2026
03

ORIGINAL ARTICLE

The effect of core stability training on improving balance moderated by strength in early age karate students

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim Core stability training is commonly used in youth martial arts practice to support postural control. Different training approaches and individual strength levels may influence balance outcomes in young karate athletes. Despite the application of various training methods, their relative effectiveness in improving balance remains a matter of practical interest. The purpose of this study was to investigate the effect of core stability training on balance improvement in young karateka.

Material and Methods This 2×2 factorial experiment included 40 male karateka (aged 6–8 years) selected through purposive sampling and grouped using matched-subject ordinal pairing. The research instruments consisted of the plank test and the star excursion balance test. Data analysis techniques were Two-Way ANOVA, Tukey's post hoc test ($p < 0.05$), and effect size calculation (partial eta squared) using SPSS version 23.

Results There was a significant effect of the training method (core stability vs. control) ($p = 0.000$; $\eta p^2 = 0.707$). There was a significant effect of core muscle strength (high vs. low) ($p = 0.000$; $\eta p^2 = 0.730$). There was a significant interaction between the training method (core stability vs. control) and core muscle strength (high vs. low) ($p = 0.009$; $\eta p^2 = 0.174$).

Conclusions The effectiveness of training in improving balance is not determined only by a single training method but is also strongly moderated by core muscle strength. Although both the core stability training method and core muscle strength factors have a moderate-to-high effect, the presence of a substantial interaction indicates that each karateka's response is different. Identifying core muscle strength in young karateka is critical for achieving optimal balance.

Keywords: core stability, core muscle strength, balance, moderating effect, early age karateka.

Introduction

Maintaining postural stability is a fundamental requirement for effective execution of technical actions in youth karate practice. During early training stages, balance development determines the ability to control body position during kicks, turns, and transitions between stances. This ability depends not only on coordination but also on neuromuscular control and trunk stabilization capacity. Variability in individual physical characteristics, particularly strength-related factors, can substantially influence how young athletes maintain stability during movement.

Karate demands both proper technique and physical fitness. Every punch and kick requires physical components such as speed, strength, and balance [1]. Karate students aged 6–8 years enter a crucial period of neuromuscular adaptation. Training programs are intended to integrate physical training to reduce injury risk and ensure a more stable transition to senior levels [2, 3]. One important physical aspect is balance. When karateka execute a punch followed by a kick with a rapid shift from stance to stance, balance stabilizes the supporting leg muscles. Instability in dynamic situations frequently leads to a loss of body control, reducing movement effectiveness and increasing the risk of injury.

The core stability training model is a cornerstone for developing karateka balance. In addition to technical training, karateka should integrate core stability training for safety during training and competition [4]. This training focuses on

doi:10.15561/26649837.2026.0304

strengthening the muscles surrounding the trunk, particularly the transversus abdominis, to improve stability [5, 6]. Core stability exercise builds a foundation for producing more efficient power in the upper and lower extremities while preserving abdominal muscle stability [7, 8]. Several studies have found a positive effect of core stability training on athlete performance in sports such as soccer, futsal, and volleyball [9, 10, 11].

Despite the extensive documentation of core stability training effectiveness, its use in karate remains debatable. Compared with karate technique training alone, core stability training enhances kicking performance and core muscle strength, according to Kamal et al. [12] and Del et al. [13]. Rahimi reported that integrating core training did not outperform karate technique training alone [14]. This inconsistency raises questions regarding factors that affect training effectiveness.

The key factor may be the synergy of stability and strength. In the context of kata movements, athletes perform complex transitions from dynamic to static actions, such as jumps and spins, which require appropriate muscle strength to maintain balance. Rahma reported that core muscle strength influences balance in martial arts [15]. Zhang et al. demonstrated that core stability training improves kicking, punching, and core muscle strength performance in taekwondo, boxing, muay thai, and karate [16]. Ebrahimi et al. showed that core stability training enhances dynamic balance, medial-posterior direction performance, and kicking performance in taekwondo [17]. Weakness in the core muscles can inhibit quadriceps and hamstring contraction [4], directly reducing technique effectiveness [18].

Several studies described above provide evidence that core muscle strength contributes to good balance. Although core muscle strength is not the only factor influencing success, Baban showed that low core muscle strength is associated with a higher risk of injury in kata and kumite athletes [19]. Empirical evidence directly linking balance level with core muscle strength in karateka remains limited. In previous research, core muscle strength was treated as a dependent variable rather than as a moderating variable that could influence balance outcomes. It remains unclear whether karateka with low core muscle strength demonstrate poorer balance. Additionally, core stability training studies still do not consider moderating variables such as training duration and level [20].

Analysis of research findings has shown that core stability training contributes to balance performance and technical effectiveness in combat sports. Researchers emphasize that the interaction between stabilization capacity and muscular strength plays an important role during complex dynamic movements typical of karate practice. At the same time, the mechanisms through which individual strength characteristics influence training outcomes remain insufficiently clarified in practical training conditions. This aspect complicates the interpretation of training effects and limits the precision of training program design for young karate athletes.

In addition, it should be noted that although these studies are relevant, they do not identify core muscle strength as a moderating influence. No research has examined core muscle strength as a moderating component influencing balance in karate, particularly at an early age.

Based on this research gap, the purpose of this study was to investigate the effect of core stability training on balance improvement in young karateka, using core muscle strength as a moderating variable. The proposed hypotheses are as follows.

1. There is a difference in the effect of the core stability training group and the conventional group on improving young karateka's balance.
2. There is a difference in the effect of high and low core muscle strength on young karateka's balance abilities.
3. There is an interaction between the core stability training group and the conventional group, as well as core muscle strength (high and low), in improving young karateka's balance.

Materials and Methods

Participants

his study used a 2×2 factorial design [21]. The 2×2 factorial approach included two independent training variables, one dependent variable, and one moderating variable [22]. The sampling technique was purposive, with the following criteria: (1) white and yellow belt levels, (2) membership in the same training club, (3) training age of one year or less to ensure the training program effect, (4) willingness to carry out the training program for six weeks, three times per week with at least 80% attendance, (5) male gender, and (6) age 6–8 years. Exclusion criteria included a history of musculoskeletal injury within the previous six months, involvement in additional strength training programs outside this trial, and withdrawal during the six-week intervention. To reduce selection bias, data were collected by a research assistant who was not involved in test administration.

Out of 47 participants, 7 did not meet the inclusion criteria because they were older than 6–8 years and had trained for more than 2 years. As a result, the study included 40 male participants with an average age of 7.2 ± 0.8 years, body mass of 27.5 ± 3.2 kg, and height of 122.4 ± 5.1 cm. To evaluate static strength, all participants underwent a plank test [23]. The scores were ranked from highest to lowest. The matched-subject ordinal pairing (MSOP) pattern was then applied from the highest to the lowest results in the A–B–B–A order, as illustrated in Table 1 [24]. Twenty participants were assigned to conventional training and twenty to core stability training. Each group was divided into high- and low-strength subgroups: A1B1, A1B2, A2B1, and A2B2. Table 2 shows the 2×2 factorial design.

Table 1. Illustration of MSOP distribution based on the A–B–B–A pattern

Score Ranking	MSOP Pattern	Group	
1	A	Experiment	-
2	B	-	Control
3	B	-	Control
4	A	Experiment	-
5	A	Experiment	-
6	B	-	Control
7	B	-	Control
8	A	Experiment	-
9	A	Experiment	-
10	B	-	Control
11	B	-	Control
12	A	Experiment	-
13	A	Experiment	-
14	B	-	Control
15	B	-	Control
16	A	Experiment	-
17	A	Experiment	-
18	B	-	Control
19	B	-	Control
20	A	Experiment	

Note. MSOP — Matched-Subject Ordinal Pairing.

Table 2. 2x2 factorial design

Training Method (A) / Strength (B)	Conventional training (A1)	Core stability training (A2)
High strength (B1)	A1B1	A2B1
Low strength (B2)	A1B2	A2B2

Note. A1B1: Conventional training with high muscle strength; A1B2: Conventional training with low muscle strength; A2B1: Core stability training with high muscle strength; A2B2: Core stability training with low muscle strength.

Research Design

The first stage was the administration of the Star Excursion Balance Test (SEBT) to the entire group as a balance pretest. A core stability training program was then conducted for six weeks, with three training sessions per week. After the intervention was completed, a posttest was administered to determine the effectiveness of the treatment.

The training program protocols were as follows: warm-up and stretching using raise, activation, mobilization, and potentiation (RAMP) [25, 26]. The raise phase consisted of coordinated movements lifting the front, side, and back thighs, as well as arm stretches, repeated 2–3 times per movement for a total of 2 minutes. Activation and mobilization exercises included squats, lateral squats, splits, and back stretches. This phase lasted approximately 5–6 repetitions per movement for a total of 3 minutes. During the potentiation phase, participants observed and performed instructor-guided core stability movements, each held for 5 seconds for a total of 15 seconds. The next step was core stability exercises. After completing core stability training, passive stretching was performed.

The conventional (control) group performed standard karate training, which included technical exercises (kihon) but no additional core stability exercises, followed by warm-up and stretching using RAMP. The difference occurred in the potentiation phase, which consisted of technical karate movements performed 5 repetitions each for a total of 15 repetitions. The training session duration was 60–90 minutes, with a frequency of three times per week, repetitions or work time of 10–15 repetitions or 15–20 seconds, intervals of 15–20 seconds, recovery of 60–90 seconds, and progressive increases in intensity or volume every 1–2 weeks by adding repetitions or work time. The program was designed by the research team based on recommendations from karate and physical conditioning trainers. Compliance was measured by manual attendance at each training session, and the average participant attendance rate was 92%, exceeding the minimum requirement of 80%. All participants included in the final analysis met the minimum attendance criteria. The training program is described in Tables 3 and 4.

Statistical Analysis

The data were processed using SPSS version 23. The Shapiro-Wilk normality test and Levene homogeneity test were used as prerequisite tests. A two-way analysis of variance (ANOVA) and a Tukey post hoc test were used to assess the hypotheses at a significance level of 0.05 [26, 27, 28]. Effect sizes were determined using partial eta squared with standard thresholds of small (0.2), moderate (0.5), and large (0.8) [29].

Results

Table 5 shows that each group increased significantly from pretest to posttest. For example, the posttest score (98) of the A1B1 group was higher than the pretest score (92). The posttest score (92) of the A1B2 group was higher than the pretest score (86). The posttest score of the A2B1 group (105) was higher than its pretest score (94). The posttest

Table 3. Technique-focused exercise program of the control group

Week	Material	Dosage
1-2	Horse stance and punch practice a. Kiba dachi (middle stance) + zuki (punch). b. Zenkutsu dachi (side stance) + zuki (punch). c. Kokutsu dachi (back-heavy stance) + zuki (punch).	a. 10-15 reps or 15-20 seconds of work time, etc. Sets 4-5-6, etc. b. 10-15 reps or 15-20 seconds of work time, etc. Sets 4-5-6, etc. c. 10-15 reps or 15-20 seconds of work time, etc. Sets 4-5-6, etc. • Interval 15-20 seconds • Recovery 60 seconds • Exercise duration 60-90 minutes
3-4	Stepping and punching exercises a. Zenkutsu dachi forward step and oi zuki (front punch). b. Zenkutsu dachi forward step and gyakuzuki (reverse punch). c. Zenkutsu dachi forward step and oi zuki + gyakuzuki.	a. Forward 5 times and backward 5 times. Sets 4-5-6, etc. b. Forward 5 times, backward 5 times. Sets 4-5-6, etc. c. Forward 5 times, backward 5 times. Sets 4-5-6, etc. • Interval 15-20 seconds • Recovery 60 seconds • Exercise duration 60-90 minutes
5-6	Practice stepping in a combination of stances and punches a. Heiko dachi (shoulder-width stance) and chudan zuki (punch to the stomach), step forward in zenkutsu dachi stance at the same time as oi zuki. b. Heiko dachi (shoulder-width stance) and 2x chudan zuki punches, step forward in zenkutsu dachi stance with oi zuki and gyakuzuki. Zenkutsu dachi steps forward and strikes 3x (oi zuki, gyakuzuki, oi zuki).	a. 5 chudan punches – 5 oi zuki. Sets 4-5-6, etc. b. 5 chudan punches – 5 oi zuki – 5 gyakuzuki. Sets 4-5-6, etc. c. 2 steps for a total of 6 forward punches, 2 steps back for a total of 6 punches. Sets 4-5-6, etc. • Interval 15-20 seconds • Recovery 60 seconds • Exercise duration 60-90 minutes

Table 4. Karate core stability training program

Week	Material	Dosage
1-2	Basic stability phase a. Low plank (knees on the floor) b. Bird dog (hands and feet facing opposite directions) c. Knee to elbow (modified crunch) Application: trunk stability, dynamic balance control	a. Hold for 15-20 seconds, etc. Sets 4-5-6, etc. b. Hold for 15-20 seconds, etc. Sets 4-5-6, etc. c. 8-10 reps, etc. Sets 4-5-6, etc. • Interval 15-20 seconds • Recovery 60 seconds • Exercise duration 60-90 minutes
3-4	Strengthening phase a. Full plank (straight legs) b. Side plank c. Boat pose Application: stabilizes movement, increases hip rotation strength	a. Hold for 15-20 seconds, etc. Sets 4-5-6, etc. b. Hold for 15-20 seconds, etc. Sets 4-5-6, etc. c. Hold for 15-20 seconds, etc. Sets 4-5-6, etc. • Interval 15-20 seconds • Recovery 60 seconds • Exercise duration 60-90 minutes
5-6	Functional stability and balance phase a. Plank with shoulder taps b. Leg raise to V-sit up c. Low plank (using stability ball) Application: maintaining posture and muscle control	a. Hold for 15-20 seconds, etc. Sets 4-5-6, etc. b. 8-10 reps, etc. Sets 4-5-6, etc. c. Hold for 15-20 seconds, etc. Sets 4-5-6, etc. • Interval 15-20 seconds • Recovery 60 seconds • Exercise duration 60-90 minutes

Table 5. Results of descriptive analysis of pretest-posttest

Method	Strength cluster	Pretest	Posttest
Conventional training	A1B1 (high)	92 ± 2.981	98 ± 3.479
	A1B2 (low)	86.8 ± 5.147	97.20 ± 5.147
Core stability training	A2B1 (high)	94 ± 3.521	105 ± 4.001
	A2B2 (low)	75.2 ± 3.028	88.20 ± 3.479

score (88.20) of the A2B2 group was higher than the pretest score (75.2).

A normality test was conducted using the Shapiro–Wilk test. All pretest groups (A1B1, A1B2, A2B1, and A2B2) and posttest groups (A1B1, A1B2, A2B1, and A2B2) had a significance value of 0.200 (> 0.05), indicating that the data were normally distributed. Therefore, the analysis proceeded to the homogeneity test.

The homogeneity test using Levene's test produced F = 1.037 with df1 = 3 and df2 = 36 and a significance value of 0.388 (> 0.05), indicating that the data had homogeneous variance.

The analysis showed a significant difference between the two training methods (Sig = 0.000 < 0.05). The Type III Sum of Squares was 1452.0251 with df = 1, Mean Square = 1452.025, and F = 87.078. The core stability group obtained a mean score of 91.5, which was higher than the conventional group (87.5). The partial eta square effect size was 0.707, indicating a moderate effect of the training method on balance scores.

There was a significant difference between the high and low core muscle strength groups (Sig = 0.000 < 0.05). The Type III Sum of Squares was 1625.625 with df = 1, Mean Square = 1625.625, and F = 97.489. The high core muscle strength group had a mean score of 95.3, whereas the low core muscle strength group had a mean score of 83.25. The partial eta square effect size was 0.730, indicating a moderate effect of core muscle strength on balance.

A significant interaction between training method and strength cluster on balance was observed (Sig = 0.009 < 0.05). The Type III Sum of Squares was 126.025 with df = 1, Mean Square = 126.025, and F = 7.558. The partial eta square effect size was 0.174, indicating a small but statistically significant interaction.

Table 6 shows that the mean difference value marked with (*) and a significance value of 0.000 < 0.05 is interpreted as a significant interaction. Examples include groups A1B1–A1B2 (conventional method with high strength moderation – conventional method with low muscle strength moderation), A1B1–A2B1 (conventional method with high strength moderation – core stability training with high strength moderation), A1B1–A2B2 (conventional method with high strength moderation – core stability training with low strength moderation), A1B2–A1B1 (conventional training with low strength moderation – conventional method with high strength moderation), A1B2–A2B2 (conventional training with low muscle strength moderation – core stability training with low muscle strength moderation), A2B1–A1B1 (core stability training with high muscle strength moderation – conventional training with high muscle strength moderation), A2B1–A2B2 (core stability training with high muscle strength moderation – core stability training with low muscle strength moderation), A2B2–A1B1 (core stability training with low muscle strength moderation – conventional training with high muscle strength moderation), A2B2–A1B2 (core stability training with moderate low muscle strength – conventional training with moderate low muscle strength), and A2B2–A2B1 (core stability training with moderate low muscle strength – core stability training with moderate high muscle strength).

Table 6. Tukey's post hoc test results

Interaction Group		Mean Difference	Std. Error	Sig.
A1B1	A1B2	9.2000*	1.82620	.000
	A2B1	8.5000*	1.82620	.000
	A2B2	24.8000*	1.82620	.000
A1B2	A1B1	-9.2000*	1.82620	.000
	A2B1	-.7000	1.82620	.981
	A2B2	15.6000*	1.82620	.000
A2B1	A1B1	-8.5000*	1.82620	.000
	A1B2	.7000	1.82620	.981
	A2B2	16.3000*	1.82620	.000
A2B2	A1B1	-24.8000*	1.82620	.000
	A1B2	-15.6000*	1.82620	.000
	A2B1	-16.3000*	1.82620	.000

Note. * indicates a significant difference at p < 0.05.

Discussion

The purpose of this study was to determine the effectiveness of core stability in improving balance in young karateka, with core muscular strength serving as a moderating variable. The findings of the research revealed that all intervention groups had a substantial increase in balance relative to pretest levels. The two-way ANOVA test revealed that the core stability method resulted in higher balance scores ($\bar{X}$ = 91.5) compared to the control group ($\bar{X}$= 87.5), with a significant effect size (p = 0.000; ηp^2 = 0.707). This suggests that core stability training produces a significantly more effective stimulus, with a moderate effect size that tends to be high. Furthermore, core muscle strength capacity plays an important role in determining optimal karateka balance. The high core strength classification had better balancing performance ($\bar{X}$ = 95.3) than the low muscular strength group ($\bar{X}$ = 83.5), with a significant effect size (p = 0.000; ηp^2 = 0.730). This suggests that strong core muscle strength is significantly better and has a moderate effect size that tends to be high.

The study's main finding was a significant interaction between training method and core muscle strength on balance (p = 0.009; ηp^2 = 0.174). This moderating effect implies that karatekas' responses to training programs are not uniform and are heavily influenced by individual core muscular strength. Post hoc results revealed significant differences between interaction groups, including the high muscle strength control group and the low muscle strength core stability group. Higher core muscle strength allows karateka to maintain steady motions, particularly those involving transitional movements such as attacking and defending while performing techniques. Body control is essential for young karateka to establish a solid foundation.

Training kihon (basic movements), kata (a series of movements), and kumite (combat) requires good core stability and strength. Karate biomotor components include flexibility, strength, speed, and endurance [30, 31, 32]. Balance is a crucial element incorporated into these physical components. Martial arts demand movement from a standing position and circular attacks, which necessitate maintenance of body balance [33].

The core muscles are a group of muscles surrounding the pelvis, abdomen, and spine, including the obliques, abdominis, and paraspinals [34]. These muscles maintain pelvic and spinal stability (lumbopelvic stability) [35]. This stability is important since the core muscles control the majority of upper and lower extremity motions [36]. According to research, core stability training is effective for enhancing physical fitness in martial arts [4]. Dynamic karate movements allow punching and kicking techniques to be completed with maximal power concentration (kime), while retaining balance during unstable position transitions [37, 38].

For example, in kumite matches, balance is critical when punching and kicking, walking toward an opponent, and returning to the starting position. In kata matches, each movement is associated with a jump, resulting in a balanced horse stance. The use of this training becomes a pedagogical principle: a trainer must grasp a karate practitioner's skill level. Training must be founded on individualistic, specialized, and pedagogical principles [26, 31]. This is consistent with earlier research, which shows that adopting a training program necessitates basic training concepts including progressive loading, regularity, and individuality [39]. Early childhood karate training programs facilitate the pedagogical premise of exploring talent development, highlighting the importance of improving personal and social skills [40].

Similarly, the concept of long-term development throughout the 6–8-year period enters the active start and fundamental stages, and training focuses not only on technique but also on physical capacities as a foundation for optimizing technical training [41, 42]. Another study found that long-term athlete development during the pre-pubertal phase (ages 6–8) demonstrates high nervous system plasticity, and training should focus on building motor control and coordination through neuromuscular mechanisms rather than only mechanical loading [43]. Neuromuscular training should start as soon as possible to enhance movement biomechanics and reduce the risk of injury [44].

Karate athletes with low core strength should focus on stabilizing exercises such as low planks and bird dogs before attempting complex kicking techniques to ensure a safe training foundation. Karate athletes with high core strength and advanced belt levels should focus on dynamic stability training. Identifying good core muscle strength is required for karate athletes to quickly shift into horse stances while simultaneously performing punch and kick combinations, as well as turning or jumping.

These findings not only offer theoretical guidance on the relationship between core strength and balance, but they also create a scientific consensus that has not previously received special attention. Furthermore, this serves as a pedagogical reorientation for the development of karate athletes aged 6–8 years, a sensitive period for neuromuscular adaptation that is often less thoroughly explored among younger karate athletes compared to the broader demographic of adolescent and senior karate athletes.

Limitations of the Study

Research limitations include the fact that participants were only young karateka with white and yellow belt levels, so these findings may not be generalizable to karateka of older age and higher belt levels, experience, and training levels. Additionally, the sample was limited to men, so the results may not be fully applicable to female karateka. The intervention period was rather brief, which may not fully reflect long-term neuromuscular changes and may only reflect acute performance, implying that permanent adaptations require longer intervention efforts. Plank tests for core muscle strength focus on isometric or static muscle contractions, which have limitations given the dynamic nature of karate.

Future Research Directions

To ensure generalizability across both genders, future studies should increase the sample size to include karateka of higher ages and belt levels, as well as female karateka. The duration of the intervention should be increased to account for more persistent neuromuscular changes rather than merely acute performance benefits. The use of test instruments for the moderating variable of core muscular strength with the plank should be replaced with dynamic tests in the future, as the dependent variable is balance, which is dynamic in character, especially given that karate movements involve motion. Other moderating variables, such as agility, speed, and coordination, should also be investigated, as these are significant aspects of karate.

Conclusions

Based on the findings and discussion, it was determined that the group that received core stability training demonstrated superior balance compared to the conventional group. The moderating variable of high muscle strength had a greater effect than low muscle strength. In addition, there was a substantial interaction between the training method (core stability and conventional) and the level of core strength (high and low) on balance. This provides theoretical support for the claim that core strength is the primary mechanism for developing dynamic balance in young karateka. Implications: Provide concrete recommendations for trainers regarding core stability as a training element for developing dynamic balance in karateka. This program is useful for mitigating the risk of injury in dynamic and difficult karate techniques, as well as for preparing for strength training in the sensitive phase of neuromuscular adaptation.

Acknowledgement

The authors would like to thank the team and karateka who assisted with the research process so that this study could be completed successfully.

Conflict of Interest

All authors declare no conflict of interest.

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Cite this article as:

Yudhistira D, Nurkholis, Wijaya A, Waskita GI, Purba PH, Fauzi MS, Naheria, Baun A, Rohadi M, Saiin M, Ismawan H. The effect of core stability training on improving balance moderated by strength in early age karate students. *Pedagogy of Physical Culture and Sports,* 2026;30(3):217–225.
https://doi.org/10.15561/26649837.2026.0304

Received: 2026-01-12
Accepted: 2026-02-21
Published: 2026-02-23