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Effectiveness of plyometric and proprioceptive training on dynamic balance among karate athletes - Randomized controlled study

Efectividad del entrenamiento pliométrico y propioceptivo sobre el equilibrio dinámico en atletas de karate - Estudio controlado aleatorio

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Abstract

Karate's increasing popularity in India has led to a rise in injuries, emphasizing the need for effective training techniques to prevent them. Dynamic balance plays a vital role for karate athletes in executing precise movements, transitioning between stances, and maintaining control during rapid actions and powerful strikes. Improved dynamic balance lowers the chance of injury and increases overall performance in competitions in addition to improving technique, speed, and agility. The Randomized controlled study was to evaluate how well plyometric and proprioceptive training enhance dynamic balance in karate athletes, which will help them perform better and avoid injuries. These training methods also promote athletes' health and wellbeing by improving neuromuscular control and reducing injury risk**.** Karate athletes were chosen for the research population using predetermined inclusion and exclusion criteria. The participants provided written consent forms. 36 subjects in all. Plyometric training group (n = 18) and proprioceptive training group (n = 18). Using the modified star excursion balance test, the pre-test and post-test were assessed. For six weeks, the training process was conducted three days a week, with a 60-minute session each time. The results confirm that both training methods significantly improve dynamic balance among karate athletes, with proprioceptive training showing superior overall effectiveness, especially in multidirectional stability. The study confirms that both plyometric and proprioceptive training significantly improve dynamic balance in karate athletes, with proprioceptive training showing superior results, particularly in multidirectional stability. This emphasizes how crucial proprioceptive exercises are for improving karate performance and lowering the chance of injury.

Key words: plyometric training; proprioceptive training; dynamic balance; karate athletes; health and wellbeing

Resumen

El aumento de la popularidad del karate en la India ha provocado un incremento de las lesiones, lo que pone de manifiesto la necesidad de técnicas de entrenamiento eficaces para prevenirlas. El equilibrio dinámico juega un papel vital para los atletas de karate en la ejecución de movimientos precisos, la transición entre posturas y el mantenimiento del control durante acciones rápidas y golpes potentes. Un mejor equilibrio dinámico reduce las posibilidades de lesión y aumenta el rendimiento general en las competiciones, además de mejorar la técnica, la velocidad y la agilidad. El objetivo de este estudio era evaluar la eficacia del entrenamiento pliométrico y propioceptivo para mejorar el equilibrio dinámico en atletas de karate, lo que les ayudará a mejorar su rendimiento y prevenir lesiones. Estos métodos de entrenamiento también promueven la salud y el bienestar de los atletas al mejorar el control neuromuscular y reducir el riesgo de lesiones. Los atletas de karate fueron seleccionados para la población de estudio utilizando criterios de inclusión y exclusión predeterminados. Los participantes proporcionaron formularios de consentimiento por escrito. 36 sujetos en total. Grupo de entrenamiento pliométrico (n = 18) y grupo de entrenamiento propioceptivo (n = 18). Se evaluaron las pruebas pre y post

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mediante la prueba de equilibrio de excursión estelar modificada. Durante seis semanas, el proceso de entrenamiento se llevó a cabo tres días a la semana, con sesiones de 60 minutos cada una. Los resultados confirman que ambos métodos de entrenamiento mejoran significativamente el equilibrio dinámico en atletas de karate, siendo el entrenamiento propioceptivo el que muestra una mayor efectividad general, especialmente en la estabilidad multidireccional. El estudio confirma que tanto el entrenamiento pliométrico como el propioceptivo mejoran significativamente el equilibrio dinámico en atletas de karate, siendo el entrenamiento propioceptivo el que muestra resultados superiores, particularmente en la estabilidad multidireccional. Esto enfatiza la importancia crucial de los ejercicios propioceptivos para mejorar el rendimiento en karate y reducir el riesgo de lesiones.

Palabras clave: entrenamiento pliométrico; entrenamiento propioceptivo; equilibrio dinámico; atletas de karate; salud y bienestar.

Introduction

The ability to keep one's line of gravity within one's Base of Support (BOS) is known as balance (Löklüoğlu et al., 2024). The somatosensory, visual, and vestibular systems must provide quick and constant feedback for balance in order to generate fluid and synchronized neuromuscular movements (Sinulingga et al., 2025). Balance is divided into two categories: dynamic and static (Kenville et al..2021). The capacity to keep the body in a constant posture is known as static balance (Gonçalves et al., 2021). Dynamic balance is the ability to keep the centre of mass above the base of support while the body's components are moving and to maintain postural stability and orientation (Luo et al., 2025) (Gencayet.al.2020) (Wilczyński et al., 2021). Maintaining balance is crucial for both preventing falls and enhancing athletic performance (Mahmoudi et al., 2023). The development of high performance and the presentation of performances both depend on balance. Performing fundamental sports movements including sudden direction changes, holding, throwing, pushing, and stopping requires balance. An individual with proper balance may do tasks and actions with more effectively (Gebel et al., 2020). In martial arts, dynamic balance is crucial, and every martial arts athlete must possess swift, forceful motions that call for exact body control. Improving dynamic balance is important for karate performance as well as for maintaining the health and wellbeing of athletes.

Karate, which roughly translates to "empty hand," is a martial art. There are two types of karate: kata and kumite. Kata consists of a predetermined series of offensive and

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defensive movements and techniques (Kabadayı et al., 2022). On the other hand, kumite is a real contest or battle between two participants with tight regulations; they can move, kick, and punch in both offensive and defensive ways (Molinaro L et al., 2020). The foundation of karate is twofold: Kata emphasizes dynamic postural control, while Kumite focuses on Postural control, both static and dynamic. Karate competitors' competitive success is mostly dependent on their basic strength and balance (Hadad et al., 2020).

Plyometric exercises are a natural component of most sports because they require jumping, hopping, and skipping, such as high jumping, throwing, or kicking (Kons et al., 2023) (Anversha et al.,2023). Plyometric exercise is defined as the rapid pre-stretching of a muscle through an eccentric motion, followed by a circular movement of the same muscle and the connective tissue underneath (Wan et al., 2022) (Shen et al., 2024) . Plyometric training is a quick, explosive workout that incorporates a full stretch-shortening cycle (SSC) plus a pre-lengthening or reverse movement (Cabrejas et al.,2022) (Ramalingam et.,al 2026). Plyometric training uses one's own body weight to help perform exercises for both the upper and lower limbs (Aztarain-Cardiel et al., 2024). According to recent research, physical therapy (PT) can improve athletes' strength, power, agility, and balance in ways that are equivalent to or even better than traditional resistance training (RT) (Lu Z et al., 2022). Plyometric training may therefore be a suitable intervention to enhance the neuromuscular capacity to regulate dynamic balance (Magendran et.al., 2025).

Proprioception, which includes both conscious and unconscious awareness of postural balance, muscle sensation, and joint stability, is the reception of stimuli generated within an organism (Gidu DV et al., 2022) (Stanković et al., 2024). Proprioceptive training aims to enhance intricate neuromuscular system activity. Proprioceptive workout program is to strengthen the afferent pathways, which will enhance motion perception and ensure that complex actions are executed accurately and without hesitation. Thus, it is recommended that the exercise program incorporates both open and closed kinetic chain workouts in a systematic way (Li JX et al., 2009). Somatosensation, or proprioception, is a unique aspect of balance. Because it gives information on the state of the body as a whole, proprioceptive training has the potential to improve sports technique (Romero-Franco N et al., 2013). Proprioceptive training has

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been shown to be successful in lowering the risk of injury in a variety of sports contexts by improving neuromuscular control, joint stability, and dynamic balance (Francavilla et al., 2025) (Domeika et al., 2020). Proprioceptive exercise regimens would continue to include balance exercises for athletes to improve brain stem motor function. The importance of proprioception in sports for preventing injuries, recovering from them, identifying talent, and improving performance is well established (Yılmaz et al., 2024).

The Modified Star Excursion Balance Test (mSEBT) is a helpful assessment tool for dynamic balance and postural control. While standing on one leg in the centre of a grid, the test taker extends the other leg as far as possible in three separate directions, often anterior, posterolateral, and posteromedial (Bulow et al., 2019) (Jagger et al., 2020). The farthest reach in each direction and the total of the distances reached in these directions determine performance during the mSEBT (Pinheiro et al., 2020). Karate is a skill based sport that demands core strength, speed, agility, and balance. In order to increase the effectiveness of particular kinetic patterns and strategies required for success, every sporting event demands better and maximum performance. This study aims to evaluate and compare the effects of plyometric and proprioception training on the dynamic balance using modified Star Excursion Balance Test of karate competitors.

Methodology

It is an experimental study to find the effectiveness of plyometric training and proprioceptive training to improve dynamic balance among karate athletes. Subjects: karate athletes from various private karate academy, Sampling technique: convenient sampling, sample size: 36.

Inclusion criteria: Male karate athletes, Age: 18 to 25 years, Athletes competing at the district and state level, Athletes with at least 1 year of karate training experience, Athletes with no prior history of dynamic balance training, Willingness to participate in a 6 week structured training program

Exclusion criteria: Athletes with recent sports injury, those who are cannot come for regular practice, Athletes with any known neurological conditions affecting balance,

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Presence of musculoskeletal conditions affecting movement or balance, Athletes currently undergoing physiotherapy or rehabilitation for balance issues

Study procedure

The study population consisted of karate athletes selected based on predefined inclusion and exclusion criteria. Written consent forms were obtained from the participants. 36 participants were split into two groups: one for proprioceptive training (n = 18) and another for plyometric training (n = 18). The pre-test and post-test were evaluated using the modified star excursion balancing test.

Plyometric training group (n-18): The training sessions lasted 60 minutes and were conducted three times a week for six weeks. Warm-up and cool-down times for a normal workout were 10 and 5 minutes, respectively. Between sets, there were 40-second break periods, and between exercises, there were 2minute rest periods.

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Table 1: 6-week plyometric training program

Week 1
Side to side ankle hops (15 sets, 2 reps)
Standing jump and reach (15 sets, 2 reps)
Front cone hops (6 sets, 5 reps)
Week 2
Side to side ankle hops (15 sets, 2 reps)
Standing long jump (6 sets, 5 reps)
Lateral jump over barrier (15 sets, 2 reps)
Double leg hops (6 sets, 5 reps)
Week 3
Side to side ankle hops (12 sets, 2 reps)
Standing long jump (6 sets, 4 reps)
Lateral jump over barrier (12 sets, 2 reps)
Double leg hops (8 sets, 3 reps)
Lateral cone hops (12 sets, 2 reps)
Week 4
Diagonal cone hops (8 sets, 4 reps)
Standing long jump with lateral sprint (8 sets, 4 reps)
Lateral cone hops (12 sets, 2 reps)
Single leg bounding (7 sets, 4 reps)
Lateral jump single leg (6 sets, 4 reps)
Week 5
Diagonal cone hops (7 sets, 2 reps)
Standing long jump with lateral sprint (7 sets, 4 reps)
Lateral cone hops (7 sets, 4 reps)
Cone hops with 180 degree turn (7 sets, 4 reps)
Single leg bounding (7 sets, 4 reps)
Lateral jump single leg (7 sets, 2 reps)
Week 6
Diagonal cone hops (8 sets, 4 reps)
Hexagon drill (8 sets, 4 reps)
Cone hops with change of direction sprint (12 sets, 2 reps)
Double leg hops (7 sets, 4 reps)
Lateral jump single leg (6 sets, 4 reps)

Proprioceptive training group (n-18) The 60 min training sessions were completed 3 times per week over a period of 6 weeks. Routine exercise included warm up for 10 min and

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cool down for 5 min. Rest periods between sets were 40 seconds and rest periods between exercise were 2 minutes.

Table 2: 6 weeks proprioceptive training program

Step	Exercise	Procedure	seconds	reps
Step 1	A	Single leg stance with knee flexed.	60	3
	B	Single leg stance with the hip and the knee flexed.	60	3
	C	One leg stance, throw and catch a ball over head.	60	3
	D	Single leg stance, throw and catch a ball over the wall.	60	3
Step 2(a pair on floor)	E	Single leg stance, throw and catch under a ball to each other.	60	3
	F	Single leg stance, throw and catch over a ball to each other.	60	3
	G	Single leg stance, throw and catch one hand under a ball to each other.	60	3
	H	Single leg stance, throw and catch one hand over a ball to each other	60	3
	I	Single leg stance, throw and catch at the same time a ball to each other.	60	3
Step 3 (on balance board)	J	Single leg stance	60	3
	K	Single leg stance with the hip and the knee flexed.	60	3
	L	Single leg stance, throw and catch a ball over head.	60	3
	M	Single leg stance, throw and catch a ball over the wall.	60	3

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Step 4 (a pair on balance board)	N	Single leg stance, throw and catch under a ball to each other.	60	3
	O	Single leg stance, throw and catch over a ball to each other	60	3
	P	Single leg stance, throw and catch one hand under a ball to each other.	60	3
	Q	Single leg stance, throw and catch one hand over a ball to each other.	60	3
	R	Single leg stance, throw and catch at the same time a ball each other.	60	3

Table 3: 6-week proprioceptive training program

Week	Session	Exercise
Week 1	Session 1	A, B, C, D
	Session 2	E, F, G, H, I
	Session 3	J, K, L, M
Week 2	Session 1	N, O, P, Q, R
	Session 2	A, B, E, F
	Session 3	C, D, G, H, I
Week 3	Session 1	J, K, N, O
	Session 2	L, M P, Q, R
	Session 3	A, B, J, K
Week 4	Session 1	C, D, L, M
	Session 2	E, F, N, O
	Session 3	G, H, I, P, Q, R
Week 5	Session 1	A, E, J, N
	Session 2	B, F, K, P
	Session 3	C, G, L, Q
Week 6	Session 1	D, H, I, M, Q
	Session 2	A, B, N, O
	Session 3	E, F, J, K

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Outcome measure

Modified star excursion balance test

The modified version typically focuses on three primary directions: anterior, posteromedial, and posterolateral (Armstrong R et al.,2018). Participants stand on a single leg at the center of the testing grid and use the opposite leg to reach as far as possible in the specified directions without losing balance. The test measures both reach distance and balance control, providing valuable insights into lower limb strength, proprioception, and neuromuscular coordination (Picot et al., 2021).

Ethical Considerations

Every measurement process complied with the following rules: informed consent processes, institutional ethical requirements, participant discomfort minimization, and thorough safety measures.

Data analysis

The information collected was analyzed. We assigned a mean and standard deviation to each parameter. Pre-test and post-test measures were statistically compared using both paired and unpaired t-tests. Calculations were performed to ascertain the variations in post-test valves. To evaluate whether there were any significant changes between the pre-test and post-test findings within the group, the paired t-test was performed. In the meanwhile, significant differences between groups were discovered using the independent t-test or unpaired t-test.

Result

Table 4: pre and post-test values of proprioceptive training group using modified star excursion balance test

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Side	Direction	Proprioceptive training	Mean	SD	T Value	P Value
Right leg	Anterior	Pre test	75.117	5.407	8.2763	<0.0001
		Post test	90.767	5.927		
	Postero-lateral	Pre test	98.150	8.529	43.4491	<0.0001
		Post test	119.500	8.569		
	Postero-medial	Pre test	99.467	9.073	39.3807	<0.0001
		Post test	117.756	7.824		
Left leg	Anterior	Pre test	68.967	5.870	41.5778	<0.0001
		Post test	81.700	5.496		
	Postero-Lateral	Pre test	96.022	8.482	26.6567	<0.0001
		Post test	107.144	8.957		
	Postero-medial	Pre test	96.894	7.563	47.6022	<0.0001
		Post test	118.894	7.279		

Table 5: pre and post-test values of plyometric training group using modified star excursion balance test

Side	Direction	Plyometric training	Mean	SD	T Value	P Value
Right leg	Anterior	Pre test	75.106	5.110	9.5443	<0.0001
		Post test	82.165	5.426		
	Postero-lateral	Pre test	98.033	8.3434	13.3063	<0.0001
		Post test	106.489	8.467		
	Postero-medial	Pre test	100.961	9.120	18.2321	<0.0001
		Post test	105.539	8.952		
Left leg	Anterior	Pre test	67.317	4.582	22.8299	<0.0001
		Post test	74.411	4.346		
	Postero-lateral	Pre test	96.022	8.462	28.2725	<0.0001
		Post test	105.328	9.003		
	Postero-medial	Pre test	96.922	8.29.6	11.3386	<0.0001
		Post test	107.361	8.258		

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Table 6: post-test value of proprioceptive training group and plyometric training group

Side	Direction	Post test	Mean	SD	T Value	P Value
Right leg	Anterior	Proprioceptive training	90.767	5.927	4.3286	<0.0001
		Plyometric training	82.528	5.485		
	Postero-lateral	Proprioceptive training	119.500	8.569	4.5823	<0.0001
		Plyometric training	106.489	8.467		
	Postero-medial	Proprioceptive training	118.894	7.279	4.4582	<0.0001
		Plyometric training	107.306	8.286		
Left leg	Anterior	Proprioceptive training	81.700	5.670	4.3287	<0.0001
		Plyometric training	74.411	4.346		
	Postero-lateral	Proprioceptive training	118.894	7.279	4.4582	<0.0001
		Plyometric training	107.306	8.286		
	Postero-medial	Proprioceptive training	119.028	7.677	4.2736	<0.0001
		Plyometric training	107.144	8.957		

using star excursion balance test

Discussion

The Modified Star Excursion Balance Test revealed that the proprioceptive training group did better than the plyometric training group in terms of improvements in dynamic balance. These results imply that proprioceptive training produces more significant improvements in neuromuscular control, postural stability, and joint position sense.

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Proprioceptive training is characterized by exercises involving single-leg stance, coordination tasks with ball throwing, and the use of unstable surfaces like balance boards. Since karate athletes regularly switch between intricate stances, make quick direction changes, and retain body control during punches, blocks, and evasive movements, these enhancements are very beneficial. The improved results might have been influenced by the design and progression of the proprioceptive training program, which progressed from simple postures to increasingly difficult dual-task exercises on unstable surfaces. The athlete's awareness and control of body movement in dynamic conditions were probably enhanced by the training's inclusion of cognitive and motor coordination in addition to balance. Significant gains were also seen by the plyometric training group, which performed workouts like sprints, hops, jumps, and direction changes. Higher neuromuscular coordination, increased muscle power, and higher reaction strength could all be responsible for these benefits. Though statistically significant, the benefits were not as noticeable as they were in the proprioceptive group Overall, this study suggests that proprioceptive training might be a better way to help karate athletes improve their dynamic balance than plyometric training alone. A fundamental element of martial arts performance is improved balance, which lowers the chance of damage, improves technique execution, and speeds up recovery from movement. A study on "The effect of proprioceptive exercises on static and dynamic balance in professional athletes" was carried out. Being the first to thoroughly assess athletes' static and dynamic balance characteristics both before and after proprioception training, this study significantly advances the field of sports science. The results show how proprioceptive training might help professional athletes improve their static and dynamic balance. The strong connection between the proprioceptive system and balance is responsible for this improvement. The body's awareness of its position and movement, or proprioception, is essential for preserving equilibrium (Beydagı MG et al..2021). These findings align with the findings of Harry-Leite et al..2022, who showed that proprioceptive workouts can help athletes improve their proprioception and balance right away. The current study also discovered that proprioceptive training produced better multidirectional stability gains than plyometric training, supporting the notion that improving joint position sense and neuromuscular control is essential for karate athletes

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to maximize their balance and avoid injuries. According to Karvelytė et al. (2023), proprioceptive and balance training greatly improved ice hockey players' postural stability and decreased their risk of lower limb injuries. These results are consistent with the current study, which found that proprioceptive training significantly enhanced karate competitors' dynamic balance. This demonstrates how important focused proprioceptive training is for maximizing performance and avoiding injuries in high-intensity sports. Combining plyometric and balancing exercises significantly improved the dynamic balance of female collegiate athletes, according to Al Attar et.al..(2022). Incorporating neuromuscular-focused training techniques, such proprioceptive and plyometric exercises, can significantly improve stability and functional performance in karate athletes, according to the results of this study. Yan et al. (2025) showed that a 12-week program that included plyometric and balance training greatly enhanced dynamic balance and decreased the incidence of lower limb injuries among collegiate dancers. The present study is supported by these findings, which also show that athletes participating in high-impact, dynamic sports like karate can benefit from systematic proprioceptive and plyometric therapies to improve stability and reduce injury risk. The results of this study align with Shen et al..2024, who showed that balance-focused plyometric training improves dynamic balance in martial arts athletes. Similar improvements were seen in our plyometric group, likely due to neuromuscular and postural control adaptations. However, the proprioceptive training group showed greater improvement, indicating that proprioceptive exercises more effectively enhance joint-position sense and sensorimotor control, making them superior for improving dynamic balance in karate athletes.

Conclusion

The conclusions of the present study provided as evidence the significant effects that plyometric and proprioceptive trainings have in improving dynamic balance of karate athletes as measured by the Modified Star Excursion Balance Test. While both methods yielded notable improvements in balance across all directions, the proprioceptive training group consistently demonstrated superior results compared to the plyometric group, particularly in multidirectional stability. These results suggest that proprioceptive-

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focused exercises may better address the intricate balance demands of karate, making them a more effective training strategy for optimizing performance and reducing injury.

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