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Original article

EXAMINATION OF ATHLETES VERTICAL JUMP HEIGHTS AND RECORDS IN THE SQUAT EMG STUDY

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Abstract

Aim. The purpose of this study was to examine the athletes vertical jump heights and records in the squat(electromyogram) EMG study.

Methods. For this purpose 34 male participants attended as volunteers who are studying in Erciyes University, School of Physical Education and Sports, and mean age, height and weight were 22.47±1.83 (year),177.38±7.60 (cm)73.21±9.84 (kg),respectively. In the examination day, the participants were requested to do physical activity, and they were subjected to 2 different measurements after preparation phase. The main muscles measured in volunteers were m. Quadricepsfemoris and m. Bicepsferomis. Firstly vertical jump measurement was made with Newtest jump mat, in the same day. When athlete's knee joint angle was 90^o and by use of arms, the highest measurement was recorded after repeating five times. Through the measurements, EMG records continued. The second test was measurement of squat with maximum weight. Maximal weight was calculated with 1RM method in athletes who begin warming with empty bar and the squat table was adjusted for each athlete's height. After that, EMG measurements of athletes, who started to perform maximal squat at the knee joint angle of 90°, were taken. The highest section was taken in both measurements.

Results. According to the results; positive correlation was determined between body weight (r=0.825, p<0.001) and anaerobic power. Positive correlation was found between Vertical Jump height (r=0.394, p<0.05) and the value of jump-BF-MF (BF: biceps femoris) (MF: median frequency). A negative correlation was observed between Vertical Jump height (r=-0.361, p<0.001) and jump-quadriceps-median frequency.

Conclusions. In conclusion, some differences were observed according to contraction type between extension and flexion of m. quadriceps femoris and m. biceps femoris muscles in athletes of whom squat and vertical jump measurements were performed simultaneously.

Key Words: EMG, vertical jump measurement, squat, anaerobic power

Introduction

Twitch able muscle cells creates electrical potentials like other active cells and skeletal muscle activities are evaluated by using records of these differences with EMG (Eston and Reilly, 1996, Petrofsky and Laymon, 2005, Vander, Sherman, Luciano, 1980, Ebersole and Malek, 2008). Although EMG measurement does not give us contraction type the strength of muscle contraction, it gives information about muscles becoming a part with the analysis of motor unit action potentials and motor nerves. Also, EMG is used to evaluate the muscles stretch during isometric or dynamic exercises, or to determine the degree of fatigue (Clarys and Cabri, 1993).

The electric signals produced by muscle cells which are contracted are directly proportionate to the number of motor unit during static and dynamic contraction and strength generated (Arheim, 1989). The number of active motor units, firing frequency and synchronization determine the amount of EMG activity (Collins, 1994, Dionisio, Almeida, Duarte, Hirata, 2006). This action potential of muscles is measured by needle or surface electrode. Especially them easurements made with surface electrodes are commonly use in sports researches (Eston and Reilly, 1996, Escamilla, Fleisig, Zheng, 2001). The studies about EMG measurement have been made in various sport types and different positions for many years.

These are some of them: EMG activities of synergist and antagonist leg muscles while lifting weight, EMG activities of leg muscles during squat at different knee angles, EMG activity of leg muscles at different foot angles during leg press and squat (Sriwarno, Shimomura, Iwanaga, Katsuura, 2008, Goodwin, Koorts, Mack, Mai, Morrissey, 1999). While an exercise is performed on joints by use of the strength produced by eccentric or concentric contraction, a force is applied to the constant objects with isometric contraction; even the muscle is active, the length of muscle-tendon does not change. Therefore, posture is maintained with isometric contraction and joint stabilization is provided (Ebersole and Malek, 2008).This amount of muscle strength generated by dynamic and static contractions is measured with various dynamometers (Richard, 2002). Squat position which is made by use of hip, knee and ankle joint flexion is used in many kinds of sports, especially

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in weightlifting to test the leg strength.

Although there are some studies about EMG records of muscles at various ankle angles during squat or about EMG records during strength measurements, there are no studies about the attendance of leg muscles during isometric strength measurement with dynamometer at different ankle angles.

Daily life movements and sportive activities depend on function. Main elements such as coordination, strength, flexibility and neuromotor functions which involve proprioception are important and directly related to the possibility of injury for all athletes (Hill, 1970). Some studies which include EMG evaluations during functional activities are available (Wilkie, 1968).Also, some studies which investigate EMG results during jump are existed (Hill, 1968).Despite all, the fewness of the studies made in sports branch in which jump is efficient or in which EMG records are taken during muscle contraction with maximum weight leads to lack of literature.

In this regard, main purpose of this study is to examine the relationship between athletes' vertical jump height and EMG records of concentric and eccentric muscle contractions with maximal weight.

Method

Subjects

Thirty four volunteers at mean age22 years, studying in Erciyes University physical education and Sport School, and doing exercise daily, participated in this research. Also ethic committee report was taken from Erciyes University Medical Faculty Deanery before starting research. All volunteers were informed about the research.

Height Measurement

Volunteers' height was measured on a standing position and barefoot with a tape measure on the wall, including 1 mm gaps, and was recorded as cm.

Bioelectric Impedance Measurement

Bioelectric Impedance analysis is a method that is used to determine body composition. Alternative currents at different frequencies are given to the tissue bed with electrodes and decline in current voltage is identified as "impedance" (Bauer, Pivarnik, Fornetti, 2005). Bioelectric impedance analysis measurement was made with the device of "Tanita-BC 418 MA (Tanita Corporation, Tokyo, Japan). Tanita device has 8 electrodes and uses high frequency constant current source (Çalışkan, 2007, Turner, Nieto, Bouffard, 2003).Volunteers were told to give up eating and drinking at least 4 hours ago and not to take a bath or sauna, not to consume alcohol during training period, and not to do exercise on the test day. Also, they were told to wait on a standing position and barefoot on the metal surface of the device thereby taking hold of definite parts and to leave free their arms parallel with their body.

Measurements lasted 1-2 minutes for each volunteers and results printed from bioelectric impedance analysis device. The values of body weight, body mass index, basal metabolic rate, body fat percentage, fat-free mass and total body water measurements were recorded on the output of bioelectric impedance analysis device.

Preparation Stage Before EMG Measurement

Putting electrodes were started on dominant leg after asking volunteers.The region of skin was shaved before putting electrodes. To decrease the skin impedance, skin surface was cleaned with alcohol. Superficial electrodes (biopac electrode) determined the puffy region of biceps femoris (BF) and quadriceps by checking with hands, and were placed lengthwise over the muscle surface with 2 cm spacing. Electrodes were stabilized on the leg with the help of bandage or plaster to prevent the arte facts arising from cables based on movement (Guyton and Hall, 2001, Maughan and Gleeson, 2010, Halson, Matthew, Romain, Bart, Michael, 2002).

Squat Measurement With Maximum Weight

Squat tables were adjusted for each athlete height. Athletes warmed up by use of a lifting bar without weight. Then, the maximal weight for squat was calculated thereby using 1RM test. Enough resting period was given to the athletes. After resting period, they were asked to take their position for maximal squat by providing motivation. They tried test after taking suitable position (at knee joint angle of 90^o)by using lifting bar without weight. Then, they performed squat with maximum weight. EMG records were taken during all measurements.

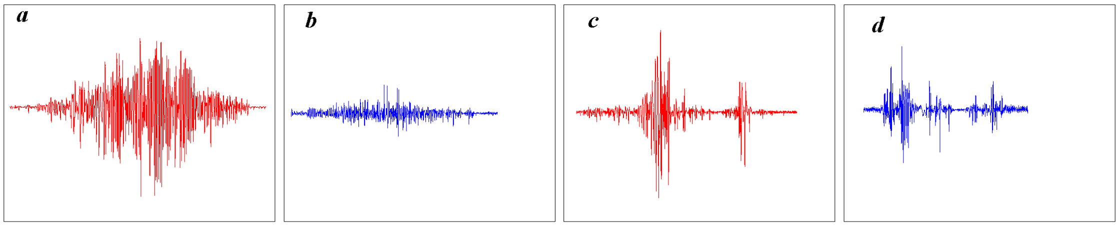
Vertical Jump Measurement

New Test Jump Mat was used to test vertical jump. Athletes were allowed to use their arms to show higher performance during jump at a knee angle of 90^o. Vertical jump was repeated five times and the highest one was used. EMG records were taken during all tests.

EMG Measurement

Electromyogram record was done via the device named as BIOPAC MP30. EMG signals of quadriceps femoris and biceps femoris muscles during squat and vertical jump with maximum weight were recorded.

Two channels were used in the research. Raw-EMG signals were preamplified (acquisition 412.) and band-pass was filtered between 30-500 Hz. It was amplified and converted into a digital from analog at the rate of 1 kHz sampling.



Figures. The sections of EMG signals: a) Quadriceps femoris muscle during squat with maximum weight, b) Bicepsfemoris muscle during squat with maximum weight, c) Quadriceps femoris muscle during maximum vertical jump height, d) Bicepsfemoris muscle during maximum vertical jump height.

Anaerobic Power Calculation

Anaerobic power was calculated with the Lewis formula as kg-m/sec, by using body weight and measuring the distance of jumping (90).

$$P=\sqrt{4.9}\ \text{x (Body weight) x}\ \sqrt{D}$$

P = Anaerobic power (kg.m/sec)
D = Vertical jump distance as (Meter)

Statistical Analysis

The SPSS 16.0 software package program for Windows was used to analyze the data.All data for descriptive statistics were reported as mean and standard deviation. The data were tested for normal distribution with the Shapiro-Wilk test. The Pearson product-moment correlation analysis was applied for variables which show normal distribution. Spearman's rank correlation coefficient analysis was conducted for data which does not show normal distribution. Significance level was taken as $p<0.05$.

Results

Table 1. Physical characteristics of male subjects (n=34)

Variable	X±SD
Age (year)	22.47±1.83
Height (cm)	177.38±7.60
Weight (kg)	73.21±9.84
BMI (kg/m^2)	23.18±2.40
Body Fat Percentage (%)	11.07±4.92
Fat mass (kg)	8.25±4.16
Fat Free mass (kg)	65.01±8.03
Muscle mass (kg)	61.92±7.63
Total Body Water (kg)	47.59±5.88
Bone Weight (kg)	3.10±0.54

BMI: Body Mass Index, X: mean, SD: Standard Deviation, n: number of subjects.

Table 2. Volunteers Descriptive Statistics About EMG Variables (n=34)

Variable	X±SD
Vertical Jump(BF)-MF	68.81±13.30
Vertical Jump(BF) – RMS	0.16±0.11
Vertical Jump(QF)- MF	62.27±15.00
Vertical Jump(QF) – RMS	0.28±0.18
Squat (BF) – MF	72.39±16.51
Squat (BF) – RMS	0.18±0.14
Squat (QF)-MF	59.52±9.50
Squat (QF)-RMS	0.40±0.23

RMS: Root MeanSquare, **BF**: BicepsFemoris Muscle, **QF:** Quadriceps Femoris Muscle, **MF:** Median Frequency, X: mean, SD: Standard Deviation, n: number of subjects.

Table 3. Volunteers Descriptive Statistics About Activity Performances (n=34)

Variable	X±SD
Vertical Jump Height (cm)	43.71±7.00
Maximum Weight Lifted (kg)	83.59±21.64
Anaerobic Power (kg.m/sec)	106.58±14.42

X: mean, SD: Standard Deviation, n: number of subjects.

Table 4. Relations between Volunteers Physical Features and sEMG Records (n=34)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Age (Year)	r	1																				
Weight (kg)	r	-.168	1																			
Height (cm)	r	-.179	**.554****	1																		
Body Mass Index (kg/m^2)	r	-.056	**.688*****	-.022	1																	
Body Fat Percentage (kg)	r	.152	**.271**	-.246	**.539****	1																
Muscle Mass (kg)	r	-.242	**.919*****	**.713*****	**.552****	-.078	1															
Fat Mass (kg)	r	.085	**.607*****	**-.058**	**.750*****	**.940*****	.246	1														
Fat Free Mass (kg)	r	-.248	**.911*****	**.712*****	**.542****	-.100	**.999*****	.225	1													
Total Body Water (kg)	r	-.247	**.911*****	**.712*****	**.542****	-.100	**.999*****	.225	**1.000*****	1												
Bone Weight (kg)	r	-.278	**.588*****	**.526****	.288	**-.383***	**.757*****	-.127	**.785*****	**.784*****	1											
Maximum Weight (kg)	r	.039	.050	-.102	.175	.000	-.030	.054	-.025	-.023	.036	1										
Vertical Jump Height (cm)	r	.139	-.234	-.064	-.221	-.165	-.160	-.258	-.157	-.158	-.065	.092	1									
Anaerobic Power (kg.m/sec)	r	-.070	**.825*****	**.499****	**.604*****	.186	**.800*****	**.413***	**.794*****	**.794*****	**.536****	.045	**.352***	1								
Jump - BF - MF	r	.006	-.170	-.220	-.077	.027	-.200	-.046	-.191	-.191	-.015	.074	.189	-.044	1							
Jump - BF-RMS	r	.291	.083	-.010	.078	-.057	.018	-.023	.034	.033	.142	-.026	**.394***	.269	.013	1						
Jump - QF - MF	r	-.021	.202	.330	-.001	-.052	.219	.058	.220	.219	.174	-.136	**-.361***	-.032	-.233	-.084	1					
Jump - QF - RMS	r	.305	-.149	.097	-.211	-.109	-.095	-.187	-.087	-.087	.045	-.316	**.417***	.104	.306	**.420***	-.337	1				
Squat - BF – MF	r	-.061	.005	-.064	.009	-.100	.052	-.147	.085	.086	.203	.162	-.092	.004	**.491****	-.116	-.197	.228	1			
Squat - BF- RMS	r	.203	-.081	-.284	.193	.008	-.179	.019	-.158	-.160	-.064	.225	.271	.031	.051	**.593****	-.103	.102	-.042	1		
Squat - QF - MF	r	-.119	.121	.055	.097	-.249	.218	-.133	.220	.219	.167	.068	-.269	-.040	-.188	**-.365***	**.587****	**-.436****	-.058	-.210	1	
Squat - QF -RMS	r	.267	-.155	-.199	.008	.086	-.187	-.029	-.178	-.178	.011	.270	**.419***	.110	.163	**.438****	**-.387***	**.627****	.029	**.485****	**-.397***	1

***P<0.05, **P<0.01, ***P<0.001, BMI:** Body Mass Index, **BF:** Biceps femoris muscle, **QF:** Quadriceps femorismuscle,**RMS:** Root mean square, **MF:** Median frequency

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Positive correlations were found among body weight and height (r=0.554, p<0.01), body weight and body mass index (r =0.668, p<0.05), body mass index and body fat percentage (r =0.539, p<0.01), body weight and body fat mass (r=0.607, p<0.001),body fat mass and body fat percentage (r=0.940, p<0.001), fat free mass and height (r=0.712, p<0.001), fat free mass and body weight(r=0.911, p<0.05) fat free mass and body mass index (r=0.542, P<0.01), muscle weight and height (r=0.713, p<0.001), muscle weight and body weight (r=0.919, p<0.05) ,muscle weight and body mass index (r=0.552, p<0.01),muscle weight and body fat free mass (r = 0.999, p<0.01), total body water and height (r=0.712, p<0.01), total body water and weight (r=0.911, p<0.01), total body water and BMI (r=0.542, p<0.01), total body water and body fat free mass (r=1.000, p<0.01), total body water and muscle weight(r=0.999, p<0.01), height and bone weight (r=0.526, p<0.01),body weight and bone weight (r=0.588, p<0.001), body fat free mass and bone weight (r=0.785, p<0.001), muscle weight and bone weight (r=0.757, p<0.001), total body water and bone weight (r=0.784, p<0.001).

Negative correlation was detected between body fat percentage and bone weight (r=- 0.383, p<0.05). Positive correlations were observed among anaerobic power and body weight (r=0.825, p<0.001), height (r=0.499, p<0.001), body mass index (r=0.604, p<0.001), muscle weight (r=0.800, p<0.001), fat mass (r=0.413, p<0.001), body fat free mass (r=0.794, p<0.001), total body water (r=0.794, p<0.001), bone weight (r=0.536, p<0.01), vertical jump height (r=0.352, p<0.001). Positive correlation was observed between vertical jump height and Jump-BF-MF (r=0.394, p<0.05). Negative correlation was found between jump height and Jump-QF-MF (r=-0.361, p<0.001). Positive correlations were found among jump height and Jump-QF-RMS (r=0.417, p<0.001), Jump-QF–RMS and Jump-BF-RMS (r=0.420, p<0.05), Jump-BF-MF and Squat-BF–MF (r=0.491, p<0.01), Squat-BF-RMS and Jump-BF-RMS (r=0.593, p<0.01).

Negative correlation was detected between Squat-QF-M Fand Jump-BF-RMS (r=-0.365, p<0.05),between Squat-QF-MF and Jump-QF-RMS (r=-0.436, p<0.01). Positive correlations were observed between Squat-QF-MF and Jump-QF-MF (r=0.587, p<0.01), and among Squat-QF-RMS and jump height (r=0.419, p<0.05), Jump-BF-RMS (r=0.438, p<0.01), Jump-QF-RMS (r=0.627, p<0.01), Squat-BF-RMS (r=0.485, p<0.01). Negative correlation was found among Squat-QF-RMS and Jump-QF-MF (r=-0.387, p<0.05), and Squat-QF-MF (r=-0.397, p<0.05).

Discussion

The most important finding of this research was determining positive correlation between vertical jump height and jump-biceps femoris. It should be considered that flexors and extensors are effective in jumping. Therefore, it is seen that muscle length becomes longer while joint angle is widen during contraction (Yaprak, Tınazcı, Ergen, 2009). Results are in accord with about that there is a positive relationship between the EMG records of biceps femoris muscle and jump height in elite female rhythmic gymnasts (Arpınar, Nalçakan, Akhisarlıoğlu, Kutlay, Koşay, 2003).

Also, the other important finding is negative correlation found between jump height and jump-quadriceps-median frequency. Quadriceps femoris, which is the most important element to affect knee joint and stabilizes knee joint via patella and patellar tendon, has difficulty in maintaining this functions long as the jump height increases.

A study compared jump height and EMG results, and found strong correlation between EMG activity of quadriceps muscle and jump height; and found weak correlation between jump height and biceps femoris muscle (Arpınar, Nalçakan, Akhisarlıoğlu, Kutlay, Koşay, 2003). In another study, no correlation was found between quadriceps muscle and jump height in rhythmic gymnasts, and it was reported that the reason of detecting no correlation is participants of whom muscle and motor development is still growing (Arpınar, Nalçakan, Akhisarlıoğlu, Kutlay, Koşay, 2003).

Therefore, it was seen that the intervention gets more difficult when jump height ofthese two tendons increases. In other words, it means that quadriceps femoris blocks knee extension (Demirel and Koşar, 2002). Also, correlation between jump height and jump-quadriceps-RMS shows the positive relationship between knee joint stabilization, via patella and patellar tendon, and the weight applied to this muscle group. Thus, it was seen that quadriceps femoris stably provides knee extension as jump height increases. This means that muscle length gets longer. This finding contrasts with the study in which no correlation was found between EMG records of quadriceps muscle and jump height in rhythmic gymnasts (Arpınar, Nalçakan, Akhisarlıoğlu, Kutlay, Koşay, 2003).

Also, positive correlation between jump-biceps femoris-MF and squat-biceps femoris-MF shows that there is a continuous and repetitive relationship among jump height and the factors consisting of warming up by use of a lifting bar without weigh, knee flexion with maximum weight at 90^o knee angle and the internal rotation of tibia during knee flexion (Demirel and Koşar, 2002).

As for another finding, positive correlation was detected between jump-biceps femoris-RMS and squat-biceps femoris-RMS. This result shows that there is a high correlation between the internal rotation of tibia during squat and the weight applied on the muscle during ertical jump (Demirel and Koşar, 2002, Dere, 1999). These results are in conflict with the alterations of biceps femoris muscle during jump in another study. It should be kept in mind that the reason is the sample group who are 12 elite Norwegian female volleyball players (Padulo, Tiloca, Powell, Granatelli, Bianco, 2013).

The positive correlation was detected between leap-quadriceps-MF and squat-quadriceps-MF. This correlation and knee joint extension prove that there is a high relationship between mean EMG records taken from jump and mean EMG records during squat. This muscle movement shows similarity to the results of a research related to quadriceps femoris muscle (Begalle, DiStefano, Blackburn, Padua, 2012).

Other important results were found in other parameters related to the squat-quadriceps-RMS. According to this, there is a positive correlation between the highest EMG records of the athletes, who perform maximal squat, and the highest EMG records of jump height.

Accordingly, in this situation, when an athlete can jump as high as possible with maximum weight, quadriceps femoris muscle makes the knee extension and prevents patella in order not to move towards the lateral (Demirel and Koşar, 2002). This also means that dynamic contraction occurs and muscle length gets shorter (Nalçakan, 20019).

A positive correlation was observed between squat-quadriceps-RMS and squat-biceps femoris-RMS. This shows that knee joint makes extension during maximal squat and rectus femoris helps thigh flexion, and so facilitates movements of knee (Demirel and Koşar, 2002).

Conclusions

Finally, a negative correlation was found between squat-quadriceps-RMS and jump-quadriceps-MF; and between squat-quadriceps-RMS and squat-quadriceps-MF. Aaccordingly, The relationship between knee extension and flexion are inversely correlated between the highest measurements in EMG records of maximal squat test and vertical jump. The other negative correlation was found between squat-quadriceps-MF and squat-quadriceps-RMS. It means that no meaningful relationship was observed between mean values and the highest values of EMG records in athletes who perform maximal squat test. It should be added that the highest values in this direction progressively increase with engagement of motor unites.

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