Spor Hekimliği Dergisi, 57(4):177-182; 2022
Turkish Journal of Sports Medicine
Turk J Sports Med. DOI: 10.47447/tjsm.0643

Research Article / Araştırma Makalesi

Knee flexor and extensor isokinetic strength profiles of elite male golfers

Elit erkek golfçülerin diz fleksör ve ekstansör izokinetik kuvvet profilleri

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ABSTRACT

Objective: Although lower extremity plays an important role for postural control and to produce power during the golf swing, it has not been clearly examined. The aim of this study was to identify the left-right, and agonist-antagonist knee muscle strength profiles and its correlation with performance in proficient golfers.

Materials and Methods: Eight male elite golfers, age 21.6±1.1 years, height 174.1±6.1 cm, and body mass 68.6±2.7 kg, with handicaps of 0-5 participated in the study. Knee flexor and extensor peak torques of the golfers were measured by using isokinetic dynamometer (at 60°/s, 120°/s and 240°/s). The number of golf shots on an 18-hole golf course was recorded to determine golf performance.

Results: In golf players, knee strength difference between right and left extremities were 0.53%, 5.77% and 5.35% for flexor muscles and 5.71%, 3.60% and 7.91% for extensor muscles at 60°/s, 120°/s and 180°/s, respectively. Right and left knee Fcon/Excon ratio was between 0.67-0.99. No correlation was found between golf performance and peak torques except for right knee flexor muscle at 120°/s angular velocity.

Conclusions: Knee muscle strength variations between right-left and agonist-antagonist muscles were below the injury risk limits. Those negligible imbalances may be the result of functional differences of knee muscles during each part of the golf swing. It is important to add appropriate drills to the training programs so that these differences do not cause injury and poor performance in the long term.

Keywords: *Golf, knee strength, strength ratio, lower extremity*

ÖZ

Amaç: Alt ekstremite, golf vuruşu sırasında postüral kontrol ve güç üretmek için önemli bir rol oynamasına karşın, detaylı olarak incelenmemiştir. Bu çalışmanın amacı, elit golfçülerde sol-sağ ve agonist-antagonist diz kas kuvvet profillerini ve performans ile ilişkisini belirlemektir.

Gereç ve Yöntem: Çalışmaya yaşları 21.6±1.1 yıl, boyları 174.0±6.1 cm ve vücut ağırlıkları 68.6±2.7 kg olan 0-5 handikaplı sekiz erkek elit golfçü katıldı. Golfçülerin diz fleksör ve ekstansör zirve torkları izokinetik dinamometre (60°/s, 120°/s ve 240°/s) kullanılarak ölçüldü. Golf performansı, 18 delikli bir golf sahasındaki golf atışlarının sayısı kaydedilerek değerlendirildi.

Bulgular: Golf oyuncularında sağ ve sol ekstremiteler arasındaki diz kuvveti farkı 60°/s, 120°/s ve 180°/s açısal hızlarda sırasıyla fleksör kaslar için %0.53, %5.77 ve %5.35; ekstansör kaslar için %5.71, %3.60 ve %7.91 olarak bulundu. Sağ ve sol diz Fcon/Excon oranı 0.67-0.99 arasındaydı. Golf performansı ile zirve torkları arasında, 120°/s açısal hızdaki sağ diz fleksör kası dışında, bir ilişki bulunmadı.

Sonuç: Sağ-sol ve agonist-antagonist kaslar arasındaki diz kas kuvveti farkları yaralanma risk limitlerinin altındaydı. Bu göz ardı edilebilir dengesizlikler, golf vuruşunun her bir bölümünde diz kaslarının fonksiyonel farklılıklarının sonucu olabilir. Bu farklılıkların uzun vadede yaralanmalara ve performans düşüklüğüne neden olmaması için antrenman programlarına gerekli egzersizlerin eklenmesi önemlidir.

Anahtar Sözcükler: *Golf, diz kuvveti, kuvvet oranı, alt ekstremite*

INTRODUCTION

A successful golf shot is achieved by the player swinging the golf club in a correct trajectory and at high angular velocities. During the golf swing, which requires coordinated movement of all body parts, reaching high swing speed and power, and transferring it to the ball is provided by increasing the muscle strength and optimizing the swing biomechanics. In addition, for a lower handicap that is the numerical measure of a golfer's potential performance, it is essential that players do not only need to hit the ball long but also require their shots to be accurate (1). Although golf is considered to be an upper extremity dominant sport, the lower extremity plays an important role in ensuring the stabilization during the swing (2) and producing force using ground reaction and transferring it to the golf club (3).

Golf swing can be divided into three parts: backswing, downswing and follow-through. The role of the lower extremity differs in each swing parts. During the backswing, it

Received / Geliş: 18.11.2021 · **Accepted / Kabul:** 15.04.2022 · **Published / Yayın Tarihi:** 26.06.2022 · **Issue:** December 2022

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Cite this article as: Odabas HI, Gercek N, Tatar Y. Knee flexor and extensor isokinetic strength profiles of elite male golfers. *Turk J Sports Med.* 2022, 57(4):177-82; https://doi.org/10.47447/tjsm.0643

provides stabilization to increase body rotation, and to create body torque that will accelerate down swing (2). In downswing, power generation begins when the lower extremity produces ground reaction force. This force is transferred to the hips, trunk, arms and the golf club with the effective use of kinematic sequencing (3,4). In the follow-through, all muscle groups contract eccentrically to slow down and stop the golf swing that reaches high speeds.

It was reported that leg and hip strength were associated with golf performance parameters such as club head speed, driving distance, handicap and golf scores (5). In a study on current golf performance and muscle strength, it was found that there was a relationship between average golf scores and leg power (standing long jump test) (6). Club head speed as a valid indicator of the handicap (1) was also correlated with squat jump and vertical jump performances in amateur golf players (3,7,8). Moreover, lower extremity strength was reported to be highly correlated with club head speed in professional golf players (9). Those studies are valuable since the functional tests used contain a triple extension. That is extremely similar to the downswing which is the power production part of the golf swing. However, objective tests are needed to measure muscle strength in order to be more reliable.

Isokinetic dynamometer tests and electromyographic (EMG) measurements are frequently preferred methods for objective evaluation of muscle strength. These methods are used in a range of sports to identify performance levels and injury risks. Lower extremity strength is often studied since it owns an important role over producing ground reaction force and transferring it through the kinetic chain with no energy loss.

Sell et. al. found that, the hip, trunk and shoulder muscle strength of players with a better handicap (golf game skills) was higher than the less proficient golfers (4). Tsai et. al. also examined that there was a negative correlation between hip abduction and adduction strength and handicap score (10). In studies evaluating knee flexor/extensor strength, it was found that electromyographic activity of the knee flexor and extensor muscles differs during each part of the golf swing (11,12). Marta et al. also found that muscle activity patterns especially on the lower extremity also differ with handicap score (12). Chung et al. found low correlation between knee muscle strength and either driving distance or the average golf score and suggested strength assessment for preventing injury rather that increasing performance (13). Considering the risk of injury, the knee is the most common injured region (3-18%) among lower extremity injuries in golfers (14,15). Exposure of the knee region to high compressive and rotational forces during golf swing indicates the necessity to strengthen this region to prevent injuries, and to return to golf following knee injury (15,16).

Isokinetic lower extremity strength tests are valuable in terms of evaluating golf performance and taking precautions to prevent injuries that may arise from repeated high-speed swing movements in training. The evaluation of lower extremity strength distributions will also guide training programs to be organized specific to golf. Therefore, the purpose of this study is to examine knee flexor and extensor isokinetic strength profiles and its correlation with golfers' playing level (handicap) and golf performance.

MATERIALS and METHODS

Participants

Eight male elite golfers (0-5 handicap) with at least six years of golf training experience were included in the study (age: 21.6±1.1 years, height: 174.0±6.1 cm, body weight: 68.6±2.7 kg, handicap: 2.46±2.04). All golfers were right hand dominant, which is the same direction as they perform in golf (right-handed). G power software was used for sample size calculation. Wilcoxon signed-rank test (matched pairs) was performed for the right and left knee flexor muscle strength using a reference study's values (13). Power analysis indicated that a sample size of nine subjects was required to detect knee strength differences between right and left extremities (α=0.05; power=0.8). Muscle strength of the athletes was measured by a physiotherapist using the Humac Norm Cybex 6000 isokinetic dynamometer (Lumex, Ronkonkoma, NY, USA). The local research ethics committee approval was obtained. The study was conducted in accordance with the Declaration of Helsinki, and approval forms were received from the participants before the study.

Measures

Body weight of the golf players were measured using a Tanita BC body composition analyzer. Body height of the players were measured with a Lafayette scale with 0.1 cm precision. In the lower extremity strength evaluation, knee flexor and extensor isokinetic concentric strength were measured using the Humac Norm Cybex 6000 isokinetic dynamometer (Lumex, Ronkonkoma, NY, USA). This dynamometer can measure trunk, hip, knee, ankle, shoulder, forearm and wrist strengths at different angular velocities and ranges of motion.

Before starting the tests, the dynamometer was calibrated in accordance with the manufacturer's instructions. Knee strength of the participant was measured with the participant in a sitting position. The participant was fixed on the dynamometer seat by adjusting the hip joint angle 100° and the knee joint angle 90°. After the participant was placed lained, the sample test videos were shown, and a familiarization trial was made before starting the measurement. The participants were told to perform each knee flexion and extension with maximum effort, and were verbally encouraged throughout the test (17). Before the test, 10 min warm up exercise (5 min bicycle ergometer, 5 min squat and forward, backward and sideways jogs, and ROM exercise for the hip, knee and ankle) was done in order to prevent injuries and to achieve maximum effort.

Isokinetic muscle strength measurements of both right and left extremities were carried out at three different angular velocities: 60°/s (three reps), 120°/s (five reps), and 240°/s (eight reps). Fcon/Excon values were used for determining H/Q ratios, and right Fcon/left Fcon and right Excon/left Excon values were used for bilateral asymmetry determination. The measurement at each angular velocity was repeated three times and 120 s rest was given between measurements. When the angular velocity changed, a 5-min rest was given.

Before starting the study, handicaps of golfers were recorded for identifying the players' golf skill levels. In order to determine golf performance, the total number of golf shots on an 18-hole golf course was recorded. Handicap was used for evaluating the general golf skill of the players and the golf course score was used to determine the instant golf skill at that date.

Data Analysis

Descriptive statistical analyses and calculations were performed using the SPSS 22 software (SPSS, SPSS Inc, Chicago, IL, USA). To assess the normality of the distribution of all data, the Shapiro-Wilk test was implemented. Results revealed that variables were not normally distributed. Therefore, nonparametric tests were used for analysis. Right and left extremity knee flexor and extensor peak torque differences were analyzed with the Wilcoxon signed-rank test. Correlation between handicap, golf performance, and knee flexor and extensor peak torque were analyzed using Spearman correlation test. All statistical tests were two-sided, and we used a $p<0.05$ for statistical significance. The maximum peak torque value of three repetitions was used for evaluation. Peak torque values were normalized using body weight. Peak torque percentage differences between the right and left extremities were also calculated. To determine the agonist-antagonist muscle imbalance of the knee joint, the knee flexor/extensor (Fcon/Excon) strength ratios were calculated.

RESULTS

Knee flexor and extensor muscle strength of the golf players are given in Table 1. The right knee flexor muscle strength varied between 142.8±25.1 and 198.4±18.4 Nm/kg at different angular velocities (Table 1). The strength of the left knee flexor muscles was between 133.8±19.6 and 197.1±22.6 Nm/kg. Extensor muscle strength of the right knee was found between 145.3±16.7 and 280.2±31.3 Nm/kg, and between 156.5±21.5 Nm/kg and 294.1±28.4 Nm/kg for the left. When knee flexor and extensor peak torque was compared between right and left extremities, the lowest difference in knee flexor strength was found at 60°/s angular velocity, and that for extensor strength was found at 120°/s angular velocity. Forknee flexor muscles, the strength of the right extremity was higher than the left extremity at only 240°/s angular velocity, whereas the left extremity knee extensor muscle strength was greater than the right extremity at all angular velocities.

Table 1. Knee flexor and extensor peak torque differences at different angular velocities

Parameter	Mean	SD	Difference(%)	p
60˚/s				
RK Flexion PT	198.4	18.4	0.53	.779
LK Flexion PT	197.1	22.6		
RK Extension PT	280.2	31.3	5.71	.327
LK Extension PT	294.1	28.4		
120˚/s				
RK Flexion PT	165.7	24.3	5.77	.123
LK Flexion PT	174.0	24.1		
RK Extension PT	209.6	13.0	3.60	.575
LK Extension PT	216.7	24.1		
240˚/s				
RK Flexion PT	142.8	25.1	5.35	.208
LK Flexion PT	133.8	19.6		
RK Extension PT	145.3	16.7	7.91	.063
LK Extension PT	156.5	21.5		

RK: right knee, LK: left knee, PT: peak torque; *: $p<0.05$

For the Fcon/Excon ratio, the right knee strength ratio varied between 0.71 and 0.99 at different angular velocities, while the left knee strength ratio varied between 0.67 and 0.86 (Table 2). When the correlation of handicap (golfers' playing level) and golf performance with knee extensor and flexor force was examined, it was found that only the right knee flexor peak torque at 120°/s angular velocity was related to golf performance (p=0.033) (Table 3).

Table 2. Knee flexor/extensor peak torque ratios at different angular velocities

Parameter	Mean	SD	Fcon/Excon
60°/s			
RK Flexion PT	198.4	18.4	0.71
RK Extension PT	280.2	31.3	
LK Flexion PT	197.1	22.6	0.67
LK Extension PT	294.1	28.4	
120°/s			
RK Flexion PT	165.7	24.3	0.79
RK Extension PT	209.6	13.0	
LK Flexion PT	174.0	24.1	0.80
LK Extension PT	216.7	24.1	
240°/s			
RK Flexion PT	142.8	25.1	0.99
RK Extension PT	145.3	16.7	
LK Flexion PT	133.8	19.6	0.86
LK Extension PT	156.5	21.5	

RK: right knee, LK: left knee, PT: peak torque

Table 3. Correlation of handicap and golf performance with knee flexor/extensor peak torques

			Handicap		Golf performance	
Parameter	**Mean**	**SD**	**r**	**p**	**r**	**p**
Handicap	2.46	2.04				
Golf score	67.9	4.5	.055	.898		
60°/s						
RK Flexion PT	198.4	18.4	.323	.435	-.337	.414
LK Flexion PT	197.1	22.6	-.252	.548	-.133	.754
RK Extension PT	280.2	31.3	-.180	.670	-.096	.820
LK Extension PT	294.1	28.4	-.252	.548	-.205	.627
120°/s						
RK Flexion PT	165.7	24.3	.335	.417	-.747	.033*
LK Flexion PT	174.0	24.1	-.072	.866	-.627	.096
RK Extension PT	209.6	13.0	.012	.978	-.482	.227
LK Extension PT	216.7	24.1	.180	.670	+.108	.798
240°/s						
RK Flexion PT	142.8	25.1	.277	.506	-.364	.376
LK Flexion PT	133.8	19.6	.240	.568	+.036	.932
RK Extension PT	145.3	16.7	.144	.734	-.482	.227
LK Extension PT	156.5	21.5	.181	.668	-.121	.775

RK: right knee, LK: left knee, PT: peak torque; *: p<0.05

DISCUSSION

In golf players, knee flexor and extensor muscle strength difference between right and left legs were found to be under 10%, and the strength of both legs decreased as the angular velocity increased. The flexor/extensor strength ratio increased as the angular velocity increased for both knees. There was no correlation between golf performance and peak torques except for flexor muscle strength at 120°/s angular velocity.

Golf swing speed can be increased by amount and direction of the ground reaction force through the lower extremity, and effectively transferring it to the upper extremity and finally to the golf club (3,11). The decrease in lower extremity strength will negatively affect the swing speed and control, as it will reduce the effectiveness of the movement. Higher knee flexor and extensor muscle strength of female professional golf players compared with sedentary individuals indicate that these muscles are actively used during the golf swing (13). In our study, knee flexor and extensor muscle strength (at 60°/s angular velocity) of male amateur golf players are found to be higher than female professional golf players. The difference in knee muscle strength may have caused male players to have longer driving distance than female players.

Considering the golf swing technique, it was also found that the overhead deep squat movement was highly associated with golf swing faults such as early hip extension and loss of posture (18). These results display the importance of knee flexor and extensor strength for generating correct swing mechanics. In addition, the correlation between vertical jump height and club head speed, ball speed and ball flight distance also point to the importance of lower extremity strength in golf performance (7,8). In professional golf players, it was reported that squat jump height is highly correlated with club head speed (9). In addition, it was hypothesized that the higher club head speeds in players aged <30s is attributed to their higher ability to utilize leg power in their swing than in players aged >30s. These studies are valuable as the functional tests used contain a triple extension, similar to the downswing motion, which is the power production part of the golf swing. Those tests involve hip, knee and ankle muscle strength, and isolated strength measurements should be applied to understand the role of different muscle groups on power production during the golf swing.

In addition to analyzing current golf performance using ball flight and club speed mechanics, golf score and players'handicap are also used for performance evaluation. Kras and Abendroth-Smith determined a relationship between long jump test and golf score (6). Chung et al. also demonstrated a correlation between isokinetic knee muscle strength and golf score (13). Although results were significant, the correlations were low to negligible. In our study, there was no correlation between isokinetic knee strength and golf score. These results can be attributed to golf score being affected by other factors rather than muscle strength and power. For lower golf scores, shots must be accurate and consistent as well as being longer. In addition, other factors such as weather conditions, golf course design differences and psychological status of the players also can affect the score.

Handicap that displays the skill level of the golf players was found to be correlated with hip abduction and adduction strength (4,10). It was also found that muscle activity patterns especially on the lower extremity also differs with handicap (12). In our study, there was no correlation between knee muscles strength and handicap. Handicap range differences of the players in our study from those in the mentioned studies may have yielded opposite results. In the aforementioned studies, low and high handicap players were compared, but in our study, correlations were made using only low handicap players. These results reveal that lower extremity strength may be an important factor affecting handicap in less proficient players, but not a criterion in low handicap players.

Chung et al. emphasized that bilateral knee flexor/extensor muscle strengths are a good indicator to characterize golf players in addition to upper extremity strength profiles (13). But they also found low correlations between muscle strength and either driving distance or the average golf score, and suggested strength assessment for preventing injury rather than increasing performance. Isolated strength measurements can be used for identifying potential strength deficits and the risk of injury.

In the study of Marta et al., the maximal isokinetic strength of left knee extensor muscles was relatively higher than in the right knee. Despite the measurement method used in this study being different than our study, the fact that left knee extensor strength is higher than the right knee is similar to our study (12). The excessive ground reaction force increases on the target side (left leg for a right-handed golfer) during the downswing (19) supports more the increased extensor muscle strength of the left knee than the right one in the mentioned studies. Through impact, quicker transfer of body weight to the target side by extending the left leg faster increases golf ball flight distance (20). This performance enhancing swing technique may have caused an increase in left knee extensor strength of golf players. Marta et al. found that in the early stages of the downswing, right knee flexor muscles displayed higher activity than the left knee, and in other parts of the golf swing, left knee flexor muscles were more active than the right one (12). Different activation patterns between both knee flexor muscles in each part of the golf swing may have caused these muscle strengths to be variable at different angular velocities in this study. But strength differences either between right-left knee or agonist-antagonist muscles were below injury risk level.

Golf players' Fcon/Excon strength ratios were found above the 2/3 injury risk rate, and increased as the angular velocity increases (21). These results display that golf players have low risk of knee injury. Mchardy, Pollard and Luo's study reporting that the incidence of knee injury in golf players is low (about 6%), supports this result (22). However, the effect of rapidly transferring body weight to the left leg with rotation immediately after the impact, and throughout the follow-through (16) should be considered. In addition, anterior cruciate ligament injuries in the left knee caused by repeated golf swing trainings (23), and the higher compressive force rates in the left knee joint (22) also indicate to injury risk. In this study, the fact that the left leg Fcon/Excon strength ratio was lower than in the right knee, especially at 240°/s angular velocity, indicated that injury risk to the left leg was higher.

This study revealed that, right and left knee muscle strength differences were below injury risk limits. When evaluated in terms of its effect on performance, it was determi–

ned that muscle groups in the knee region have different functions during each part of the golf swing. Due to this difference, right knee flexor muscle strength was found higher at higher angular velocities (240°/s), while left knee flexor muscle strength was higher at 120°/s. This result suggests the need to add knee flexor muscle strength drills at different angular velocities in both extremities to the training programs. In knee extensor muscle strength, the fact that the left extremity generates more strength at all angular velocities than the right extremity indicates that right knee extensor muscle strength should be increased in order to avoid muscle imbalances in the long term. In terms of agonist-antagonist muscle imbalances, the risk of injury was found to be low in both extremities and at all angular velocities. However, it was found that right knee flexor muscles could not adapt to left knee extensor strength increases at high speeds, which are thought to be due to the nature of the golf swing movement. Therefore, it is considered important to develop right knee flexor muscle strength with high-speed movements.

Ethics Committee Approval / Etik Komite Onayı

The approval for this study was obtained from Clinical Research Ethics Board of Haliç University (Approval number: 04/08, Date: 18.05.2020).

Conflict of Interest / Çıkar Çatışması

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

Financial Disclosure / Finansal Destek

The authors received no financial support for the research and/or publication of this article.

Author Contributions / Yazar Katkıları

Concept: HIO, YT; Design: HIO, NG; Supervision: YT; Materials: HIO, NG; Data Collection and Processing: HIO; Analysis and Interpretation: NG; Literature Review: NG; Writing Manuscript: HIO, NG, YT; Critical Reviews: YT.

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