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Investigation of the Relationship Between Isokinetic Knee Strength and Ultrasonographic Muscle Thickness in Young Male Soccer Players

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ORIGINAL ARTICLE

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Abstract

The aim of this study is assessment of correlation between isokinetic muscle strength and muscle thickness. 54 young male athletes playing in the U17 and U19 age groups of Denizlispor, a Turkish professional soccer 1st league team, voluntarily participated in the study. Muscle thickness (rectus femoris, vastus intermedius, gluteus maximus) was measured using Real-time ultrasound (RTUS) imaging. Muscle strength (30°/s-1, 60°/s-1, 180°/s-1) was measured using Humac Norm/Cybex dynamometry. Statistically, the difference between isokinetic muscle strength and muscle thickness between Gluteus maximus - 30°/s-1 Gluteus concentric torque, Rectus femoris - 60°/s-1 Knee concentric torque, Vastus intermedius - 180°/s-1 Knee concentric torque, Rectus femoris+vastus intermedius - 60°/s-1 Knee concentric torque values was significant. In conclusion, this study showed significant and high correlations between quadriceps thickness measurements and muscle strength. This study may allow one to determine the convenient load on the players' knee joints and to prevent injuries.

Keywords: Strength, Isokinetic, Ultrasonographic, Muscle Thickness, Soccer.

Genç Erkek Futbolcularda İzokinetik Diz Kuvveti ile Ultrasonografik Kas Kalınlığı Arasındaki İlişkinin İncelenmesi

Öz

Bu çalışmanın amacı, izokinetik kas kuvveti ile kas kalınlığı arasındaki ilişkinin değerlendirilmesidir. Araştırmaya Türkiye profesyonel futbol 1. ligi takımlarından Denizlispor'un U17 ve U19 yaş gruplarında oynayan 54 genç erkek sporcu gönüllü olarak katılmıştır. Kas kalınlığı (rektus femoris, vastus intermedius, gluteus maksimus) gerçek zamanlı ultrason (RTUS) görüntüleme kullanılarak ölçülmüştür. Kas kuvveti (30°/s-1, 60°/s-1, 180°/s-1) Humac Norm/Cybex dinamometri kullanılarak ölçülmüştür. İstatistiksel olarak izokinetik kas kuvveti ve kas kalınlığı arasında Gluteus maximus - 30°/s-1 Gluteus konsantrik tork, Rectus femoris - 60°/s-1 Diz konsantrik tork, Vastus intermedius - 180°/s-1 Diz konsantrik tork, Rectus femoris+vastus intermedius - 60°/s-1 Diz konsantrik tork değerleri arasındaki fark anlamlıdır. Sonuç olarak, bu çalışma kuadriseps kalınlık ölçümleri ile kas kuvveti arasında anlamlı ve yüksek korelasyonlar göstermiştir. Bu çalışma, oyuncuların diz eklemleri üzerindeki uygun yükün belirlenmesine ve sakatlıkların önlenmesine olanak sağlayabilir.

Anahtar kelimeler: Kuvvet, Izokinetik, Ultrason, Kas Kalınlığı, Futbol.

Introduction

In practice, assessments of muscle mass and muscle strength are performed for various conditions. In fact, the ability to perform activities of sports is determined by the performance of the muscle function. The number of tools available to perform such assessments is substantial (Magalhaes et al., 2004; Freiberger et al., 2012). To date, limited information is available about the tools used to assess muscle strength and muscle mass in sporting performance. The gap between research findings and their translation into practice is a, in part, common problem that affects activities of sports (Cooper et al., 2013). With this information, there are many methods that can be used to assess muscle mass. These methods can be summarized as US, MRI, CT, BIA, DXA, and anthropometric measurements (Cooper et al., 2013; Walowski et al., 2020). Although BT and MRI are accepted as the gold standard in evaluating muscle mass, their use in daily practice is not recommended except for clinical studies so that by using these two imaging methods, the validity of other methods is being investigated and the use of less costly and more practical methods is tried to be expanded (Maden-Wilkinson et al., 2013; Walowski et al., 2020). Since ultrasonography is a radiation-free, non-invasive and low-cost imaging method, it is suitable for use in the evaluation of muscle tissue (Stringer et al., 2018). It is a very advantageous method when it is considered that it is easily accessible and reproducible, allows regional evaluation, and increases the quality of evaluation with the developing technology, despite the limitation of being dependent on individuals (Heymsfield et al., 2015; Walowski et al., 2020; Watanabe et al., 2013; Smith et al., 2016). This can be explained as the reason why we used ultrasound imaging in this study. On the other hand muscular strength is one of the most important components of sport for high performance (van Dyk N et al., 2018). In elite sport, the use of strength testing to establish muscle function and performance is common. Furthermore strength tests determine muscle function and performance, and isokinetic strength tests are traditionally used to measure torque during concentric and eccentric muscle movements (van Dyk N et al., 2018). In particular, evaluation of isokinetic peak torque is one of the most frequently applied and reliable methods in evaluating lower extremity muscle strength, especially in sports (Jenkins et al., 2013, Juneja et al., 2012). In isokinetic testing lower concentric angular velocities are most often used for measuring maximum strength and higher concentric angular velocities for determining endurance (Anderson et al., 1991). The assessment of knee flexor and extensor strength levels could help develop an effective training program focused on improving speed and agility skills in soccer. All these elements will allow the determination of the convenient load on the knee joints of the athletes, the reflection of the increase in strength on performance by isokinetic muscle strength measurement, the determination of hypertrophy level and the prevention of injuries. The aim of this study was to evaluate the correlation between isokinetic muscle strength and muscle thickness.

Materials and Methods

Participants

54 young male athletes (mean age: 18.52 ± 1.44 years, mean height 174.33 ± 8.11 cm; mean body weight 66.30 ± 8.85 kg) playing in the U17 and U19 age groups of a Turkish professional football 1st league team voluntarily participated in the study. Athletes who did not smoke, did not have a known history of cardiovascular disease and chronic disability, did not use any medication, and had no disease/infection status were included in the study. The study started with 60 athletes and 3 athletes were excluded from the study due to injuries.

Testing Protocols

Athletes completed the tests on 4 different days. They were instructed to avoid any strenuous physical activity for at least 2 days before each visit. In their first visit, 24 athletes completed the isokinetic muscle strength test. In their second visit, 30 athletes completed the isokinetic muscle strength test. After 48 hours, 24 athletes who participated in the first visit completed their ultrasonographic muscle thickness measurements. One day later, 20 athletes who participated in the second visit completed their ultrasonographic muscle thickness measurements (Evangelidis et al., 2021).

Day 1: Isokinetic muscle strength test *24 Athletes*	*Rest (24 h)*	**Day 2:** Isokinetic muscle strength test *30 Athletes*	*Rest (48 h)*	**Day 3:** Ultrasonographic muscle thickness measurement *24 Athletes*	*Rest (24 h)*	**Day 4:** Ultrasonographic muscle thickness measurement *30 Athletes*

Figure 1. Testing protocols

Anthropometric Data

Subjects' height was measured with a stadiometer with an accuracy of ± 0.01 meters and their body weight with a stadiometer with a precision of ± 0.1 kilograms (Seca, Germany).

Isokinetic Muscle Strength Test

Lower limb isokinetic muscle strength tests were performed with Cybex (Humac norm 770 USA) and the data were recorded in the computer. After giving preliminary information about the test to the subjects, the subjects were taken to the Cybex one by one, anthropometric data were entered, and the device adjustments were made specifically for each subject. The range of motion of that joint was found by the computer by making the subject do a sample motion. The isokinetic muscle strength tests of the subjects were performed with 3 repetitions at concentric 60°.s-1 in the knee joint, 3 repetitions in concentric 180°.s-1 in the knee joint, and 3 repetitions in the concentric 30°.s-1 in the gluteus maximus (Harput el al., 2016). Isokinetic muscle strength tests are shown in figure 1.

Figure 2. Isokinetic muscle strength measurements.

Ultrasonographic Measurement

Thickness measurement was performed with a B-mode ultrasound imaging device (GE Logiq E9, Wauwatosa, USA) with a 4.4 cm, 9-MHz linear probe. The probe was positioned axially 90 degrees perpendicular to the muscle fibers, and after applying sufficient water-based gel (Aquasonics-100, Parker Laboratories, USA) pressure was applied to the extent that the subcutaneous adipose tissue was deformed to a minimum. Ultrasound measurements were performed by a physical therapy and rehabilitation specialist with training and experience in the subject. Measurements of 3 muscle regions were made. For the quadriceps muscle, the quadriceps muscle lying between the anterior superior of the spina iliac, and the upper end of the patella was determined, and the midpoint of this point was found, and the muscle thickness was measured over this midpoint, where the muscle has the largest area. For the Gluteus Maximus muscle, the ischial tuberosity was first detected by hand and then by ultrasound, and the distance from the ischial tuberosity to the skin-horse adipose tissue was measured. For the vastus intermedius muscle, the thickness of the vastus intermedius muscle, located just below the rectus femoris and above the femur, was measured from the midpoint of the anterior thigh (Giles et al., 2015). Ultrasound measurements of the rectus femoris, vastus intermedius and gluteus maximus muscles are shown in figure 2.

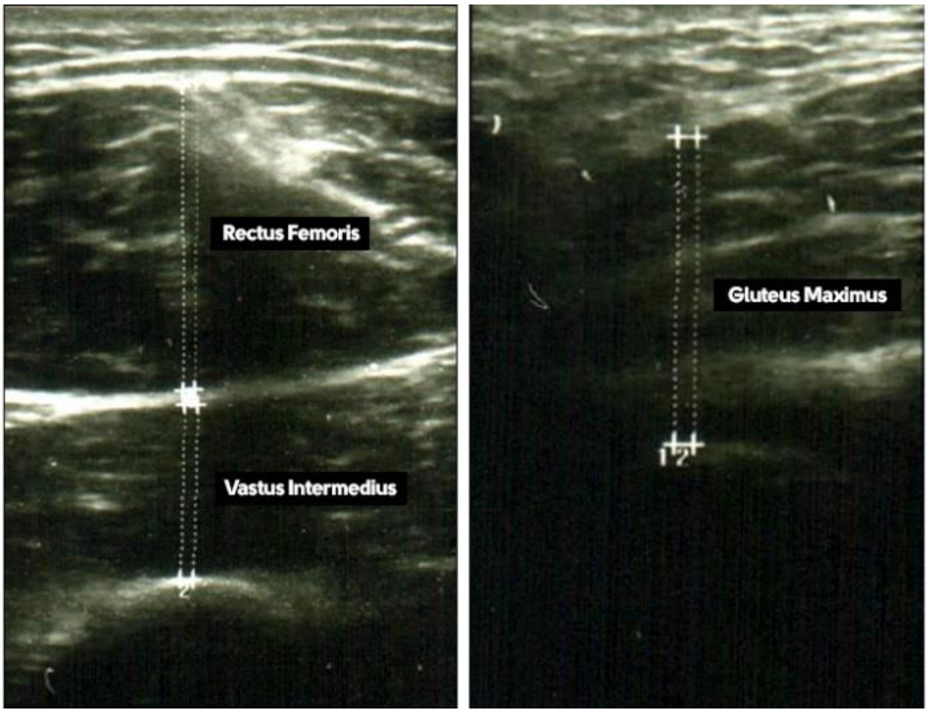


Figure 3. Ultrasound measurements of the rectus femoris, vastus intermedius and gluteus maximus muscles.

Statistical Analyses

Means and standard deviations are given as descriptive statistics and the relationship between isokinetic knee strength and muscle thickness was evaluated using the Pearson Product Moment Correlation. Normal distribution of the data was examined with the Shapiro-Wilk test. All analyses were executed in SPSS for Windows version 22.0 and the statistical significance was set at $p<0,05$.

Results

Table 1 shows an overview of the physical characteristics of soccer players. Their mean age, body weight and height were 18,296±1,312 year, 67,037±6,564 kg, 177,592±5,063 cm, respectively.

Table 1

Physical Characteristics Of Soccer Players.

Variable	**n**	**Mean (Sd)**
Age (year)	54	18,296 (1,312)
Body weight (kg)	54	67,037 (6,564)
Height (cm)	54	177,592 (5,063)

An overview of the means and standard deviations of isokinetic knee strength characteristics and muscle thickness of soccer players are summarized in Table 2.

Table 2

Isokinetic Knee Strength Characteristics and Muscle Thickness of Soccer Players.

Variable	**n**	**Mean (Sd)**
RF (cm)	54	2,607 (0,297)
VI (cm)	54	1,838 (0,328)
RF+VI (cm)	54	4,445 (0,472)
GMAX (cm)	54	3,621 (0,765)
30°/s^{-1} Glut Con Torque (N.m^{-1})	54	176,333 (50,652)
60°/s^{-1} Knee Con Torque (N.m^{-1})	54	189,574 (35,885)
180°/s^{-1} Knee Con Torque (N.m^{-1})	54	135,092 (38,053)

RF: Ultrasound-measured thickness of the rectus femoris; VI: Ultrasound-measured thickness of the vastus intermedius; RF+VI: Sums of ultrasound-measured thicknesses of the rectus femoris and vastus intermedius; GMAX: Ultrasound-measured thickness of the gluteus maximus; Glut Con Torque: Concentric peak isokinetic force of the gluteus maximus; Knee Con Torque: Concentric peak isokinetic force of the knee.

Table 3

Correlations Between Isokinetic Knee Strength and Muscle Thickness of Soccer Players.

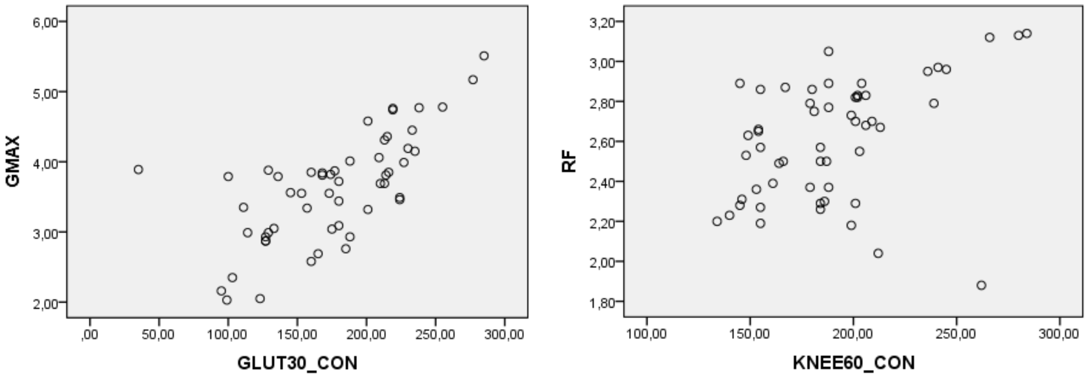
Variable		**r**	**p**
GMAX (cm)	30°/s^{-1} Glut Con Torque (N.m^{-1})	0,793*	0,000
RF (cm)	60°/s^{-1} Knee Con Torque (N.m^{-1})	0,422*	0,001
RF (cm)	180°/s^{-1} Knee Con Torque (N.m^{-1})	0,094	0,497
VI (cm)	60°/s^{-1} Knee Con Torque (N.m^{-1})	-0,091	0,511
VI (cm)	180°/s^{-1} Knee Con Torque (N.m^{-1})	0,470*	0,000
RF+VI (cm)	60°/s^{-1} Knee Con Torque (N.m^{-1})	0,385*	0,004
RF+VI (cm)	180°/s^{-1} Knee Con Torque (N.m^{-1})	0,202	0,142

$p<0.05$

In Table 3, according to Pearson correlation analysis, the correlation coefficient between GMAX and 30°/s^{-1} Glut Con Torque ($r=0,693$, $p<0,000$), RF and 60°/s^{-1} Knee Con Torque ($r=0,422$, $p<0,001$), VI and 180°/s^{-1} Knee Con Torque ($r=0,470$, $p<0,000$), RF+VI and 60°/s^{-1} Knee Con Torque ($r=0,385$, $p<0,004$) were significant.

(a) Relationship between gluteus maximus thickness and 30°/s^{-1} Glut Con Torque

(b) Relationship between rectus femoris thickness and 60°/s^{-1} Knee Con Torque



(c) Relationship between vastus intermedius thickness and 180°/s^{-1} Knee Con Torque

(d) Relationship between rectus femoris+ vastus intermedius thickness and 60°/s^{-1} Knee Con Torque

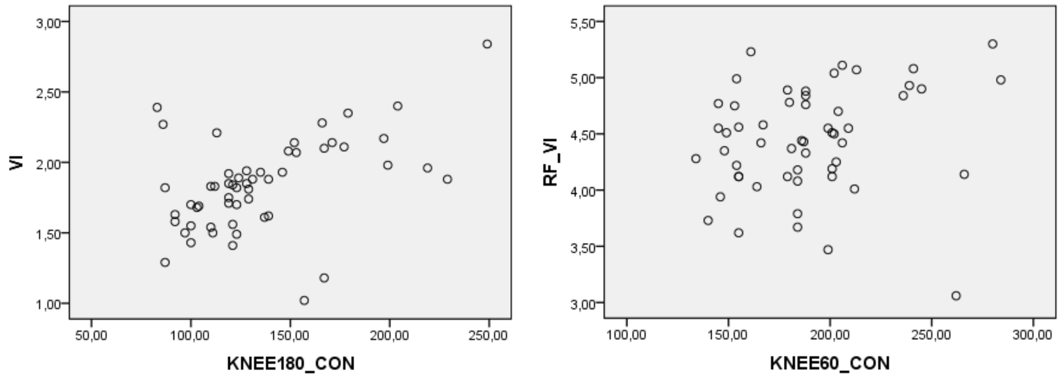


Figure 4. Relationship between gluteus maximus thickness and gluteus maximus strength (a), rectus femoris thickness and knee strength (b), vastus intermedius thickness and knee strength (c), rectus femoris + vastus intermedius thickness and knee strength (d)

Table 4

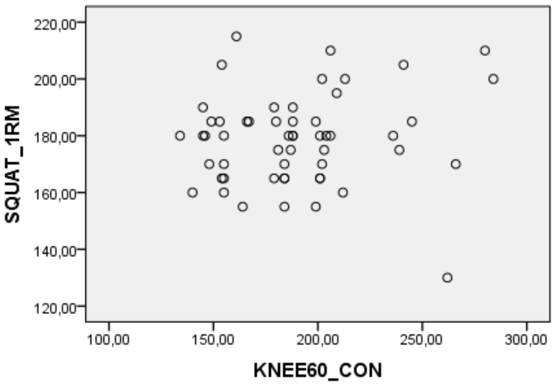
Correlations Between Isokinetic Knee Strength and 1RM of Soccer Players.

Variable		**r**	**p**
1RM Squat (kg)	30°/s^{-1} Glut Con Torque (N.m^{-1})	0,029	0,833
	60°/s^{-1} Knee Con Torque (N.m^{-1})	0,110*	0,002
	180°/s^{-1} Knee Con Torque (N.m^{-1})	0,388*	0,004
1RM Deadlift (kg)	30°/s^{-1} Glut Con Torque (N.m^{-1})	-0,159	0,251
	60°/s^{-1} Knee Con Torque (N.m^{-1})	0,130*	0,048
	180°/s^{-1} Knee Con Torque (N.m^{-1})	0,299*	0,028
1RM Hip Thrust (kg)	30°/s^{-1} Glut Con Torque (N.m^{-1})	0,639*	0,000
	60°/s^{-1} Knee Con Torque (N.m^{-1})	0,033	0,812
	180°/s^{-1} Knee Con Torque (N.m^{-1})	0,162	0,243

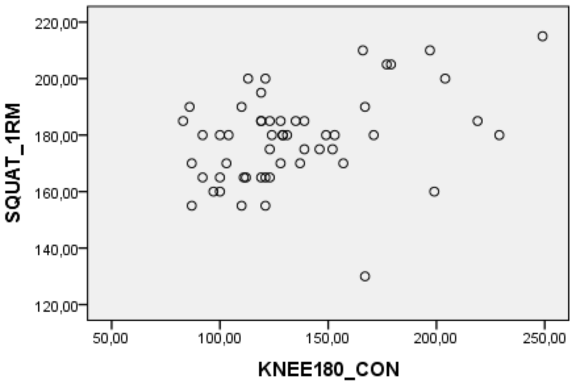
$p<0.05$

In Table 4, according to Pearson correlation analysis, the correlation coefficient between 1RM Squat and 60°/s^{-1} Knee Con Torque (r=0,110, p<0,002), 1RM Squat and 180°/s^{-1} Knee Con Torque (r=0,388, p<0,004), 1RM Deadlift and 60°/s^{-1} Knee Con Torque (r=0,130, p<0,048), 1RM Deadlift and 180°/s^{-1} Knee Con Torque (r=0,289, p<0,028), 1RM Hip Thrust and 30°/s^{-1} Glut Con Torque (r=0,639, p<0,000) were significant.

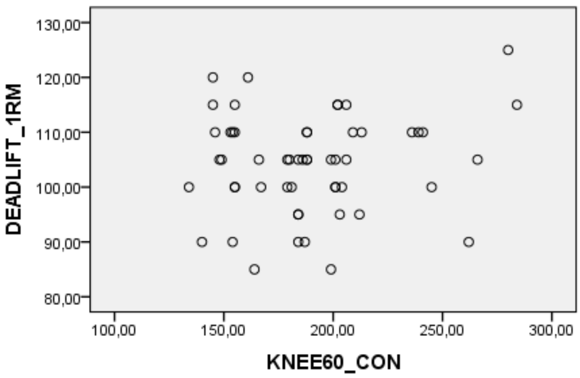
(a) Relationship between 1RM Squat and 60°/s-1 Knee Con Torque



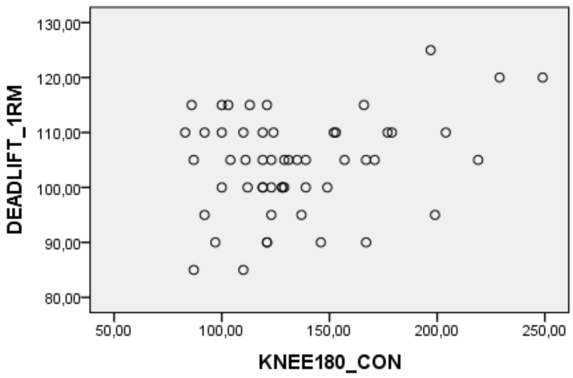
(b) Relationship between 1RM Squat and 180°/s^{-1} Knee Con Torque



(c) Relationship between 1RM Deadlift and 60°/s^{-1} Knee Con Torque



(d) Relationship between 1RM Deadlift and 180°/s^{-1} Knee Con Torque



(e) Relationship between 1RM Hip Thrust and 30°/s^{-1} Glut Con Torque

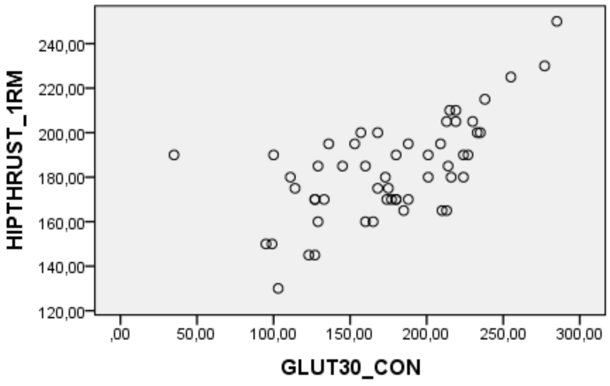


Figure 5. Relationship between 1RM Squat and 60°/s-1 Knee Con Torque (a), 1RM Squat and 180°/s^{-1} Knee Con Torque (b), 1RM Deadlift and 60°/s^{-1} Knee Con Torque (c), 1RM Deadlift and 180°/s^{-1} Knee Con Torque (d), 1RM Hip Thrust and 30°/s^{-1} Glut Con Torque (e)

Table 5

Correlations Between Muscle Thickness and 1RM of Soccer Players.

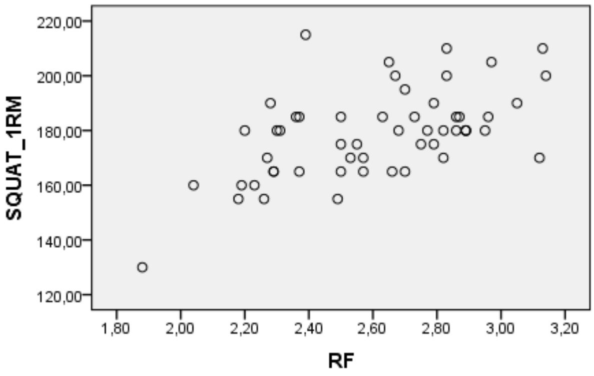
Variable		**r**	**p**
1RM Squat (kg)	RF (cm)	0,561*	0,000
	VI (cm)	0,784*	0,000
	GMAX (cm)	0,121	0,383
1RM Deadlift (kg)	RF (cm)	0,460*	0,000
	VI (cm)	0,573*	0,000
	GMAX (cm)	-0,084	0,544
1RM Hip Thrust (kg)	RF (cm)	-0,005	0,973
	VI (cm)	0,214	0,120
	GMAX (cm)	0,887*	0,000

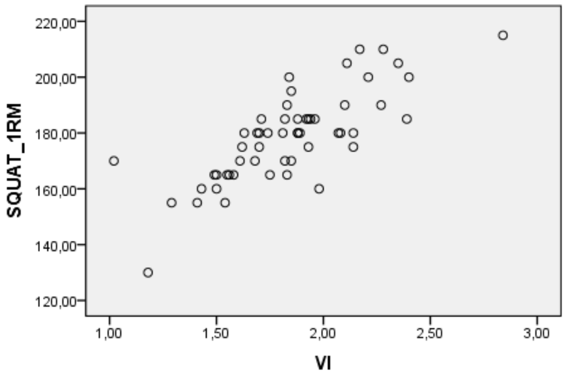
p<0.05

In Table 5, according to Pearson correlation analysis, the correlation coefficient between 1RM Squat and RF (r=0,561, p<0,000), 1RM Squat and VI (r=0,784, p<0,000), 1RM Deadlift and RF (r=0,460, p<0,000), 1RM Deadlift and VI (r=0,573, p<0,000), 1RM Hip Thrust and GMAX (r=0,887, p<0,000) were significant.

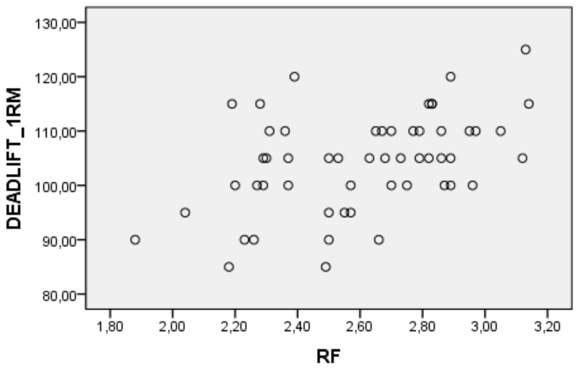
(a) Relationship between 1RM Squat and RF muscle thickness

(b) Relationship between 1RM Squat and VI muscle thickness

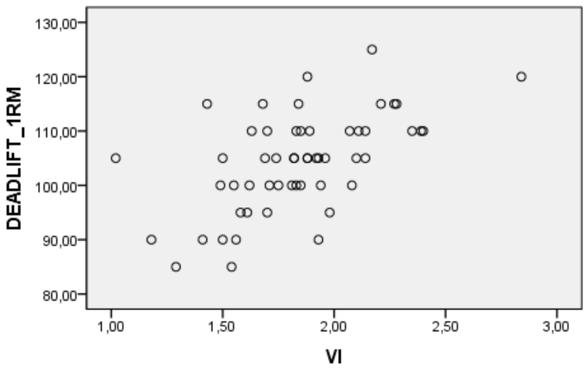




(c) Relationship between 1RM Deadlift and RF muscle thickness



(d) Relationship between 1RM Deadlift and VI muscle thickness



(e) Relationship between 1RM Hip Thrust and GMAX muscle thickness

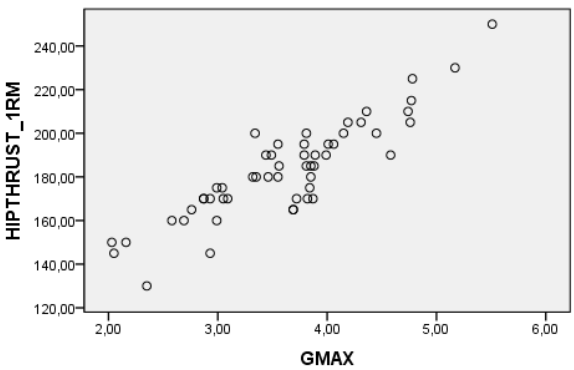


Figure 6. Relationship between 1RM Squat and RF muscle thickness (a), 1RM Squat and VI muscle thickness (b), 1RM Deadlift and RF muscle thickness (c), 1RM Deadlift and VI muscle thickness (d), 1RM Hip Thrust and GMAX muscle thickness (e)

Discussion

This study aim to explore isokinetic muscle strength and muscle thickness in soccer players via ultrasound imaging. In addition, we investigated the relationship between knee muscle strength and thickness of knee muscles and 1TM muscle strength. To our knowledge, few studies examined the relationship between isokinetic muscle strength and muscle thickness (Birchmeier et al., 2020; Fukunaga, Johnson, Nicholas, and McHugh, 2019; Giles, Webster, McClelland, and Cook, 2015). The main findings of this study are that there is a high correlation between GMAX and 30°/s^{-1} Glut Con Torque, 1RM Squat and VI, 1RM Hip Thrust and GMAX and that there is a moderate correlation between RF and 60°/s^{-1} Knee Con Torque, VI and 180°/s^{-1} Knee Con Torque, RF+VI and 60°/s^{-1} Knee Con Torque, 1RM Squat and 180°/s-1 Knee Con Torque, 1RM Hip Thrust and 30°/s-1 Glut Con Torque, 1RM Squat and RF, 1RM Deadlift and RF, 1RM Deadlift and VI also there is a low correlation between 1RM Squat and 60°/s-1 Knee Con Torque, 1RM Deadlift and 60°/s-1 Knee Con Torque, 1RM Deadlift and 180°/s-1 Knee Con Torque. Our results indicate that quadriceps and gluteus maximus muscle strength was associated with rectus femoris, vastus intermedius and gluteus maximus muscle thicknesses. Our results also indicate that quadriceps and gluteus maximus muscle strength and muscle thickness are associated with 1RM muscle strength. El-Ansary et al. (2019) evaluated the relationship between RF and VI muscles thickness measured by ultrasound and quadriceps muscle strength. In contrast to results of our study, they could not find a relationship between rectus femoris muscle thickness and quadriceps strength. In the study, quadriceps muscle strength measurement was made with a hand-hand dynamometer. It can be stated that this result may depends on quadriceps force measurement method. Paris et al. (2022) maximal isometric torque of the knee extensors was significantly associated with anterior upper leg muscle thickness, similar to the results of our study. In addition, peak isokinetic power of the knee extensors at 60 and 180 °/s were significantly associated with anterior upper leg muscle thickness. Strasser et al (2013) in a study comparing young and older groups, they stated that the isometric maximum contraction force was related to quadriceps muscle thickness. In addition, rectus femoris and vastus intermedius muscle thicknesses have significant effects isometric maximum contraction force, and isometric maximum contraction force increased with increasing muscle thicknesses of all muscles of quadriceps. Raj Selva et al. (2017) evaluated the relationship between knee extensor strength and muscle thickness. It has been stated that there are significant correlations between quadriceps thickness measurements and all strength measurements. In this study, significant correlations between combined RF+VI muscle thickness and 60º/s concentric peak isokinetic strength, and this result was similar to our study. Contrary to Strasser et al. (2013) and Raj Selva et al. (2017), a significant relationship was found between quadriceps strength and rectus femoris thickness in this study. Unlike other studies may come from the differences in quadriceps strength measure methodology including method of the test. In many studies in the literature (Raj Selva et al., 2017; Strasser et al., 2013; Watanabe et al., 2013), utilized dynamometers were used to measure knee extension strength (isometric at 60°–90° knee flexion, while subjects were seated position). As this study with an instructive sample size, the results should be interpreted with caution by the researchers.

As the tester is required to match participant's isometric strength, weaker assessors may encounter difficulties in assessing stronger participants. However, we minimized dynamometer-related limitations by having a standardized assessment position, instructions and encouragement for participants. As this was a study it was not sufficiently powered to control for participants' activity level and past medical history. There was one assessor who performed all assessments, whilst this is a limitation, an experienced sonographer (DEA) with more than 15 years of experience was present at all assessment sessions. Previous studies have also reported that eccentric actions have less pronounced fatigue compared to concentric muscle actions (Grabiner et al., 1999; Baroni et al., 2011). One possible explanation is that during eccentric actions, cross-bridges seem to become suspended in an active state (bound to actin), are then forcibly detached, and then rapidly re-attached, not allowing for a complete contraction cycle (Douglas et al., 2017). Since a full contraction cycle is not completed, less ATP is required to maintain force output. In addition to the possible reduced energy demands of eccentric actions, the greater intrinsic force capacity during eccentric actions requires fewer active motor units to attain a given absolute force (Westing et al., 1991). Therefore, fewer active motor units using less ATP results in less metabolic demand during exercise, which may explain the greater fatigue resistance in ECC actions (Douglas et al., 2017). On the opposite end of the spectrum, CON was more fatiguing, and although not measured in the present study, likely utilized more ATP (Kemp 2007).

Conclusion

In conclusion, this study showed significant and high correlations of quadriceps thickness measurements with muscle strength. Although there is emerging evidence that ultrasound-derived measurements correlate well in athletes, future studies should investigate the relationship between quadriceps strength and ultrasound-measured muscle thickness. In addition, further research is warranted in larger cohort that consider of the quadriceps muscle and their relationship to strength outcome measures. This study also highlights the importance of considering quantitative data pertaining to superficial and deep quadriceps muscle components in conjunction with qualitative review of ultrasound imaging to formulate a cohesive understanding of an athlete's muscle function. Ultrasound-derived muscle anatomical data may guide trainers both in preparing strength training and in monitoring athletes.

Ethics Committee Permission Information

Ethics review board: Pamukkale University Ethics Committee

Date of ethics assessment document: 21/06/2022

Ethics assessment document number: E-60116787-020-244607

Author Contributions

EGA: designed the study, data acquisition, draft the manuscript, review the final version. AY: designed the study, data acquisition,. GFE: designed the study, review the final version.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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