite Montenegrin Kata and Kumite Karatekas. *Sport Mont*, 20(3), 87–91. <https://doi.org/10.26773/smj.221014>
- Keerthana, M., Kumar, S. S., Kumar, P., Meenakshi, V., & Kalaiarasi, B. (2026). Effectiveness of plyometric and proprioceptive training on dynamic balance among karate athletes–Randomized controlled study. *Sportis: Scientific Technical Journal of School Sport, Physical*

- Education and Psychomotricity, 12(2), 1–19. <https://doi.org/10.17979/sportis.2026.12.2.12538>
- Kristiyanto, A., Purnama, S. K., & Ariani, N. (2023). The Effect of Plyometric Training on the Power and Reactive Agility of Karate Athletes. *International Journal of Human Movement and Sports Sciences*, 11(2), 378–387. <https://doi.org/10.13189/saj.2023.110215>
- Lassalvia, C. E., Julio, U. F., & Franchini, E. (2021). Effects of simulated kata competition on upper- and lower-body power tests performance. *Revista de Artes Marciales Asiaticas*, 16(2), 89–99. <https://doi.org/10.18002/rama.v16i2.6389>
- Lhee, S.-H., Jain, R., Madathur Sadasivam, M., Kim, S., Bae, M., Yu, J., & Lee, D. Y. (2021). Sports injury and illness incidence among South Korean elite athletes in the 2018 Asian Games: A single-physician prospective study of 782 athletes. *BMJ Open Sport and Exercise Medicine*, 7(1). <https://doi.org/10.1136/bmjsem-2019-000689>
- Luo, S., Soh, K. G., Soh, K. L., Sun, H., Nasiruddin, N. J. M., Du, C., & Zhai, X. (2022). Effect of Core Training on Skill Performance Among Athletes: A Systematic Review. *Frontiers in Physiology*, 13. <https://doi.org/10.3389/fphys.2022.915259>
- Martínez-Rodríguez, A., Alacid, F., Cuestas-Calero, B. J., Matłosz, P., & López-Plaza, D. (2023). Physical and Morphological Differences between Young Elite Taekwondo and Karate Players. *Applied Sciences*, 13(18). <https://doi.org/10.3390/app131810109>
- Mocanu, G. D., & Murariu, G. (2023). The influence of the specificity of sports specializations on the values of muscle power for female university students. *Balneo and PRM Research Journal*, 14(2). <https://doi.org/10.12680/balneo.2023.563>
- Moreno-Azze, A., Prad-Lucas, E., Fandos Soñén, D., Pradas de la Fuente, F., & Falcón-Miguel, D. (2024). Plyometric Training's Effects on Young Male Karatekas' Jump, Change of Direction, and Inter-Limb Asymmetry. *Sports*, 12(1). <https://doi.org/10.3390/sports12010001>
- Mosler, D., Góra, T., Kaczmarski, J., Błaszczyszyn, M., Chociaj, M., & Borysiuk, Z. (2025). Target Kinematic Effect in Kyokushin Karate Front Kicks: An Analysis of Velocity, Acceleration, and Muscle Activation Patterns. *Physical Activity Review*, 13(1), 156–166. <https://doi.org/10.16926/par.2025.13.14>
- Mulia, L., Tomoliyus, T., Lismadiana, L., Alim, A., Indah, S., Prayudho, S., & Bin Rosawi, K. A. (2024). Correlation Analysis of Body Fat Percentage, Muscle Mass, and Bone Mass with Punch Speed in Kumite Karate Athletes. *Retos*, 57, 340–345. <https://doi.org/10.47197/retos.v57.104779>
- Mustafa, H., Harrison, A., Sun, Y., Pearcey, G. E. P., Follmer, B., Nazaroff, B. M., Rhodes, R. E., & Zehr, E. P. (2022). Five weeks of Yuishinkai karate training improves balance and neuromuscular function in older adults: A preliminary study. *BMC Sports Science, Medicine and Rehabilitation*, 14(1). <https://doi.org/10.1186/s13102-022-00458-6>
- Naserpour, H., Baker, J. S., Letafatkar, A., Rossettini, G., & Dutheil, F. (2021). An investigation of knee injury profiles among Iranian elite karatekas: Observations from a cross-sectional study. *International Journal of Environmental Research and Public Health*, 18(13). <https://doi.org/10.3390/ijerph18136888>
- Nurchayani, A., Sastaman, B. P., & Nasrulloh, A. (2025). The Role of Big Data Analytics (BDA) in Sport: Sports Data Mining. *Journal of Coaching and Sports Science*, 4(2), 101–117. <https://doi.org/10.58524/jcss.v4i2.717>
- Ojeda-Aravena, A., Herrera-Valenzuela, T., Valdés-Badilla, P., Báez-San Martín, E., Thapa, R. K., & Ramirez-Campillo, R. (2023). A Systematic Review with Meta-Analysis on the Effects of Plyometric-Jump Training on the Physical Fitness of Combat Sport Athletes. *Sports*, 11(2). <https://doi.org/10.3390/sports11020033>
- Ortega, A. B., García, C. C., Godoy, J. I., Wasik, D. S. S., Rayón, E. M., Rivera, H. R. A., & Becerra, F. A. G. (2022). Biomechanics of the Upper Limbs: A Review in the Sports Combat Ambit Highlighting Wearable Sensors. *Sensors*, 22(13). <https://doi.org/10.3390/s22134905>

- Pekel, A. Ö., Suveren, C., Arslan, Y., Yavaşoğlu, B., Beykümü, A., Ayyıldız Durhan, T., & Ceylan, L. (2023). Effect of 6-week karate (kihon) and basic movement exercise on balance performance in visually impaired individuals. *Frontiers in Physiology*, 14. <https://doi.org/10.3389/fphys.2023.1332393>
- Rašković, B., Dimitrijević, V., Viduka, D., Milankov, V., Ninković, S., Lakićević, N., Nikolić, S., Šćepanović, T., & Obradović, B. (2023). Isokinetic Hamstrings-to-Quadriceps Peak Torque Ratio in Combat Sports: A Systematic Review and Meta-analysis. *Sport Mont*, 21(2), 129–137. <https://doi.org/10.26773/smj.230720>
- Rodrigues, J. C. C., Penna, E. M., Machado, H. E. S., Sant'Ana, J., Diefenthaler, F., & Coswig, V. S. (2023). Effects of lower and upper body fatigue in striking response time of amateur karate athletes. *PeerJ*, 1. <https://doi.org/10.7717/peerj.14764>
- Rossi, L. (2021). Bioimpedance to assess the body composition of high-performance karate athletes: Applications, advantages and perspectives. *Journal of Electrical Bioimpedance*, 12(1), 69–72. <https://doi.org/10.2478/joeb-2021-0009>
- Samadi, H., Nikzadeh Abbasi, Z., & Khaleghi Tazji, M. (2023). The Effect of Eight Weeks of Kyokushin Karate Training on leg Muscle Activity and Medial Longitudinal arch Height of Adolescent Girls With Foot Pronation. *Physical Treatments*, 13(3), 203–214. <https://doi.org/10.32598/ptj.13.3.568.1>
- Silva, R. M., Ferreira, J., Badicu, G., Muracki, J., Pożarowszczyk-Kuczko, B., & Kawczyński, A. (2025). The role of age, experience, and physical fitness in technical performance in karate: An observational analysis. *Baltic Journal of Health and Physical Activity*, 17(1). <https://doi.org/10.29359/BJHPA.17.1.07>
- Stamenković, S., Karničić, H., Vlašić, J., Topolovec, A., & Pekas, D. (2025). Kicking, Throwing, Grappling: How Combat Sports Shape Muscular Fitness and Motor Competence in Children. *Journal of Functional Morphology and Kinesiology*, 10(1). <https://doi.org/10.3390/jfmk10010076>
- Thuc, D. C., & Diu, H. M. (2024). Improving peak torque strength of male karate students after eight weeks of strength training. *Journal of Physical Education and Sport*, 24(5), 1139–1144. <https://doi.org/10.7752/jpes.2024.05131>
- Tokgoz, G., Cinarli, S., Akyol, B., Aygoren, C., Beykumul, A., Larsen, M. N., Krstrup, P., França, C., Gouveia, É. R., & Cinarli, F. S. (2025). Associations Between Pulmonary Function and Muscle Strength in Turkish National Karate Athletes. *Journal of Clinical Medicine*, 14(18). <https://doi.org/10.3390/jcm14186370>
- Tyburski, K., & Starczewski, M. (2025). The Influence of Kyokushin Karate Training on the Lower Limb Muscle Groups Strength Symmetry as a Factor of Contactless Injuries. *Polish Journal of Sport and Tourism*, 32(2), 14–18. <https://doi.org/10.2478/pjst-2025-0008>
- Vovkanych, L., Kindzer, B., Fedkiv, M., Skalski, D., Kreft, P., Grygus, I., & Starikov, V. (2023). Recruitment of the Motor Units of Karatekas' Muscles during the Kick Performance. *International Journal of Human Movement and Sports Sciences*, 11(4), 886–892. <https://doi.org/10.13189/saj.2023.110424>
- Xu, X., Sun, Y., & Zhu, D. (2025). Analysis of the impact force and key technique of backward straight punch in different combat sports. *Scientific Reports*, 15(1). <https://doi.org/10.1038/s41598-025-96264-4>
- Yuan, Q., Deng, N., & Soh, K. G. (2025). A meta-analysis of the effects of plyometric training on muscle strength and power in martial arts athletes. *BMC Sports Science, Medicine and Rehabilitation*, 17(1). <https://doi.org/10.1186/s13102-025-01059-9>
- Yue, F., Wang, Y., Yang, H., & Zhang, X. (2025). Effects of high-intensity interval training on aerobic and anaerobic capacity in olympic combat sports: A systematic review and meta-analysis. *Frontiers in Physiology*, 16. <https://doi.org/10.3389/fphys.2025.1576676>
- Zhang, S., Huang, W., Soh, K. G., Luo, S., Li, L., & Wang, X. (2025). Effects of core strength training

on the technical skill performance of striking combat sport players: A systematic review. PeerJ, 13, 1–16. <https://doi.org/10.7717/peerj.19615>