OPEN ACCESS
Advances in Health and Exercise

ORIGINAL RESEARCH

Effect of warm-up on visual response times in taekwondo athletes

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Received:
July 19, 2025

Accepted:
November 05, 2025

Online Published:
December 07, 2025

Keywords:
Laterality, response time, taekwondo, visual, warm-up, young athletes.

Abstract

Response time is a critical component of performance in combat sports, where quick visual processing and immediate motor response can determine the outcome of competition. This study aimed to examine the effect of a warm-up on the visual response times of youth taekwondo athletes. The study was approved by the Ethics Committee of the University (Decision Date: 23.06.2023, No: 63), and included 23 voluntarily participating taekwondo athletes (age: 14.39±1.85 years; height: 166.61±11.04 cm; body weight: 49.83±8.34 kg). Visual response times were measured using the Fitlight reaction system (Fitlight Sports Corp., Canada), applied three times to both the dominant and non-dominant hands, with the best score recorded. On the test day, athletes first completed the visual reaction test followed by a taekwondo-specific warm-up protocol and then repeated the test. Paired sample t-tests were used to compare pre- and post-warm-up results, as well as differences between hands. A significant difference was found between dominant and non-dominant hand response times both before (dominant: 0.60±0.04 s vs. non-dominant: 0.63±0.06 s) and after warming up (dominant: 0.57±0.04 s vs. non-dominant: 0.59±0.04 s) in favor of the dominant hand ($p<0.05$). Additionally, post-warm-up scores showed significant improvement compared to pre-test scores for both dominant (0.60±0.04 s vs. 0.57±0.04 s) and non-dominant hands (0.63±0.06 s vs. 0.59±0.04 s) ($p<0.05$). These findings suggest that warm-up exercises can positively influence visual response performance in youth taekwondo athletes, potentially contributing to improved readiness and performance during competition.

Introduction

Taekwondo, a traditional Korean martial art, has been recognized as an official Olympic discipline since the 2000 Sydney Olympic Games (Kazemi et al., 2010). Taekwondo thus is the technique of unarmed combat for self-defense that involves the skillful application of techniques including punching; jumping kicks, blocks, dodges and parrying actions with hands and feet (Singh et al., 2017). In taekwondo as in other combat sports it is important to take into consideration stimulus response in order to anticipate the opponent's actions and act accordingly to win the bout (Witkowski et al., 2019; Witkowski et al., 2020). Taekwondo and other martial art games have a direct link to agility, rhythm, reaction time and balance because it requires defense against attack from all directions using both sides of their body (Singh et al., 2017). This evolution underscores the crucial role of movement execution speed in achieving competitive success.

Elite performance in taekwondo is not solely determined by technical skill, but also relies heavily on a broad array of physical attributes, including agility, balance, coordination, speed, reaction time and the capacity to deliver repeated, forceful kicks (Bridge et al., 2014). Athletes must be capable of both reacting instantaneously to an opponent's actions and initiating their own, often through feints or counterattacks (Martinez de Quel & Bennett, 2014). Consequently, the rapid perception and processing of environmental stimuli particularly visual cues are fundamental to effective decision making and motor execution (Williams, 2008).

Previous research has demonstrated that athletes generally outperform non-athletes in several visual and cognitive domains, such as hand-eye coordination and visual-spatial intelligence (Akarsu et al., 2009). Reaction time, which measures the interval between stimulus presentation and movement initiation, is a critical marker of underlying cognitive processes like stimulus recognition, response selection and motor

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To Cite: Kocaoğlu, Y. (2025). Effect of warm-up on visual response times in taekwondo athletes. *Adv Health Exerc*, 5(2), 180-187.

programming (Schmidt et al., 2019). In this regard, visual reaction time serves as a key indicator of both cognitive efficiency and neuromotor readiness, particularly in open-skill sports like taekwondo.

The role of warm-up routines in optimizing athletic performance is well-documented. Warm-up activities, targeting both physiological and neurological systems, are essential in preparing the body and mind for high-intensity efforts (McGowan et al., 2015). Among these dynamic warm-up protocols have been shown to positively influence muscle strength, joint flexibility, balance and reaction time (Busquets-Ferrer et al., 2022; Fradkin et al., 2010, González-Fernández et al., 2022; McGowan et al., 2015). Contemporary frameworks such as the RAMP model (Raise, Activate, Mobilize, Potentiate) aim to enhance both central and peripheral nervous system activation, thereby improving readiness for sport-specific movements (Jeffreys, 2007). Moreover, empirical studies utilizing technologies like Fitlight have reported significant enhancements in visual reaction times post-warm-up (Arguz et al., 2023; Cieśluk et al., 2024; Göğebakan et al., 2024).

However, findings regarding the relationship between warm-up and reaction time are somewhat inconsistent in the literature. Some studies have reported that dynamic warm-up protocols significantly improve visual reaction times in athletes (Arabacı & Görgülü, 2010; Chen et al., 2021). Conversely, Topcu and Arabacı (2017) reported that specific warm-up protocols did not elicit statistically significant changes in reaction time performance. These discrepancies may be attributed to variations in warm-up duration, intensity, protocol type, and the extremity tested. Particularly, there is limited research focusing on the effects of warm-up on dominant and non-dominant hand reaction times in adolescent taekwondo practitioners, highlighting the need for further investigation in this area.

Previous studies on taekwondo have primarily focused on the effects of different warm-up protocols on various performance indicators such as flexibility, asymmetry, agility, and kick frequency (Chen et al., 2021), front kick biomechanics (Ibrahim et al., 2022), knee and ankle muscle strength and endurance (Park, 2025) and lower extremity isokinetic strength (Tan, 2020). However, most of this research has been conducted on elite-level athletes and there is limited data on how warm-up routines influence visual reaction time in adolescent taekwondo practitioners.

The present study aims to investigate the effect of sport-specific dynamic warm-up on visual reaction time in taekwondo athletes aged 12–17. In particular, by comparing dominant and non-dominant hand reaction times, the study seeks to evaluate the contribution of dynamic warm-up to neuromotor performance. The findings may help structure pre-competition and training routines for youth athletes based on scientific evidence, and provide coaches with practical insights into enhancing cognitive-motor performance through effective warm-up strategies.

Methods

Participants

This study employed a quasi-experimental research design based on a single-group pre-test and post-test model. The visual reaction times of participants were assessed comparatively before and after a warm-up protocol. The sample consisted of 23 voluntary (male and female) taekwondo athletes (age: 14.39 ± 1.85 years; height: 166.61 ± 11.04 cm; body weight: 49.83 ±8.34 kg) all of whom were actively competing and registered with the Turkish Taekwondo Federation, with a minimum of two years of training experience. Participants were selected based on the absence of any neurological, musculoskeletal, or visual impairments. Ethical approval for the study was obtained from the Non-Interventional Clinical Research Ethics Committee of Selçuk University (Decision No: 63, Date: 23.06.2023). Written informed consent was collected from all participants and their legal guardians.

Procedure

All measurements were conducted in a quiet and controlled laboratory environment during the morning hours prior to the participants' regular training sessions. One day before the test participants were introduced to the measurement system and allowed three familiarization trials to minimize learning effects. Anthropometric data, including age, height and body weight, were also recorded. On the test day, the procedure consisted of pre-test visual reaction time measurements for both dominant and non-dominant hands followed by a 15-minute sport-specific dynamic warm-up protocol, and post-test measurements immediately after the warm-up. A 30-second rest interval was provided between each trial to standardize the testing procedure. Participants were excluded if they had engaged in intense exercise in the previous 24 hours, experienced sleep deprivation, or used medications known to affect the nervous system.

A 30-second rest interval was provided between each trial to standardize the testing procedure. Participants who engaged in intense exercise within 24 hours experienced sleep deprivation or used medications affecting the nervous system were excluded.

The warm-up protocol was designed to prepare both the physiological and neuromuscular systems. Participants performed 5 minutes of low-intensity running to elevate heart rate, increase muscle temperature, and enhance muscle elasticity, facilitating rapid force production and stimulating the central nervous system (Fradkin, Zazryn, & Smoliga, 2010). This was followed by 5 minutes of dynamic mobilization exercises for the hips, knees and shoulders to increase joint range of motion, optimize musculoskeletal function, and improve neuromuscular efficiency (Behm & Chaouachi, 2011). Next, 3 minutes of reaction-based technical exercises, including taekwondo-specific kicks and blocks, were performed to promote rapid and accurate motor responses to visual and auditory stimuli, improving perceptual-cognitive and motor reaction speed (Williams, 2008). The final stage consisted of 2 minutes of short-duration high-intensity plyometric exercises aimed at facilitating rapid activation of motor units and enhancing explosive muscle strength, which is critical for sudden movements and fast responses in combat sports (Markovic & Mikulic, 2010). This integrated warm-up protocol was intended to optimize both physiological readiness and neuromuscular and cognitive-motor functions thereby enhancing reaction time in young taekwondo athletes.

Anthropometric Measurements

Height was measured using a Seca 213 stadiometer, while body weight was assessed using a Xiaomi digital body composition scale. During measurement, participants were asked to stand upright and still, with both feet placed evenly on the platform to ensure accuracy.

Visual-Motor Response Test

Visual-motor response time was assessed using the FitLight™ (Fitlight Sports Corp., Canada) system. The test consisted of a simple reaction task lasting 10 seconds, in which participants responded to randomly illuminated stimuli on six wireless LED discs. The discs were arranged in a semicircle on a table, with each disc positioned 40 cm from the center and spaced 25 cm apart. Participants placed one hand at the center of the semicircle before beginning the test. Upon stimulus onset, they were instructed to reach out and deactivate the illuminated disc by touch, returning their hand to the center between each response. The number of accurate responses and the average reaction time over the 10-second period were recorded (Tatlıcı & Özer, 2022).

Each participant performed the test three times with both the dominant and non-dominant hand, and the best score was used for analysis. Using the best score is a widely accepted approach in the literature, as it more accurately reflects each participant’s maximal neuromotor performance and increases the reliability of measurements. This method is particularly useful in youth populations, where selecting the best trial helps ensure consistency and validity of the test results (Lima et al., 2021; Çağın et al., 2024).

Table 1
Warm-up protocol.

Stage	Duration	Exercise	Purpose	References
Low-Intensity Running	5 min	Light running	Elevate heart rate, increase muscle temperature, enhance muscle elasticity, facilitate rapid force production and stimulate CNS for motor preparation	Fradkin, Zazryn, & Smoliga, 2010
Mobilization Exercises	5 min	Dynamic mobilization of hips, knees and shoulders	Increase joint ROM, optimize musculoskeletal function, improve neuromuscular efficiency, enhance quick response to stimuli	Behm & Chaouachi, 2011
Reaction-Based Technical Exercises	3 min	Taekwondo techniques (kicking, blocking)	Promote rapid and accurate motor responses to visual and auditory stimuli improve perceptual-cognitive and motor reaction speed	Williams, 2008
Plyometric Exercises	2 min	Short-duration high-intensity plyometric movements	Facilitate rapid motor unit activation enhance explosive muscle strength, improve sudden movements and fast reactions	Markovic & Mikulic, 2010

Data Analysis

Data were analyzed using IBM SPSS Statistics 25.0. Normality was assessed via the Kolmogorov-Smirnov test. For normally distributed variables, paired samples t-tests were conducted to compare pre- and post-test values. All statistical tests were two-tailed, and significance was set at $p < 0.05$. Results are presented as mean ± standard deviation (M ± SD).

Results

Descriptive characteristics of the participants are presented in Table 2 when pre- and post-warm-up measurements were examined, significant differences were observed in visual reaction times between the dominant and non-dominant hands. Prior to the warm-up, the mean reaction time was 0.60 ± 0.04 seconds for the dominant hand and 0.63 ± 0.06 seconds for the non-dominant hand. After the warm-up, these values improved to 0.57 ± 0.04 seconds and 0.59 ± 0.04 seconds, respectively. In both conditions, the dominant hand showed faster reaction times, and the differences were statistically significant ($p < 0.05$). Additionally, when pre- and post-warm-up reaction times were compared, significant improvements were observed in both the dominant hand (from 0.60 ± 0.04 s to 0.57 ± 0.04 s) and the non-dominant hand (from 0.63 ± 0.06 s to 0.59 ± 0.04 s), with faster responses recorded after the warm-up ($p < 0.05$) (see Table 3 and Table 4).

Table 2

Descriptive characteristics of the participants (n=23).

Variables	Mean	SD	Min	Max
Age (years)	14.39	1.85	12	17
Height (cm)	166.61	11.04	147	187
Body Weight (kg)	49.83	8.34	33	63

Table 3

Visual response time of dominant and non-dominant hands before and after warm-up.

Variables	Before Warm-Up		After Warm-Up	
	Mean	SD	Mean	SD
DH	0.60	0.05	0.57	0.04
N-DH	0.63	0.06	0.59	0.05

DH: Dominant Hand; N-DH: Non-Dominant Hand

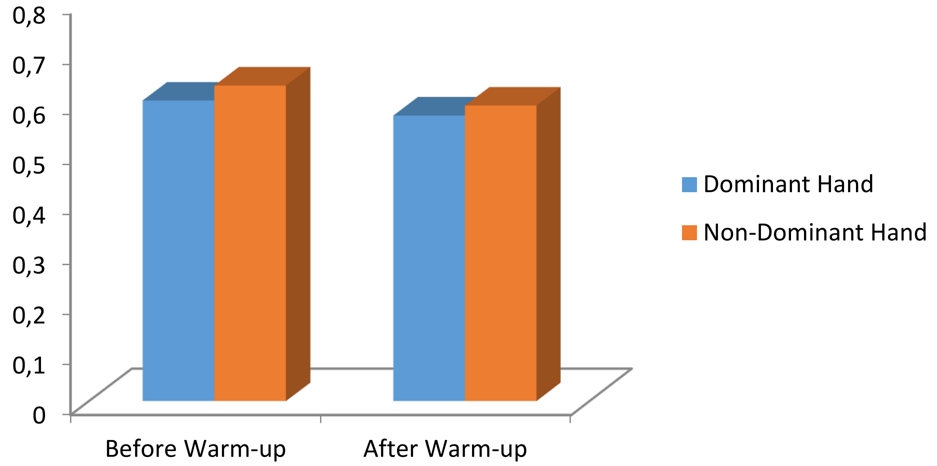

Figure 1. Response times before and after warm-up.

Table 4

Comparisons for visual response times of dominant and non-dominant hands.

		Paired Differences		t	*p*
		Mean	SD		
Dominant & Non-Dominant	Before Warm-Up	-.03	0.06	-2.63	0.015*
	After Warm-Up	-.02	0.04	-2.31	0.031*
Before and After Warm-Up	Dominant Hand	0.03	0.04	3.42	0.002*
	Non-Dominant Hand	0.04	0.07	2.80	0.010*

$^*p<0.05$

Discussion

The present study investigated the effects of a sport-specific warm-up protocol on visual reaction time in young taekwondo athletes, demonstrating significant improvements in both dominant and non-dominant hand performance. The notably faster reaction times observed in the dominant hand are consistent with the influence of neuromuscular dominance and habitual hand use on motor performance. This is supported by previous research comparing dominant and non-dominant hands, which found that the average reaction time in the dominant hand was 237 ms compared to 270 ms in the non-dominant hand, with dominant hand responses being less variable and more consistent (Chouamo, Griego & Martinez Lopez, 2021).

Studies conducted across different years have consistently demonstrated that warm-up protocols effectively optimize neuromuscular function, leading to short-term (acute) improvements in motor performance (Enes et al., 2025; Fradkin et al., 2010; McGowan et al., 2015). The pre-activation of motor units during warm-up lowers their activation thresholds, thereby increasing excitability within the central nervous system and facilitating more efficient motor unit recruitment during subsequent performance (Aytaç & İşler, 2025). These neurophysiological adaptations likely underpin the observed improvements in reaction time immediately following warm-up.

The findings of the study (Magner et al., 2012) complement our results by demonstrating that dynamic warm-up protocols produce significantly faster choice reaction times compared to static stretching. While static stretching showed minimal or no acute improvements, dynamic warm-up enhanced neuromuscular responsiveness and reaction accuracy, particularly in tasks requiring rapid decision-making and multi-directional responses. These results support the notion that warm-up exercises involving movement and neuromotor engagement are more effective for preparing athletes for sport-specific cognitive-motor demands, aligning with the improvements we observed using the Fitlight system.

The use of the Fitlight reaction system provided objective and reliable measurements, further substantiating the efficacy of warm-up in improving sport-specific performance parameters. The superior performance of the dominant hand aligns with existing evidence on hand dominance effects in motor control (Badau & Badau, 2022; Badau et al., 2023). However, the significant gains observed in the non-dominant hand suggest that warm-up elicits bilateral enhancements in neuromuscular function. Dynamic warm-up exercises, as shown in the Magner et al., (2012) study, may be particularly beneficial in reducing inter-limb discrepancies, as they engage both sides of the body in rapid, reactive movements, thereby enhancing neuromotor symmetry.

Recent studies further support these findings. For example, Bayraktar and Arguz (2024) demonstrated that Kung Fu training significantly improves reaction times in children aged 7–9, highlighting the effectiveness of structured martial arts exercises on neuromotor responsiveness. Similarly, Bayraktar et al. (2025) found that ambient sound conditions can influence visual reaction times in 12–15-year-old Kung Fu athletes, suggesting that environmental factors interact with neuromuscular performance. Göğebakan et al. (2025) reported significant correlations between speed, agility and reaction time in young football players, reinforcing the link between motor skills and perceptual-motor efficiency.

Furthermore, proprioceptive training has been shown to enhance lower extremity response times in both dominant and non-dominant limbs in Kung Fu athletes, indicating that targeted neuromotor exercises can reduce asymmetries between sides (Arguz et al., 2025). Similarly, Kocaoğlu (2024) demonstrated that grip strength differences between dominant and non-dominant hands are associated with visual reaction time in kickboxing athletes, emphasizing the importance of balanced strength development. Aslan et al. (2023) highlighted that music type can modulate hand-eye reaction times in children aged 11–14 and Aslan et al. (2024) showed a relationship between hand-eye reaction time and stereopsis in adolescents aged 15–19; these findings indicate that sensory and perceptual-cognitive factors can acutely influence reaction performance and should be considered in training.

The practical application of these findings should be emphasized, particularly in terms of how coaches can implement this warm-up protocol to reduce asymmetries between the dominant and non-dominant sides. unilateral warm-up exercises targeting the non-dominant side can be incorporated to enhance neuromuscular activation and potentially diminish inter-limb asymmetries, which are known risk factors for injury and performance deficits (Bishop et al., 2018). Warm-up routines that equally stimulate both sides of the body may contribute to better motor symmetry and balance, which is crucial in taekwondo due to its asymmetric movement patterns (Miller & Chagas, 2021).

Additionally, the concept of cross-education, where training one limb results in strength and neuromotor improvements in the contralateral, untrained limb, can be utilized during warm-up and training to support the non-dominant side (Lee & Carroll, 2007). Coaches are encouraged to individualize warm-up protocols by assessing athletes' asymmetry levels pre-competition and incorporating exercises that specifically target weaker or less reactive limbs. Regular monitoring and adjustment of warm-up routines can optimize neuromotor readiness while minimizing injury risk.

Limitations

The study only assessed immediate effects of a single warm-up session, so long-term effects remain unknown. Psychological factors such as motivation and arousal, known to influence reaction time, were not controlled or measured. Additionally, sensory and perceptual-cognitive factors highlighted in the discussion (e.g., music type, ambient sound, stereopsis) may also influence reaction time, but these were not systematically assessed in this study. The relatively small sample size (n=23) limits generalizability, and only visual reaction time was evaluated; other sensory modalities and complex decision-making processes inherent in taekwondo were not investigated.

Recommendations for Future Research

Future studies should examine the long-term effects of various warm-up protocols and their interaction with perceptual-cognitive factors (e.g., music type, ambient sound, stereopsis). Larger, more diverse samples should be included, and psychological assessments integrated to clarify interactions between cognitive and physiological factors influencing reaction time. Investigating multisensory reaction times and sport-specific decision-making in conjunction with individualized warm-up programs would provide a more comprehensive understanding of performance enhancement in combat sports.

Conclusion

This study demonstrated that a taekwondo-specific dynamic warm-up protocol significantly improved visual reaction time in young athletes for both the dominant and non-dominant hands. The findings indicate that warm-up enhances neuromotor readiness, promotes bilateral performance improvements and may help reduce inter-limb asymmetries. Consistent with previous research showing that dynamic warm-up increases neuromuscular excitability and reaction accuracy compared to static stretching, the present protocol effectively prepared athletes for the sport-specific cognitive and motor demands of taekwondo. In conclusion, scientifically grounded, individualized and sport-specific warm-up routines are effective tools for improving reaction speed, neuromotor balance and performance symmetry in taekwondo athletes.

Authors Contributions

The author's contribution encompassed the design of the study, the collection of data, the statistical analysis, the preparation of the manuscript, and the approval of the final version.

Ethical Approval

Ethical approval for the study was obtained from the Non-Interventional Clinical Research Ethics Committee of Selçuk University (Decision No: 63, Date: 23.06.2023).

Funding

The authors declare that the study received no funding.

Competing Interests

The author declares no competing interests.

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