

## Original Article

# Investigation of the Relationship Between Core Stability and Reaction Time in Taekwondo Athletes

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## Abstract

**Objectives:** To examine the relationship between technical reaction time and core stabilization in taekwondo athletes.**Methods:** Cross-sectional correlational study of healthy male and female taekwondo athletes (n = 41; mean age 12.76 ± 1.07 years). Reaction performance was assessed using FITLIGHT Trainer sensors mounted on a taekwondo striking stand. Core stabilization was assessed using the Stabilizer Pressure Biofeedback Unit (PBU), a device employed to evaluate core muscle stabilization and deep abdominal muscle function. Spearman correlations (non-normal data) and Mann-Whitney U tests (sex comparisons) were applied. **Results:** Shorter reaction times were associated with a higher number of successful strikes (p < 0.05). Higher PBU task performance (time held) of the transversus abdominis muscle and multifidus muscle correlated with higher strike success rates. In unadjusted comparisons, male athletes achieved more successful strikes on both right and left sides and completed tasks with fewer errors; however, after adjusting for age, height, and weight, sex was not a significant predictor of outcomes. Transversus abdominis PBU task performance (time held) was significantly higher in males in unadjusted analyses, indicating superior core stabilization compared to females. **Conclusion:** These findings suggest that deep core muscles are important not only for postural stability but also for dynamic motor performance.**Keywords:** Athletic Performance, Multifidus Muscle, Reaction Time, Transversus Abdominis Muscle

## Introduction

Taekwondo is one of the oldest martial arts in the world with a history of approximately 1500 years. It has gained great popularity especially in the last 50 years and has become the most widely practiced martial art today<sup>1,2</sup>. This sport, notable for its dynamic kicks, includes versatile techniques such as punches, kicks, blocks, and evasions. Success in taekwondo depends on the athlete's technical, tactical, mental, physical, and physiological competencies. When evaluated in terms of physical preparation, the main objective of taekwondo training is to prepare athletes to

effectively manage both intense physical effort and the physiological requirements of competitions. Due to the nature of taekwondo competitions, athletes need to possess various physical competencies such as aerobic and anaerobic power, muscle strength, explosive power, flexibility, speed, reaction time, and agility<sup>3,4,5</sup>. In this context, the concept of speed, which is critically important in taekwondo, is defined as the ability of the athlete to move their body or a specific limb from one point to another as quickly as possible. This movement ability is supported by cognitive processes and willpower<sup>6,7,8,9</sup>. Neuromuscular functions play a central role in the cognitive dimension of speed, directly affecting the rate and force of muscle contraction as a result of the interaction between the central nervous system and the muscles. Increases in neural activity can accelerate an athlete's reaction time, enabling faster responses to external stimuli<sup>10</sup>. Reaction speed is directly related to the rate of maximal force production and includes the ability to respond rapidly in all movement planes and functional activities. The accurate evaluation of visual, auditory, and kinesthetic stimuli and the ability to respond to them with appropriate physical actions in the shortest time are

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fundamental factors affecting reaction speed. Additionally, psychological factors such as motivation, arousal level, and focus also directly influence reaction time<sup>11,12</sup>.

In sports like taekwondo, which require high speed and agility, postural balance and core stability are of great importance. Maintaining balance, especially when moving on unstable surfaces or responding to sudden external forces, plays a critical role for athletes<sup>13,14,15</sup>. The musculoskeletal core of the body includes the spine, hips, pelvis, proximal lower extremities, and abdominal structures. The core muscle system ensures the stability of the spine and pelvis and assists in the transfer of energy from large to small body segments during sports activities<sup>16,17</sup>. Moreover, muscles in the hips, pelvis, and spine provide the proximal stability necessary for the mobility and functionality of the limbs. Core muscles play an active role not only in stability and force production but also in extremity movements such as running, kicking, and throwing. Previous research has shown that scoring in taekwondo predominantly relies on kicking techniques<sup>18,19</sup>. Kicking techniques largely depend on maintaining body balance, sustaining postural control, and achieving high linear velocities of the lower extremity segments. In this regard, proper activation of the core muscle groups is of great importance for enhancing athletic performance and ensuring movement efficiency<sup>20,21,22</sup>.

Core stability muscles may include only the extensors, flexors, lateral flexors, or rotators of the spine. A more holistic approach includes all the muscles between the shoulders and pelvis<sup>23,24</sup>. Core stability involves the ability to effectively control the posture and movement of the trunk and is necessary for the optimal transfer of force and efficient execution of movement<sup>24,25</sup>. Furthermore, as the core region plays a central role in nearly all kinetic chains of the body, stability and control in this region directly affect the functions of the upper and lower extremities, contributing to the optimization of overall motor performance<sup>16</sup>. Core stability is achieved not merely through the presence of muscles but through their effective activation. The frequently independently used concepts of “stabilization”, “strengthening”, and “performance on PBU task” are, in reality, closely interrelated. Stabilization is essentially the result of forces generated by muscle mass and their activation through the central nervous system (CNS)<sup>24,26</sup>. While muscle mass determines how much force can be produced, the ability to utilize this potential depends on intra- and inter-muscular coordination<sup>27</sup>. Core stability and reaction time are interconnected aspects of neuromuscular control. Therefore, core stability is a dynamic process involving both muscle morphology (contractile potential) and neuromuscular control (activation). When supported by strengthening exercises, this process contributes to improvements in both stability and athletic performance. Research has shown that core stability exercises can lead to rapid improvements in muscle reaction time, especially in the transversus abdominis and obliquus internus muscles<sup>28</sup>.

Core stability is ensured through the coordination of bones (passive system), muscles (active system), and neural

control. These systems influence athletic performance and reaction time by maintaining balance. In sports like taekwondo, which require rapid responses, the effect of core stability on reaction time has not been sufficiently investigated. This study aims to examine this relationship in 11–14-year-old taekwondo athletes. The selection of this age group is based on the fact that neuromuscular development is at a critical stage. The findings will contribute to the training programs of young athletes.

## Materials and Methods

### Procedure

This study uses a correlational approach with a cross-sectional research design. Correlational research allows for insightful predictions and attempts to understand naturally occurring relationships between variables without experimental manipulation<sup>29</sup>. The research sample was determined using the “convenience sampling” method.

### Participants

The research sample consisted of 41 athletes (27 female, 14 male) with a mean age of  $12.76 \pm 1.07$  with red belt or higher rank from Mersin Toros Sports Club, who voluntarily agreed to participate in the study. While the target population comprised all red belt and higher ranked taekwondo athletes in Mersin, the sample group was selected from licensed athletes at Toros Sports Club. To be included in the study, athletes were required to have at least a red belt in taekwondo and no recent injuries. Athletes with less than one year of training experience were excluded from the study.

### Data Collection

The measurement process was carried out in two separate stages. First, the participants' technical reaction times were measured using the FITLIGHT Trainer device. Subsequently, core stabilization was evaluated using the Stabilizer Pressure Biofeedback Unit.

### Technical Reaction Time Measurements

During the data collection phase, the athletes' reaction times were measured using the FITLIGHT Trainer (FITLIGHT Sport Corp., Ontario, Canada). This system, consisting of wireless LED lights and controlled via an Android tablet, is not specifically designed for a particular age group; however, it has been recognized in the literature as a valid and reliable method for measuring reaction time, selective attention, directed speed, reactive agility, balance, and dynamic response time in children<sup>30</sup>.

For the taekwondo technical reaction test, six sensors were placed on the striking stand: two at the middle level on the right and left sides (palding chagi level), two at the upper level on the right and left sides (dollyo chagi level), one at the abdominal level (yeop chagi level), and one at the



**Figure 1.** FITLIGHT Trainer Taekwondo Technical Reaction Test.

chest level (ap chagi level). Throughout the test, athletes were instructed to stand on their non-kicking support leg, ensuring their kicking foot did not touch the ground for the entire duration of the 10-strike sequence. The protocol involved the random activation of a sensor, which occurred at a fixed interval of one second after the deactivation of the previous sensor. This process was repeated until a total of 10 sensors had been activated and deactivated. Athletes performed the full test series beginning with the leg of their choice and were provided a two-minute rest period between testing each leg. As part of this protocol, the athletes' leg dominance was not recorded. Prior to the test, participants were allowed to practice with three sensors. The measurement results were recorded on a data sheet as the number of deactivated sensors, average reaction time, and total duration (Figure 1). A Hit was recorded when a lit sensor was deactivated by a valid kick; an error was any missed or out-of-sequence attempt or a failure to deactivate a lit sensor within the trial window; errors were excluded from Hits but contributed to total duration.

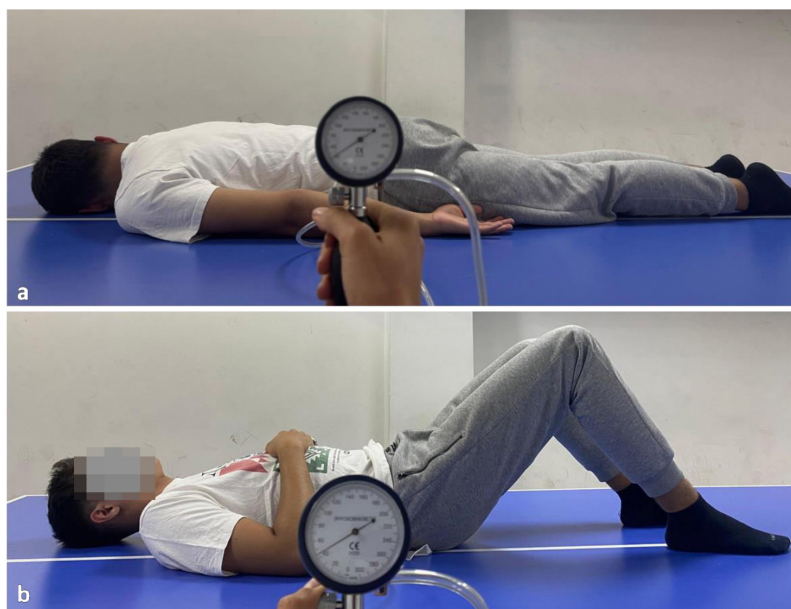
#### *Assessment of Core Muscle Stabilization*

The Stabilizer Pressure Biofeedback Unit (Stabilizer, Chattanooga Group Inc., Hixson, USA), a reliable and valid clinical tool for evaluating core muscle stabilization and deep abdominal muscle function, was used in this study<sup>31</sup>. The device operates within an analog pressure range of 0–200 mmHg and helps determine whether the athlete can selectively and independently contract the cervical and lumbopelvic core stabilization muscles<sup>32</sup>. Abdominal muscles are capable of decreasing the device pressure by 4–10 mmHg<sup>33</sup>. A pressure reduction of less than 2 mmHg, no change, or an increase in pressure indicates weakness in these muscles. A decrease of 6–10 mmHg is considered

a successful outcome<sup>34</sup>. Before the measurements, athletes were informed about the device and the activation techniques of the multifidus and transversus abdominis muscle, which play a key role in lumbopelvic stability.

To assess the transversus abdominis muscle, the athlete was asked to lie prone on a mat with the head turned to one side<sup>35</sup>. The individual lies face down on a firm surface, with their arms resting by their sides and their head completely relaxed, either turned to the more comfortable side or supported by the headrest of the treatment table<sup>35</sup>. The device was placed under the abdomen in the prone position, at the midpoint between the two anterior superior iliac spines. The pressure on the manometer was set to 70 mmHg, and the athlete was instructed to contract the transversus abdominis muscle without flexing the trunk. Duration of muscle contraction (in seconds) was recorded by monitoring the pressure change<sup>33,36</sup>. Care was taken to ensure that there was no trunk flexion, contraction of the hip muscles, or pelvic tilting during the test<sup>37,38</sup>. The best result of three trials was used for analysis to represent the athlete's maximal performance capability on the task (Figure 2a)<sup>39,40</sup>.

The supine 40 mmHg task reflects deep trunk stabilizer control (including transversus abdominis/internal oblique and multifidus); it does not isolate multifidus activity. To assess the multifidus muscle, the athletes lay supine on a mat with their heads turned to one side and knees bent. The device was placed under the lumbar lordosis in the supine position, with specified target pressure changes and holds. After setting the manometer pressure to 40 mmHg, the athletes were instructed to draw in the abdominal wall without moving the spine or pelvis. Duration of muscle contraction (in seconds) was recorded by monitoring the pressure change. The test was considered successful if



**Figure 2.** Evaluation of Core Muscle Stabilization and Deep Abdominal Muscle Function a. Assessment of transversus abdominis muscle, b. Assessment of multifidus muscle.

**Table 1.** Descriptive statistics of demographic parameters.

Sex	Parameters	N	Min	Max	Mean	SD
Female	Age (year)	27	11	14	12.52	1.01
	Body Height (cm)	27	134	178	154.37	11.73
	Body Weight (kg)	27	30	65	43.93	10.49
Male	Age (year)	14	11	14	13.21	1.05
	Body Height (cm)	14	145	187	166.00	12.79
	Body Weight (kg)	14	36	74	50.79	10.98

the pressure remained at 40 mmHg. The procedure was repeated three times, and the best measurement was taken into account (Figure 2b)<sup>40</sup>.

### Statistical Analysis

The data were analyzed using correlation analysis to determine the relationship between participants' technical reaction times and core stabilization scores. The normality of the distribution was tested using the Shapiro-Wilk test and Skewness-Kurtosis values<sup>41</sup>. Since the distribution was not normal, the Spearman correlation coefficient was calculated to assess the relationship between reaction time and core stabilization. To address the problem of

inflated Type I error rate resulting from multiple correlation analyses, the Benjamini-Hochberg (BH) False Discovery Rate (FDR) correction was applied to the set of p-values. Correlation coefficients with 95% CIs were reported. For Mann-Whitney U, an effect size and 95% CI were provided. In response to potential confounding effects stemming from baseline differences in anthropometric characteristics (age, body height, and body weight) between sex groups, and to address the requirement for a non-parametric approach, Partial Spearman Correlation Analysis was employed. This method allowed us to isolate the pure effect of sex independent of somatic factors. Prior to the partial correlation, all continuous variables were transformed to their respective ranks to ensure a robust, non-parametric

**Table 2.** Sex-related differences in reaction time and core region.

Parameters	Sex	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	Asymp. Sig. (2-tailed)
Hit R	Female	27	18.35	495.5	117.500	-2.021	<b>0.043*</b>
	Male	14	26.11	365.5			
Average reaction time R (sec)	Female	27	22.76	614.5	141.500	-1.306	0.191
	Male	14	17.61	246.5			
Total time R (sec)	Female	27	23.8	642.5	113.500	-2.076	<b>0.038*</b>
	Male	14	15.61	218.5			
Hit L	Female	27	17.78	480	102.000	-2.474	<b>0.013*</b>
	Male	14	27.21	381			
Average reaction time L (sec)	Female	27	21.81	589	167.000	-0.605	0.545
	Male	14	19.43	272			
Total time L (sec)	Female	27	23.04	622	134.000	-1.512	0.131
	Male	14	17.07	239			
Transversus Abdominis Muscle (time held)	Female	27	17.2	464.5	86.500	-2.821	0.005*
	Male	14	28.32	396.5			
Multifidus Muscle (time held)	Female	27	19.19	518	140.000	-1.361	0.173
	Male	14	24.5	343			

\* $p < 0.05$ , R= Right foot, L= Left foot.

analysis equivalent to Spearman's method. The partial correlation was then computed between the Rank of the Outcome Variable and sex, while statistically controlling for the Ranks of age, body height, and body weight.

The correlation coefficient indicates the direction and magnitude of the relationship between independent variables and ranges from (-1) to (+1). Positive values indicate a direct linear relationship, while negative values indicate an inverse linear relationship.

## Results

In the present study, the participants' demographic data are presented in Table 1, reaction time and core region results by sex are shown in Table 2, and the results of the correlation analysis are provided in Table 3.

Male participants extinguished more lights on both the right and left sides within the allotted time and completed the task with fewer errors. Transversus abdominis PBU task performance (time held) was significantly higher in males, indicating superior core region stabilization compared to females. Females had higher total time R (right total time) values, suggesting that they took longer to complete the task. However, no significant difference was observed in terms of average reaction time. Unlike transversus abdominis, no sex differences were found in multifidus muscle activation. Similarity was observed between the right and left sides (Table 2).

A negative correlation was observed between Hit

R/L and reaction time. An increase in successful strikes corresponds to a decrease in missed strikes. As reaction time decreases, the number of successful strikes increases ( $p < 0.05$ ). Our results suggest that athletes with faster reaction times perform better. A positive correlation was found between the PBU task performance (time held) of the transversus abdominis and multifidus tasks and the number of successful strikes (Hit). As the PBU holding time/performance increases, Hit R increases as well ( $r = 0.418$ ). This suggests that stronger core muscles positively influence performance. Similarly, a negative correlation was found between multifidus muscle activity and average reaction time ( $r = -0.400$ ), meaning that as multifidus activity increases, reaction time decreases (Table 3).

To address the problem of inflated Type I error rate resulting from multiple correlation analyses, the Benjamini-Hochberg (BH) False Discovery Rate (FDR) correction was applied to the set of p-values (Table 3). The family of tests was defined as the  $n = 23$  correlation pairs, and the significance level was controlled at an FDR of  $Q = 0.05$ . Following the Benjamini-Hochberg correction ( $n = 23$ ,  $Q = 0.05$ ), 21 of the 23 computed correlations remained statistically significant. Specifically, all correlations with an original p-value up to  $p = 0.030$  (corresponding to  $p_{adj} \leq 0.031$ ) were retained as significant. The two correlations with the largest original p-values (0.183 and 0.206) were not significant after correction. Table 3 reports the adjusted p-values ( $p_{adj}$ ) for all correlation pairs. Following BH-FDR ( $n = 23$ ;  $Q = 0.05$ ), 21/23 correlations remained significant; those with original

**Table 3.** Spearman's Correlation Coefficients (r) and Benjamini–Hochberg Adjusted p-Values ( $p_{adj}$ ) for all Variable Pairs.

Variable Pair		Original p-Value	(r)	BCa 95%	$p_{adj}$	Significance ( $p_{adj} \leq 0.05$ )
Average reaction time Right	Hit R	0.000**	-0.615	-0.816 to -0.352	0.000	Significant
Total time Right	Hit R	0.000**	-0.904	-0.951 to -0.806	0.000	Significant
Total time Right	Average reaction time R	0.000**	0.828	0.660 to 0.936	0.000	Significant
Hit Left	Hit R	0.000**	0.792	0.668 to 0.872	0.000	Significant
Hit Left	Average reaction time R	0.000**	-0.543	-0.759 to -0.257	0.000	Significant
Hit Left	Total time R	0.000**	-0.722	-0.847 to -0.521	0.000	Significant
Average reaction time Left	Hit R	0.000**	-0.56	-0.759 to -0.305	0.000	Significant
Average reaction time Left	Average reaction time R	0.000**	0.609	0.321 to 0.808	0.000	Significant
Average reaction time Left	Total time R	0.000**	0.593	0.345 to 0.776	0.000	Significant
Average reaction time Left	Hit L	0.000**	-0.554	-0.722 to -0.327	0.000	Significant
Total time Left	Hit R	0.000**	-0.755	-0.879 to -0.536	0.000	Significant
Total time Left	Average reaction time R	0.000**	0.621	0.277 to 0.841	0.000	Significant
Total time Left	Total time R	0.000**	0.73	0.555 to 0.840	0.000	Significant
Total time Left	Hit L	0.000**	-0.793	-0.885 to -0.633	0.000	Significant
Total time Left	Average reaction time L	0.000**	0.894	0.843 to 0.917	0.000	Significant
Abdominis Muscle	Hit R	0.007*	0.418	0.122 to 0.654	0.010	Significant
Abdominis Muscle	Average reaction time R	0.019*	-0.365	-0.599 to -0.075	0.021	Significant
Abdominis Muscle	Total time R	0.002*	-0.464	-0.683 to -0.162	0.003	Significant
Abdominis Muscle	Hit L	0.018*	0.369	0.028 to 0.637	0.021	Significant
Abdominis Muscle	Average reaction time L	0.183	-0.212	-0.517 to 0.118	0.183	Not Significant
Abdominis Muscle	Total time L	0.030*	-0.34	-0.623 to -0.011	0.031	Significant
Multifidus Muscle	Hit R	0.033*	0.333	0.058 to 0.584	0.033	Significant
Multifidus Muscle	Average reaction time R	0.009*	-0.4	-0.717 to -0.063	0.012	Significant
Multifidus Muscle	Total time R	0.014*	-0.382	-0.683 to -0.061	0.017	Significant
Multifidus Muscle	Hit L	0.008*	0.406	0.102 to 0.641	0.011	Significant
Multifidus Muscle	Average reaction time L	0.000**	-0.599	-0.816 to -0.285	0.000	Significant
Multifidus Muscle	Total time L	0.000**	-0.539	-0.778 to -0.174	0.000	Significant
Multifidus Muscle	Abdominis Muscle	0.206	0.202	-0.197 to 0.517	0.206	Not Significant

\* Correlation is significant at the 0.05 level (2-tailed), \*\* Correlation is significant at the 0.01 level (2-tailed).

$p=0.183$  and  $0.206$  did not.

To account for potential confounding effects, a partial correlation analysis was conducted to assess the relationship between sex and the outcome variable after adjusting for the ranks of age, body height, and body weight. The analysis indicated that, once the variance associated with these anthropometric covariates was statistically removed, the relationship between sex and all parameters (hit right, average reaction time right, total time right, hit left, average reaction time left, total time left, transversus abdominis muscle, multifidus muscle) was not statistically significant across all tested parameters. Specifically, the partial correlation coefficient between sex and the Rank of all parameters (hit right, average reaction time right, total time right, hit left, average reaction time left, total time left, transversus abdominis muscle, multifidus muscle),

controlling for age, body height, and body weight, was observed to be minor and failed to reach the established level of significance ( $p>0.05$ ).

The analysis reveals statistically significant differences between sex groups for four of the eight variables tested, based on the asymptotic significance level ( $p < 0.05$ ). The non-parametric effect size measure  $r = z/\sqrt{N}$  revealed varying magnitudes of sex differences across variables. Medium effects were observed for the two bilateral closure tasks (Hit R  $r=0.32$ , Hit L  $r=0.39$ ) and for the Right Total Time ( $r=0.32$ ). Most other variables, including the average reaction times (Average reaction time R/L) and Left Total Time, showed small-to-medium effects ( $r=0.20$  to  $r=0.24$ ). The strongest relationship was found for the Transversus Abdominis muscle variable ( $r=0.44$ , medium-to-large effect), while the Multifidus muscle showed a

**Table 4.** Mann–Whitney U Test Results Including Effect Sizes (r).

Variable Name	Mann-Whitney U	Z	Asymp. Sig.	r	Interpretation	95%CI
Hit R	167.000	-2.021	0.043	0.32	Medium	(0.03, 0.50)
Average reaction time R (sec)	246.500	-1.306	0.191	0.20	Small/Medium	(-0.09, 0.41)
Total time R (sec)	134.000	-2.076	0.038	0.32	Medium	(0.04, 0.51)
Hit L	102.000	-2.474	0.013	0.39	Medium	(0.10, 0.58)
Average reaction time L (sec)	272.000	-0.605	0.545	0.09	Small/Medium	(-0.20, 0.38)
Total time L (sec)	239.000	-1.512	0.131	0.24	Small/Medium	(-0.05, 0.45)
Transversus Abdominis Muscle (time held)	117.500	-2.821	0.005	0.44	Medium/Large	(0.14, 0.61)
Multifidus Muscle (time held)	343.000	-1.361	0.185	0.21	Small/Medium	(-0.08, 0.42)

small-to-medium effect ( $r=0.21$ ). These standardized  $r$  values clarify the practical significance of the observed differences (Table 4).

## Discussion

In this study, which aimed to examine the relationship between reaction time and core muscle performance on PBU task levels in Taekwondo athletes, various variables such as reaction time, hit and miss counts, reaction durations, and total time were assessed. The correlations between these motor outcomes and the PBU task performance of transversus abdominis muscle and multifidus muscle were analyzed. The findings were interpreted both descriptively and statistically, showing significant relationships between motor performance and the deep core muscles responsible for postural stability.

Upon examining the correlation results, our study found that athletes who reacted faster also had a higher hit rate. Literature on combat sports typically links the application of techniques with performance<sup>20,42,43,44</sup>. Monteiro et al. (2015) compared response times and error rates in response to visual and auditory stimuli, noting that novice athletes reacted more slowly and made more errors than elite athletes<sup>45</sup>. Studies examining reaction time and response time during various Taekwondo kicking techniques, such as roundhouse kicks, have highlighted factors such as target distance<sup>46,47</sup> and success determinants<sup>48</sup>. A study investigating the effects of fatigue on reaction time, response time, performance time, and kick impact during roundhouse kicks showed a moderate correlation between response time and kick impact, with performance time increasing as the kick's impact force grew<sup>49</sup>. In line with this literature, our findings also show a negative correlation between average reaction time and hit count for both legs, supporting the idea that quick decision-making and motor response contribute positively to performance.

Core strength and endurance are critical for

performance<sup>50</sup> and injury prevention<sup>51</sup>. In a recent study that assessed the wing kick (Naeryo chagi) performance of Taekwondo athletes with varying levels of core stability, similar to our study, the inclusion of core stability training in Taekwondo sessions was shown to have the potential to enhance wing kick performance<sup>52</sup>. In our study, the significant relationships between transversus abdominis muscle and multifidus muscle performance on PBU task and reaction time performance are noteworthy. Abdominis muscle, particularly involved in stabilizing the inner abdominal wall and regulating intra-abdominal pressure around the spine<sup>53</sup>, demonstrated an association with total time on the left foot, suggesting that this muscle may play a significant role in postural control and motor speed. Similarly, multifidus muscle performance on PBU task was significantly related to performance, particularly in tests performed on the left foot, indicating that these muscles contribute to lower extremity coordination through spinal stabilization. Our findings underscore the importance of transversus abdominis muscle and multifidus muscle in balance control and motor response organization. Similar to our study, another research focused on the correlation between core stability, muscle performance on PBU task, lower extremity kinematics, and dynamics in Taekwondo athletes showed that as core stability increased, execution time decreased<sup>52</sup>. Since Taekwondo kicks typically involve a proximal-to-distal sequence, proximal stabilization is crucial<sup>54</sup>. Therefore, it can be suggested that exercises targeting transversus abdominis muscle and multifidus muscle could improve motor response speed and hit accuracy.

When sex-specific findings were examined, it was found that men performed better than women in Hit scores with the right and left legs and completed the task with fewer errors on both sides. However, after adjusting for age, height, and weight using non-parametric partial correlations, sex was no longer a significant predictor of any outcome. Previous studies on sex differences in motor performance suggest that men have advantages

in faster nerve conduction, greater muscle strength, and neuromuscular efficiency<sup>55,56</sup>. Notably, our study found a statistically significant difference in the performance on PBU task levels of transversus abdominis muscle in favor of men. Given the role of this muscle in deep postural stability and force transfer<sup>57</sup>, men may have reflected this advantage in their reaction performance. However, no sex differences were found in multifidus performance on PBU task, which could be due to the smaller size and more segmental nature of this muscle<sup>58</sup>, or because of larger individual variability.

Descriptive statistics showed similar performance trends between the right and left limbs in the lower extremities. Reaction time and total time values were closely matched for both sides. The average hit count was reported as 7.59 for the right foot and 7.44 for the left foot, suggesting homogeneous bilateral motor control levels among the participants. Tang et al. (2007) reported that symmetric kicking skills are important for elite-level Taekwondo athletes<sup>59</sup>. Falco et al. (2009) found no mechanical differences between the dominant and non-dominant legs during roundhouse kicks, indicating no asymmetry between the limbs<sup>60</sup>. Since the dominant leg was not specifically measured in this study, the bilateral data align with the notion that bilateral motor control may provide an advantage in sports like Taekwondo that require symmetry.

In conclusion, the overall findings of our study demonstrate that deep core muscles are crucial not only for postural stability but also for dynamic motor performance. Therefore, neuromotor tests like reaction time should assess not only peripheral muscle strength but also muscle groups that maintain central stability.

## Conclusion

In this study, the relationships between reaction time performance with both the right and left foot and core muscle performance on PBU tasks were examined. The findings revealed significant relationships between motor performance and the deep core muscles that provide postural stability. In taekwondo athletes, strengthening the core muscles and improving reaction time can contribute to enhanced performance. These findings may serve as guidance for designing training programs for athletes or individuals undergoing rehabilitation. In conclusion, exercises targeting core stabilization can be said to have a performance-enhancing effect in sports such as taekwondo, which require high speed, agility, and balance. Supporting training programs with systematic exercises targeting these muscle groups may improve reaction time and increase athletes' technical accuracy. Future studies should consider different age groups, skill levels, and the use of longitudinal research designs.

### Limitations

This study has several limitations. First, the reaction time evaluations were focused solely on technical strikes,

without considering other potential factors such as cognitive decision-making processes. The supine 40 mmHg task reflects deep trunk stabilizer control (including transversus abdominis/internal oblique and multifidus); it does not isolate multifidus activity. Within-session reliability (ICC, CV%) could not be estimated because only summary (best-of-three) values were archived. Additionally, the lack of data on dominant leg usage limited the assessment of performance differences between sides. Lastly, the cross-sectional design of the study is insufficient for establishing cause-and-effect relationships. Therefore, it is recommended that future longitudinal studies be conducted to explore these aspects further. Evaluations were interpreted based on mean ages without considering Tanner stage or maturity offset.

### Ethics approval

*The study protocol was reviewed and approved by the Ethics Committee of Mersin University Sports Sciences (Approval No: 22/05/2024-035), and all procedures were conducted in accordance with the ethical standards of the committee and with the Declaration of Helsinki (1964) and its later amendments.*

### Consent to participate

*Informed written consent was obtained from all individual participants and from the parents/legal representatives of minors included in the study.*

### Authors' contributions

*Conceptualization: İ.K., A.H.B. Data Curation: A.H.B., F.B.Y. Formal Analysis: İ.K., M.A., A.H.B. Writing – Original Draft: İ.K., A.H.B. Writing – Review & Editing: F.B.Y., M.A. All authors read and approved the final version of the manuscript.*

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