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RESEARCH ARTICLE

The Effect of Core Training Practices on Some Strength, Lower Limb Functions and Balance Performance in Judo Athletes

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Abstract
This study investigates the effects of core training on some strength, lower extremity functions, and balance performances in judoka. The study was based on a two-group pretest-posttest experimental design with repeated measures. The study included 12 female (F) judo athletes aged 12-18 years and 10 male (M) judo athletes aged 12-17 years. Three measurements for core strength (push-ups, planks, sit-ups), six different single leg hop tests (SLHT) for lower extremity muscle strength and YBT for balance were performed before and after 6-week core training. Shapiro-Wilk, Levene, and Paired sample t-tests were used in statistical analyses. The increases in limb symmetry index (LSI) scores were remarkable. When the push-up and plank times and sit-up scores of F and M participants were compared with the pre-test, a significant increase was observed in favor of the post-test. When we examined the dominant (D) leg hop for distance, we found that M and F judoka's SL_D, TH_D, $MSTH_D$, MRH_D, and CH_D post-test scores all increased (except F; CH_D) and also M and F showed better performance in $SL6M_D$. Similar performance outputs were seen in the non-dominant (ND) leg hop for distance measurements (only not changed F; TH_{ND}). Finally, it was valuable to note that both right and left leg YBT scores showed a considerable rise in the post-test assessments. As a result, core exercise practices may improve the sit-up score by improving the time in push-ups and planks in judoka. In addition, it may improve balance performance by affecting lower extremity functions.

Keywords
Core Treaning, Combat Sports, Limb Symmetry Index, Judo, Hop Tests, Y Balance Test

INTRODUCTION

Judo is a complex martial art in which competitors must constantly maintain control of their dynamic stance and have effective balance control in response to unexpected moves made by their opponents (Barbado et al., 2016; Perrin et al., 2002; Yoshitomi et al., 2006). Many different parameters such as speed, anaerobic power, lower and upper extremity strength, and trunk muscle function are effective in a successful judo performance (Franchini et al., 2011; Iwai et al., 2008). Among these parameters, balance and lower extremity muscle strength are especially important in specific movements such as various throwing and pulling techniques (Acar and Yilmaz, 2021). The core is defined as an anatomical cage containing various muscles in the

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anterior (rectus abdominis), lateral (internal and external obliques), posterior (erector spinae, lumbar multifidus, and quadratus lumborum), upper (diaphragm) and lower (iliac psoas) sections (Akuthotaand Nadler, 2004; Shinkle et al., 2012).

Core muscles are mainly responsible for trunk stabilization and balance, as well as being involved in the transmission of forces generated in the lower and upper extremities (Joyce and Kotler, 2017; Kibler et al., 2006). Various training programs are used in the development of core muscles (Martuscello et al., 2013). Core strength training ensures that the body has a balanced distribution of force (Kabadayı et al., 2022). At the same time, the development of core strength contributes to performance, especially in sports such as judo, where balance, lower and upper limb strength, and complex technical skills are intensively involved (Chok, 2020; Van Dieën et al., 2012). Improved lower extremity muscle strength, which is a requirement of judo sport, also increases the balance performance of the athlete (Drid et al., 2015; Franchini et al., 2011).

Although there are many different methods in the evaluation of lower extremity muscle strength and function, which is an important parameter in sporting success, one of the most commonly used methods is single leg hop tests (SLHTs) (Reid et al., 2007). SLHTs have many advantages such as minimal time requirements, ease of implementation, and functionality (Guild et al., 2021). SLHTs allow the assessment of lower limb muscle strength as well as inter-limb asymmetries (Noyes et al., 1991). While traditional SLHTs include only straight and forward movements, there are also tests with multidirectional movements, such as the 90° medial rotation hop for distance (MRH) and medial side triple hop for distance (MSTH), where researchers reported increased rates of asymmetry compared to traditional tests (Dingenen and Gokeler, 2017; Gokeler et al., 2017). In addition, the importance of using at least two SLHTs applied in different directions in the evaluation of lower extremity strength and asymmetries was emphasized by various researchers (Augustsson et al., 2004; Dingenen et al., 2019). In addition to lower extremity muscle strength, balance, which must be maintained throughout the competition, is also very important in a successful judo performance (Heitkamp et al., 2002). There are many different methods for functional assessment of balance performance (Coughlan et al., 2012; Plisky et al., 2009). Y balance test (YBT) is one of the widely used tests for the assessment of lower limb performance and dynamic balance (Shaffer et al., 2013). In addition to being efficient in terms of time and implementation, YBT allows the assessment of asymmetric balance in three directions, anterior (ANT), posteromedial (PM), and posterolateral (PL) (Plisky et al., 2009).

Although there are several studies in the literature in which training programs for core muscles were applied with various subject groups and lower extremity strength and balance performance were evaluated, there are no studies in which both parameters were evaluated together (Cai, 2022; Martins et al., 2019; Meierbachtol et al., 2017). In Judo, where lower extremity strength and balance are at the forefront, it is thought that improved core strength will make significant contributions to performance components. When this information was evaluated, the study aimed to investigate the effect of a 6-week core training program applied to female and male judo athletes on core and lower extremity strength and balance performances of the athletes. The study hypothesized that the core training program would contribute positively to the lower extremity strength and balance performances of female and male judo athletes.

MATERIALS AND METHODS

Experimental Design

This study was based on a two-group pre-test/post-test experimental design with repeated measures. When the judoka came to the laboratory for the first time, their age, weight, height, BMI levels, and information about their age were recorded. Then, information was given about the core exercise practices to be applied for 6 weeks (Table 1). Judoka who voluntarily agreed to participate in the study were introduced to the tests and allowed to practice. The judokas came to the laboratory 4 times in total for both the pre-test and the post-test. When the judoka came to the laboratory for the first time, their time data in push-ups, planks, and sit-ups were recorded, on the second visit, the score of the SLHT with the D leg ($SLHT_D$) on the third visit, the scores of the

SLHT with ND leg ($SLHT_{ND}$) and on the fourth visit, the scores of the YBT test were recorded. The same procedure was followed for the post-test measurements. The conduct of this research was approved by the Van Yüzüncü Yıl University Ethics Committee with session 2023/18, decision 16 and document number 16813.

Subjects

According to G-power, the minimum sample size required to detect a significant difference using this test should be at least 10 in each group (20 in total), given a type I error (alpha) of 0.05, a power (1-beta) of 0.8, an effect size of 1.38 and a two-sided alternative hypothesis (H1). Therefore, twelve F participants aged 12-18 years (age 15.00 years, weight 57.00 kg, height 1.65 m, and BMI 20.93 kg/m^2) voluntarily participated in the study. F participants had been practicing judo for an average of 5.66 years. Ten M participants aged 12-17 years (age 14.40 years, weight 63.70 kg, height 1.70 m, and BMI 21.78 kg/m^2) voluntarily participated in the study. M participants had been practicing judo for an average of 3.30 years. All participants had no health problems or neuromuscular diseases in both D and ND legs. All participants signed a consent form before starting the study.

Procedures

All judoka ended their exercise practice 24 h before the SLHT and YBT test measurements to eliminate delayed muscle soreness (DOMS) exposure. On the first day of the post-test measurements, dynamic (push-ups and sit-ups) and static strength (planks) time scores of all athletes were recorded. On the second day, $SLHT_D$ scores and on the third day, $SLHT_{ND}$ scores were measured and recorded. Functional SLHT tests consisted of SL, TH, CH, MSTH, and MRH. On the final day, YBT test scores were obtained for balance measurements of all athletes. The YBT test consisted of three different directions as ANT, PL, and PM.

Single Leg Hop Tests (SLHT)

The starting lines in the practice area in SLHTs were 5 cm wide, while the horizontal long line at the start was 30 cm. The length of the vertical hop line from the center of this line was 6 m. Each hop test was performed three times and each score was recorded. After each hop, the athlete rested for 2 min. Athletes were allowed to use arm and leg movements while on a single leg, before and during the movement. The success standard in the tests was accepted as 3 seconds.

Single and Triple Hop for Distance (SL and TH)

The athletes were standing on one leg with their toes in the middle and on the border of the starting line. In SL, athletes were asked to take the best step forwards while standing on one leg. In the TH, they were asked to make the best possible, consecutive three-step hop forwards. The athletes were asked to complete the forward movement on one leg at a predetermined line and wait in this position for three seconds. The distance between the heel level and the starting line of the athletes who completed the test was measured and recorded in cm (Munro and Herrington, 2011).

Crossover Triple Hop for Distance Test (CH)

Athletes stood on one leg at the starting line and performed three hops forwards. Step diagonally to the opposite side of the leg used in the first hopand continue laterally to the dropped side (Peebles et al., 2019).

Medial Side Triple Hop for Distance Test (MSTH)

The athletes had one leg in the middle of the baseline and the medial part of the leg at the baseline borderline. They were asked to take the best three hops in the medial direction with one leg on the line and wait for 3 seconds when they reached the third step. The distance between the medial level of the leg and the baseline of the athletes who were considered successful was measured and recorded in cm (Kivlan et al., 2013; Reid et al., 2007).

90° Medial Rotation Hop For Distance Test (MRH)

The athletes had one leg in the middle of the baseline and the medial part of the leg at the border of the baseline. They completed the movement with right-angled medial rotation by taking the best single step forward in the medial direction on one leg and holding this position for 3 seconds. The distance between the heel level and the baseline of the athletes who were considered to be successful in the test was measured and recorded in cm (Kivlan et al., 2013; Reid et al., 2007).

6m Timed Hop Test (SL6M)

Athletes stood on one leg behind the photocell at the starting line and hopped on one leg along the 6-meter tape, trying to finish as fast as they could.

The test ended with the athletes passing the photocell at the end of the 6-meter band. All athletes were tested 3 times and rested for 2 minutes at the end of each test (Yilmaz and Kabadayı, 2022).

Y Balance Test (YBT)

YBT assesses dynamic balance in ANT, PL, and PM directions. The floor was marked in 3 different directions (⅄-shaped) with a 15 cm wide tape. The angle between the ANT, PM, and PL strips was 135 degrees and the angle between the two posterior strips was 90 degrees. The athletes participating in the YBT test were asked to place their stance leg in the zero mark position, reach out with the other leg as far as possible in the reach direction and then bring the extended leg back to the starting point. ANT score points were from the toe of the stance leg to the point reached, while PL and PM score points were from the heel of the stance leg to the point reached. If the athletes could not maintain their balance or could not bring the outstretched leg back to the stance leg after reaching the maximum reach distance, the trials were considered unsuccessful and the measurement was repeated. Each athlete performed three barefoot trials in each direction (ANT, PL, and PM) (Plisky et al., 2006, 2009).

Statistical Analyses

All statistical analyses were carried out using SPSS 21 (Statistical Package for the Social Sciences) package program. Descriptive data in the current study were expressed as mean, standard deviation (SD), minimum (Min), and maximum (Max). Shapiro-Wilk test, histogram graphs, Q-Q plot, kurtosis, and skewness ranges were examinedto test the normal distribution of the data. The independent sample t-test was used to determine pre-test or post-test differences between genders. Paired sample t-test was used for pre-post testcomparisons within genders. Significance was evaluated as $p<0.05$ with 95% confidence intervals.

Table 1. This is shows 6 weeks of core exercise practices

Weeks	Monday	Wednesday	Friday
I	plank, push-up, reverse crunch, bird dog, basic squat	plank, push-up, reverse crunch, superman, basic squat	plank, push-up, back bridge, toe taps, earthquake
II	side plank, sit-ups, bird dog, toe taps, squat leg raise	side plank, sit-ups, back bridge, T stabilization, single-leg squat	side plank, sit-ups, bird dog, squat with cross leg raise
III-IV	plank, push-up, T stabilization, squat with single leg squat	plank, push-up, reverse crunch, superman, squat with cross-leg raise	plank, push-up, reverse crunch, superman, back bridge, squat leg raise
V-VI	side plank, sit-ups, back bridge, squat with cross leg raise	side plank, sit-ups, reverse crunch, superman bird dog, squat leg raise	side plank, sit-ups, toe taps, T stabilization, single leg squat
Warm-up min/hr (10 min)			
aerobic running, active warm-up (Leg and arm rotation, lunges, squat pulses, etc.)			
Main training session min/hr (30- 40 min)			
Cool down min/hr (10 min)			
flexion, rotation, extension, and stretch of regions and muscles such as the lumbar, hamstring, hip adductors, gluteal and rotator muscles, hip abductor, soleus, triceps, pectoral muscles, biceps, supraspinatus			

According to Table 1, each movement consisted of 2 sets of 3 repetitions. The duration of the movement was between 15-20 seconds in the first week. Until the sixth week, the progress of the athletes was observed and the principle of increasing loading was obeyed. The duration of the movement in the last exercise intervention was between 40-50 seconds. The rest between sets was set to be 2 minutes. Rest between repetitions was modeled as 1:4 in the first week, 1:3 in the second week, 1:2 in the third week, and 1:1 from in the fourth to sixth week.

RESULTS

According to Table 2, the F participants had an average age of 15 years, weight of 57, height of 1.65, BMI of 20.93, and training age of 5.66, while the M participants had an average age of 14.4 years, weight of 63.7, height 1.70, BMI 21.78 and training age 3.30.

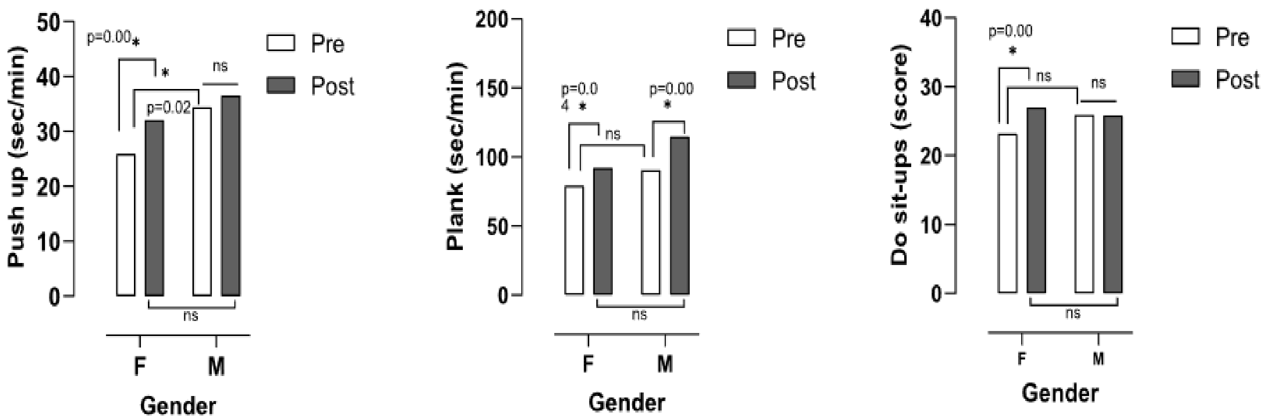
Table 2. This is descriptive data of subjects (at column width)

Gender		Mean	SS	Min.	Max.
Female (12)	Age (year)	15.00	2.33	12.33	18.00
	Weight (kg)	57.00	6.81	50.81	74.00
	Height (m)	1.65	0.04	1.60	1.73
	BMI (kg/m^2)	20.93	1.92	19.05	24.73
	Training Age (year)	5.66	2.88	2.00	13.00
Male (10)	Age (year)	14.40	2.22	12.00	17.00
	Weight (kg)	63.70	7.13	52.00	75.00
	Height (m)	1.70	0.04	1.65	1.76
	BMI (kg/m^2)	21.78	1.99	19.10	24.34
	Training Age (year)	3.30	1.56	1.00	5.00

SD: Standard deviation; Min: Minimum; Max: Maximum; BMI: Body mass index.

According to Figure 1, there was a significant difference in F pre-test/post-test push-up, plank, and sit-up scores. M participants were not significantly different in pre-post push-up and sit-up scores, but there was a significant difference between plank pre-post scores.

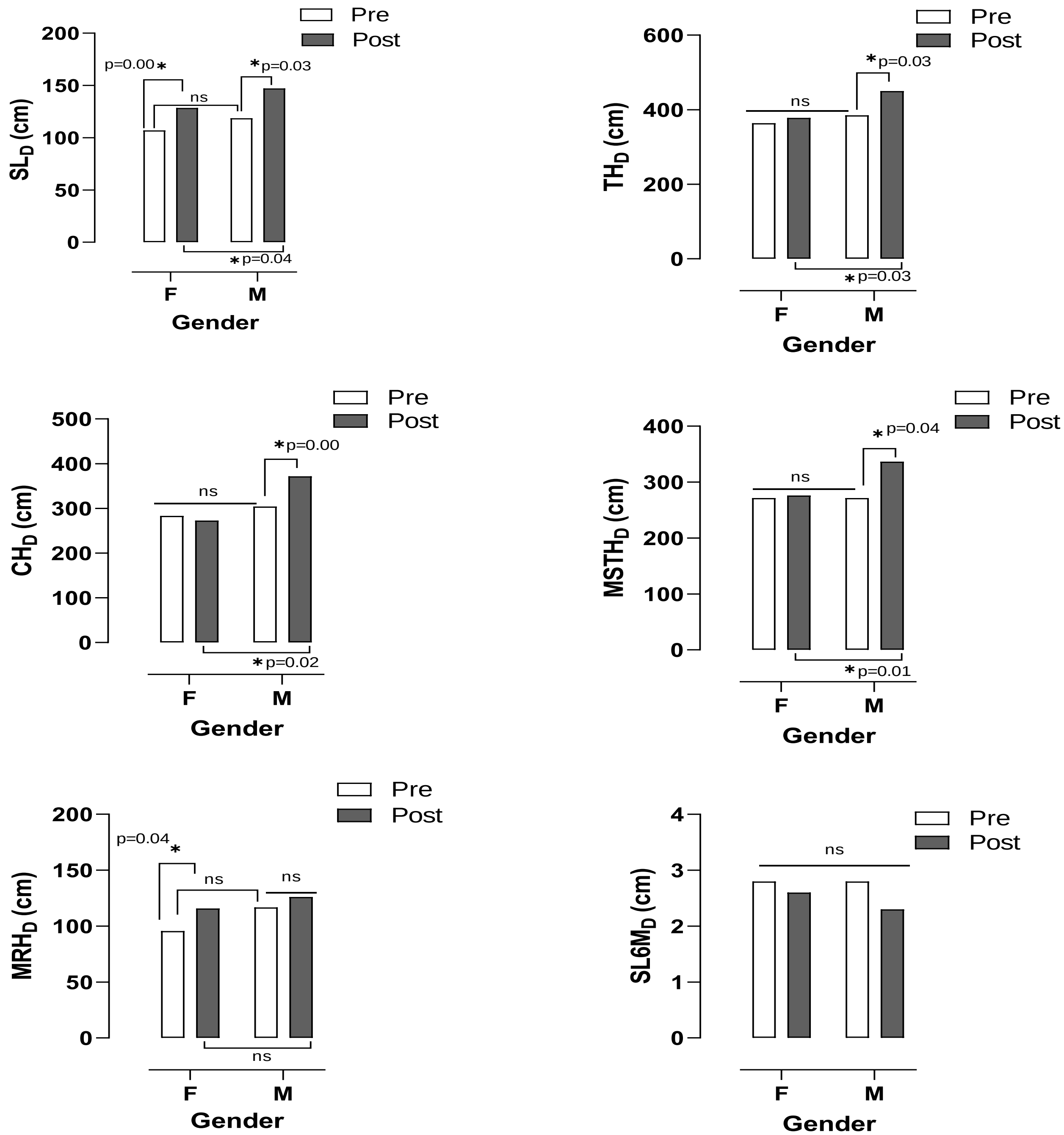
When comparing the pre-test scores between F and M, there was a significant difference in push-up scores, but there was no significant difference between planks and sit-ups. Finally, there was no significant difference between F and M in all post-test scores.



*: p<0.05; ns: non-significant; F: female; M: Male; t: independent sample t test.

Figure 1. This is shows the athletes' push up, plank time, and sit-ups scores

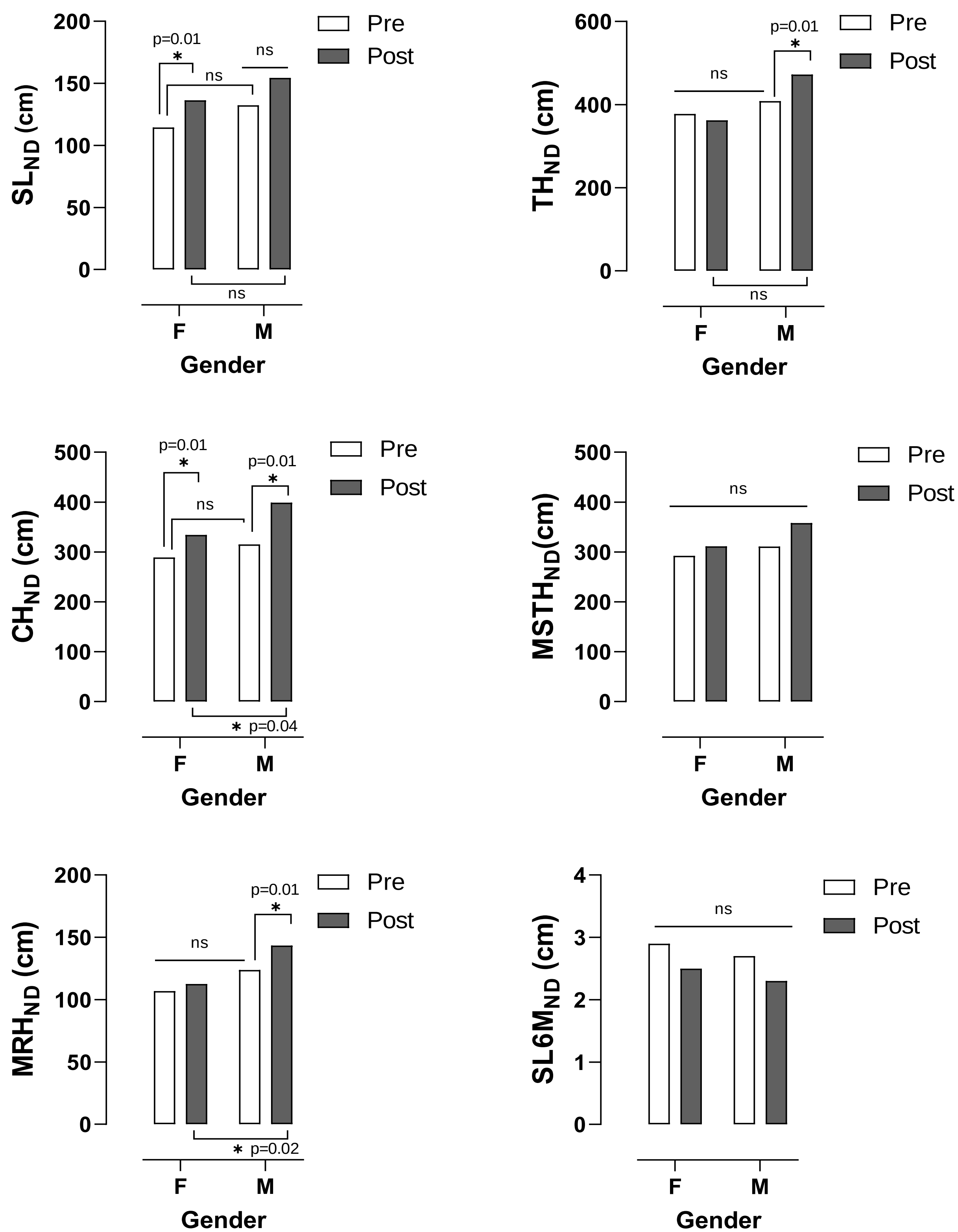
According to Figure 2, there was a significant difference in F pre-post SL_D and MRH_D scores, while there was no significant difference in TH_D, CH_D, $MSTH_D$, and $SL6M_D$ scores. When M pre-post SL_D, TH_D, CH_D, and $MSTH_D$ scores were compared, there was a significant difference, but no significant difference in MRH_D and $SL6M_D$ scores. There was also no significant difference between F and M when the pre-test SL_D, TH_D, CH_D, $MSTH_D$, MRH_D, and $SL6M_D$ scores were compared. Post-test MRH_D and $SL6M_D$ scores between F and M were not significantly different. However, there was a significant difference between F and M when post-test SL_D, TH_D, CH_D, and $MSTH_D$ scores were compared.



*: $p<0.05$; ns: non-significant; F: female; M: male; t: independent sample t-test; SL_D: single leg for distance; TH_D: triple hop of distance; CH_D: crossover triple hop for distance; $MSTH_D$: medial side triple hop for distance; MRH_D: 90° medial rotation hop for distance; $SL6M_D$: single leg 6 meter.

Figure 2. This is shows the differences in D leg hop for the distance between genders

According to Figure 3, there was a significant difference in F pre-post SL_{ND} and CHD_{ND} scores, while there was no significant difference in TH_{ND}, $MSTH_{ND}$, $MRH_{ND,}$ and $SL6M_{ND}$ scores. When M pre-post TH_{ND}, CH_{ND}, and MRH_{ND} scores were compared, there was a significant difference, but no significant difference in SL_{ND}, $MSTH_{ND,}$ and $SL6M_{ND}$ scores. There was also no significant difference between F and M when the pre-test SL_{ND}, TH_{ND}, CH_{ND}, $MSTH_{ND}$, $MRH_{ND,}$ and $SL6M_{ND}$ scores were compared. Post-test SL_{ND}, TH_{ND}, $MSTH_{ND,}$ and $SL6M_{ND}$ scores between F and M were not significantly different. However, there was a significant difference between F and M when post-test CH_{ND} and MRH_{ND} scores were compared.



*: p<0.05; ns: non-significant; F: female; M: male; t: independent sample t-test; SLND: single leg for distance; THND: triple hop of distance; CHND: crossover triple hop for distance; MSTHND: medial side triple hop for distance; MRHND: 90° medial rotation hop for distance; $SL6M_{ND}$: single leg 6 meter.

Figure 3. This is shows the differences in ND leg hop for the distance between genders

According to Table 3, there was no significant difference when the pre-post and pre* post-LSI scores of M and F were compared. However, there was a significant difference only in the $MSTH_{LSI}$ post-test score.

Table 3. This is shows the differences in the limb symmetry index (LSI) between genders

			Pre			Post			Pre*Post	
		Gender	Mean±SD	t	*p*-Value	Mean±SD	t	*p*-Value	t	*p*-Value
LSI Score	SL	Female	92.7±9.5	.631	0.53	95.4±14.4	-.409	0.68	-.505	0.62
		Male	88.9±17.8			98.3±18.8			-.934	0.37
	TH	Female	96.3±7.6	.800	0.43	96.4±7.3	-.201	0.74	.330	0.74
		Male	94.1±4.7			96.1±11.0			-.519	0.61
	CH	Female	94.5±13.6	-.533	0.60	94.8±24.2	-1.150	0.26	1.362	0.20
		Male	97.0±7.0			99.9±6.3			1.420	0.18
	MSTH	Female	93.2±11.7	.279	0.78	93.7±8.3	-3.013	0.00*	.959	0.35
		Male	91.9±8.9			100.1±9.4			-1.927	0.08
	MRH	Female	93.8±7.0	.131	0.87	94.6±6.2	.147	0.88	-.136	0.89
		Male	93.0±11.3			94.2±6.6			-.373	0.71

*: p<0.05; SD: standard deviation; Pre t: between-gender; post t: between-gender; Pre*Post t: within-gender; SL: single leg for distance; TH: triple hop of distance; CH: crossover triple hop for distance; MSTH: medial side triple hop for distance; MRH: 90° medial rotation hop for distance.

According to Table 4, there wasn't a significant difference in the pre-post and pre*post scores of the participants' right leg YBT (ANT, PL, and PM). However, there was a significant difference in PL post-test scores. In addition, a significant difference was found between M and F when the post-test scores of right leg YBT (ANT, PL, and PM) were compared. In addition, a significant difference was found between men and women when the total post-test scores of the right foot YBT (ANT, PL, and PM) were compared. When we analyzed the results of the left leg YBT (ANT, PL, and PM), the pre-test and post-test ANT scores were significantly different between M and F. However, there was not any significant difference in the comparison of the other YBT (ANT, PL, and PM) and the total score.

Table 4. This is shows the reaching distances of the right and left legs (ANT, PL, and PM) in YBT.

			Pre			Post			Pre*Post
YBT			Median (Min-Max)	t	*p*-Value	Median (Min-Max)	t	*p*-Value	*p*-Value
Right Leg	ANT	Female	59.3 (54.33-76.00)	-1.024	0.36	59.5 (48.00-77.33)	-1.601	0.11	0.83
		Male	65.0 (57.00-81.33)			66.3 (47.33-87.67)			0.82
	PM	Female	56.1 (50.33-73.33)	-.996	0.37	59.8 (44.33-88.33)	-1.110	0.12	0.40
		Male	61.8 (55.67-81.33)			68.3 (42.67-89.00)			0.42
	PL	Female	51.8 (47.67-72.67)	-1.449	0.22	55.3 (38.00-72.00)	-1.217	0.04*	0.53
		Male	55.8 (51.00-65.00)			66.1 (42.67-87.33)			0.10
Total Score		Female	56.7 (51.80-59-30)	-2.091	0.10	58.2 (55.32-59.89)	-5.525	0.00*	0.32
		Male	64.8 (55.80-65.00)			66.9 (66.11-68.35)			0.76
Left Leg	ANT	Female	54.5 (44.33-80.33)	-2.849	0.04*	60.3 (49.00-75.33)	-4.221	0.03*	0.30
		Male	68.6 (47.33-79.00)			71.5 (48.00-80.33)			0.53
	PM	Female	58.3 (40.33-83.00)	-.945	0.39	60.1 (44.00-80.67)	-.941	0.22	0.51
		Male	65.1 (46.67-77.67)			68.5 (38.00-93.67)			0.24
	PL	Female	51.6 (40.33-80.00)	-1.657	0.17	51.0 (43.33-82.00)	-.703	0.76	0.40
		Male	60.5 (45.67-79.33)			60.6 (40.33-93.33)			0.99
Total Score		Female	57.4 (51.61-58.30)	-1.094	0.33	56.4 (51.12-60.38)	-1.803	0.14	0.74
		Male	64.7 (60.52-68.65)			66.2 (60.61-71.56)			0.63

*: p<0.05; YBT: Y Balance Test; Min: Minimum; Max: Maximum; ANT: Anterior; PM: Posteromedial; PL: Posterolateral.

DISCUSSION

When the main findings of our study are evaluated, the results are as follows; the post-test scores of Fs in push-ups, plank, and sit-ups increased significantly. In M's, only the time in plank increased. When we compared F and M, while there was a significant difference in the pre-test scores in push-ups, this difference closed in the post-test and the duration of F's stay in push-ups reached a similar level with E's. F's SL_D and MRH_D and M's SL_D, TH_D, CH_D, $MSTH_D$ D leg hop for distance posttest scores increased significantly. When we compare F and M, SL_D, TH_D, CH_D, $MSTH_D$, MRH_D, and $SL6M_D$ D leg hop for distance pre-test scores were similar, while M's SL_D, TH_D, CH, CH_D, $MSTH_D$ post-test scores increased significantly compared to F's. F's SL_{ND} and CH_{ND}, M's TH_{ND}, CH_{ND}, and MRH_{ND} ND leg hop for distance posttest scores increased significantly. When we compared F and M, SL_{ND}, TH_{ND}, CH_{ND}, $MSTH_{ND}$, MRH_{ND} and $SL6M_{ND}$ pre-test scores were similar, while M's CH_{ND} and MRH_{ND} post-test scores increased significantly compared to F's. When LSI scores between F and M were evaluated, there was a significant difference only in MSTH posttest scores and M judoka's MSTH scores increased more than F's. While there was a significant difference between F and M YBT right leg posttest total scores, there was no significant difference between right leg posttest total scores. In addition, M's both right leg PL and left leg ANT scores increased significantly more than F's. In general, there were significant increases in some test scores, while there was no significant increase in some test scores. However, when all test measurements of F and M were evaluated, post-test measurements were scored higher than pre-test measurements. Therefore, core exercises improved strength functions such as push-ups, planks, and sit-ups, as well as LSI scores in the lower extremities and YBT dynamic balance functions.

Core stability increases trunk flexion angle, vastusmedialis and vastuslateralis muscle activation ratio, and quadriceps (H:Q) coactivation ratio, while decreasing knee valgus and hip adduction angles (Jeong et al., 2021) may alter motor control strategies and joint kinematics of the trunk and lower extremities. There may also be a strong relationship between core stability and dynamic balance stability (Barrio et al., 2022). A recent study reported that an eight-week core exercise program improved the biomechanics of the lower limbs and trunk (Sasaki et al., 2019). In an experimental study with 40 athletes with trunk instability, it was reported that the trunk stability of athletes increased after nine weeks of core training (Sharma et al., 2012). In a different study, an increase in the retention time of core exercises horizontal bar pull-ups, sit-ups, and push-ups was observed compared to baseline (Chen et al., 2023). In a study with adolescent male handball players, six weeks of core exercises showed significant improvements in dynamic balance (Ozmen et al., 2020). In 29 female soccer players, eight weeks of core exercises significantly decreased frontal plane projection angle (FPPA) in dynamic landing in both D and ND lower extremities, increased knee flexion and peak hip angle, and significantly increased both bilateral and unilateral jumps in the experimental group compared to the control group (Ferri-Caruana et al., 2020). A meta-analysis of 13 studies found that individuals who participated in core programs improved dynamic balance stability (DBS) and developed a more solid and balanced base for lower extremity movements (Barrio et al., 2022). In a study of 16 male junior high school volleyball team players, the posttest measurements of the athletes demonstrated decreased trunk flexion angle during the box landing task and reduced maximum knee internal rotation angle during the spike jump landing task. In the same study, it was reported that the average isokinetic power of hip flexors and extensor rotators and knee flexors and extensors increased significantly (Tsai et al., 2020).

SLHT usually assesses movement in the forward direction to determine functional performance. This movement involves taking one or more steps in any direction with the same foot and keeping the other foot (pivot foot) in contact with the ground (Dingenen et al., 2019). In this context, in combat sports such as judo, where balance and body stabilization are at the forefront (Akdemir et al., 2022) We have the opinion that core exercise practices will be effective in increasing the functional performance scores of SLHT. Especially, the increases in the post-test scores of SLHT and LSI in the study are noteworthy because they make a significant contribution to the development process of balance and body stabilization. Because Barbado et al (2016) stated that some physical and physiological characteristics should be dominant in judo where competition is of great importance and also pushing, pulling, and different techniques (throws, pins, chokes, arm bars, etc.) are intensively applied. This statement is associated with the ability to perform judo-specific movements correctly and efficiently with different contractions that often differ in kinesiological terms, skeletal muscles being strong enough, and body stabilization during training or competition (Franchini et al., 2005). In another aspect, having core stabilization in judo players during the execution of important movements such as pushes and pulls can reduce or eliminate both the power imbalance and the risk of injury (Ermiş et al., 2019; Thomeé et al., 2011). When we look at recent studies, it was stated that although LSI scores were not significant after 8 weeks of core practices in 24 professional athletes with anterior cruciate ligament reconstruction, the increases in post-test scores were worthwhile. In addition, the positive effect of core practices on reducing inter-limb asymmetries during SL and TH tests was noted and it was determined that functional performance was more symmetrical after core stability exercises (Fallah Mohammadi et al., 2022). A study of women with and without patellofemoral pain (PFP) reported a positive correlation between anterior and lateral trunk muscle endurance and performance on SLHT in patients without PFP (Botta et al., 2021). Following 6 weeks of core training with adolescents on core strength on fixed and non-fixed surfaces, it was reported that ventral and the lateral left chain following dorsal trunk muscle strength increased significantly in the core group (Granacher et al., 2014).

Upper and lower body strength and endurance, speed, anaerobic power, and trunk muscle function are important factors for success in judo competitions (Franchini et al., 2011). In relation to trunk muscle function, improving trunk strength and endurance will enable judo practitioners (judoists) to increase their ability to generate and sustain force throughout a fight. Hence, core stability is the ability to transfer the forces generated by the lower body to the upper body (and vice versa) during judo techniques (Kibler et al., 2006) and balance control, which is a key factor in dealing with opponent-induced disturbances (Van Dieën et al., 2012) can contribute to the judoka's performance as it will improve (Perrin et al., 2002). In this context, we used YBT to reveal the effect of core exercises on the dynamic balance performances of the judo athletes who participated in the study. In studies conducted with athletes in different branches, it was emphasized that YBT is an important guide in predicting lower extremity injuries and time to return to sports, and the functional dynamic abilities of athletes. In the current study, it is noteworthy that there was an increase in all of the right and left foot YBT post-test scores, although it was not significant. In addition, the increase in the right foot PL and total scores of the M's was greater than that of the F's. In the left foot, there was a similar increase in all of the YBT posttest scores, and also the ANT score of the M judoka was significantly higher than that of the Fs. Although it was not significant in the current study, we think that this increase in post-test scores is related to core exercise practices. When we look at the previous studies, it was found that the distance reached in the Star Excursion Balance Test (SEBT) improved significantly from the post-test in the group with 15 healthy participants and a 6-week core stability intervention (Filipa et al., 2010). Another evaluation of a similar improvement in SEBT performance was observed in junior netball athletes (Kahleand Gribble, 2009). In the group with 12-week trunk stabilization exercises, there was a significant group-time interaction in SEBT PL and PM directions and significant improvements in static balance scores (Imai et al., 2014). Again, it was found that core intervention applied to 28 elite basketball players for 8 weeks in addition to their normal training routines improved their ICT dynamic balance development by affecting postural control and lower extremity stability (Benis et al., 2016). In recent studies, 8 weeks of core intervention in elite youth skiers showed significant improvements in both lower extremities according to the combined score of AN, PM, PL, and YBT (Vitale et al., 2018). According to the results of the 8-week core stability program applied to college athletes, not only the functional movement patterns of the participants improved, but also their dynamic postural control increased (Bagherian et al., 2019). It was emphasized that core exercises performed 2 days a week for 8 weeks in adult soccer players can be an important strategy for the balanced development of athletes (Belli et al., 2022). At the end of an 8-week intervention in which the effects of core exercise practices on balance were investigated in 30 deaf students, both dynamic and static balance development increased significantly according to the YBT test scores (Zarei and Norasteh, 2023).

Our study has certain limitations. These are that we did not have any control group except the core strength group. In addition, male and female judoka in the study were evaluated separately and therefore the number of subjects was low. Finally, although all core training of the subjects was performed under the supervision of the researchers, their daily diet and meals were not monitored.

Conclusion

Core exercise practices can maintain structural integrity and keep the balance of the vertebral column within physiologic limits by reducing the displacement caused by perturbations in the lumbopelvic-hip complex in Judo players. This may affect the development of dynamic balance in the lower limbs. In addition, development in the core may also reduce the risk of injury in Judoka by forming the basis of the kinetic chain responsible for facilitating the transfer of torque and momentum between the lower and upper extremities. Therefore, the development of core stability can give Judoka a significant advantage over their opponents in performing pushing, pulling, or different techniques such as throws, pins, chokes, arm bars, pushes and pulls, etc.

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Ethics Committee

The study was approved by the van yüzüncü yıl unıversıty socıal and human scıences publıcatıon ethıcs commıttee presıdency with the decision of 07/07/2023 and number 2023/18

Author Contribution

YY, AKY conceived and designed the study, and conducted the research. Material preparation and data collection were performed by EA, BA, EK, and MPK. YY, AKY and SÖ performed the data analysis and statistical interpretation and wrote part of there sultssection. The first draft of the manuscript was written by YY, AKY and all authors commented on previous versions of the manuscript. All the authors have critically reviewed and approved the final draft and are responsible for the content.

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