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Comparison of bilateral isokinetic and isometric strength differences in elite young male and female taekwondo athletes

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Definition of strength imbalance between legs and muscles does not only play a decisive role for higher performance but also prevents sport injury. The purpose of this study was to determine bilateral differences on isokinetic and isometric strength of knee extensor and flexor muscles in male and female elite young taekwondo athletes. Ten male (age: 19.40±0.84 years) and female (age: 18.24±1.42 years) taekwondo athletes of the Turkish national team between 17–20-year of age participated in the study. Concentric peak torque of hamstring (H) and quadriceps (Q) of the dominant (D) and nondominant leg (ND) was evaluated using isokinetic machine (Cybex Humac Norm) at 60° and 180°/sec. Isometric peak torque of both legs was determined at 60°. Significant differences were found between genders ($P<0.05$). Concentric and isometric knee strength was significantly greater in male than that of female ($P<0.05$). Although no significant bilateral strength difference was found in both sexes in concentric and isometric strength ($P>0.05$), and isometric H strength was in favor of the dominant leg 15% for men athletes and 11% for women. H/Q ratio was similar between gender and legs. The study revealed no bilateral knee strength asymmetry in both male and female taekwondo athletes. However, male had 20%–30% higher isometric and concentric knee extensor and flexor strength than female in both legs.

Keywords: İsokinetic strength, Isometric strength, Dominant leg, Nondominant leg, Elite taekwondo athlete

INTRODUCTION

Bilateral strength asymmetry usually refers to the relative difference between the two legs (Impellizzeri et al., 2007). Imbalance between legs and/or muscles is a potential risk factor in knee injuries (Hewett et al., 2008; Jones and Bampouras 2010). Strength difference between limbs and/or agonist and antagonist muscles were reported in many studies to have a correlation with injuries and muscle strain (Aagaard et al., 1998; Bennell et al., 1998; Cheung et al., 2012; Hewett et al., 2008; Knapik et al., 1991). Decreased hamstrings strength relative to the quadriceps (H/Q) is implicated as a potential mechanism for increased lower extremity injuries (Hewett et al., 2008), and in female collegiate athletes, bilateral hamstrings strength (dominant leg flexor >15% stronger than nondominant) correlates to greater incidence of lower extremity injury (Knapik et al., 1991). However, previous studies investigating the strength difference between legs in individual and mostly team sports showed conflicting results in that some studies found the dominant leg to be stronger (Jones and Bampouras, 2010) while in others, the nondominant leg was stronger (Cheung et al., 2012; Thomas et al., 2017), and still other studies reported no difference between legs (Daneshjoo et al., 2013; Magalhães et al., 2004). Specific unilateral sporting and positional demands, previous injury, dominant kicking and striking limb and limb length differences have been shown among possible causes of bilateral strength asymmetry (Thomas et al., 2017). However, according to our knowledge, a study has never been reported on bilateral strength differences in taekwondo athletes although there is also the limited data on the isokinetic strength characteristics of taekwondo athletes (Alp et al., 2018; Bridge et al., 2014; Cetin et al., 2009; Kim et al., 2010;

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Kim et al., 2011; Seo et al., 2015).

Technical analysis of Olympic taekwondo combat showed that kicks are the primary attacking skills in competition because the target area for kicking is larger (including the head), legs can reach farther than arms, and kicking transfers a greater impact to the opponent than punching (Casolino et al., 2012a; Kim et al., 2010; Tornello et al., 2014). Since more than 90% of scoring is based on kicking skills (Seo et al., 2015), muscle power and endurance in the lower extremities are decisive role in taekwondo (Casolino et al., 2012b). Although taekwondo athletes are supposed to achieve scores by using both legs during matches, they prefer to use their dominant leg in practice for a more effective kick, since as a result of chronic repetition, there is a strength increase in favor of the dominant leg, which makes the athlete more vulnerable to injuries due to the increasing strength difference between dominant and nondominant legs (Croisier et al., 2008). On the other hand, stronger limbs may be more advantageous in generating higher scores as they have a greater impact in kicking techniques (Moreira et al., 2021). As a result, assessment of the isokinetic strength difference between legs in elite youth taekwondo athletes may help to prevent injuries and to develop training programs. In the rehabilitation of both hamstring and quadriceps muscle injuries, isokinetic evaluations contribute positively to the efficiency and manageability of the process. The purpose of this study was to determine the effects of gender and bilateral differences on isokinetic strength of knee extensor and flexor muscles in under 21 (U21) elite athletes. We hypothesized that there is a balance between dominant and nondominant leg in the isokinetic strength of the knee flexors and extensors in young elite male and female taekwondo athletes.

MATERIALS AND METHODS

Participants

Ten male (54, 58, 63, 68, 74, 80, 87+ kg) and female (46, 53, 57, 62, 67, 73+ kg) athletes of the national taekwondo team between 17–20 years of age participated in the study. All isokinetic strength was tested in competition season. Taekwondo athletes were informed of the test procedures, including the possible risks involved, before providing written consent. Written informed consent was obtained from all participants. The study was approved by the non-interventional clinical research ethics committee of the University of Selçuk (US: 37/2022).

Procedures

To determine concentric and isometric peak torques of hamstring (H) and quadriceps muscles (Q) in both legs was used the isokinetic dynamometer (Cybex Humac Norm, CSMI, Stoughton, MA, USA). The Cybex Humac Norm was calibrated as suggested by the manufacturer before study. Before isokinetic testing, each subject warmed up at 50 W on a cycle ergometer (Monark 894E model, Varberg, Sweden) for 5–10 min followed by 5 min of rest. After the warm-up, the taekwondo athletes were secured to the dynamometer with chest, hip, and thigh straps. The taekwondo athletes were tested in the seated position with the hips snugly against the back of the chair of the dynamometer. The axis of rotation of the knees (lateral femoral epicondyle) was aligned with the mechanical axis of the dynamometer, and the shin pad was secured just superior to the lateral malleolus. The athletes were questioned as to their preferred leg for manipulating the ball. The dominant leg (D) was considered to be the preferred leg for kicking and thus the contra-lateral leg or support leg was the nondominant leg (ND). Concentric peak torque measurements were taken for H and Q muscles of D and ND at angular velocities of 60° and 180°/sec. After three trials and following by 2-min rest interval (de Araujo Ribeiro Alvares et al., 2015), subjects were voluntarily performed five maximum contractions at angular velocity of 60 and 180 deg/sec, respectively. After isokinetic test, isometric peak torque of the H and Q muscles was determined at knee angle of 60° with duration of 5 sec. Data were normalized to each athlete's body mass and calculated as torque.

Statistical analysis

All data are presented as mean and standard deviation values. Normal distribution of data was tested using Kolmogorov–Smirnov test, and homogeneity was performed with Levene test. Independent-samples *t*-test was used to compare gender and bilateral differences in isokinetic knee strength in taekwondo athletes. Significant level was set at $P < 0.05$.

RESULTS

The physical characteristics of the elite taekwondo athletes were presented in Table 1. Height was significantly higher in male than that of female athletes ($P < 0.05$). Gender and bilateral differences in isokinetic knee strength are shown in Table 2 for elite taekwondo athletes. When peak torque values were examined at 60°/sec, peak torque of knee extensor and flexor muscles of dominant leg was significantly greater in male than that of female taekwondo ath-

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Table 1. The characteristics of the elite taekwondo athletes

Characteristic	Female (n=10)		Female (n=10)		*t*-value
	Mean±SD	Range	Mean±SD	Range	
Age (yr)	19.40±0.84	18–20	18.24±1.42	17–20	1.342
Body mass (kg)	75.30±14.06	55.50–104	62.75±13.34	46–88	2.047
Height (cm)	187.40±10.90	171–205	172.79±9.15	157–183	3.223*
BMI (kg/m)	21.29±2.39	18.40–26.80	20.77±2.65	18.30–26.30	0.461
Training age (yr)	9.95±2.81	6–15	9.00±2.36	5–13	0.819

BMI, body mass index.
*$P<0.05$.

Table 2. Absolute (Nm) and normalized peak torque (Nm/kg) values of isokinetic concentric strength of the knee flexor (H) and extensor (Q) muscles of dominant and nondominant leg in elite male and female taekwondo athletes

Muscle concentric peak torque	Male (n=10)			Female (n=10)		
	D	ND	Deficit ratio (%)	D	ND	Deficit ratio (%)
H60 (Nm)	147.90±35.21*	141.42±45.31*	4.38	92.80±18.34	90.40±17.14	2.58
H180 (Nm)	101.00±31.27*	98.30±39.66*	2.67	58.9±9.59	57.50±8.95	2.37
Q60 (Nm)	281.10±58.45*	256.70±44.33*	8.68	171.90±27.77	171.40±28.94	0.29
Q180 (Nm)	171.70±29.48*	175.10±35.30*	-1.98	112.40±17.49	111.70±17.80	0.62
$H60_N$ (Nm/kg)	1.98±0.40*	1.87±0.50*	5.55	1.50±0.24	1.48±0.33	1.33
$H180_N$ (Nm/kg)	1.35±0.35*	1.29±0.43*	4.44	0.96±0.15	0.94±0.18	2.08
$Q60_N$ (Nm/kg)	3.73±0.34*	3.43±0.36*	8.04	2.78±0.29	2.77±0.29	0.35
$Q180_N$ (Nm/kg)	2.31±0.35*	2.34±0.33*	-1.29	1.82±0.17	1.80±0.19	1.09
H/Q60 (%)	53.40±11.34	54.40±12.10	-1.87	54.40±9.64	53.40±9.65	1.83
H/Q180 (%)	58.70±15.07	54.40±13.48	7.32	52.90±7.29	52.10±7.24	1.51

Q_N, peak extensor torque normalized as Newton-meters per kilogram of body mass; H_N, peak flexor torque normalized as Newton-meters per kilogram of body mass; D, dominant leg; ND, nondominant leg.
*$P<0.05$, significant difference from female athletes for the same leg.

letes in both absolute ($t_{18}=5.336$, $t_{18}=4.388$, $P<0.05$, respectively) and normalized values ($t_{18}=6.698$, $t_{18}=3.260$, $P<0.05$). Peak torque of knee extensor and flexor muscles of nondominant leg, male taekwondo athletes had a significantly greater knee extensor and flexor strength than that of female athletes in both absolute ($t_{18}=5.094$, $t_{18}=3.299$, $P<0.05$, respectively) and normalized values ($t_{18}=4.506$, $P<0.05$), except for flexor strength values ($t_{18}=2.085$, $P<0.05$). When peak torque values were examined at 180 deg/sec, peak torque of knee extensor and flexor muscles of dominant leg was significantly greater in male than that of female taekwondo athletes in terms of both absolute values ($t_{18}=5.470$, $t_{18}=4.069$, $P<0.05$) and normalized ($t_{18}=4.015$, $t_{18}=3.199$, $P<0.05$, respectively). Peak torque of knee extensor and flexor muscles of nondominant leg was significantly greater in male than that of female taekwondo athletes in terms of both absolute values ($t_{18}=5.070$, $t_{18}=3.173$, $P<0.05$) and normalized ($t_{18}=4.396$, $t_{18}=2.336$, $P<0.05$, respectively). On the other hand, a significant H/Q difference was not found between gender in dominant and nondominant leg at both angular velocities. Also, no bilateral isokinetic strength difference was shown in both male and female taekwondo athletes. While significant differences were determined between gender in extensor and flexor muscle strength of the knee, bilateral strength differences were not found in both male and female taekwondo athletes.

Isometric strength of dominant and nondominant leg was presented in Table 3. Isometric knee extensor and flexor strength of dominant leg was significantly greater in male athletes than that of female athletes in terms of both absolute ($t_{18}=4.848$, $t_{18}=2.837$, $P<0.05$, respectively) and normalized values ($t_{18}=4.643$, $t_{18}=2.170$, $P<0.05$, respectively). Similarly, in nondominant leg, male athletes had significantly greater knee extensor and flexor strength than that of female athletes in both absolute ($t_{18}=4.418$, $t_{18}=2.867$, $P<0.05$, respectively) and normalized value ($t_{18}=3.400$, $P<0.05$), but not normalized flexor isometric strength ($t_{18}=1.698$, $P<0.05$).

Table 3. Absolute (Nm) and normalized peak torque (Nm/kg) values of isometric strength (at knee angle of 60°) of the knee flexor (H) and extensor (Q) muscles in elite male and female taekwondo athletes

Muscle isometric peak torque	Male (n=10)			Female (n=10)		
	D	ND	Deficit ratio (%)	D	ND	Deficit ratio (%)
H (Nm)	131.00±44.49*	111.40±33.29*	15.00	86.40±22.17	76.60±19.10	11.34
Q (Nm)	324.30±50.92*	304.60±51.79*	6.10	212.00±52.64	199.10±54.95	6.08
H_N (Nm/kg)	1.71±0.45*	1.48±0.42	13.45	1.37±0.18	1.22±0.22	10.94
Q_N (Nm/kg)	4.33±0.31*	4.12±0.70*	4.84	3.39±0.55	3.16±0.55	6.78

Q_N, peak extensor torque normalized as Newton-meters per kilogram of body mass; H_N, peak flexor torque normalized as Newton-meters per kilogram of body mass; D, dominant leg; ND, nondominant leg.
*$P<0.05$, significant difference from female athletes for the same leg.

DISCUSSION

In literature, isokinetic testing of the bilateral leg strength difference and H/Q ratio has been considered as a possible screening tool for injury risk (Bennell et al., 1998; Cheung et al., 2012; Impellizzeri et al., 2007). Bilateral strength difference is not only the prevention of injuries, but also the side-to-side muscle strength differences within the normative data (less than 10%–15%) is bilateral pattern of the specific activities of a sport (Kabacinski et al., 2018). Daneshjoo et al. (2013) reported that physical performance and movement pattern experienced during soccer playing may negatively change the balance of strength in both legs (bilateral strength balance), but not on the same leg of the young male professional soccer players. In the present study, there was no significant bilateral isokinetic and isometric strength asymmetry in lower limbs. Although there were not any significant differences, strength difference in both male and female athletes was in favor of the dominant leg. Similarly, isometric hamstring strength was 15% higher in the dominant leg in male athletes and 11% in females. Although strength differences were observed between the dominant and nondominant legs, it did not exceed 15%, as suggested in literature (Knapik et al., 1991). A comprehensive search of the existing literature (Andrade et al., 2012; Cheung et al., 2012; Magalhães et al., 2004; Zakas et al., 1995) showed that there were conflicting results in comparison of isokinetic strength difference between dominant and the nondominant leg (Daneshjoo et al., 2013; Frutuoso et al., 2016; Jones and Bampouras 2010; Kobayashi et al., 2013; Thomas et al., 2017). Thomas et al. (2017) reported that significant differences were found between D and ND limbs in knee flexor and extensor strength in 17 youth male basketball players. Jones and Bampouras (2010) reported that significant differences of 10% were found for concentric strength between D and ND limbs in male athletes. Cheung et al. (2012) showed weaker hamstrings muscles of the dominant leg in court sport players and higher H/Q ratio in dominant leg than nondominant leg in field players. However, it was reported that no significant strength difference was between dominant and nondominant leg in volleyball and soccer players (Magalhães et al., 2004), in males (Kobayashi et al., 2013). Frutuoso et al. (2016) revealed in rhythmic gymnastics athletes that the dominant limb showed higher hip flexor torque at 60 deg/sec compared to the nondominant limb. Daneshjoo et al. (2013) reported that peak torques in the nondominant leg at all angular velocities seemed higher than the dominant leg, however, that no significant differences were between legs in soccer players. Hadzić et al. (2013) revealed that bilateral strength asymmetry is noticeable in senior basketball players relating predominantly to the quadriceps. Menzel et al. (2013) found that the means of bilateral strength asymmetry was 9.14% in male professional soccer players. There was no study in the current literature that compared bilateral leg strength difference in taekwondo athletes.

Imbalances in hamstrings to quadriceps strength (i.e., a knee flexor/knee extensor ratio of less than 75% at 180°/sec) are associated with lower extremity injuries in female collegiate athletes (Knapik et al., 1991). In the present study, H/Q ratio ranged from 51% to 59% for both leg at 60° and 180°/sec, which was considerably lower than what Knapik et al. (1991) reported. In previous studies, it was reported that normal concentric H/Q for healthy individuals ranged from 50% to 80% (Bennell et al., 1998; Cheung et al., 2012; Kabacinski et al., 2018). The comparatively lower H/Q ratio found in this study than in literature for elite youth and adult athletes might have resulted from stronger quadriceps muscles. A faster and more effective kicking in taekwondo depends greatly on quadriceps muscle strength. In one of the few studies analyzing this correlation, Seo et al. (2015) reported that eight-week of the taekwondo training resulted in significant increase for in knee extensor strength rather than knee flexor strength in male and female athletes of 18–21 years old. On the other hand, it was also reported in literature that higher H/Q ratios were observed in

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greater angular velocity. Another important finding of the present study was that when H/Q ratio did not change in female athletes when angular velocity increased (from 60° to 180°/sec). Daneshjoo et al. (2013) revealed in male young professional soccer players that H/Q at velocity of 60° and 180°/sec ranged from 50% to 56% in dominant and nondominant leg, respectively. When the angular velocity increased 300°/sec, H/Q increased 20%–25% approximately for both legs. In field athletes, it was reported that H/Q was 58%–63% for dominant and nondominant leg at velocity of 60°/sec, that this ratio raised 75%–82% at 300°/sec (Cheung et al., 2012). Hewett et al. (2008) reported that gender differences in isokinetic H/Q ratios were not observed at higher angular velocities, but not slower velocities.

This study has some limitations. Bilateral differences in the study were measured in a limited number of elite young taekwondo players during the competition period when the performance level of the athletes was high. Additionally, it will be more beneficial for taekwondo to monitor the bilateral strength differences in different age groups throughout the season and by increasing the sample size. The results of the present study showed that while no significant bilateral strength difference was found in both male and female athletes. However, concentric and isometric knee strength was significantly greater in male than that of female. The deficit ratio did not appear in the male and female athletes' H/Q ratio was similar between gender and legs. There may be a situation that shows that the training practices of taekwondo athletes were done efficiently. The study revealed no bilateral knee strength asymmetry in both male and female taekwondo athletes. However, men had 20%–30% higher concentric and isometric knee extensor and flexor strength than females in both legs.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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