AN INVESTIGATION OF THE RELATIONSHIP BETWEEN ISOKINETIC STRENGTH OF KNEE FLEXOR AND EXTENSOR MUSCLES AND VERTICAL JUMP PERFORMANCE IN ELITE MALE VOLLEYBALL PLAYERS ¹

ELİT ERKEK VOLEYBOL SPORCULARINDA DİZ FLEKSÖR VE EKSTANSÖR KASLARININ İZOKİNETİK KAS KUVVETİ İLE SİÇRAMA PERFORMANSI ARASINDAKİ İLİŞKİNİN İNCELENMESİ

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Öz: Amaç: Araştırmanın amacı, elit erkek voleybolcuların diz fleksör ve ekstansör kaslarının izometrik kas kuvveti ile sıçrama performansı arasındaki ilişkiyi belirlemek oluşturmaktadır. **Yöntem:** Araştırmaya 28 elit erkek voleybolcu (Yaş=17,56±1,94 yıl) dahil edildi. Sporcuların squat ve aktif dikey sıçrama yükseklikleri optojump® cihazı kullanılarak elde edildi. Aynı zamanda Voleybolcuların diz eklemi fleksör ve ekstansör kaslarının izometrik kas kuvveti Isomed 2000® cihazı ile konsantrik ve eksantrik olarak ölçüldü. Değişkenler arasındaki ilişkiyi incelemek amacıyla; Pearson korelasyon analizi kullanıldı. Aralarında ilişki olduğu belirlenen parametrelerden bağımsız değişkenlerin, bağımlı değişkenleri yordama düzeylerini belirlemek amacıyla regresyon analizi uygulandı. **Bulgular:** Uygulanan regresyon analizi sonuçlarına göre, kuadriceps kasi squat sıçrama yüksekliğindeki değişimin %61'ini, aktif sıçrama yüksekliğindeki değişimin ise %60'ını etkilemektedir. Hamstring kasi, squat sıçrama yüksekliğindeki değişimin %56'sını, aktif sıçrama yüksekliğindeki değişimin ise %59'unu etkilemektedir. Bununla birlikte segmental analizler kullanıldığında, sol taraf kuadriceps kasının 60°/sn hızdaki konsantrik kas kuvvetinin squat sıçrama ve aktif sıçrama performansını zayıf düzeyde pozitif yönde etkilediği ve kuadriceps kasının 180°/sn açısal hızdaki konsantrik ve eksantrik kas kuvvetinin squat sıçrama ve aktif sıçrama performansını orta düzeyde pozitif yönde etkilediği belirlendi. Aynı zamanda sağ taraf hamstring kasının 60°/sn hızdaki eksantrik kasılmasının squat sıçrama ve aktif sıçramada önemli bir yordayıcı olduğu belirlendi. **Sonuç:** Çalışmamız sonucunda; kuadriceps ve hamstring grubu kasların konsantrik ve eksantrik kas kuvvetinin hem squat sıçrama hem de aktif sıçrama performansını etkilediği belirlendi. Sıçrama performansının artırılması için sol taraf 60°/sn hızda kuadriceps kasının konsantrik, sağ taraf hamstring kasının eksantrik kas kuvveti ile her iki taraf kuadriceps kasının 180°/sn açısal hızdaki konsantrik ve eksantrik kas kuvvetinin artırılması gerektiğini düşünmekteyiz.

Anahtar Kelimeler: Voleybol, Sıçrama, Kas Kuvveti, İzometrik

Abstract: Aim: The purpose of the study is to determine the relationship between the isokinetic strength of the knee flexor and extensor muscles and vertical jump performance. **Method:** 28 elite male volleyball players (Xage = 17.56 ± 1.94 years) were included in the study. Squat and counter-movement jump heights of the athletes were obtained using the OptoJump® device. At the same time, the isokinetic muscle strength of flexor and extensor muscles of knee joints of volleyball players was measured concentrically and eccentrically with an Isomed 2000® device. In order to examine the relation between variables; Pearson correlation analysis was used. Regression analysis was used in order to determine the levels of predicting dependent variables of the independent variables which were determined to be correlated with each other. **Results:** According to the regression analysis result, quadriceps muscle strength affects 61% of change in squat splash height and 60% of change in counter-movement jump height. Hamstring muscle affects 56% of the change in squat jump height and 59% of the change in active jump height. However, when using segmental analysis, it was determined that concentric strength of the left-sided quadriceps muscle at 60°/sec affected squat jump and counter-movement jump performance positively on the weak level. The concentric and eccentric muscle strength of quadriceps muscle at 180°/sec angular velocity affected moderately positively the squat jump and counter-movement jump performance. At the same time, the right side eccentric contraction of the hamstring muscle at 60°/sec velocity was found to be an important predictor of squat jump and counter-movement jump. **Conclusion:** According to the results of the study, it was determined that the concentric and eccentric muscle strength of the quadriceps and hamstring muscles affected both the squat and counter-movement performance. We think that to increase the vertical jump performance, the eccentric muscle strength of the right hamstring muscle's and the concentric muscle strength of the left quadriceps muscle at the 60°/sec velocity and the concentric and eccentric muscle strength of the quadriceps muscle of both sides at the 180°/sn angular velocity should be increased.

Key Words: Volleyball, Jump, Muscle Strength, Isokinetic

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INTRODUCTION

Volleyball is one of the most popular sports in the world. In volleyball sports, explosive movements, fast moving, jumping and blocks are often used (Kim and Jeoung, 2016:429-437). Because the volleyball is played over a 2.43 meter high for men, vertical jump performance is particularly important. Volleyball players often make vertical jump during competition or training, during various defensive and offensive variations. Vertical jump height is considered to be an important predictor of many sports' performance which requires action to explosive power (Kenny and Gregory, 2006). Different vertical jump tests such as squat and countermovement jump are used in vertical jump evaluations. The Squat Jump has a mainly concentric working phase. However, in countermovement jump, a large centered eccentric movement is followed by homocentric concentric movement. The height reached in such jumps depends on the strength that the muscles can develop during stimulation (Pupo et al., 2012: 41-51).

This suggests the hypothesis that the concentric and eccentric muscular strength of knee extensors, an important parameter of sports performance of volleyball players, will be related to vertical jump performance. When the literature is examined in this respect; in a study while there were moderate and strong relationships between isokinetic muscle

strength of the knee joint and jump performance (Tsiokanos et al. 2002:107–115), low or negligible results were shown in other studies (Alemdaroglu, 2012:149–158; Iossifidou et al., 2005:1121–1127). However, in studies including well-trained, highly competitive athletes in this field, it was observed that the relationship between jump performance and concentric muscle strength of only the quadriceps muscle was generally investigated (Harrison et al., 2013: 175-180; Tsiokanos et al. 2002: 107-115). In the literature, the number of studies that shows a relationship between jump performance and concentric, eccentric muscle strength of quadriceps and hamstring group muscles is very small. Determining the relationship between concentric and eccentric muscle strength of hamstring and quadriceps muscles and jump performance will provide important information for the development of effective training methods and regeneration methods for elite volleyball players.

For this reason, the purpose of this study is to determine the relationship between the concentric and eccentric muscle strength of the quadriceps and hamstring muscles and jump performance of the elite male volleyball players.

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METHOD

Research group

The study included elite volleyball players who came to Turkey Olympic Training Center from September 15 to October 15, 2017. The exclusion criteria for participation in the study were as follows: playing volleyball in the first league less than three years, continuous pain in the lower extremities, having an orthopedic problem in the lower and upper extremities within the last six months, and no volunteering to participate in the study. Four of 32 players included in the study at the beginning were excluded from the study because of having the exclusion criteria, and so the study was completed with 28 elite male

volleyball players. In order to do the research, ethical committee approval was provided from Ankara Yıldırım Beyazıt University Social and Human Sciences Ethics Committee [642 (13.09.2017 / 15)] and before starting to work, the athletes were informed about the purpose, process, and activity of the study and written consent was obtained from volunteers based on volunteerism. The jump performance test and each isokinetic strength test were evaluated on different days after the players' dates of birth, body weights and heights were recorded.

The descriptive statistical results of the age, body weight, height, fat percentage, fat weight and lean body mass values of the players are given in table 1.

Table 1. Descriptive Statistical Results of the Age, Body Weight, Height, Fat Percentage, Fat Weight and Lean Body Mass Values of the Players

Descriptive Statistics (n = 28)	Age (years)	Body Weight (kg)	Height (cm)	Fat %	Body mass (kg)	Lean Mass (kg)	Sport Age (year)
Average	17,56	83,56	192,96	12,42	10,58	72,98	6,43
Standard deviation	1,94	10,63	6,36	3,18	3,81	7,94	1,21

Evaluation

The strength of knee flexors and extensor muscles of volleyball players was assessed with an Isomed 2000® isokinetic dynamometer (Ferstl, Germany). Before the test, the athletes were asked to run slowly (jogging) for 10 minutes. Tests were applied in sitting

position. The athletes were stabilized over the shoulders with device's shoulder pad, over the waist and distal femur with stabilization bands. The lateral condyle of femur was adjusted to be a pivot point. During the tests, the athletes were verbally encouraged. The strength of knee flexor and extender muscles

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was evaluated as being concentric and eccentric at 60 °/sec and 180 °/sec. At the end of the evaluation, peak torque (PT) values were obtained for knee extensor muscles at 60 °/sec and 180 °/sec. (Alemdaroglu, 2012:149–158; Soslu et al., 2016:164-173). In the evaluation protocol, knee flexion-extension movement: eccentric-concentric (quadriceps femoris muscle); knee flexion-extension movement: concentric-eccentric (hamstring muscles) were evaluated. During the evaluation, 3 repetitively warming and comprehension movements were performed before every velocity. The tests were then carried out at 60 °/sec and 180 °/sec angular velocities.

With the jump performance test, the players's jump height was measured. The players' jump performance tests were measured with the Opto Jump[®] Tester in the following protocols and the obtained results were recorded by the Opto Jump[®] device. The players were tested in turn after 15-minute personal warm-up periods. The Jump Performance tests were performed on two different protocols (squat and countermovement).

The squat jump test was applied in the form of a full jump in the upward direction when the knees were at 90° flexor and the hands

were in the belly (Sattler et al., 2012:1532-1538).

The countermovement jump test was performed by quickly squatting and then suddenly jumping vertically while the knees were fully in the extension and in the upright position. (Sattler et al, 2012: 1532-1538).

Statistical analysis

Statistics of the study were made using the SPSS 21 package program. Visual (histogram, probability plots) and analytical method (Kolmogorov-Smirnov test) were used to identify whether the variables were normally distributed. It was determined that all variables showed normal distribution. In order to examine the relation between variables, Pearson correlation analysis was used. To determine the levels to predict the dependent variables of independent variables from parameters which were correlated with each other, regression analysis was used. Statistical error level was determined as $p < 0.05$.

FINDINGS

The mean and standard deviation values belongs to right and left quadriceps (Q) and hamstring (H) values of the study group are given in Table 2.

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Table 2. The Mean and Standard Deviation Values Belongs to the Right and Left Quadriceps (Q) and Hamstring (H) Values of the Study Group

Variables	Mean	SD	Variables	Mean	SD
Right Q Ecc PT 60°/sn (Nm)	255,49	90,02	Right H Con PT 60°/sn (Nm)	130,62	27,91
Right Q Con PT 60°/sn (Nm)	264,47	62,21	Right H Ecc PT 60°/sn (Nm)	154,95	40,54
Left Q Ecc PT 60°/sn (Nm)	263,92	79,92	Left H Con PT 60°/sn (Nm)	121,62	30,17
Left Q Con PT 60°/sn (Nm)	259,99	53,96	Left Ecc PT 60°/sn (Nm)	149,97	41,60
Right Q Ecc PT 180°/sn (Nm)	268,10	70,46	Right H Con PT 180°/sn (Nm)	133,06	35,16
Right Q Con PT 180°/sn (Nm)	243,13	48,50	Right H Ecc PT 180°/sn (Nm)	153,93	44,64
Left Q Ecc PT 180°/sn (Nm)	267,88	91,83	Left H Con PT 180°/sn (Nm)	134,45	32,56
Left Q Con PT 180°/sn (Nm)	234,46	49,24	Left H Ecc PT 180°/sn (Nm)	153,28	40,52
Squat jumping (cm)	33,82	5,86	Squat jumping (cm)	35,47	5,66

Ecc: Eccentric; Con: Concentric; PT: Peak Tork.

The regression analysis results related to being evaluated of concentric and eccentric

muscle strength values of the right and left quadriceps muscles at 60-180 °/sec angular velocities of squat jump applied to the research group are given in table 3.

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Table 3. Regression Analysis Results on the Rediction of Squat Jump Skill Applied to Volleyball Players

Variable	B	Standard error	β	T	p	Relation r	Partial r
Constant	18,507	6,457		2,866	,012		
Right Q ECC PT 60	,035	,032	,537	1,107	,286	,119	,275
Right Q CON PT 60	-,044	,049	-,466	-,900	,382	,307	-,226
Left Q ECC PT 60	-,095	,049	-1,301	-1,948	,070	,158	-,449
Left Q CON PT 60	,059	,058	,547	1,026	,321	,374*	,256
Right Q ECC PT 180	,027	,032	,328	,863	,160	,402*	,217
Right Q CON PT 180	,067	,045	,552	1,473	,161	,531*	,355
Left Q ECC PT 180	,048	,028	,744	1,715	,107	,417*	,405
Left Q CON PT 180	,026	,043	,219	,611	,550	,628*	,156
R=,780	R ² =,608						
F ₍₈₋₁₅₎ =2,907	P=,036						

Ecc: Eccentric; Con: Concentric; PT: Peak Tork.

Table 3 shows that the right and left quadriceps muscles' concentric and eccentric muscle strength values at 60-180 °/sec angular velocity have a high and significant relationship with the squat jump ($R = ,780$, $R^2 = 608$, $p < 0,05$). The variables mentioned together represent about 61% of the variance in the squat jump. According to the standardized regression coefficient (β), it is seen that the predictive variables have no significant effect on the squat jump. When the relation between the predictor variables and the squat jump and partial correlations were examined,

it was found that the left quadriceps muscle at 60 °/sec angular velocity has a low level of correlation with the concentric muscle strength, on the other hand the right and left quadriceps muscles at 180 °/sec angular velocity have moderate and positive correlations with the concentric eccentric muscle strength variables.

Regression analysis results of being co-evaluated of concentric and eccentric values of the right and left hamstring muscles at 60-180 °/sec angular velocity of squat jump applied to the research group are given in Table 4.

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Table 4. Regression Analysis Results on the Prediction of Squat Jump Skill Applied to Volleyball Players

Variable	B	Standard error	β	T	p	Relation r	Partial r
Constant	27,008	5,266		5,129	,000		
Right H CON PT 60	,087	,080	,414	1,100	,289	,159	,273
Right H ECC PT 60	,170	,059	1,156	2,861	,012	,305*	,594
Left H CON PT 60	,050	,120	,258	,421	,680	,064	,108
Left H ECC PT 60	-,063	,107	-,441	-,588	,566	-,039	-,150
Right H CON PT 180	-,048	,091	-,289	-,532	,603	-,007	-,136
Right H ECC PT 180	-,055	,059	-,409	-,935	,365	-,114	-,235
Left H CON PT 180	-,019	,092	,106	,204	,841	-,081	-,052
Left H ECC PT 180	-,099	,098	-,682	-1,015	,326	-,072	-,254
R=,747	R ² =,559						
F ₍₈₋₁₅₎ =2,373	P=,041						

Ecc: Eccentric; Con: Concentric; PT: Peak Tork.

Table 4 shows that the concentric and eccentric muscle strength values of the right and left hamstring muscles at 60-180 °/sec angular velocity give a high and significant relationship with the squat jump ($R = ,747$, $R^2 = 559$, $p < 0,05$). The variables mentioned together represent about 56% of the variance in the squat jump. According to the standardized regression coefficient (β), the predictive variables were found to be a significant predictor of the eccentric muscle strength variable of right hamstring muscle at only 60 °/sec angular velocity on squat jump. Other variables appear to have no significant effect. When the relation between the predictor variables and

the squat jump and partial correlations are examined, At 60 °/sec angular velocity, the right hamstring muscle was found to have a low and positive relationship with eccentric muscle strength change.

Regression analysis results of being co-evaluated of concentric and eccentric muscle strength values of the right and left quadriceps muscles at 60-180 °/sec angular velocity applied to the study group are given in Table 5.

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Table 5. Regression Analysis Results on the Prediction of Countermovement Jump Skill Applied to Volleyball Players

Variable	B	Standard error	β	T	P	Relation r	Partial r
Constant	18,011	6,313		2,853	,012		
Right Q ECC PT 60	,023	,031	,372	,758	,460	,146	,192
Right Q CON PT 60	-,044	,048	-,481	-,918	,373	,280	-,231
Left Q ECC PT 60	-,059	,048	-,833	-1,233	,237	,280	-,303
Left Q CON PT 60	,052	,057	,492	,913	,376	,465*	,230
Right Q ECC PT 180	,027	,031	-,336	,873	,204	,396*	,220
Right Q CON PT 180	,074	,044	,631	1,666	,117	,569*	,395
Left Q ECC PT 180	,030	,027	,488	1,112	,284	,470*	,276
Left Q CON PT 180	,028	,042	,239	,660	,519	,684*	,168
R=,774	R ² =,599						
F ₍₈₋₁₅₎ =2,798	P=,041						

Ecc: Eccentric; Con: Concentric; PT: Peak Tork.

Table 5 shows that the concentric and eccentric muscle strength values of the right and left quadriceps muscles at 60-180 °/sec angular velocity have a high and meaningful relationship with countermovement jump ($R = ,774$, $R^2 = ,599$, $p < 0,05$). The variables mentioned together represent about 60% of the variance in the countermovement jump. According to the standardized regression coefficient (β), it is seen that the predictive variables have no significant effect on the countermovement jump. When the relation between the predictor variables and the squat jump and partial correlations were examined, it was determined that the left quadriceps muscle at 60 °/sec

angular velocity has a low relationship with the concentric muscle strength, and also the right and left quadriceps muscles at 180 °/sec angular velocity have moderate and positive relationships with the concentric eccentric muscle strength variables.

Regression analysis results of being co-evaluated of concentric and eccentric muscle strength values of the right and left quadriceps muscles at 60-180 °/sec angular velocity ($X_{ort} = 35.48 \pm 5.66$ cm) of the countermovement jump skill applied to the study group are given in Table 6.

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Table 6. Regression Analysis Results on the Prediction of Countermovement Jump Skill Applied to Volleyball Players

Variable	B	Standard error	β	T	p	Relation r	Partial r
Constant	29,210	4,905		5,956	,000		
Right H CON PT 60	,064	,074	,313	,863	,402	,136	,217
Right H ECC PT 60	,156	,055	1,094	2,808	,013	,318*	,587
Left H CON PT 60	,071	,112	,378	,639	,532	,143	,163
Left H ECC PT 60	-,011	,100	-,077	-,106	,917	,023	-,027
Right H CON PT 180	-,020	,085	-,123	-,234	,818	,028	-,060
Right H ECC PT 180	-,094	,055	-,724	-1,717	,107	-,148	-,405
Left H CON PT 180	,005	,085	,027	,054	,958	,127	,014
Left H ECC PT 180	-,109	,091	-,774	-1,195	,250	-,052	-,295
R=,768	R ² =,590						
F ₍₈₋₁₅₎ =2,699	P=,046						

Ecc: Eccentric; Con: Concentric; PT: Peak Tork.

Table 5 shows that the concentric and eccentric muscle strength values of the right and left hamstring muscles at 60-180 °/sec angular velocity have a high and significant relationship with countermovement jump ($R = ,768$, $R^2 = 590$, $p < 0,05$). The variables mentioned together represent about 59% of the variance in the countermovement jump. According to the standardized regression coefficient (β), the predictive variables are an important predictor of the eccentric muscle strength variable of the right hamstring muscle at 60 °/sec angular velocity on the countermovement jump. Other variables do not seem to have a

significant effect. When the relation between the predictor variables and the countermovement jump and partial correlations were examined, it was determined that the right hamstring muscle at 60 °/sec angular velocity has a low level of positive relationship with the eccentric muscle strength variables.

DISCUSSION

Volleyball is one of the most popular sports in the world. Jump is one of the most used movements in the volleyball game. It is reported that muscle strength is among the factors affecting the jump movement (Magalhaes et

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al., 2004: 119-125; Voelzke et al., 2012: 457-462). The purpose of this article is to determine the independent muscular variables that predict the vertical jump performance in elite male volleyball players. In elite male volleyball players, a simple linear regression analysis was used to estimate the effect on different contraction types (concentric, eccentric) of two different muscles (quadriceps, hamstring) and vertical jump height at different angular velocities (60 and 180 °/sec). According to the observed regression values, quadriceps and hamstring muscles have over 50% effect on the changes in squat and countermovement jump heights. However, when segmental analyzes are used, it was determined that the quadriceps muscle affected the squat and countermovement jump performance of the concentric and eccentric muscle strength at 180 °/sec angular velocity moderately and positively.

Vertical jump movements are closely related to the explosive power and anaerobic capacity of the leg extender muscles (Harrison et al., 2013: 175-180; Tsiokanos et al., 2002: 107-115; Rousanoglou et al., 2008; 22(4):1375-1378). In the literature, it is reported that jump performance can be influenced by many factors such as age, training status, muscle strength, anthropometric properties and jumping depth (Sheppard et al., 2008: 758-765; Malliou et al., 2003: 165-169). At

the same time there are studies showing that jump height is related to the concentric muscle strength of the knee extensors (Rouis et al., 2015: 1-2), and vertical jump increases as a result of the lower extremity muscle strength training (Voelzke et al., 2012: 457-462).

When the jump activity is examined in terms of the activity of the quadriceps muscle, it is seen that the squat jump movement occurs with the concentric explosive power of the quadriceps muscle followed by eccentric quadriceps contraction during the landing (Sattler et al., 2012: 1532-1538). In the case of countermovement jump, a concentric contraction follows the eccentric contraction of the quadriceps muscle. In this context, it is reasonable to hypothesize that the jump performance is related to both the concentric and eccentric muscle strength of the quadriceps muscle. As a matter of fact, our study results support this hypothesis. In the literature, in parallel with these results there are studies showing the relation between jump performance and lower extremity muscle strength (Tsiokanos et al., 2002: 107-115; Paasuke et al., 2001: 354-361).

When the jump performance is examined in terms of activity of the hamstring muscle, it is detected that the jump movement occurs as a result of contracting effectively and generating force of the flexor and extensor muscles in the thigh. In the literature, although there

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have been several studies showing that knee extensor muscles affect jump performance (Rouis et al. 2001: 354-361; De Ruiter et al., 2006: 1843-1852), there are very few studies (Sattler et al., 2012:1532-1538) examining the relation with jump performance of the knee flexors (De Ruiter et al., 2006:1843-1852), which are also hip extensor muscles. Knee flexors are important not only for standing up from squatting position but also for balancing and protecting posture during taking off after jumping and landing (De Ruiter et al., 2006: 1843-1852).

In the study of Sattler et al. showing similar features with our work, in female volleyball players, the flexor and extensor muscles of the knee joint in the lower extremity were found to be an important determinant of the jump performance of eccentric and concentric strength (Sattler et al., 2012: 1532-1538). Similarly, in our study, it was determined that the isokinetic muscle strength of the quadriceps muscle was highly correlated with the squat and countermovement jump test, and that the isokinetic muscle strength of the quadriceps muscle was a factor influencing the countermovement jump by 60%. It was also found that the left quadriceps muscle was related to concentric muscle strength at 60 °/sec angular velocity and the left and right quadriceps muscles were correlated with concentric and eccentric muscle strength in the moderate

range and positive direction at 180 °/sec angular velocity. In parallel with this situation, it was determined that the isokinetic muscle strength of the hamstring muscle group was highly correlated with the countermovement jump test and the isokinetic muscle strength of this muscle group was a factor that affected the squat jump by 56% and countermovement jump by 59%. According to the standardized regression coefficient (β), the predictive variables were found to be a significant predictor of the eccentric muscle strength variable at the only right hand hamstring muscle on the countermovement jump 60 °/sec angular velocity. In volleyball players, it was determined that there was a positive weak correlation between the eccentric muscle strength of the right hamstring muscle group and jump height at 60 °/sec angular velocity.

As a result of our work, it was determined that the jump performance was affected by the strength of the quadriceps muscle rather than the strength of the hamstring muscle group, and that the quadriceps muscle was influenced by both eccentric and concentric muscle strength. It was also concluded that the left side quadriceps muscle strength with respect to the right side and the concentric muscle strength of the quadriceps muscle at 180 °/sec angular velocity with respect to 60 °/sec angular velocity are more effective parameters on the jump performance. Our results are si-

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milar to those existing in the literature (De Ruiter et al., 2006:1843-1852; Saliba and Hrysimallis, 2001:336-47; Genuario and Dolgener, 1980:593-8; Gauffin et al., 1989:215-24). We think that this situation was due to the fact that the type of muscle fiber involved during vertical jumping, that is, type IIa fibers that engaged in high-speed movements was also related to being activated at high angular velocities (Gregor et al., 1979: 388-92; Glenmark 1994: 1-47). Indeed, vertical jump performance has a positive correlation with the percentage of type IIA muscle fibers (Glenmark 1994: 1-47).

The limitations of our study are to take only male volleyball players and use two angular velocities. At the same time, that the relationship between conventional and functional ratios and jump performance has not been investigated is another limitation. There is a need for studies which will examine the relationship between muscle strength, jump performance, and muscle strength rates at different angular velocities in both genders including more people and sports branches.

CONCLUSION

In our study; it was determined that concentric and eccentric muscular strength of quadriceps and hamstring group muscles affected both squat and countermovement jump performance. It was also found that the concentric and eccentric muscular strength of the quadriceps

muscle at 180 °/sec angular velocity significantly affected the squat jump and countermovement jump performance. To increase jump performance, we think that the concentric and hamstring muscular strength at 60 °/sec angular velocity of the left quadriceps muscle as well as the concentric and eccentric muscle strength at 180 °/sec angular velocity of the quadriceps muscle on both sides should be increased. Because of that, concentric and eccentric strengthening of the quadriceps muscle at 180 °/sec angular velocity can increase the jump performance.

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