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| RESEARCH ARTICLE

Acute Effects of Dynamic and Plyometric Warm-Up Protocols on Speed Strength Flexibility and Jump Performance in Taekwondo Athletes

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| ABSTRACT

This study investigates the acute effects of dynamic warm-up (DWU) and plyometric warm-up (PWU) protocols on sprint, strength, flexibility, and jump performance in young taekwondo athletes. A total of 17 participants (9 females, 8 males; mean age = 13.06 ± 0.97 years) completed two warm-up sessions in randomized order, separated by a 48-hour interval. Performance outcomes included 10 m and 20 m sprint times, leg strength, sit-and-reach flexibility, and countermovement jump (CMJ). Data collection was conducted under standardized conditions in a school gymnasium to minimize external variability. Results showed no significant differences between protocols for 10 m and 20 m sprint tests ($p > 0.05$). However, PWU produced significantly greater improvements in leg strength, flexibility, and CMJ performance compared to DWU ($p < 0.05$), with large effect sizes observed. These findings highlight that PWU strategies may offer superior acute benefits for enhancing explosive strength and flexibility in taekwondo athletes. This study contributes novel evidence to combat sports literature, emphasizing the importance of tailored warm-up protocols for optimizing athletic performance.

| KEYWORDS

Dynamic Warm-Up, Plyometric Warm-Up, Sprint , Flexibility, Leg Strength, CMJ

| ARTICLE INFORMATION

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1. Introduction

Warm-up is an important factor in order to maximize performance efficiency in training or competitions. (Kapnia et al., 2022). Warm-up exercises performed before training or competitions are important in terms of athlete performance, as they increase efficiency and cool-down exercises performed afterwards provide advantages in terms of rapid recovery and minimize the risk of injury in both cases (Thacker et al., 2004). Warm-up is an indispensable component of sports performance preparation, designed to optimize physiological readiness and minimize the risk of injury. In competitive environments, athletes frequently use structured warm-up strategies to acutely enhance neuromuscular function, flexibility, and psychological preparedness. Among these strategies, dynamic warm-up and plyometric warm-up have gained particular attention due to their effectiveness in targeting multiple aspects of physical performance (Behm and Chaouachi 2016; Chaouachi et al., 2010).

Dynamic warm-up consists of controlled active movements that increase core temperature, joint mobility, and muscle compliance while stimulating the nervous system. Studies have demonstrated that dynamic warm-up can acutely improve sprinting ability, agility, and range of motion in both team sport and combat sport athletes (Fradkin et al., 2010; Fletcher and Monte-Colombo, 2010). Conversely, plyometric warm-up incorporates rapid stretch shortening cycle (SSC) actions such as hops, bounds, and vertical jumps. These activities increase muscle tendon stiffness, potentiate neural drive, and may acutely enhance explosive strength and jump performance (Ramírez-Campillo et al., 2014). By definition, plyometric training is designed to enhance muscular strength capacity and improve explosive power-oriented movements. Its content typically includes exercises that simultaneously stimulate both speed and strength (Ateş et al., 2007).

Taekwondo is an Olympic combat sport characterized by explosive kicking techniques, rapid direction changes, and substantial demands on lower-limb strength and flexibility. Success in taekwondo depends on the integration of speed, reactive strength, and joint mobility to deliver powerful kicks while maintaining agility during matches (Bridge et al., 2011). Recent research has emphasized that combining warm-up strategies with additional stimuli can further optimize performance in combat sports. In this context, Messaoudi et al. (2024) reported that integrating plyometric-based conditioning activities with athletes' self-selected preferred music produced significant improvements in sprinting, agility, and kick-specific performance among male taekwondo practitioners. Warm-up and stretching routines play a particularly important role in taekwondo, where high flexibility and rapid lower-limb movements are required for successful performance. Nuri et al., (2013) emphasized that different warm-up approaches can acutely influence joint mobility in taekwondo athletes, supporting the idea that appropriate preparation enhances readiness for explosive kicking techniques and overall technical execution.

The aim of the present study was to examine the acute effects of two different warm-up protocols dynamic and plyometric on multiple physical performance parameters in taekwondo athletes, including sprint speed, lower-limb strength, flexibility, and vertical jump performance. Considering the technical and physical demands of taekwondo, identifying the most effective warm-up strategy may provide valuable insights for optimizing training and competition readiness.

2. Methodology

2.1. Participants

Seventeen youth taekwondo athletes (9 females and 8 males; mean age = 13.06 ± 0.97 years; height = 155.06 ± 11.80 cm; body mass = 48.24 ± 14.84 kg) voluntarily participated in this study. All participants were actively training at least three times per week and had a minimum of two years of competitive experience. None of the athletes reported musculoskeletal injuries or medical conditions in the three months preceding the study. Written informed consent was obtained from both the athletes and their legal guardians. The study was approved by the Non-Interventional Clinical Research Ethics Committee of Bitlis Eren University (Date: 05.02.2025; Decision No: 2025/1-11; File No: E.6925), and conducted in accordance with the Declaration of Helsinki.

2.2. Research Design

A randomized crossover design was employed to investigate the acute effects of dynamic warm-up (DWU) and plyometric warm-up (PWU) protocols on performance variables. Each participant performed both warm-up protocols on separate days, with a minimum rest interval of 48 hours between sessions to minimize fatigue and carryover effects. To ensure balance, the order of the protocols was randomly assigned to the athletes. All testing was carried out in the same school gymnasium under standardized environmental conditions, thereby minimizing external variability. Following each warm-up protocol, the athletes completed the performance tests in a fixed sequence: 10 m and 20 m sprint tests, leg strength assessment, sit-and-reach flexibility test, and countermovement jump (CMJ). Standardized instructions and verbal encouragement were provided to ensure maximal effort during all assessments. This design allowed for within-subject comparisons between the two warm-up protocols, thereby increasing statistical power and reducing the impact of inter-individual variability. The minimum required sample size for this study was determined using G*Power software (version 3.1.9.7) (Faul et al., 2009). A power analysis based on a correlation model was conducted, with an alpha level of 0.05, a statistical power of 0.80 (1-β error probability), and an effect size of 0.50. The analysis indicated that at least 17 participants were required to achieve the desired statistical power.

2.3. Warm-Up Protocols

Dynamic Warm-Up Protocol

The dynamic warm-up (DWU) protocol targeted both upper- and lower-body muscle groups and was performed in two sets with controlled intensity. Each exercise was executed for 20 seconds, followed by 10 seconds of rest between exercises. A standardized 60-second rest interval was provided between Set 1 and Set 2 to ensure consistency with the plyometric condition. The total duration of the DWU protocol was 660 seconds (11 minutes). Details are presented in Table 1.

Table 1. Dynamic warm-up protocol

Warm-Up Exercises	Set / Repetition	Execution Time (sec)	Rest Time Between Repetitions (sec)
Shoulder Circles	2×1	20	10
Arm Swings	2×1	20	10
Hip Circles	2×1	20	10
Jumping Jacks	2×1	20	10
Leg Swings	2×1	20	10
Walking High Kicks	2×1	20	10
Squats	2×1	20	10
High Knees	2×1	20	10
Butt Kicks	2×1	20	10
Walking Lunge	2×1	20	10
Set Rest (between Set 1 & Set 2)			60
Total		400	260

Plyometric Warm-Up Protocol

The plyometric warm-up (PWU) protocol was designed to acutely stimulate the stretch–shortening cycle (SSC) of the lower limbs. Five jump-based drills were performed in two sets of four repetitions each. Each exercise set lasted 20 seconds of execution time, followed by 10 seconds of rest between exercises to balance cumulative load and recovery. A standardized 60-second rest interval was provided between Set 1 and Set 2. The total duration of the PWU protocol was 660 seconds (11 minutes). Details are presented in Table 2.

Table 2. Plyometric Warm-Up Protocol

Warm-Up Exercises	Set / Repetition	Execution Time (sec)	Rest Time Between Repetitions (sec)
Standing Long Jump	2×4	20	10
Split Squat Jump	2×4	20	10
Box Jump	2×4	20	10
Depth Drop Jump	2×4	20	10
Jumping Over Obstacle	2×4	20	10
Set Rest (between Set 1 & Set 2)			60
Total		400	260

2.3. Data Collection Tools

Stature Measurement. Participants' standing height was measured to the nearest 0.01 m using a stadiometer (SECA, Germany). All measurements were taken barefoot, with participants standing upright in light clothing (shorts and t-shirt).

Body Mass Measurement. Body mass (BM) was assessed to the nearest 0.1 kg using a calibrated electronic scale (Tanita BC-418 MA, Japan). Measurements were performed under standardized conditions, with participants barefoot and wearing only shorts and a t-shirt.

Countermovement Jump (CMJ) Test. Explosive lower-limb power and vertical jump height were assessed using the countermovement jump test. Measurements were obtained with the Smart Speed Lite Smart Jump system (Fusion Sport, Australia). Participants stood on the measurement mat with hands placed on the hips, performed a countermovement by flexing the knees to approximately 90°, and then executed a maximal vertical jump. Landings were controlled on the mat. Three trials were performed, separated by one-minute recovery periods, and the best jump height was used for analysis (Karahan & Kaya, 2022).

10m and 20m Speed Tests. Linear sprint performance was assessed using 10 m and 20 m sprint tests with electronic timing gates (Fusion Sport Smartspeed PRO, Australia). Four photocell gates were positioned along a straight sprinting lane at the starting line and at 10 m and 20 m intervals. The gates were fixed at a height of 1 m from the ground, and participants initiated the sprint from a standing start positioned 0.5 m behind the first gate. Each test was performed twice, and the fastest trial was recorded for analysis. Verbal encouragement was provided to maximize performance (Sari et al., 2022).

Sit-and-Reach Test. Flexibility was evaluated using the sit-and-reach test, which required participants to extend their upper body forward without bending the knees. A custom-built testing box (35 cm lower surface, 55 cm upper surface, 45 cm width, 32 cm height) equipped with a measurement scale ranging from 0–50 cm and an additional fixed 30 cm ruler was used. With their feet flat against the front edge of the box, participants reached forward as far as possible, and the farthest point reached was recorded in centimeters (Esmer & Eskiyecek, 2020).

Leg Strength Test. Lower limb strength was measured using a Baseline leg dynamometer. Following a five-minute standardized warm-up, participants were positioned with their feet placed on the dynamometer platform, knees slightly flexed, arms extended, back straight, and trunk leaning slightly forward. While grasping the dynamometer bar with both hands, participants exerted maximal effort by pulling vertically upward, predominantly engaging the leg muscles (Kahraman & Kızılca, 2025).

2.4. Statistical Analysis

The data obtained from the study were processed and analyzed using the SPSS statistical package. The assumption of normality was verified with the Shapiro–Wilk test. For data showing a normal distribution, parametric analyses were conducted, including repeated-measures ANOVA, followed by LSD post hoc tests where appropriate. Partial eta squared (ηp^2) values were interpreted as follows: small = 0.01, medium = 0.06, and large = 0.14 (Cohen, 1988). The level of statistical significance was set at $p < 0.05$.

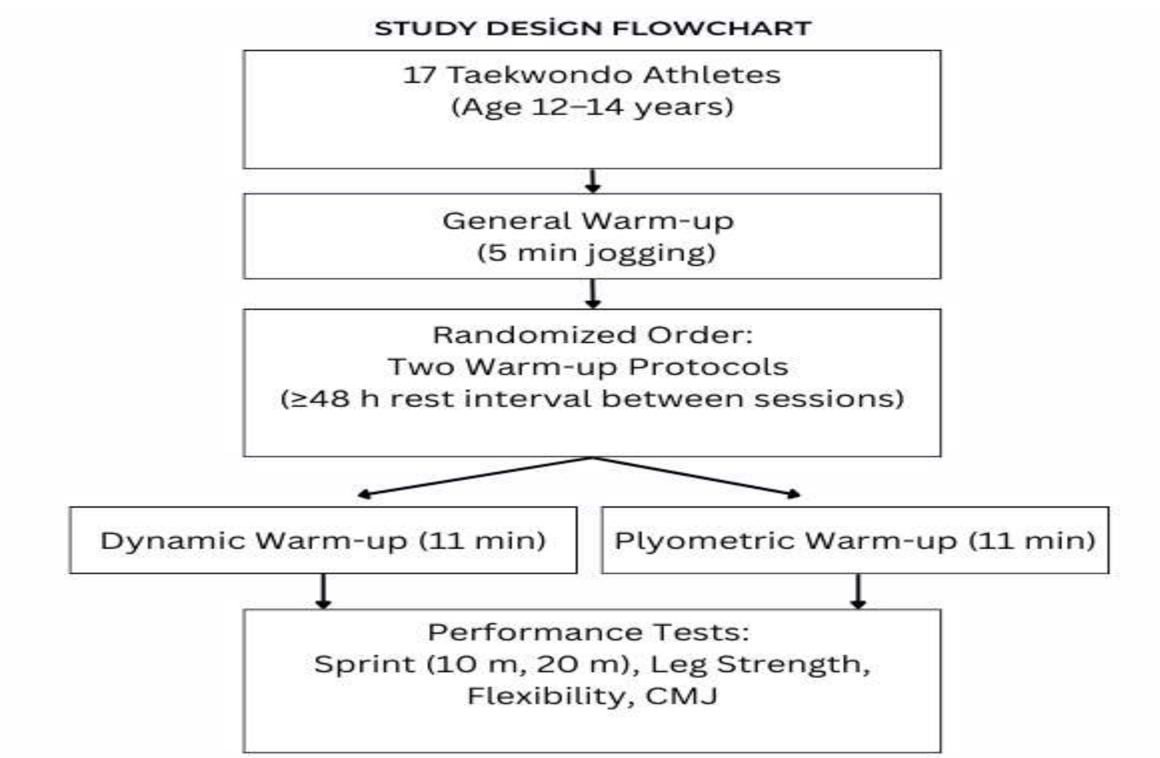

Figure 1. Study design flowchart. The participants (n = 17 taekwondo athletes, aged 12–14 years) first completed a standardized general warm-up (5 min jogging). Thereafter, in a randomized order, athletes performed either a dynamic warm-up or a plyometric warm-up protocol, with a minimum rest interval of ≥48 h between sessions. Following each warm-up condition, athletes underwent performance testing, which included 10 m and 20 m sprint tests, leg strength assessment, sit-and-reach flexibility test, and countermovement jump (CMJ) evaluation.

3. Results

The descriptive statistical results regarding the general characteristics of the taekwondo athletes participating in the study are presented in Table 3. The results of the biomotor tests related to the dynamic and plyometric warm-up protocols are provided in Table 4 and Figure 2.

Table 3. Descriptive statistics of the participants' general characteristics

General characteristics	N	Mean (X̄)	SD
Age (years)	17	13.06	0.97
Height (cm)	17	155.06	11.80
Body weight (kg)	17	48.24	14.84

Table 4. Biomotor test results of taekwondo athletes according to warm-up protocols

Tests	Warm-up Protocols (n=17)		f	p	ηp^2
	Dynamic X̄ ± SS	Plyometric X̄ ± SS			
10 m Sprint (sec)	2.08 ± 0.19	2.09 ± 0.18	0.001	0.975	0.00
20 m Sprint (sec)	3.75 ± 0.37	3.76 ± 0.32	1.151	0.299	0.07
Leg Strength (kg)	66.82 ± 16.36	78.79 ± 19.30	22.641	**0.000**	0.59
Flexibility (cm)	38.82 ± 6.05	42.29 ± 5.86	19.948	**0.000**	0.55
CMJ (cm)	24.65 ± 6.06	26.18 ± 7.21	5.573	**0.031**	0.26

According to the findings presented in Table 4, no significant differences were observed between the dynamic and plyometric warm-up protocols in the 10 m and 20 m sprint tests ($p > 0.05$). In contrast, the plyometric warm-up protocol produced significantly higher values compared to the dynamic warm-up in leg strength, flexibility, and CMJ performance ($p < 0.05$). Notably, the effect sizes were found to be very large for leg strength ($\eta p^2 = 0.59$) and flexibility ($\eta p^2 = 0.55$), and large for CMJ ($\eta p^2 = 0.258$).

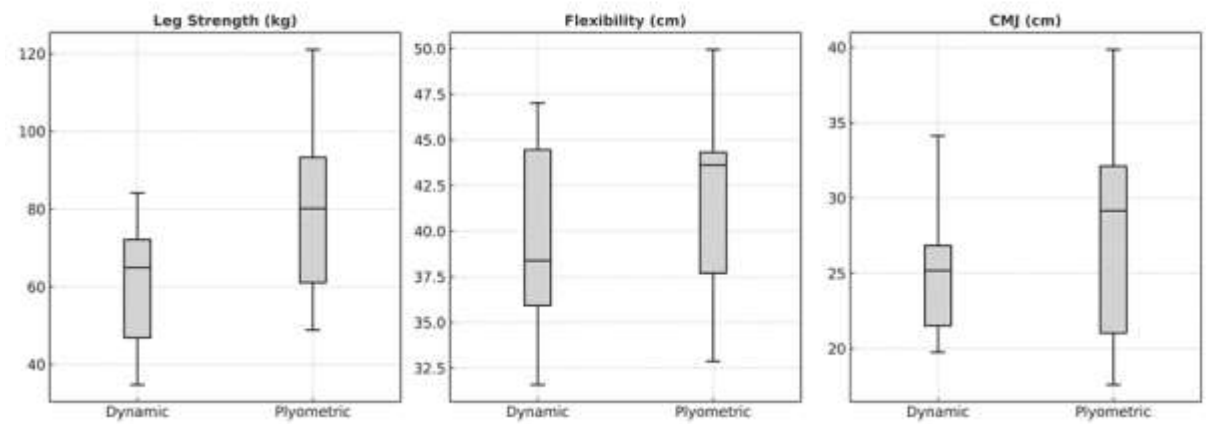

Figure 2. Effects of dynamic and plyometric warm-up protocols on leg strength, flexibility, and CMJ performance. Effects of dynamic warm-up (DWU) and plyometric warm-up (PWU) protocols on leg strength, flexibility, and countermovement jump (CMJ) performance in young taekwondo athletes (n = 17). Data are presented as box plots showing median, interquartile range, and minimum–maximum values. PWU produced significantly higher values than DWU across all three parameters (*$p < 0.05$).

4. Discussion

The present study examined the acute effects of dynamic warm-up (DWU) and plyometric warm-up (PWU) protocols on sprint, strength, flexibility, and countermovement jump (CMJ) performance in young taekwondo athletes. The main findings revealed that PWU significantly improved leg strength, flexibility, and CMJ compared to DWU, while no differences were observed in sprint performance over 10 m and 20 m distances.

These results indicate that while both protocols provide adequate physiological preparation, PWU offers superior acute benefits for explosive strength and mobility. The observed enhancements in CMJ and leg strength are consistent with previous research suggesting that plyometric-based warm-up activities increase neuromuscular activation, optimize the stretch–shortening cycle, and enhance muscle–tendon stiffness (Ramírez-Campillo et al., 2014; Behm and Chaouachi, 2011). Similarly, Wei et al. (2020) demonstrated that a plyometric warm-up significantly improved running economy in recreational endurance athletes, partly mediated by an increase in leg stiffness. Although our study focused on explosive performance metrics rather than endurance outcomes, this finding suggests a broader physiological mechanism, namely enhanced neuromuscular efficiency via plyometric activity, that may underpin improved performance across diverse athletic tasks. Furthermore, the improvement in flexibility following PWU may be explained by the inclusion of dynamic stretch–shortening actions, which can acutely increase joint mobility through potentiation of agonist–antagonist muscle function (Chaouachi et al., 2010).

Several studies support these findings. Harmancı et al. (2024) reported that plyometric warm-up exercises improved vertical jump performance in athletes, reinforcing the role of plyometric protocols in enhancing explosive power. Similarly, Johnson et al. (2019) showed that plyometric-based warm-ups enhanced quadriceps force production more effectively than traditional warm-up methods. Şener et al. (2021) also demonstrated acute benefits of plyometric warm-up on sprint and agility in national-level athletes, which complements our results by highlighting its broader impact on performance.

Evidence from other sports further strengthens our conclusions. Mancilla et al. (2023) found significant improvements in jump height and power in adolescent female volleyball players following plyometric warm-up compared to sprint-based warm-up. Kim et al. (2014) also noted that plyometric and dynamic warm-ups provided greater benefits for balance than static protocols, supporting the general effectiveness of plyometric routines across physical domains. In taekwondo specifically, Da Silva et al. (2015) demonstrated that plyometric and combined conditioning activities enhanced CMJ and kicking speed, while Krčmár et al. (2016) reported superior improvements in CMJ height following plyometric warm-up compared to static or dynamic protocols. Supporting evidence also comes from taekwondo-specific research. Genç and Dağlıoğlu (2021) reported that a structured plyometric training program significantly enhanced sprint, agility, and jump performance in young taekwondo athletes. Although their study examined chronic adaptations, the findings align with our results by emphasizing the effectiveness of plyometric protocols in improving explosive performance capacities in combat sport athletes.

In contrast, the lack of significant differences between DWU and PWU in short-distance sprint performance suggests that sprinting ability over 10–20 m may depend more on technical efficiency and stride mechanics, factors that are less likely to be acutely influenced by warm-up modality. Similar findings were reported by Messaoudi et al. (2024), who observed that warm-up interventions produced greater benefits for jumping and strength outcomes than for sprint performance in combat sport athletes. Similarly, Zylberberg et al. (2024) examined the effects of a potentiation warm-up protocol in female football players and reported no significant acute improvements in sprint or change-of-direction performance. This supports the notion that short-distance sprint ability may be less responsive to warm-up interventions and more reliant on technical and biomechanical factors.

Collectively, these findings indicate that PWU confers superior acute benefits over DWU in developing explosive strength, flexibility, and jumping ability in young taekwondo athletes, confirming the practical applicability of plyometric warm-up strategies in combat sports.

5. Conclusions

The present study investigated the acute effects of dynamic warm-up (DWU) and plyometric warm-up (PWU) protocols on sprint, strength, flexibility, and countermovement jump (CMJ) performance in young taekwondo athletes. The findings demonstrated that PWU was significantly more effective than DWU in enhancing leg strength, flexibility, and CMJ, while no differences were observed in short-distance sprint performance.

These results suggest that although both DWU and PWU provide adequate physiological preparation, plyometric-based protocols offer superior acute benefits for explosive strength and mobility. From a practical perspective, coaches and practitioners working with combat sport athletes may consider incorporating plyometric warm-up routines to optimize immediate performance outcomes. However, since sprint performance did not show improvements, further research is needed to explore the interaction between warm-up modalities, sprint mechanics, and sport-specific demands in taekwondo athletes.

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