Effect of plyometric training and ladder drill training on sprint 20-meters agility and VO2max in karate athletes

Efecto del entrenamiento pliométrico y el entrenamiento con escalera sobre la agilidad en carreras de 20 metros y el VO2máx en atletas de karate

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Abstract

Introduction: Karate is a highly popular martial art that involves participants from various age groups. In the kumite category, athletes are required to have optimal physical abilities such as speed, agility, and endurance to maintain competitive advantage.
Objective: Therefore, this study aims to compare the effects of plyometric training and ladder drills on speed, agility, and VO2max in karate athletes.
Methodology: The participants in this study included 30 karate (kumite) athletes aged 18-20 years with an average weight of 60.88±7.5 kg, who were divided into three groups: (A1; n=10) control group, (A2; n=10) plyometric group, and (A3; n=10) ladder drill group. Training was conducted with a frequency of 3x/week for 6 weeks. Speed, agility, and VO2max were measured before and after the intervention in all groups. Data analysis was conducted using one-way ANOVA followed by the Least Significant Difference (LSD) post-hoc test with a 5% significance level.
Results: The results showed that plyometric and ladder drill training for 6 weeks significantly improved the physical performance of karate athletes ($p \leq 0.05$). Plyometric training was proven to be more effective in increasing sprint speed and aerobic capacity ($p \leq 0.05$), while ladder drill training was more effective in improving agility ($p \leq 0.05$).
Conclusions: This study found that the use of plyometric and ladder drill training in karate athletes is highly effective in improving speed, agility, and VO2max in Kumite athletes, providing practical guidance for coaches in designing effective and targeted training programs to enhance the physical performance of karate athletes.

Keywords

Karate athletes, ladder drill training, physical performance, plyometric training.

Resumen

Introducción: El karate es un arte marcial muy popular que involucra a participantes de diversas edades. En la categoría de kumite, los atletas deben poseer habilidades físicas óptimas como velocidad, agilidad y resistencia para mantener una ventaja competitiva.
Objetivo: Por lo tanto, este estudio busca comparar los efectos del entrenamiento pliométrico y los ejercicios de escalera sobre la velocidad, la agilidad y el VO2máx en karatecas.
Metodología: Participaron 30 karatecas (kumite) de entre 18 y 20 años con un peso promedio de 60,88 ± 7,5 kg, divididos en tres grupos: (A1; n = 10) grupo control, (A2; n = 10) grupo pliométrico y (A3; n = 10) grupo de ejercicios de escalera. El entrenamiento se realizó con una frecuencia de 3 veces por semana durante 6 semanas. Se midieron la velocidad, la agilidad y el VO2máx antes y después de la intervención en todos los grupos. El análisis de datos se realizó mediante un ANOVA unidireccional seguido de la prueba post-hoc de Diferencia Mínima Significativa (LSD) con un nivel de significancia del 5%.
Resultados: Los resultados mostraron que el entrenamiento pliométrico y de ejercicios de escalera durante 6 semanas mejoró significativamente el rendimiento físico de los karatecas ($p \leq 0,05$). El entrenamiento pliométrico demostró ser más eficaz para aumentar la velocidad de sprint y la capacidad aeróbica ($p \leq 0,05$), mientras que el entrenamiento de ejercicios de escalera fue más eficaz para mejorar la agilidad ($p \leq 0,05$).
Conclusiones: Este estudio reveló que el uso del entrenamiento pliométrico y de ejercicios de escalera en karatecas es altamente eficaz para mejorar la velocidad, la agilidad y el VO2máx en los atletas de Kumite, lo que proporciona una guía práctica para los entrenadores en el diseño de programas de entrenamiento efectivos y específicos para mejorar el rendimiento físico de los karatecas.

Palabras clave

Atletas de karate, entrenamiento con escalera, rendimiento físico, entrenamiento pliométrico.

Introduction

Karate is a highly popular martial art sport worldwide and involves various age groups, from children to adults (Zetaruk et al., 2000). Karate consists of two main categories: art (kata) and combat (kumite). Kumite emphasizes the dynamic aspects of attack and defense, requiring high levels of physical abilities and strategy (Bok et al., 2022). Kumite demands optimal physical abilities such as speed, agility, and endurance, as sudden changes of direction and quick movements are essential elements in gaining a competitive edge (Chindarkar et al., 2021). Although the role of physical factors in kumite has been well understood, there is still no clear consensus or specific guidance on the most effective training methods to enhance these physical abilities in kumite athletes (Ketelhut & Ketelhut, 2020; Yudhistira et al., 2021).

Plyometric training has been proven to be an effective method for improving explosive strength, agility, and endurance through the rapid stretching and shortening cycles of muscles (Eraslan et al., 2021; Huang et al., 2023; Kons et al., 2023). Plyometric exercises are often applied to increase power and physical responsiveness, especially in sports that demand high physical intensity (Türkarslan & Deliceoglu, 2024). However, in the context of karate, the effectiveness of plyometric training needs to be considered in comparison to other methods, such as ladder drills, which are more focused on improving speed, precision, and adaptive abilities in changing movement direction (Hikmah et al., 2023). Therefore, it is important to conduct comparative research on how these two methods can affect the specific performance of kumite athletes, who require a high level of physical responsiveness.

Ladder drill training plays a crucial role in improving agility and motor adaptation abilities, which are critical aspects of kumite due to its dynamic nature, requiring fast and precise movements (Hikmah et al., 2023). This method emphasizes lateral movement patterns and precise acceleration, aligning with the needs of Kumite, which demands quick and effective positional changes (Bassa et al., 2024). However, to date, no literature has directly compared the effects of plyometric training and ladder drills on specific physical performance indicators, such as speed, agility, and VO2max in kumite athletes. This has led to a lack of practical guidance for coaches in selecting the most effective training programs to enhance the physical performance of Kumite athletes (Ketelhut & Ketelhut, 2020).

This study aims to compare the effects of plyometric training and ladder drill training on speed, agility, and VO2max in kumite karate athletes. Given the distinct nature of each training method, plyometric exercises are expected to enhance explosive power and endurance, while ladder drills are anticipated to have a greater impact on agility and movement adaptability. By investigating these differences, this research seeks to provide empirical insights that can help coaches develop more effective training programs tailored to the specific needs of kumite athletes (Przybylski et al., 2021). The findings are expected to contribute to evidence-based recommendations for optimizing athletic performance, particularly in high-intensity competitive environments.

Method

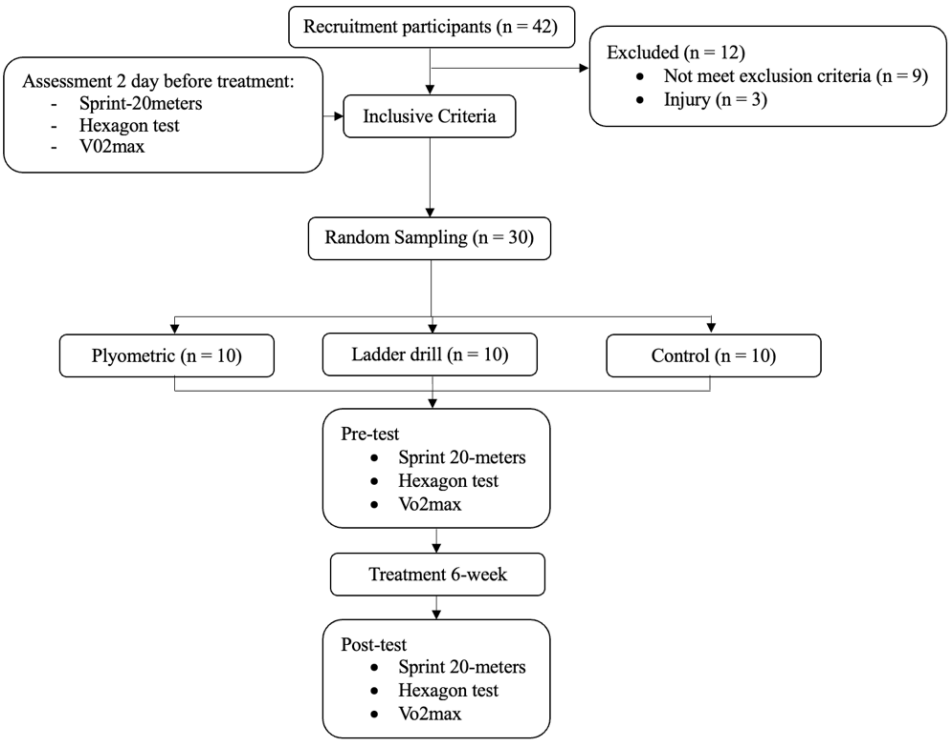
Research design

This study employed an experimental design with pre-test and post-test on 3 group designs. The participants were selected using random sampling, and they were divided into 3 groups (A1; n=10) control group, (A2; n=10) plyometric group, and (A3; n=10) ladder drill group.

Participants

A total of 30 male karate (kumite) athletes participated in this study (participant characteristics are shown in Table 1). The study set specific inclusion and exclusion criteria to determine whether the subjects qualified for participation. The inclusion criteria were male athletes aged between 18-20 years with a normal body mass index (BMI). The exclusion criteria were athletes younger than 18 years old or those with a history of injury within 1 month before the testing.

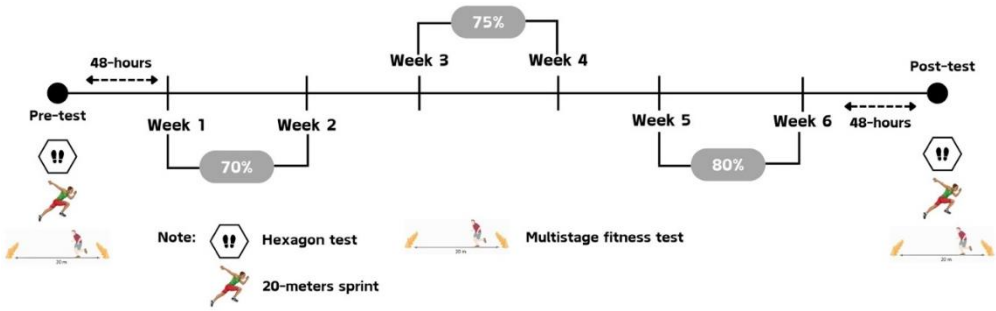
Figure 1. Flowchart of study design



Data collection procedure

The pre-test data collection was conducted two days before the training began by gathering data on participant characteristics (Figure 2). Before data collection, participants were asked to perform a 10-minute warm-up.

Figure 2. Intervention protocol and data collection



20-Meter Sprint Test

For this test, four spike poles were placed at two positions with a 20-meter distance between them (2 at the start and 2 at the finish line). At the start, participants stood precisely in the middle of the spike poles, spaced 60 cm apart. The evaluator gave a signal to the participants, instructing them with "Ready... Set... Go," while simultaneously pressing the start button on the stopwatch as the participants sprinted as fast as possible to cross the finish line. The evaluator stood exactly in line with the poles to stop the time accurately when the participant crossed the finish line. Each participant was given three attempts with a 3-minute interval between them, and the best time was recorded by the assessor (Johnson et al., 2010).

Hexagon agility test

This test followed a modified version of the original testing norms (Hernández-Davó et al., 2021). The test used a hexagon with 24-inch sides. For a 120-degree central angle, tape was used to mark the starting position. The participant stood in the center of the hexagon, facing forward with feet close together, awaiting the evaluator's signal. When the evaluator said "Ready... Go," the participant began by jumping with both feet forward, returning to the center, and then hopping clockwise around the hexagon for three complete rounds. The stopwatch was stopped once the participant completed three full rounds and landed at the original start position. Failure to jump into each side of the hexagon in sequence resulted in a failed attempt (Usra et al., 2024).

Multistage fitness test

To measure participants' VO2max, the researchers used the Multi-Stage 20-m Shuttle Run Fitness Test (Puspodari et al., 2022). Participants performed a series of 20-meter shuttle runs until they felt unable to continue. The test started at a speed of 8.5 km/h-1 which increased by 0.5 km/h-1 each minute. Verbal encouragement was provided to ensure that participants completed the test until they were fatigued.

Training protocol

Participants underwent a 6-week training program with a frequency of 3 days per week. The plyometric and ladder drill groups trained (as shown in Table 1) at an intensity of 70% of their maximum heart rate (HRmax) during weeks 1 and 2. The control group followed regular training without additional interventions. The HR max of each participant was calculated using the formula (220-age). During the training sessions, the researcher used a Polar H10 device (Malaysia) to monitor each participant's intensity (Avandi et al., 2024).

Table 1. Plyometric and ladder drill training programs over 6 weeks

Group	Week	Exercise	Frequencies	Intensity	Set	Recovery	Interval
Plyometric	1 - 2	Tuck Jump Squat Jump	3 days/week	70%	3	2-minute	3-minute
Ladder drill		Double Leg Run Double Leg Hop					
Plyometric	3 - 4	Tuck Jump Squat Jump	3 days/week	75%	3	2-minute	3-minute
Ladder drill		Double Leg Run Double Leg Hop					
Plyometric	5 - 6	Tuck Jump Squat Jump	3 days/week	80%	3	2-minute	3-minute
Ladder drill		Double Leg Run Double Leg Hop					

Statistical Analysis

After all data were collected, statistical analysis was performed using SPSS software (IBM SPSS Statistics 29, Inc. Chicago, USA). Descriptive statistics were calculated to obtain mean and standard deviation (SD) values. The Shapiro-Wilk test was used to assess data normality. Once a normal distribution was confirmed, a paired sample t-test was conducted. Group differences were tested using one-way ANOVA, followed by the Least Significant Difference (LSD) post-hoc test. All statistical results were set at a significance level of 5%.

Results

Based on Table 2 shows that there were no significant differences in the basic characteristics of participants among the control group (A1), the plyometric group (A2), and the ladder drill group (A3). Meanwhile, the results of the analysis of speed, agility, and VO2max differences between pre and post in each group are shown in Figure 3-5. Table 3 displays the results of comparative analysis of speed, agility, and VO2max between groups (A1, A2, A3).

Table 2. Descriptive data of participants

Variable	A_1 (n = 10)	A_2 (n = 10)	A_3 (n = 10)	p-value
Age (years)	19.3±0.82	19±0.81	18.7±0.82	0.271
BW (kg)	58.56±6.07	62.66±8.43	61.44±8	0.535
BH (cm)	165±9	168±6	168±6	0.625
BMI (kg/m²)	21.27±1.48	22.12±1.89	21.06±1.37	0.434
Pre-Speed (s)	3.82±0.68	3.81±0.23	3.89±0.27	0.917
Pre-Agility (s)	14.67±2.05	14.18±1.24	14.54±0.84	0.742
Pre-VO_2max (mL/kg/min)	42.43±3.61	42.23±3.52	43.02±2.92	0.863

Description: BW: Body weight; BH: Body height; BMI: Body mass index. The p-value was obtained by one-way ANOVA.

Figure 3. Difference of speed (s) between pre and post in each group. (*) significant at pre ($p \leq 0.05$). The p-value was obtained by paired samples t-test

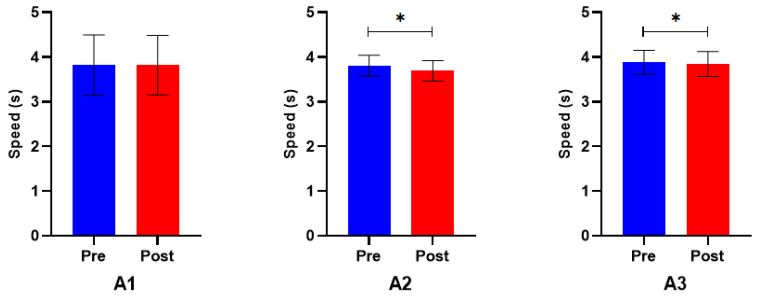


Figure 4. Difference of agility (s) between pre and post in each group. (*) significant at pre ($p \leq 0.05$). The p-value was obtained by paired samples t-test.

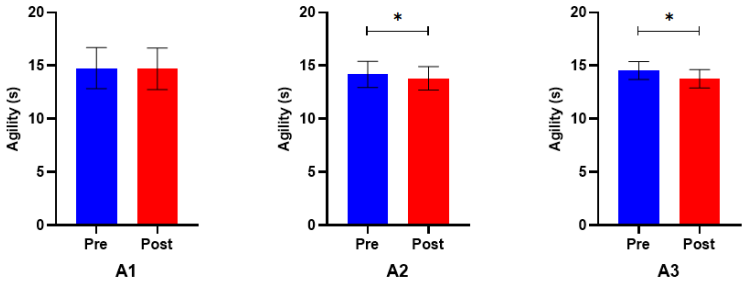


Figure 5. Difference of VO2max (mL/kg/min) between pre and post in each group. (*) significant at pre ($p \leq 0.05$). The p-value was obtained by paired samples t-test.

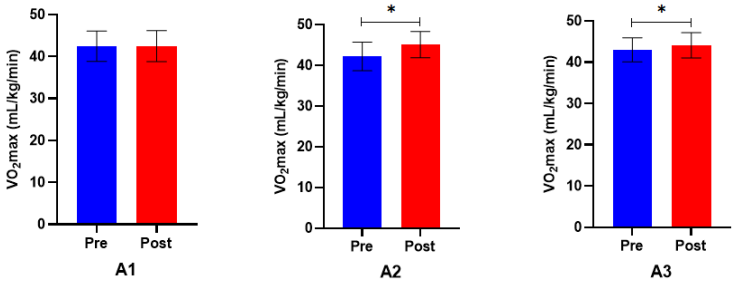


Table 3. Difference of speed, agility, and VO2max results

Variable	A_1 (n = 10)	A_2 (n = 10)	A_3 (n = 10)	p-value
Post-Speed (s)	3.82±0.67	3.69±0.23	3.84±0.28	0.717
Δ-Speed (s)	-0.01±0.02	-0.12±0.02*†	-0.04±0.01*	0.000
Post-Agility (s)	14.59±2.07	13.81±1.11	13.76±0.86	0.360
Δ-Agility (s)	-0.07±0.12	-0.36±0.31*	-0.78±0.08*¥	0.000
Post-VO_2max (mL/kg/min)	42.46±3.68	45.08±3.24	44.12±3.05	0.224
Δ-VO_2max (mL/kg/min)	0.02±0.41	2.85±1.02*†	1.09±0.63*	0.000

Description: The p-value was obtained by one-way ANOVA and followed by the Least Significant Difference (LSD) post-hoc test. (*) significant at A1 ($p \leq 0.05$). (¥) significant at A2 ($p \leq 0.05$). (†) significant at A3 ($p \leq 0.05$).

Discussion

This study aimed to compare the effects of plyometric training and ladder drill training on speed, agility, and VO2max in karate athletes. The results showed significant improvements in the plyometric and ladder drill groups compared to the control group. Plyometric training proved to be effective in improving speed, agility, and VO2max. These findings are consistent with the literature stating that plyometric training is effective in increasing muscle strength, explosive power, and speed (Eraslan et al., 2021; Huang et al., 2023). The effectiveness of this training can be attributed to neuromuscular adaptations involving increased motor unit recruitment and more efficient energy transfer through the stretch-shortening cycle of the muscles (Seiberl et al., 2021). These adaptations are highly relevant in kumite, where quick responses and explosive movements are essential in combat situations (Gumienna et al., 2024) Additionally, the increase in VO2max indicates that plyometric training also has significant effects on improving aerobic capacity (Deliceoğlu et al., 2023). This may be due to the intense and repetitive nature of plyometric movements, which demand higher efficiency in the cardiorespiratory system (Deng et al., 2024). Improving VO2max is crucial for karate athletes, particularly in Kumite, where good endurance is necessary to maintain performance throughout the match (Vasconcelos et al., 2020). Ladder drill training also showed significant improvements in speed, agility, and VO2max. Ladder drills emphasize fast and specific movement patterns that enhance athletes' abilities to change direction and adjust body movements efficiently, which is in line with the demands of Kumite, where high agility is required (Hikmah et al., 2023)

The differences between the plyometric and ladder drill results suggest that while both are effective, they may induce different types of adaptations. Ladder drills emphasize repeated, rapid lateral movements, which directly correlate with the need for Kumite athletes to possess excellent agility in dealing with opponents (Ojeda-Aravena et al., 2023). This supports previous findings that agility training involving specific movement patterns significantly improves agility and motor reflexes (Türkarslan & Deliceoglu, 2024).

The control group showed no significant changes in speed, agility, or VO2max, confirming that without structured training, no improvements occur in these physical attributes. This emphasizes the importance of implementing targeted training programs in karate, especially for the kumite category, which requires high physical capabilities (Cid-Calfucura et al., 2023). These findings align with Ketelhut & Ketelhut (2020), who reported that specific biomotor improvements require structured and directed training to enhance physical performance.

The practical implications of these findings are highly relevant for karate coaches in designing training programs for their athletes. Plyometric training showed more significant improvements in speed and endurance, making it an ideal choice when the training target is to enhance explosive speed and aerobic capacity (Cid-Calfucura et al., 2023). Meanwhile, ladder drills resulted in significant improvements in agility, making it suitable for maximizing lateral movement capabilities and responses to changes in combat situations (Afonso et al., 2020; Barley et al., 2019). A combination of plyometric and ladder drill training can also be considered, targeting the advantages of both methods to achieve comprehensive results in enhancing kumite athletes' performance (Bassa et al., 2024).

While both methods provide benefits, the selection of training should be adapted to the athlete's experience level and training phase. For novice kumite athletes, ladder drills may be more beneficial as a foundational exercise to develop agility and coordination before progressing to more intense plyometric training. Advanced athletes, on the other hand, may benefit more from a combination of both methods, integrating plyometric exercises to enhance power and endurance, while utilizing ladder drills to refine movement precision and reaction speed. Furthermore, during the competition preparation phases, a structured combination of both methods may be optimal, ensuring a balance between agility, endurance, and explosive strength.

This study has some limitations, including the relatively small sample size (n = 10 per group), which may affect the generalizability of the results. Additionally, the duration of the intervention could be further evaluated to see whether these significant changes can be sustained over the long term. Future studies should involve larger sample sizes and assess the long-term effects of combined plyometric and ladder drill training to gain a more comprehensive understanding of their impact on kumite performance. Future studies should involve larger and more diverse sample sizes, including participants

of different skill levels, genders, and age groups, to determine whether these factors influence training adaptations. Moreover, investigating the long-term retention of performance improvements and the effectiveness of combined plyometric and ladder drill training protocols could provide more comprehensive insights into optimizing training for kumite athletes.

Conclusions

This study demonstrated that plyometric and ladder drill training significantly improved the physical performance of karate athletes, particularly in the Kumite category. Plyometric training was shown to be more effective in enhancing sprint speed and aerobic capacity, while ladder drill training was more effective in optimizing agility. These findings support the use of structured training programs that combine both methods to improve the biomotor abilities required in Kumite matches, which demand quick responses, high endurance, and fast movement.

Conflict of interest

The authors declare that they have no competing interests.

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