Comparison of Isokinetic Knee Strength Between the Dominant and Non-dominant Legs and Relationships Among Isokinetic Strength, Vertical Jump, and Speed Performance in Soccer Players

Futbolcularda Baskın ve Baskın Olmayan Bacak İzokinetik Diz Kuvvetinin Karşılaştırması ve İzokinetik Kuvvet, Dikey Sıçrama ve Sürat Performansı Arasındaki İlişkiler

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ABSTRACT Objective: The purpose of this study was to compare isokinetic knee strength of the dominant and non-dominant legs in 17-20 year-old soccer players and to investigate the relationships among isokinetic knee strength, vertical jump, and 30-m sprint performance. **Material and Methods:** Thirty-six soccer players volunteered to participate in the study. The vertical jump height, 30-m sprint time, and the isokinetic strength of hamstring (HM) and quadriceps muscles (QM) at angular velocities of 60 and 240°•s^{-1} were determined using jump-meter, photocell, and an isokinetic dynamometer, respectively. Isokinetic knee strength between the dominant and non-dominant legs was compared using the paired t-test. Pearson correlation coefficient was used to analyze the relationships among the peak torque values and vertical jump and 30-m sprint performance. **Results:** H/Q ratio at 60°•s^{-1} and HM strength at 240°•s^{-1} were significantly greater in the dominant leg than that of the non-dominant leg (p<0.05). Vertical jump height correlated with 30-m sprint time (r=-0.40, p<0.05). QM strength correlated with 30-m sprint performance in the dominant and the non-dominant leg at 60°•s^{-1} (r=-0.36, p<0.05; r=-0.43, p<0.01, respectively) and at 240°•s^{-1} (r=-0.36, p<0.05; r=-0.34, p<0.05, respectively), and with vertical jumping at 60°•s^{-1} (r=0.37, r=0.38, p<0.05, respectively). Besides, dominant leg HM strength only showed a significant correlation with 30-m sprint performance at 240°•s^{-1} (r=-0.36, p<0.05). **Conclusion:** The results revealed that H/Q ratio at low velocity and HM strength at high velocity were higher in favor of dominant leg in 17-20 year-old players. The QM strength had a decisive role in vertical jump and 30-m sprint performances at low angular velocity, and in 30-m sprint performance at high angular velocity. In addition, only the HM strength of the dominant leg at high velocity was effective in 30-m sprint performance.

Key Words: Soccer; hamstring; quadriceps; angular velocity

ÖZET Amaç: Bu araştırmanın amacı, 17-20 yaş futbolcularda baskın ve baskın olmayan bacak izokinetik diz kuvvetini karşılaştırmak ve izokinetik diz kuvveti, dikey sıçrama ve 30-m sürat performansı arasındaki ilişkileri incelemekti. **Gereç ve Yöntemler:** Çalışmaya otuz altı futbolcu gönüllü olarak katılmıştır. Dikey sıçrama yüksekliği, 30-m sürat koşu süresi ve hamstring (HM) ve quadriceps kaslarının (QM) 60 ve 240°/s açısal hızlarda izokinetik kuvveti sırasıyla jumpmetre, fotosel ve izokinetik dinamometre kullanılarak belirlenmiştir. Baskın ve baskın olmayan bacak arasındaki izokinetik diz kuvveti bağımlı gruplarda t testi kullanılarak karşılaştırılmıştır. Zirve tork değerleri, dikey sıçrama yüksekliği ve sürat koşu süresi arasındaki ilişkiler Pearson korelasyon katsayısı ile analiz edilmiştir. **Bulgular:** 60°/s'de H/Q kuvvet oranı ve 240°/s'de HM kuvveti baskın bacakta baskın olmayan bacağa göre daha yüksek bulunmuştur (p<0,05). Dikey sıçrama yüksekliği 30-m sürat koşu süresi ile ilişkili bulunmuştur (r=-0,40, p<0,05). QM kuvveti 60°/s'de (sırasıyla, r=-0,36, p<0,05; r=-0,43, p<0,01), 240°/s'de (sırasıyla, r=-0,36, p<0,05; r=-0,34, p<0,05) baskın ve baskın olmayan bacakta 30-m sürat koşu performansıyla ve 60°/s'de (sırasıyla, r=0,37, r=0,38, p<0,05) dikey sıçrama ile ilişkili bulunmuştur. Bununla birlikte, baskın bacağın HM kuvveti sadece 240°/s'de (r=-0,36, p<0,05) 30-m sürat koşu performansıyla anlamlı bir ilişki göstermiştir. **Sonuç:** 17-20 yaş arası futbolcularda düşük açısal hızda H/Q oranı ve yüksek açısal hızda HM kuvvetinin baskın bacak lehine daha yüksek olduğu ortaya çıkmıştır. QM kuvvetinin düşük açısal hızda dikey sıçrama ve 30-m sürat performansı, yüksek açısal hızda ise sadece 30-m sürat performansında belirleyici rolü olduğu belirlenmiştir. Ayrıca, yüksek hızda sadece baskın bacağın HM kuvveti 30-m sürat performansında etkili olmuştur.

Anahtar Kelimeler: Futbol; hamstring; quadriceps; açısal hız

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Soccer depends upon aerobic and anaerobic power, strength and muscular endurance.[1,2] The game is relatively low-intensity movements interspersed with maximal bouts of high-intensity exercise.[3] High-intensity movements (i.e., sprinting, jumping, or cutting) and low-intensity movements (jogging or standing) occur in varying lengths depending upon an array of factors that include playing position, skill level, style of play of the athlete, and tactical strategies employed by the team.[4] Although low-intensity activities including standing, walking, and jogging have been identified as the predominant movement patterns (upward of 90% of the 90-minute game), the distance covered, and the high-intensity activities including vertical jumping and sprinting are the main determinants between higher and lower standards of play.[5]

The high-intensity performance, such as sprint performance, vertical jumps, and kicking, is considered to be key factor and integral elements for success in elite soccer.[6-8] High-intensity performance is dependent on maximal strength and speed characteristics of the individual player, which should be developed from a young age.[5] A sprint bout occurred approximately every 90 seconds, each lasting an average of 2–4 seconds and corresponding to a maximum distance of approximately 30 m.[9-11] Sprint performance is a direct result of the impulse (the product of the mean force and time of contact) applied by the athlete against the ground during the propulsive phase of the stride. To increase the impulse in sprint performance, therefore, the muscular strength of the lower body is required to be increased for any given time of contact.[12] In addition, vertical jumping (VJ), characterized by explosive strength, has been assumed to be functional to optimal performance in soccer, considered in testing for fitness and talent selection, and related to competitive success in elite club teams.[6,13] Some players perform approximately 15 maximal vertical jumps in the penalty area during a game, which makes jumping an essential motor skill in soccer.[14] Both sprinting and jumping depend on maximal and explosive strength of the lower limbs.[6]

Lower limb muscle strength enhances sprinting and jumping performances of players in soccer. The quadriceps muscles (QM) are concentrically used in jumping, balance and kicking; and the hamstring muscles (HM) are eccentrically used to control, decelerate and stabilize the knee, but are also used concentrically to sprint, turn and tackle.[1,2,15,16] Many previous studies investigated the effect of the isokinetic muscle strength on vertical jump and sprint performance.[8,14,17-20] Dowson et al. reported the strongest relationship between concentric knee extension (at $240°{\cdot}s^{-1}$) and sprint performance over 0-15 m (during the acceleration phase).[12] In another study, Newman et al. showed that single-sprint performance correlated with peak extensor and flexor torque at angular velocities of 60, 150, and $240°{\cdot}s^{-1}$.[21] The strongest correlation was observed between relative knee extensor torque at $240°{\cdot}s^{-1}$ and the initial acceleration phase (0-10 m) of the single-sprint performance. However, there were fewer studies which focused on the relation between isokinetic concentric muscle strength of the lower limb, VJ and sprint in soccer.[22,23] In the studies, low-to-moderate significant correlations were reported between the isokinetic measures and VJ height in Australian football players of 19 years of age.[23] Ostenberg et al. demonstrated that there were low correlations between the isokinetic strength and VJ.[22] Chamari et al. found that the 5-jump test correlated significantly with knee extensors $240°{\cdot}s^{-1}$ and knee flexors $90°{\cdot}s^{-1}$ in under 23 soccer players.[24] Currently, there was a lack of data on the relation between isokinetic strength and power performance such as sprint and jumping capacities in young soccer players.

The correlation between leg muscle strength and VJ and sprinting in 17-20-year old male soccer players can be beneficial for monitoring the trainings and exercises needed to increase the performance for soccer. In addition, a difference in the muscle strength of the 2 legs has a potential risk for injury, especially in young players. Some possible reasons for the difference in strength between the 2 legs might be inadequate training programs, specific motor demands of different sports and training methods, and bilateral differences of agonist-antagonist ratio.[25] As a result, the purpose of the present study was to compare the isokinetic concentric strength of the extensor and the flexor muscles of the knee joints in the dominant and non-dominant legs and to investigate the relationships among isokinetic strength, VJ, and 30-m sprint performance. We hypothesized that there would be bilateral strength imbalances in the lower limbs and strong correlations between the QM and HM strength and VJ and sprint performance.

MATERIAL AND METHODS

EXPERIMENTAL APPROACH TO THE PROBLEM

The study was designed to assess the bilateral strength differences in the lower limb of soccer players by the isokinetic knee extension test. The isokinetic strength of the extensor and flexor muscles of the knee joints of both legs was assessed using isokinetic dynamometer. In addition, this study was performed to reveal the relationships between isokinetic knee strength, VJ, and 30-m sprint performance.

SUBJECTS

Thirty-six male soccer players in 17-20 years-old volunteered to participate in the study (goalkeeper, n=3; defenders, n=14; midfielders, n=17; forward, n=2). The soccer players had no history of major lower limb injury. This study was conducted in accordance with the guidelines set forth by the Institutional Review Board of Selçuk University (Number: 2013-06). Written consent was obtained from all the players. The tests were performed by players in season.

PROCEDURES

Vertical Jump Test

In VJ tests, the subjects performed the squat jump. The soccer players jumped vertically with maximum effort with a knee angle of 90° of flexion with their hands on the waist. The height of the VJ was digitally measured using jump-meter (Takei, Japan). The jump-meter consists of a rope fastened to the platform from one end and to the electronic meter on the waist of the person from the other end. Each player performed three maximal squat jumps in a random order, with approximately 2 min rest between jumps. The highest jump was recorded for analysis.

30-m Sprint Test

Sprint test was performed on wood tiled floor. Photocell timing gates were placed at 0- and 30-m at a height of 1-m. Soccer players warmed up for 10 min before 30-m sprint test. The subjects started from a standing-up position placing the lead-off foot 1-m behind the first timing gate. The time started and stopped automatically when the soccer players passed through the timing gates at the start and finish lines, and the time was recorded. Each player repeated 30-m sprint twice, with a 5 min rest between trials. The best (quickest) 30-m sprint time was selected for analysis.

Isokinetic Peak Torque Test

Before the isokinetic test, the isokinetic dynamometer (Cybex Norm, CSMI, Stoughton, Massachusetts, USA) was calibrated as suggested by the manufacturer. Then, the soccer players warmed up in cycle ergometer (Monark 894E model, Varberg, Sweden) for 5-10 min at 50 W and 50 rpm followed by 5 min of rest before test. After the warm-up exercise, each soccer player was tested in the seated position using the isokinetic dynamometer. Soccer players were fixed to the seat from their body, waist, and femur. 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. Moreover, they held the handles of the seat on both sides to prevent the freeness of the arms and get support from the seat. The players' dominant leg (D) was considered to be the preferred leg for kicking and, inversely, the contra-lateral leg was the non-dominant leg (ND). Concentric peak torque of the HM and QM of D and ND of the subjects was evaluated at angular velocities of 60 and $240°\cdot s^{-1}$. Before actual testing, the subjects were allowed 5 familiarization trials followed by 3 min of rest. Then, the subjects performed 10 maximal concentric knee extension-flexions at $60°\cdot s^{-1}$, followed by 15 maximal concentric knee extension-flexions at $240°\cdot s^{-1}$ for both D and ND. Subjects were allowed 5-min rest between each trial to reduce the effects of fatigue on peak torque values. The soccer players were verbally encouraged for a higher performance during the test. Isokinetic peak torque of HM and QM (N·m) and the hamstring-to-quadriceps peak torque (H/Q) ratio (%) were evaluated for each player.

STATISTICAL ANALYSIS

The data were presented as mean and standard deviation (SD). The assumption of normally distributed data was tested using the one-sample Kolmogorov-Smirnov test, and the assumption of homogeneity of the variances was tested using the Levene test. The paired *t*-test was used to compare isokinetic knee strength between the dominant and non-dominant legs. Pearson correlation coefficient was used to analyze the relationships among the peak torque values, vertical jump, and 30-m sprint performance. 0.00-0.25 interval of the Pearson's correlation coefficient was evaluated as very weak, 0.26-0.49 as weak, 0.50-0.69 as moderate, 0.70-0.89 as high, and 0.90-1.00 as very high. The level of significance was set at $p \leq 0.05$.

RESULTS

Physical characteristics of the 36 male soccer players were presented in Table 1. The one-sample Kolmogorov-Smirnov test revealed that extensor muscles peak torque values were normally distributed at angular velocities of 60 (z =.551, z =.556; p>0.05) and 240°·s^{-1} (z =.377, z =.592; p>0.05) in the dominant and non-dominant legs, respectively. In addition, flexor muscles peak torque values indicated a normal distribution at 60 (z =.662, z =.717; p>0.05) and 240°·s^{-1} (z =.679, z =.671; p>0.05) in the dominant and non-dominant legs, respectively. Normal distributions were also observed for variables of the vertical jump height and 30-m sprint time, respectively (z=1.202, z=.608; p>0.05).

Absolute and relative torque values of the HM (Table 2) were significantly higher in D than those of ND at 240°·s^{-1} (t_{35}=3.20, t_{35}=2.95, p<0.05, respectively). H/Q peak torque ratio at 60°·s^{-1} was significantly higher in D (t_{35}=2.46, p<0.05), except at 240°·s^{-1}.

TABLE 1: Physical characteristics of the soccer players (n=36).

Variables	Mean ± SD
Age (years)	18.33±0.96
Height (cm)	177.33±4.53
Body mass (kg)	66.80±7.26
Training age (years)	7.28±1.77
Vertical jump height (cm)	49.56±4.25
30-m sprint time (s)	4.10±0.22

SD: Standard deviation.

TABLE 2: Isokinetic peak torque values of the knee flexor (H) and extensor (Q) muscles and H/Q ratio between the dominant (D) and non-dominant legs (ND) in soccer players (Mean ± SD).

Peak torque	D	ND
H_{60} (Nm)	133.36±19.17	130.83±20.28
H_{60} (Nm(kg^{-1})	1.95±0.29	1.92±0.23
Q_{60} (Nm)	204.77±33.04	209.88±30.88
Q_{60} (Nm/kg^{-1})	3.00±0.33	3.07±0.33
H/Q_{60} (%)	66.69±10.12*	62.72±7.09
H_{240} (Nm)	85.86±13.31*	79.00±14.26
H_{240} (Nm/kg^{-1})	1.26±0.20*	1.13±0.27
Q_{240} (Nm)	114.83±19.56	110.58±25.67
Q_{240} (Nm/kg^{-1})	1.69±0.25	1.62±0.33
H/Q_{240} (%)	75.94±11.37	75.25±16.43

* p<0.05, significant difference from non-dominant leg.

There was a significant weak correlation between VJ height and 30-m sprint time (Table 3). QM strength of both legs correlated with 30-m sprinting performance at both angular velocities, and with VJ at 60°·s^{-1} angular velocity. On the other hand, HM strength of D significantly correlated with 30-m sprint performance at 240°·s^{-1} angular velocity.

DISCUSSION

DIFFERENCES IN HM AND QM PEAK TORQUE VALUES AND H/Q RATIO BETWEEN D AND ND

In the present study, H/Q ratio and HM strength was significantly greater in favor of the dominant leg (6% at 60°·s^{-1}, and 8% at 240°·s^{-1}, respectively). Although HM was used effectively during running and sprints, which are dominant athletic characteristics of soccer, bilateral HM strength differences should be thought as a po-

TABLE 3: The correlations among dominant (D) and nondominant leg (ND) isokinetic quadriceps (Q) and hamstring (H) muscle peak torque values, vertical jump height, and 30-m sprint time.

	Vertical jump	QD60	QND60	QD240	QND240	HD60	HND60	HD240	HND240
30-m sprint	-0.40*	-0.36*	-0.43‡	-0.36*	-0.34*	-0.08	-0.16	-0.36*	-0.21
Vertical jump		0.37*	0.38*	0.16	-0.08	0.10	-0.25	0.12	-0.08

*p<0.05, ‡p<0.01.

tential injury factor for HM. It was previously reported that bilateral HM strength was more than 15% in favor of the dominant leg, which was correlated with greater incidence of lower extremity injury in female collegiate athletes.[26] Tourny-Chollet et al. demonstrated that the knee flexor strength of the dominant leg tended to be stronger than that of the non-dominant leg in amateur female soccer players.[27] Also, Daneshjoo et al. reported that there were no significant differences in knee extensors and flexors between the dominant and non-dominant legs in young male professional soccer players.[28] On the other hand, H/Q ratio of a healthy knee ranges from 66% to <75% for all sports.[26,29-31] Lees and Nolan reported that the imbalance observed between H/Q ratio of both legs in soccer players may be due to the players' predominantly kicking and passing the ball with their dominant leg.[32] Ergün et al. demonstrated that knee flexion peak torque and H/Q ratio at 180°·s^{-1} were significantly greater in the dominant side than that of the non-dominant side in soccer players.[33] It was reported that one in four of 42 professional male soccer players had preseason HM strength imbalance; and all strength deficits were observed in the stance leg.[34]

THE RELATIONSHIPS AMONG ISOKINETIC QM AND HM STRENGTH, VJ, AND SPRINT PERFORMANCE

In the present study, significant weak correlations were found among isokinetic knee strength, vertical jump, and 30-m sprint performance. QM strength of both legs correlated with 30-m sprint performance at both angular velocities and with VJ at low angular velocity; and HM strength of D correlated with 30-m sprint performance at high angular velocity. The correlation observed only between the HM strength of D and 30-m sprint performance at high angular velocity might be indicative of bilateral strength differences between D and ND. If the HM strength of ND had been similar to that of D, a correlation between the HM strength of ND and 30-m sprint would have probably been observed at high angular velocity also. It has been well documented that sprint ability correlated strongly with the HM strength.[1,2] On the other hand, the high proportion of type II muscle fibers in the HM, characterized by a greater fatigability than type I muscle fibers makes this muscle group more vulnerable during long duration exercises.[35] At the end of a soccer game, the HM is probably more vulnerable to muscle tear.[36] When players become older (U17–U19), other functional characteristics become important with increase in muscle strength, such as speed, explosive power and agility.[37] Castagna and Castellini reported that VJ and sprinting ability assessments, which demonstrated acceleration and speed in skills critical to soccer, might help detect elite-standard players' abilities from a chronologic age of 17 years.[13] Changes in VJ performance in the range of approximately 1 cm should be regarded of interest and considered as a sign of probable improvement or underperformance depending on change direction.[13] Significant relationships were determined between the isokinetic QM strength and jumping performance for 30 healthy individuals and Australian football players.[23,38] On the other hand, the relationship between strength variables and single sprint had been widely studied and revealed clearly.[11,21,39,40] Newman et al. reported that the strongest correlation was between the relative knee extensor torque at 240°·s^{-1} and the initial acceleration phase (0-10 m) of the single-sprint performance (r = -0.714).[21] Another study showed that the level of 1RM correlated well with the 10-m and 30-m sprint times and jumping height.[11] Significant correlations were also observed between VJ height and 10-m and 30-m sprint times. However, it was reported in several studies that there was no relation between any measure of strength and single sprint performance.[39,41] Cronin and Hansen demonstrated no correlations between maximal strength (3RM), drop jump, isokinetic strength, and 5-m, 10-m, and 30-m times.[39] However, they reported significant correlations between the squat jump (height and relative power output) and counter-movement jump height and 5-m, 10-m, 30-m times (r= -0.43 to -0.66). It was reported that there was a significant relationship between concentric knee extensor strength at 240°·s^{-1} and 0-15 m and 30-35 m sprint times.[12] In another study, although no absolute 3-RM strength or power score was significantly related to 10-m and 40-m sprint performance in professional rugby league players, almost all the scores relative to body mass were significantly related to sprint.[42]

The results revealed that H/Q ratio at low velocity and HM strength at high velocity were higher in favor of dominant leg in 17-20 year-old players. The QM strength had a decisive role in vertical jump and 30-m sprint performances at low angular velocity, and in 30-m sprint performance at high angular velocity. In addition, only the HM strength of the dominant leg at high velocity was effective in 30-m sprint performance.

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