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Effect of static and dynamic core exercises on kicking impact, kicking speed and balance in adolescent taekwondo athletes

Aylin ÖZTÜRK[1,2], Elif CENGIZEL[3*], & Mehmet GÜNAY[4]

[1] *Graduate School of Health Sciences, Gazi University (Turkey)*

[2] *Department of Physical Education, Istanbul Technical University (Turkey)*

[3] *Department of Coaching Education, Faculty of Sport Sciences, Gazi University (Turkey)*

[4] *Department of Physical Education and Sports, Faculty of Sport Sciences, Gazi University (Turkey)*

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ORIGINAL PAPER

Abstract

The aim of this study was to determine the effects of static and dynamic core exercises on kicking impact (KI), kicking speed, and balance in adolescent taekwondo athletes. Thirty-three adolescent taekwondo athletes were randomly divided into three groups: static core (SC, n=11), dynamic core (DC, n=11), and control group (CON, n=11). SC and DC group performed core exercise programs in addition to taekwondo training three days a week for eight weeks. KI was determined with the electronic body protector. The frequency speed of kick test ($FSKT_{10s}$) was applied to kicking speed. The flamingo balance test for static balance (SB) and lower and upper quarter Y-balance test (YBT-LQ & YBT-UQ) for dynamic balance were used. KI increased significantly only on the non-dominant side in the DC group (p=.001). A significant improvement in $FSKT_{10s}$ score was detected in the SC group (dominant, p<.001; non-dominant, p<.001) and the DC group (dominant, p<.001; non-dominant, p<.001). SB score showed a significant decrement in the DC group (dominant, p<.001; non-dominant, p=.010). YBT-LQ significantly improved on the dominant side (SC group, p=.003; DC group, p=<.001), and on the non-dominant side was observed in the SC group (p<.001), and the DC group (p<.001). YBT-UQ showed a significant decrement in the CON group (dominant, p<.001; non-dominant, p<.001) and in the DC group on the non-dominant side (p=.016). SC group and DC group improved $FSKT_{10s}$ and YBT-LQ performance. Additionally, DC group led to a decrement SB scores, and YBT-UQ, but significantly improved KI on the non-dominant side. Therefore, based on the results obtained in this study, core exercises can be recommended in adolescent taekwondo athletes to improve balance and kicking speed, and DC should also be preferred to increase KI and improve static balance performance.

Keywords: Martial arts; combat sports; taekwondo; core exercises; balance; kicking impact; kicking speed.

Efecto de ejercicios estáticos y dinámicos de *core* sobre el impacto y velocidad de las patadas y sobre el equilibrio en atletas adolescentes de taekwondo

Resumen

El objetivo de este estudio fue determinar los efectos de ejercicios estáticos y dinámicos de *core* sobre el impacto de la patada (KI), la velocidad de la patada y el equilibrio en atletas adolescentes de taekwondo. Treinta y tres participantes fueron asignados aleatoriamente a tres grupos: *core* estático (SC, n=11), *core* dinámico (DC, n=11) y grupo control (CON, n=11). Los grupos SC y DC realizaron programas de ejercicios de *core* además del entrenamiento de taekwondo, tres veces por semana durante ocho semanas. El KI se determinó mediante un

Efeito de exercícios estáticos e dinâmicos do *core* sobre o impacto e a velocidade dos chutes e sobre o equilíbrio em atletas adolescentes de taekwondo

Resumo

O objetivo deste estudo foi determinar os efeitos do exercício de core estático e dinâmico sobre o impacto do chute (KI), a velocidade do chute e o equilíbrio em atletas adolescentes de taekwondo. Trinta e três atletas adolescentes de taekwondo foram divididos aleatoriamente em três grupos: *core* estático (SC, n=11), *core* dinâmico (DC, n=11) e grupo controle (CON, n=11). Os grupos SC e DC realizaram programas de exercícios de core, além do treinamento de taekwondo, três vezes por semana durante oito semanas. O KI foi determinado com o

* *Corresponding author*: Elif Cengizel (elifoz@gazi.edu.tr)

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peto electrónico. La prueba de frecuencia de patadas en 10 segundos ($FSKT_{10s}$) se utilizó para evaluar la velocidad de la patada, el test de equilibrio del flamenco para el equilibrio estático (SB) y el lower and upper quarter Y-balance test (YBT-LQ y YBT-UQ) para el equilibrio dinámico. El KI aumentó significativamente solo en el lado no dominante en el grupo DC (p=.001). Se detectó una mejora significativa en la puntuación del $FSKT_{10s}$ en los grupos SC (dominante, p<.001; no dominante, p<.001) y DC (dominante, p<.001; no dominante, p<.001). La puntuación en SB disminuyó significativamente en el grupo DC (dominante, p<.001; no dominante, p=.010). El YBT-LQ mejoró significativamente en el lado dominante (SC, p=.003; DC, p<.001) y también en el lado no dominante en los grupos SC (p<.001) y DC (p<.001). El YBT-UQ disminuyó significativamente en el grupo CON (dominante, p<.001; no dominante, p<.001) y en el grupo DC en el lado no dominante (p=.016). Los grupos SC y DC mejoraron el rendimiento en $FSKT_{10s}$ y YBT-LQ. Además, el grupo DC mostró una disminución en los puntajes SB y YBT-UQ, pero mejoró significativamente el KI en el lado no dominante. Por tanto, a partir de los resultados obtenidos en este estudio se pueden recomendar ejercicios de *core* en atletas adolescentes de taekwondo para mejorar el equilibrio y la velocidad de patada, y el entrenamiento DC sería preferible para aumentar el KI y mejorar el rendimiento en equilibrio estático.

Palabras clave: Artes marciales; deportes de combate; taekwondo; ejercicios de core; equilibrio; impacto de patada; frecuencia de patada.

colete eletrônico. O teste de frequência de chutes em 10 segundos ($FSKT_{10s}$) foi aplicado para avaliar a velocidade do chute. O teste de equilíbrio do flamingo foi utilizado para o equilíbrio estático (SB) e o lower and upper quarter Y-balance test (YBT-LQ e YBT-UQ) para o equilíbrio dinâmico. O KI aumentou significativamente apenas no lado não dominante no grupo DC (p=.001). Uma melhora significativa no escore $FSKT_{10s}$ foi observada nos grupos SC (dominante, p<.001; não dominante, p<.001) e DC (dominante, p<.001; não dominante, p<.001). O escore SB apresentou uma diminuição significativa no grupo DC (dominante, p<.001; não dominante, p=.010). O YBT-LQ melhorou significativamente no lado dominante (SC, p=.003; DC, p<.001) e também no lado não dominante nos grupos SC (p<.001) e DC (p<.001). O YBT-UQ apresentou uma diminuição significativa no grupo CON (dominante, p<.001; não dominante, p<.001) e no grupo DC no lado não dominante (p=.016). Os grupos SC e DC melhoraram o desempenho no $FSKT_{10s}$ e no YBT-LQ. Além disso, o grupo DC apresentou uma diminuição nos escores SB e YBT-UQ, mas melhorou significativamente o KI no lado não dominante. Portanto, com base nos resultados obtidos neste estudo, podem ser recomendados exercícios para o *core* em atletas adolescentes de taekwondo. a fim de melhorar o equilíbrio e a velocidade do chute, e o treinamento DC deve ser preferido para aumentar o KI e melhorar o desempenho do equilíbrio estático.

Palavras-chave: Artes marciais; desportos de combate; taekwondo; exercícios para o core; equilíbrio; impacto do chute; frequência do chute.

1. Introduction

As an official Olympic sport since 2000, taekwondo has been popular worldwide (Han & Ju, 2025; Sousa et al., 2024). Taekwondo is unique with its predominant use of powerful kicking techniques (Tayshete et al., 2020) and is a high-intensity combat sport (Khazaei et al., 2023) in which hand and foot techniques are applied to specific target areas – the body (*momtong*) and head (*ollyo*) in foot strikes, and the body in hand strikes (Keum-Jae, 2021). Kicks are the most important movement in taekwondo competitions, 98% of the techniques applied are kicks, and the main technical action performed is the crescent kick or *bandal chagui* (Antonaccio et al., 2022; Moreira et al., 2014). Taekwondo is a full-contact combat sport where the most successful techniques are delivered by powerful kicks to the opponent's chest or head gear (Liu et al., 2021; Sousa et al., 2024). In taekwondo competitions, athletes must score points by effectively performing technical and tactical movements such as kicking, punching, blocking, pushing, and footwork (Bulak & Özdal, 2021), and improving kicking performance is the key performance indicator to winning in competition (Guan et al., 2024).

Kicking in taekwondo has specific demands such as strength, speed, endurance, balance, flexibility, and coordination (Zhang et al., 2025). Muscle strength and flexibility are essential to perform complex techniques and maintain balance during competitions (Hassan et al., 2024). The kicking performance of taekwondo athletes is correlated to explosive power, agility, muscle stretch-shortening cycle, and linear speed (Ojeda-Aravena et al., 2021). Taekwondo training and competitions also involve many high, fast, and jumping kicks that require athletes' superior balance abilities and motor responses (Bulak & Özdal, 2021; Khazaei et al., 2023). The competitor's kick must be fast and powerful enough to disrupt the opponent's defensive stance, hit the electronic body protector, and reach the target scoring force set in a competition (Liu et al., 2021; Moreira et al., 2016). Strength and speed training are needed to kick the opponent quickly and effectively to ensure that kicks reach the target effectively and produce sufficient force during competition (Zhang et al., 2025). Kicking impact, which is determined in appropriate units of measurement for World Taekwondo Federation (WT) via a body protector but is not defined by the International System of

Units (SI), is associated with power, force and kinetic energy (Moreira et al., 2021), and the highest possible speed of the proximal segment that interacts with the distal segments plays an important role in determining the magnitude of the kicking impact (Estevan et al., 2011, 2013).

Taekwondo athletes perform much asymmetrical activity during training and competition when performing fast kicking techniques, and the kick is mainly performed on one leg (Zhang et al., 2025). Therefore, unilateral postural stability is crucial for taekwondo athletes and demonstrates the need for balance. In addition, the ability to control balance and posture is a crucial factor for the performance of taekwondo athletes in competitions (Açıkgöz & Cengizel, 2023). Taekwondo athletes must complete movements quickly and steadily during competitions and return to their original positions. For this purpose, athletes maintain vertical stability, upward force output, and movement efficiency to provide rapid and accurate target strikes while maintaining body balance and stability (Zhang et al., 2025). Static balance, which is related to stability while maintaining a certain posture, and dynamic balance, which involves adjusting an individual's posture during movement (Han & Ju, 2025; Tayshete et al., 2020), are among the critical factors affecting the performance and career longevity of adolescent taekwondo athletes (Shen, 2024). It is known that postural control changes in athletes through long-term training (Zhang et al., 2025) and that physical activity is a method that enhances balance (Han & Ju, 2025).

Core muscles are of great importance in maintaining kick execution time, lower extremity speed, and posture control in scoring points in taekwondo (Guan et al., 2024), and specialized training focused on developing core and lower extremity strength is required to increase kicking speed and attack frequency (Chun et al., 2021). In a previous study, balance improved in taekwondo athletes after eight weeks of core exercises (Yoon et al., 2015). Similarly, significant improvement in balance was achieved with core muscle exercises in adolescent taekwondo athletes, but the improvement after proprioception training was greater (Tayshete et al., 2020). In a meta-analysis and systematic review, Han and Ju (2025) emphasized that taekwondo training improves static and dynamic balance and that static balance was optimized after 12 weeks with taekwondo training for 60-70 minutes once a week. Previous studies have examined the effects of balance during different kicks (Zhang et al., 2025), the effect of taekwondo training (Han & Ju, 2025) or core training on balance (Xiao & He, 2023), the relationship between core stability and kicking speed (Guan et al., 2024; Li et al., 2024), the relationship between kicking speed and isokinetic leg torque (Moreira et al., 2021), the effects of different strength training on kicking performance (Bulak & Özdal, 2021; Hassan et al., 2024), and balance (Khazaei et al., 2023; Shen, 2024; Tayshete et al., 2020) in taekwondo. However, to the best of authors' knowledge, no study examines the effects of core exercises on kicking impact (KI), kicking speed and balance in adolescent taekwondo athletes. The present study aimed to determine the effects of static and dynamic core exercises on KI, kicking speed, and balance in adolescent taekwondo athletes. We addressed two hypotheses:

(1) Static core exercises will increase kicking speed, and static and dynamic balance performance

(2) Dynamic core exercises will increase KI, kicking speed, static and dynamic balance performance.

2. Methods

2.1. Participants

Thirty-three adolescent taekwondo athletes aged 12-15 years were randomly divided into three groups: static core exercise group (SC, n=11), dynamic core exercise group (DC, n=11), and control group (CON, n=11) (Table 1). Each group consisted of six girls and five boys. Before starting the study, participants were informed verbally, and consent forms were collected from their families. The inclusion criteria for the study were: (a) Being a licensed and competitive taekwondo athlete, (b) Participating in taekwondo training regularly at least 3 days a week for the last two years, and (c) Being between the ages of 12-15. The exclusion criteria were: (a) Having had a musculoskeletal injury or surgery within the last six months, (b) Having hearing or visual impairment, (c) Not participating in training three times during the eight-week training period, (d) Not completing any of the pre- or post-tests, and (e) Withdrawing voluntarily at any stage of the study. The research was conducted in accordance with the Declaration of Helsinki and was approved by the Gazi University Ethics Committee (Research Code: 2023-85).

Table 1. Characteristics of participants

Variables	Static core exercise group	Dynamic core exercise group	Control group
Age (years)	13.0±1.0	13.1±1.2	13.4±1.0
Years of experience	3.8±1.8	4.3±2.5	2.1±1.4
Body height (cm)	162.1±11.2	160.1±12.6	158.1±9.7
Body mass (kg)	54.4±10.7	54.0±12.1	51.5±7.7
Body mass index - BMI (kg.m^{-2})	20.5±2.2	20.9±3.3	20.6±2.4

Note: No statistically significant differences in participants' characteristics were observed between the groups (p>.05).

2.2. Study design

In this study, in addition to taekwondo training, the SC and DC followed a core exercise program 3 days a week for 8 weeks, each lasting approximately 20-25 min, while the CON only participated in taekwondo training during this period and did not participate in any resistance or aerobic exercise. All groups completed the same taekwondo training to isolate the effect of core exercises. Tables 2 and 3 present the static and dynamic core exercise programmes, respectively.

Table 2. Static core exercise drills

Exercise	Duration	Set	W1	W2	W3	W4	Set	W5	W6	W7	W8
Prone Plank	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Side Bridge (right-left)	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Swimmer	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Stance in Jackknife with feet 20cm high	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Superman (hands up stance)	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Flutter kick stance	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Stance in squat position	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Stance in Russian twist	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Stance in bridge	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Stance in push-up position	20 sec	2	-	✓	✓	✓	3	-	✓	✓	✓
Stance in push-up position with feet 30cm high	20 sec	2	-	-	✓	✓	3	-	-	✓	✓
Stance in side plank with single-leg lift (right-left)	20 sec	2	-	-	-	✓	3	-	-	-	✓

Note: W: Week, Total time (TT) in W1 & W2 = 12-15 min; TT in W3 & W4 =15-16 min; TT in W5 & W6 = 18-20 min; TT in W7 & W8 = 22-25 min.

SC and DC performed core exercises with gradually increasing volume 3 days per week for 8 weeks. The work-rest ratio was 1:1, and the interval between training sessions was at least 48 hours. Medicine ball weight was determined as 1.5 kg in the first two weeks, 2 kg in the third and fourth weeks, 2.5 kg in the fifth and sixth weeks, and 3 kg in the seventh and eighth weeks, with a half kg increase every two weeks. The number of sets was determined as two for all exercises in the first four weeks and three after the fourth week. The rest period between sets was one minute. In the first week, the total duration of the core exercise program was approximately13-15 min, and at the end of the eighth week, it was 22-25 min. All athletes adapted to the gradual increase in training load.

The performance tests were completed in two separate sessions: a pre-test before starting training and a post-test after eight weeks of training to determine the effect of core exercises on KI, kicking speed, and balance. The familiarization session was conducted with trial repetitions in the same session immediately before the tests. The measurements were performed on the same day at

10-minute intervals for static balance, dynamic balance, taekwondo-specific warm-up, KI, and kicking speed, respectively. In kicking and balance measurements, the dominant leg was determined by asking which leg they kicked most often. In upper extremity balance measurements, the dominant side was determined by asking which hand the athlete used most often.

Table 3. Dynamic core exercise drills

Exercises	Duration/ Repetition	Set	W1	W2	W3	W4	Set	W5	W6	W7	W8
Jackknife	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Bridge	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Dynamic side plank (right-left)	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Prone plank	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Squat with a medicine ball	10 rep	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Archer push-up	20 sec	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Palding chagi with resistance band (right-left)	10 rep	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Yop chagi with resistance band (right-left)	10 rep	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Leg abduction with resistance band (right-left)	10 rep	2	✓	✓	✓	✓	3	✓	✓	✓	✓
Chest pass with medicine ball (right-left)	20 sec	2	-	✓	✓	✓	3	-	✓	✓	✓
Push-up	10 rep	2	-	-	✓	✓	3	-	-	✓	✓
Push-up with feet 30cm high	10 rep	2	-	-	-	✓	3	-	-	-	✓

Note: W: Week, Total time (TT) in W1 & W2 = 12-15 min; TT in W3 & W4 =15-16 min; TT in W5 & W6 = 18-20 min; TT in W7 & W8 = 22-25 min.

Before the exercise programs and performance tests, all participants were applied the following 10-minute warm-up protocol. The warm-up protocol consisted of two phases: general warm-up (approximately 5 min) and taekwondo-specific warm-up (approximately 5 min). The general warm-up protocol included jogging (2 min), arm and leg swings-flexion to extension (10 rep for each limb), hip rotation and kneeling (10 rep for each limb), skipping (30 sec), Jumping Jack (30 sec) with 10 sec interval. Taekwondo-specific warm-up consisted of walking lunges (10 rep), lateral leg swings (10 rep for each limb), plank to downward dog (10 rep), *bandal chagui* (5 rep for each limb), *yop chagui* (5 rep for each limb) with 10 sec interval.

2.3. Data Collection

KI. KI magnitude was measured with the Daedo 2015 Gen 1 sensor electronic body protector (EBP) system. This system provides equal criteria for taekwondo athletes in all member countries of the WT according to standard practices (Daedo Truescore, USA). This system was used in the 2012 London Olympics, 2016 Rio de Janeiro Olympics, and 2020 Tokyo Olympics and was adopted to obtain the kicking impact magnitude (Liu et al., 2021). The following equipment was used to determine KI: Truescore Daedo 2015 Gen 1 EBP; system antenna, 2 EBP-mounted electronic rechargeable chips, one blue and one red number 2 EBP, 2 EBP-dressed sand or water-filled 'Haşado' brand human dummy, 4 Gen 1 sensor foot protectors and TK-strike Truescore Daedo 2014-2015 system competition program package on the computer. After the blue and red EBP chips were identified in the system, they were placed on the dummies in a vertical position. Each athlete first performed a set of three repetitions of a roundhouse kicks (*bandal chagui*) to the dummy's body area with their right rear foot in the guard position, then completed a set of three repetitions of a *bandal chagui* with their left rear foot. The rest interval between repetitions was 15 seconds. KI was measured separately for the dominant and non-dominant sides. The trunk protector registered the impact power in units of measurement appropriate for WT but not defined by the International System of Units (SI) (Moreira et al., 2021). The KI magnitude determined with sensor protectors was recorded on the computer, and the highest score in three kicking trials was analysed.

Kicking speed. Kicking speed was determined using the FSKT test. The $FSKT_{10s}$ measures the maximum number of kicks athletes can perform against a helmeted, weighted training dummy for 10 seconds. The $FSKT_{10s}$ is a reliable taekwondo-specific field test (ICC and SEM for absolute and relative performance during $FSKT_{10s}$ were 0.95 and 0.60, respectively) for assessing taekwondo performance (da Silva Santos et al., 2020), and the test and retest coefficient of variation was 2.9%. (Santos et al., 2019). A pre-test trial was administered with familiarisation followed by two test repetitions with five-minute rest intervals. The $FSKT_{10s}$ test was randomly applied to the dominant and non-dominant legs and recorded using a video camera with an ultra-slow-motion feature (GoPro MAX 360 Action Camera, USA). After the start signal, athletes were asked to kick with the *bandal chagui* technique at maximum speed and frequency for 10 seconds, and valid kicks were recorded. In the test, kicks not performed with the correct technique or directed outside the target were considered invalid. After invalid kicks, athletes were given a five-minute rest period, and the test was repeated in accordance with the protocol.

Static balance. Static balance was performed in a quiet, adequately lit environment with the Flamingo balance test. Familiarization was applied to the athletes for 10 seconds before the test. While balancing with one foot on a metal balance beam (50 cm long, 4 cm high, and 3 cm wide), the participants bent the other foot backward from the knee, pulled it towards the hip, and held it with the hand on the same side. In this position, the athletes tried to stay in balance by maintaining their body integrity, and as soon as they reached the correct position, the time was started with a stopwatch. The participants were asked to maintain this steady state for 30 sec. The timer was stopped in the following cases: (i) if the foot held by the hand was released, (ii) if he/she fell off the balance beam, and (iii) if any part of the body touched the ground (Afyon, 2014). When the athlete got on the balance beam and regained his/her balance, the time was restarted from where it left off. The test continued in this manner for 30 seconds, and the number of times the athlete stopped the timer during this period was recorded as the static balance score (number of falls). This test was applied to both sides randomly, alternating on the same side non-consecutively, and repeated twice for each side. The lowest score was determined as the static balance score.

Dynamic balance. Lower extremity dynamic balance (YBT-LQ) was measured with the lower quarter Y-Balance (YBT; Move2Perform, Evansville, IN) according to criteria described by Plisky et al. (2009). In this test, athletes stood in balance with one foot in the centre of a Y-shaped strip on the ground (with an angle of 135° between the anterior and posterior directions and 90° between the posterior directions) and reached toward the determined directions (anterior, posteromedial, posterolateral) with the other foot. Lower extremity length was measured as the distance between the anterior superior crista iliac and the medial malleolus. YBT-LQ was applied three times in each direction. Scores were recorded separately for the dominant and non-dominant leg. The composite score was calculated by dividing the sum of the three directions by three times the leg length (Myers et al., 2018).

Upper extremity dynamic balance (YBT-UQ) was measured with the Upper quarter Y-Balance test (YBT; Move2Perform, Evansville, IN). In this test, athletes balanced with one hand on a Y-shaped strip centre on the ground (135° between the medial and lateral directions, 90° between the lateral directions) and reached towards the determined directions (medial, superolateral, inferolateral) with the other hand (Schwiertz et al., 2020). The upper extremity lengths of the athletes were measured as the distance between the C7 cervical vertebra processus spinosus and the tip of the middle finger while the shoulder was in 90° abduction. YBT-UQ was applied three times in each direction. Scores were recorded separately for the dominant and non-dominant sides. The composite score was calculated by dividing the sum of the three directions by three times the arm length (Bauer et al., 2020).

2.4. Data Analysis

The data are presented as M±SD. The normality of the data was tested via the Shapiro–Wilk test. A two-way repeated measures ANOVA was conducted to examine the group × time interaction as well as the main effects of group and time. Holm–Sidak post-hoc pairwise comparisons were consistently applied for all outcomes, regardless of whether the interaction term reached statistical significance, to explore potential pairwise differences. The effect size (ES) was classified using

Cohen's d according to the following scale in the comparisons of pre-and post-tests: trivial<0.2, small 0.2–0.5, moderate 0.5–0.8, and large>0.8. Partial eta squared effect sizes (η^2_p) were classified as follows in the inter-group comparisons: small (0.01), moderate (0.06), and large (0.14) (Cohen, 1988). The percentage change was calculated by subtracting the pre-test data from the post-test data, then dividing the result by the pre-test data. Data analysis was performed using SigmaPlot 11.0 software (from Systat Software, Inc., San Jose, California, USA). The significance level was set at 0.05.

3. Results

Adolescent taekwondo players' KI increased significantly only on the non-dominant side in the DC group (p=.001, ES=.679 "moderate" % change=14.9). A significant group × time interaction was found for KI on the non-dominant side (F=5.03, p=.013, "large" η^2_p=251), whereas no significant interaction was observed on the dominant side (F=3.09, p=.060, η^2_p=.171). $FSKT_{10s}$ score increased significantly in SC (dominant p<.001, ES=1.00 "large" % change=21.1; non-dominant p<.001, ES=1.271 "large" % change=33.3), and DC groups on both sides (dominant p<.001, ES=.916 "large" % change=20.7; non-dominant p<.001, ES=1.017 "large" % change=28.0). The CON group athletes who participated only in taekwondo training for eight weeks showed no significant difference in KI and $FSKT_{10s}$ scores between the pre-and post-tests. KI and kicking speed was not significantly different between the groups in pre-test comparisons (p>.05). In the post-test comparisons between the groups, kicking speed performance on both sides of SC and DC was significantly higher than the CON group (dominant: SC vs CON F=10.59, p<.001, "large", η^2_p=.457; DC vs. CON F=10.71, p<.001, "large" η^2_p=.460; non-dominant: SC vs. CON F=11.02, p<.001, "large" η^2_p =.454; DC vs. CON F=10.64, p=.002, "large" η^2_p=.462), but KI was not significantly different between the groups (p>.05) (Table 4). Significant group × time interactions were found for kicking speed on both the dominant (F=5.46, p=.010, "large" η^2_p=.266) and non-dominant sides (F=9.85, p<.001, "large" η^2_p=.397),

Table 4. KI and kicking speed performance of adolescent taekwondo athletes before and after core exercises

	Dominant side				**Non-dominant side**			
KI (a.u.)	**Pre**	**Post**	**Time**	**Group**	**Pre**	**Post**	**Time**	**Group**
SC	43.8±7.3	43.5±5.9	*.913* (<.001)	*.108* (.138)	38.0±9.1	40.5±6.4	*.070* (.261)	*.358* (.066)
DC	37.3±10.5	39.2±8.9			31.5±7.4	36.2±6.4	*.001* (.567)	
CON	36.5±10.5	35.1±8.6			36.1±12.8	35.0±10.9	*.411* (.065)	
$FSKT_{10s}$ (rep)	**Pre**	**Post**	**Time**	**Group**	**Pre**	**Post**	**Time**	**Group**
SC	9.0±1.9	10.9±1.9	*<.001* (.619)	SC vs CON *<.001*(.457)	8.4±2.3	11.2±2.1	*<.001* (.738)	SC vs CON *<.001*(.454)
DC	8.2±1.7	9.9±2.0	*<.001* (.571)	DC vs CON *<.001*(.460)	7.5±2.3	9.6±1.8	*<.001* (.608)	DC vs CON *.002*(.462)
CON	7.2±1.2	7.1±1.0	*.849* (.004)		7.4±1.6	7.0±1.0	*.499* (.045)	

Note: Data are presented as M±SD. SC: Static core exercise group, DC: Dynamic core exercise group, CON: Control group. KI: Kicking impact, a.u.: arbitrary unit, FSKT: Frequency speed of kick test, rep: repetition. Time indicates the pre–post comparison within each group (p-value and partial eta squared, η^2_p); Group indicates pairwise post-hoc comparisons between groups (p-value and η^2_p) obtained following a significant main group effect in the two-way repeated-measures ANOVA. Values in parentheses denote η^2_p.

Static balance error scores showed a significant decrement in the DC group (dominant side p<.001, ES=.979 "large", % change=-27.0). A significant group × time interaction was observed on the dominant side static balance (F=3.50, p=.043, "large" η^2_p=.187). For non-dominant side static balance, there was a significant main effect of time (F=8.07, p=.008, "large" η^2_p=.212), indicating overall improvement from pre- to post-test in the SC and DC group (Table 5). No significant main effect of group (F=.16, p=.853, η^2_p=.011) and no significant group × time interaction (F=3.16, p=.057, η^2_p=.174) were found on the non-dominant side static balance.

Table 5. Static balance performance of adolescent taekwondo athletes before and after core exercises

Number of falls	Dominant side				Non-dominant side			
	Pre	Post	Time	Group	Pre	Post	Time	Group
SC	7.3±2.1	6.3±1.8	*.111* (.211)		8.6±2.1	6.8±2.0	*.014* (.424)	
DC	8.8±2.4	6.5±2.3	*<.001* (.583)	*.179*(.057)	8.3±3.2	6.5±2.4	*.010* (.443)	*.853*(.011)
CON	8.4±2.5	8.4±2.2	*1.00* (0.00)		7.8±2.9	8.1±2.3	*.685* (.027)	

Note: Data are presented as M±SD. SC: Static core exercise group, DC: Dynamic core exercise group, CON: Control group. No of falls: number of falls. Time indicates the pre–post comparison within each group (p-value and partial eta squared, η^2_p); Group indicates pairwise post-hoc comparisons between groups (p-value and η^2_p) obtained following a significant main group effect in the two-way repeated-measures ANOVA. Values in parentheses denote η^2_p.

YBT-LQ dynamic balance composite scores showed a significant increase in the SC and DC groups on the dominant side (SC: p=.003, ES=.470 "small" % change=4.4; DC: p<.001, ES=.647 "moderate" diff%=6.5), and on the non-dominant side in the SC (p<.001, ES=.592 "moderate" % change=3.1) and DC groups (p=.002, ES=.808 "large" % change=6.6). YBT-UQ dynamic balance composite scores were significantly decreased on both sides in the CON group (dominant: p<.001, ES=.716 "moderate" % change=-9.0; non-dominant: p<.001, ES=.835 "large" % change=-8.9), and additionally significantly decreased on the non-dominant side in the DC group (p=.016, ES=.690 "moderate" % change=-5.3). Dynamic balance was not significantly different between the groups in pre-and post-test comparisons (p>.05) (Table 6). Significant group × time interactions were found for YBT-LQ dynamic balance on both the dominant (F=3.80, p=.034, "large" η^2_p=.202) and non-dominant sides (F=6.28, p=.005, "large" η^2_p=.295). No significant group × time interactions were observed for YBT-UQ dynamic balance on either the dominant (F=1.93, p=.163, η^2_p=.114) or non-dominant side (F=1.59, p=.221, η^2_p=.096).

Table 6. Lower extremity and upper extremity dynamic balance composite scores of adolescent taekwondo athletes before and after core exercises

	Dominant side				Non-dominant side			
YBT-LQ	**Pre**	**Post**	**Time**	**Group**	**Pre**	**Post**	**Time**	**Group**
SC	81.3±8.1	84.9±7.2	*.003* (.511)	*.761* (.018)	80.2±7.9	84.7±7.3	*<.001* (.633)	*.746* (.019)
DC	78.4±8.6	83.5±7.1	*<.001* (.663)		77.8±5.9	82.9±6.7	*<.001* (.694)	
CON	80.1±11.3	80.8±11.7	*.538* (.037)		79.6±12.4	79.7±12.2	*.884* (.002)	
YBT-UQ	**Pre**	**Post**	**Time**	**Group**	**Pre**	**Post**	**Time**	**Group**
SC	97.9±9.6	94.0±7.0	*.095* (.229)	*.819* (.013)	97.4±8.5	94.0±6.8	*.107* (.216)	*.274* (.083)
DC	96.9±9.7	93.9±6.3	*.187* (.154)		98.8±8.7	93.5±6.5	*.016* (.395)	
CON	98.0±14.0	89.2±10.3	*<.001* (.606)		95.4±11.7	86.9±8.4	*<.001* (.633)	

Note: Data are presented as mean±SD. SC: Static core exercise group, DC: Dynamic core exercise group, CON: Control group. YBT-LQ: Lower extremity dynamic balance, YBT-UQ: Upper extremity dynamic balance. Time indicates the pre–post comparison within each group (p-value and partial eta squared, η^2_p); Group indicates pairwise post-hoc comparisons between groups (p-value and η^2_p) obtained following a significant main group effect in the two-way repeated-measures ANOVA. Values in parentheses denote η^2_p.

4. Discussion

The aim of this current study was to determine the effects of static and dynamic core exercises on KI, kicking speed, and balance in adolescent taekwondo athletes. We hypothesized that static and dynamic core exercises would increase kicking speed and static and dynamic balance performance, and additionally, dynamic core exercises would increase KI. Our main findings were (i) static core exercises increased kicking speed, non-dominant side static balance, and lower extremity dynamic balance on both sides (ii) dynamic core exercises increased KI, kicking speed, static balance, lower extremity dynamic balance, and decreased upper extremity dynamic balance in non-dominant side (iii) in the CON athletes who participated only in taekwondo training, upper extremity dynamic balance decreased on both sides and a non-significant difference in KI, kicking speed, and static balance. Additionally, significant group × time interactions were observed for KI (non-dominant side), kicking speed, static balance (dominant side), and dynamic balance, indicating that the effects of training differed between the static and dynamic core exercise groups. These results collectively highlight that core training modalities involving dynamic and sport-specific movement patterns may provide greater transfer effects to functional performance in taekwondo athletes compared with static approaches. Our research findings confirm our hypotheses except for no significant increase on the dominant side static balance performance in the SC and a significant decrease in upper extremity dynamic balance in the DC group.

KI increased significantly by 14.9% only in the DC on the non-dominant side in adolescent taekwondo athletes (p=.001, ES=.679). The absence of a significant increase in the SC may be related to the specific content of the DC protocol, which included resistance band and kicking drills that might have provided additional sport-specific activation. However, this interpretation should be approached with caution, as direct causal inferences between groups cannot be established within the current design. Dynamic stabilization of the trunk facilitates the sequential energy transfer from proximal to distal segments, enhancing impact and accuracy (Kibler et al., 2006; Prieske et al., 2016). In taekwondo, where most technical actions rely on kicking techniques (Harbili et al., 2022), improved proximal stability is essential for maximizing lower-limb velocity and impact force. Typical kicking actions require rapid and repetitive force production to meet the scoring threshold on electronic protectors (Apollaro et al., 2024). In this context, it can be suggested that dynamic, multi-planar trunk exercises may promote greater neuromuscular coordination compared with static stabilization, which could partly explain the higher KI improvement observed in the DC group. Consistent with our findings, previous interventions have shown that core-focused training enhances both core strength and impact performance in taekwondo athletes (Guan et al., 2024; Vagner et al., 2021). Therefore, dynamic core exercises that enhance intermuscular synchronization and proximal fixation within the kinetic chain appear to be an effective approach to increasing kicking impact in adolescent taekwondo athletes.

Eight weeks of static and dynamic core exercises showed significant increases in bilateral kicking speed in taekwondo athletes (SC, dominant: p<.001, ES=1.00, non-dominant: p<.001, ES=1.271; DC, dominant: p<.001, ES=.916, non-dominant: p<.001, ES=1.017). The largest improvements were observed on the non-dominant side (SC: +33.3%, DC: +28.0%), indicating that both training modalities effectively enhanced sport-specific performance in adolescent athletes. Considering that bilateral kicking ability provides a major advantage in competition (Harbili et al., 2022), these findings demonstrate the transferability of core training adaptations to taekwondo techniques. On the other hand, there was no significant difference in kicking speed in the CON group, which only performed taekwondo training. The kicking speed increase obtained with SC and DC exercises was also significantly higher than in the CON (p<.001). The improvement in kicking speed observed after core training supports previous evidence showing that both static and dynamic trunk stabilization can enhance power and coordination in striking actions (Bulak & Özdal, 2021; Chun et al., 2021). Core stability is known to improve intersegmental coordination and the efficiency of force transmission along the kinetic chain (Guan et al., 2024; Li et al., 2024; Sofuoğlu et al., 2024). These mechanisms likely explain why athletes with greater trunk stability exhibit faster execution time and higher angular velocities during kicking movements. In this study, $FSKT_{10s}$ was used to evaluate kicking speed performance and previous studies have determined that $FSKT_{10s}$ may be more effective in detecting smaller performance changes with a lower minimal detectable change value compared to counter movement jump and is a reliable method showing reproducible results in performance evaluation in combat sports as a functional field test (Silva Santos & Franchini, 2018; Ulupınar et al., 2020, 2023), and it also showed low-to-large correlation with countermovement jumping and squat jumping (Ouergui et al., 2025). Notably, our findings extend previous research in adult and young athletes (da Silva Santos & Franchini, 2016; Xiao & He, 2023) by showing similar improvements in adolescents — a population for which evidence is limited. This suggests that both static and dynamic core training may be effective strategies to enhance kicking velocity even in developing athletes, possibly through improved neuromuscular control and postural efficiency. Future research should examine whether different core activation strategies (e.g., rotational vs. anti-rotational) yield distinct performance benefits across age groups.

Static balance performance improved with dynamic core exercises in adolescent taekwondo athletes. In the DC, there was significant improvement on dominant side (p<.001, ES=.979). Static balance showed improvement exceeding 20% through dynamic core exercises, while there was no significant difference in static balance in the SC and CON. Maintaining the centre of gravity is important in taekwondo competitions to improve performance (Choi et al., 2021). Balance and speed are physical fitness factors that help provide strength while maintaining stability during attack and defence (Chun et al., 2021). Taekwondo athletes also have positions where they remain in static balance on one leg while kicking during competition. Maintaining static balance during this phase can also affect the quality of the following dynamic action (kicking, bringing the leg back to the landing position, etc.). In addition, postural imbalance can cause overloading of the musculoskeletal structures and injuries, pain, and falls (Zhang et al., 2025). In a previous study, the dominant side static balance error score in adolescent taekwondo athletes (11-14 years, n=23) was 14.6±4.8 (95%CI: 12.6-16.6), and the non-dominant side static balance error score was 14.7±4.3 (95%CI: 12.9-16.5) (Açıkgöz & Cengizel, 2023). This previous study did not include any strength training intervention. However, similar to the findings, our study shows that taekwondo athletes have similar static balance performance on the dominant and non-dominant sides. On the other hand, the fact that improvement in static balance on both sides was observed only in the DC is an important finding, likely due to the inclusion of resistance bands and kicking drills in its program design, which may have provided additional proprioceptive stimuli and task-specific activation, and shows that the DC exercises in our study are a more appropriate intervention for static balance performance. However, considering the different motor demands for different sports disciplines, this result may not be the same for every sports discipline.

YBT-LQ dynamic balance composite scores showed a significant increase in the SC and DC on the dominant side (SC: p=.003, ES=.470; DC: p<.001, ES=.647) and on the non-dominant side (SC: p<.001, ES=.592; DC: p<.001, ES=.808). Eight weeks of functional and traditional strength training in young taekwondo athletes resulted in an 11-20% improvement in Y balance (ES range=1.29-5.28) (Khazaei et al., 2023). This finding was accompanied by other motor features: speed, strength, reaction time, agility, and aerobic and anaerobic fitness. In our study, a 3.1%-6.6% improvement in lower extremity dynamic balance was observed with core exercises in adolescent taekwondo athletes. The differences in the participants' chronological age and growth-development period may have affected this result. However, similarly, the positive results of strength training on lower extremity dynamic balance performance are clearly seen. In another study, the dynamic balance composite score of adolescent taekwondo athletes was 81.5±9.3 (95%CI: 77.7-85.3) on the dominant side and 83.2±11.3 (95%CI: 78.6-87.8) on the non-dominant side (Açıkgöz & Cengizel, 2023). These findings are consistent with our research. Although it is known that core muscles maintain balance when we move (Tayshete et al., 2020), enhancing lower extremity dynamic balance through core exercises should also be considered by coaches. Regarding balance performance, both core training programs improved lower-quarter dynamic balance, which is consistent with previous findings (Ozmen & Aydogmus, 2016). This suggests that strengthening of trunk stabilizers can positively influence the control of centre of mass and the efficiency of anticipatory postural adjustments.

YBT-UQ dynamic balance composite scores were significantly decreased on both sides in the CON (dominant: p<.001, ES=.716; non-dominant: p<.001, ES=.835), and significantly decreased on the non-dominant side in the DC (p=.016, ES=.690). Therefore, this result revealed a decrease in upper extremity dynamic balance performance with only taekwondo training and that the DC exercises in our study did not contribute positively to the non-dominant side upper extremity dynamic balance. On the other hand, the lack of a significant decrease in upper extremity dynamic balance with SC exercises and the significant decrease in athletes who only practiced taekwondo training indicated that core exercises could be an important intervention to prevent loss of upper extremity dynamic balance. Because upper extremity dynamic balance showed a significant decrease of 9% on the dominant side and 8.9% on the non-dominant side in the CON, while it showed a significant decrease of 5.3% only on the non-dominant side in the DC. These data were insignificant in the SC group, with a loss of upper extremity balance performance of 3.9% for the dominant side and 3.4% for the non-dominant side. Therefore, the magnitude of possible upper extremity balance performance loss was reduced by core exercises. It is noteworthy that upper-quarter dynamic balance decreased slightly in the dynamic core and control groups. This could be related to the training emphasis on lower-limb stability and kicking mechanics, leading to an imbalance in trunk–shoulder stabilization demands. Future studies might integrate combined upper- and lower-body core protocols to achieve more balanced neuromuscular adaptations.

In summary, the present findings demonstrate that both static and dynamic core training are effective for improving kicking performance and balance in adolescent taekwondo athletes. However, the superiority of dynamic core training suggests that incorporating sport-specific movement patterns, resistance bands, and unilateral tasks may enhance transferability to performance outcomes. These results emphasize the need for tailored core programs that reflect the biomechanical and neuromuscular requirements of the sport.

5. Limitations

This study has some limitations. The first of these is the sample size of the participant groups. It was tough to include thirty-three adolescent taekwondo athletes in the study for eight weeks and to sustain this, the number of participants was initially forty-eight. However, a total of thirty-three athletes were included in the study for the exclusion criteria and homogeneous distribution of the groups. In addition, athletes in the same club and who practiced the same taekwondo training for eight weeks were included in the study to determine the effect of isolated core exercises. This is one of the strengths of the study and eliminated the post-test findings that could occur with different taekwondo training. However, at the same time, the fact that we use this sampling method and do not perform a priori sample size calculation is one of the limitations of the research. The second limitation is that the experimental groups performed additional training (core exercises) in addition to taekwondo trainings, while the control group only performed taekwondo training in this study. Therefore, the intervention groups had higher total training volume, which may have influenced the results independently of the core exercise type. Another limitation is the lack of previous research. The effect of core exercises has mainly been studied in adult or young taekwondo athletes, which is a limitation when comparing our current research findings.

6. Conclusion

SC and DC exercises performed in addition to eight weeks of taekwondo training positively increased kicking speed, and YBT-LQ in adolescent taekwondo athletes. Additionally, DC decreased YBT-UQ on the non-dominant side, but significantly improved static balance performance on both sides, and increased KI on the non-dominant side. These research findings provide practical insights and recommendations to coaches, athletes, and practitioners. Therefore, SC and DC exercises can be recommended for adolescent taekwondo athletes to increase balance and kicking speed, and additionally DC should be preferred to improve static balance performance and to increase KI. As a result, core training may be emphasized to support performance development in adolescent taekwondo athletes. Future studies may provide more comprehensive results by examining the long-term effects of core exercises and/or strength training and their effects on athletes' performance in different age groups.

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Authors' biographical data

Aylin Öztürk (Turkey) is a lecturer in the Department of Physical Education at Istanbul Technical University, where she also coordinates the Martial Arts and Combat Sports Research Group. She is currently pursuing a Ph.D. in Training and Movement Sciences at Gazi University. Additionally, she serves as the head coach of the Kickboxing, Taekwondo, and Muay Thai teams at Istanbul Technical University. Throughout her athletic career, she has achieved significant success, including a silver medal at the Kickboxing World Championship and five championship titles in Turkey Championships. She won a silver medal at the World Championship held in Budapest, Hungary. She holds a 4th Dan in both Taekwondo and Kickboxing and is also a certified national Taekwondo referee. E-mail: aylin.ozturk@gazi.edu.tr

Elif Cengizel (Turkey) is an associate professor in Department of Coaching Education, Faculty of Sport Sciences, Gazi University, Turkey, since 2005. Her research topics mainly include training sciences, sports biomechanics, the effect os strength training on athletic performance in various sports disciplines, laboratory and field test and athletic performance in martial arts. E-mail: elifoz@gazi.edu.tr

Mehmet Günay (Turkey) is a full professor in the Department of Physical Education and Sports, Faculty of Sport Sciences, Gazi University, Turkey. He has been conducting research on sports sciences since 1993. He was the President of the Turkish University Sports Federation and is currently a member of the FISU Board of Directors. He was actively involved in several national and international projects and is an author of more than 30 scientific articles published in SCI list journals. E-mail: mgunay@gazi.edu.tr