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An investigation of the relationship between lower limb muscle size, strength, and tibia length: A specific analysis of the hamstring and quadriceps muscles

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Abstract

The primary aim of this investigation was to assess the interrelations among the ratios of hamstring-to-quadriceps muscle size and strength, as well as the associations with hamstring and quadriceps muscle size, tibia length, and muscle strength. A total of 47 recreationally active male participants voluntarily took part in the study, with an average age of 21.06±1.52 years, height of 179.47±6.21 cm, body weight of 77.18±10.51 kg, and a body mass index of 23.96±2.97. The knee flexion and extension strength were assessed at a velocity of 60º/s. Additionally, using ultrasonography, the thickness of the total quadriceps muscle, (vastus lateralis, vastus medialis, vastus intermedius, and rectus femoris), and the thickness of the total hamstring muscle (biceps femoris short and long head, semitendinosus, and semimembranosus) were measured at 50% of muscle length. The data were presented as mean and standard deviation, and Pearson product-moment correlation and related samples t-test were utilized for data analysis. The results of the study revealed no significant correlation between the size and strength of the hamstring and quadriceps muscles ($r=0.166$, $p>0.05$; $r=0.279$, $p>0.05$) and between the H: Q size ratio and H: Q strength ratio ($r=0.129$, $p>0.05$). The research findings indicate that the muscle thickness of the knee extensor and flexor muscle groups is not related to the isokinetic force produced in the corresponding muscles, and that muscle thickness is insufficient in determining isokinetic force.

Keywords: H:Q size ratio, H:Q strength ratio, muscle strength, muscle size

Alt ekstremite kas kütlesi, kas kuvveti ve tibia uzunluğu arasındaki ilişkinin incelenmesi: Hamstring ve kuadriseps kasları özelinde bir inceleme

Öz

Bu araştırmada, kuadriceps ve hamstring kaslarının kuvvet oranı ile kütle oranı arasındaki ilişki ve kas kütlesi ve tibia uzunluğu ile kas kuvveti arasındaki ilişki incelenmiştir. Araştırmaya rekreatif düzeyde aktif, 47 spor bilimleri fakültesi öğrencisi (yaş:21,06±1,52yıl, boy:179,47±6,21cm, vücut-ağırlığı:77,18±10,51kg, VKİ:23,96±2,97) gönüllü olarak katılmıştır. Kuadriceps ve hamstring kaslarına ilişkin konsantrik diz ekstansiyon ve fleksiyon zirve tork değerleri dominant taraftan, 60º/s açısal hızda ölçülmüştür. Katılımcıların kuadriceps kas kalınlığı için vastus lateralis, vastus medialis, vastus intermedius ve rektus femoris; hamstring için biceps femoris kısa baş, biceps femoris uzun baş, semitendinosus ve semimembranosus kas kalınlıkları en kalın noktadan (%50) ultrasonografi aracılığı ile belirlenmiştir. Veriler ortalama ve standart sapma olarak sunulmuş, ilişki analizi için pearson momentler çarpım korelasyonu, kuadriceps ve hamstringe ilişkin karşılaştırmalar için bağımlı gruplar için t testi kullanılmıştır. Sonuç olarak, hamstring ve kuadriceps kas kütlesi ile kas kuvveti arasında anlamlı bir ilişki tespit edilememiştir ($r=0,166$, $p>0,05$; $r=0,279$, $p>0,05$). H:Q kas kütle oranı ile H:Q kas kuvvet oranı arasında anlamlı bir ilişki olmadığı görülmüştür ($r=0,129$, $p>0,05$). Araştırma bulguları, diz ekstensör ve fleksör kas gruplarına ilişkin kas kalınlığının, ilgili kaslarda üretilen izokinetik kuvvet ile ilişkili olmadığını, kas kalınlığının izokinetik kuvveti belirlemede yetersiz olduğunu göstermektedir.

Anahtar Kelimeler: *H:Q kas oranı, H:Q kuvvet oranı, kas kuvveti, kas kütlesi*

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Genişletilmiş Türkçe Özet makalenin sonunda yer almaktadır.

INTRODUCTION

For many years, it has been generally recognized that the magnitude of an individual's skeletal muscle mass is the most influential determinant of the maximum force or torque, commonly referred to as strength, that the muscle can produce (Ikai & Fukunaga, 1968). Larger muscles have more sarcomeres and actin-myosin cross-bridges arranged in parallel, enabling them to generate greater contractile force (Powell et al., 1984; Pancar, 2023). Muscle strength plays a significant role in both daily functional activities and athletic performance, as well as being a risk factor for muscle injury and potentially impacting the development and progression of joint degeneration (Suchomel et al., 2016; Beaudart et al., 2019; Balshaw et al., 2021). Understanding the determinants of strength and its alterations is crucial for evaluating, monitoring, and potentially modifying the principal factors that contribute to it. Although the positive association between muscle size and maximum strength is a widely recognized phenomenon (Bamman et al., 2000; Abe et al., 2007), it remains unclear whether an increase in muscle mass inevitably leads to a corresponding increase in muscle strength or whether gains in muscle strength can be attained without an accompanying increase in muscle mass (Chen et al., 2013; Sartori et al., 2021). For example, when comparing the physical attributes of a bodybuilder and a weightlifter, visual distinctions and similarities can be observed. However, an assessment of their contractile performance, as exemplified by the measurement of maximal voluntary contraction (MVC), is likely to reveal that trained athletes outperform bodybuilders (Reggiani & Schiaffino, 2020). Muscular strength is also influenced by factors such as bone and limb length, which tend to remain consistent throughout an individual's lifespan. Previous research has demonstrated contradictory findings regarding the relationship between limb length and muscular strength. (Hamzat et al., 2001; Chevidikunnan & Khan, 2020; Dean et al., 2022).

For years, the hamstrings-to-quadriceps (H:Q) muscle strength ratio has been utilized to identify muscle asymmetry, track the stability of the knee joint, delineate muscular strength characteristics and functionality, and provide a critical tool for injury prevention and rehabilitation in the lower extremities (Coombs & Garbutt, 2002; Ruas et al., 2015). It also has been determined to be significant, as a low ratio has been linked to a significantly elevated likelihood of suffering a hamstring strain injury (Croisier et al., 2008). Although the H:Q strength ratio is a valuable tool in evaluating strength imbalances and identifying potential risk factors for hamstring strain injuries, there is a limited comprehension of the factors that affect this ratio. The size of opposing muscle groups may impact their corresponding muscular functionality, including the H:Q strength ratio. The relationship between the size of an agonist muscle and its corresponding antagonist muscle has not been thoroughly documented (Evangelidis et al., 2015). As such, the association between the size of the quadriceps and hamstrings musculature remains unclear. In addition, it remains uncertain whether the proportional dimensions of opposing muscle groups, such as the quadriceps and hamstrings, directly impact their relative strength balance, despite the assumption that such a relationship would be expected.

The primary objective of this study was to investigate the interrelationship between the size of the knee extensors (quadriceps) and flexors (hamstrings) muscles, focusing on evaluating the correlation between the size of each muscle and its corresponding concentric strength. Additionally, the investigation aimed to examine the connection between the strength of each muscle and the length of the tibia and to assess whether a correlation exists between the ratio of muscle size and the ratio of strength.

METHOD

Participants

Due to the absence of available reference values for G power analysis, a convenience sampling approach was employed for data collection, with efforts made to establish a cohort size comparable to that of previous investigations (Evangelidis et al., 2015). 47 recreationally active healthy men (age: 21.06±1.52 years, weight: 77.18±10.51 kg; height: 179.47±6.21 cm; body mass index: 23.96±2.97) volunteered for the study. Individuals who had undergone surgical intervention or had a lower extremity injury were not considered eligible to participate in the study. A preliminary meeting was conducted with the volunteers wherein the inclusion criteria were expressed, and subsequently, eligible participants were enrolled in the study before the commencement of data collection. Following a thorough explanation of the research procedures, potential risks associated with the study, and the expectations from the participants, they were requested to provide written consent by filling out and signing an informed consent form. The study was carried out in concordance with the Declaration of Helsinki, and the Gazi University Ethics Commission granted ethical clearance (04.04.2023/7).

Data collection tools

Weighing Machine: Participant body weight was measured utilizing a Seca digital precision balance (SECA 807 AURA, USA) with a measuring capacity of 150 kg and a precision feature of 0.1 kg.

Stadiometer: Height measurements were obtained using a Seka stadiometer, which has a measurement range of 207 cm and a precision of 1 mm.

Tape: Measurement of tibia length was conducted using a flexible measuring tape manufactured by SECA.

IsoMed 2000 Isokinetic Dynamometer: The quadriceps and hamstring muscle strength were evaluated during flexion and extension on an isokinetic dynamometer (IsoMed 2000; D&R Ferstl, Hemnau, Germany).

MyLab 70 XV, Esaote Biomedica, Genoa, Italy: In the dominant leg, muscle thickness measurements of the rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), vastus intermedius (VI), biceps femoris short head (BF), biceps femoris long head, semitendinosus (ST), and semimembranosus (SM) muscles were obtained using a 6-12 MHz linear probe ultrasound imaging device.

Data collection

Before the measurements were taken, the participants were given clear instructions to refrain from engaging in any vigorous physical activity, and to avoid consuming substances such as alcohol, coke, and other diuretics in the 48-72 hours leading up to the measurements. Anthropometric measurements: Participants were instructed to wear only shorts and stand barefoot on the scale to ensure accurate measurements during the weighing procedure. The height measurement was conducted in the anatomical position, with participants standing upright, and the distance between the vertex and the point of the feet on the ground was measured. Body mass index was calculated by dividing the participant's body weight in kilograms by the square of their height in meters.

Isokinetic muscle strength assessment: Following a 10-minute warm-up period involving cycling on an ergometer with a resistance of 2% of the participant's body weight with a pedal rate of 70 rpm, individuals were instructed to perform 5 bodyweight squats. After completing the initial warm-up, the participants were placed in a seated position on the IsoMed 2000 dynamometer chair, with the hip joint flexed at approximately 75 degrees relative to full extension (0 degrees), and the popliteal fossa of the leg being tested aligned with the front edge of the seat. To ensure stability during the testing procedure, the participants were secured using adjustable straps and pads placed across the shoulders, chest, hip, and right femur. Additionally, they were instructed to grasp the side handles located laterally to the right hip. The weight of the leg of the participants was measured with the dynamometer then gravity elimination was provided. The lateral femoral epicondyle was utilized as a bony reference point to ensure accurate alignment of the knee joint with the dynamometer's mechanical axis. A strap was used to secure the distal shin pad of the dynamometer lever arm, positioning it about 2-3 cm superior to the lateral malleolus and at a 90-degree knee flexion angle. The range of motion (ROM) was established to extend from 10 to 90 degrees, with a rapid acceleration setting at the start and a firm deceleration cushion at the conclusion of the movement. The isokinetic assessment was performed with 5 reps protocol at maximal voluntary contraction at a velocity of 60°/s. Before the testing phase, the participants were directed to perform 5 moderate trials with the angular velocity being tested. After completing the trial runs, the participants were instructed to rest for 1 minute before commencing the subsequent test, during which they were directed to exert maximal force while pushing and pulling throughout the full range of motion. Throughout the assessment, verbal encouragement was provided to the participants. Peak torque values for each movement the dynamometer provided (i.e., extension, flexion) were used for data analysis.

Muscle thickness assessment: The present study utilized B-mode ultrasonography (MyLab 70 XV, Esaote Biomedica, Genoa, Italy) to perform measurements of muscle thickness of thigh muscles. The measurement of muscle thickness in the quadriceps and hamstring muscles was performed at a location corresponding to 50% of the thigh length. The length of the thigh was determined by measuring the distance between the anatomical landmarks of the lateral condyle of the femur and the greater trochanter. Following this, the measurement sites were marked with a marker pen. The measurements were taken while the participants were in a supine position. To minimize distortion, surplus gel was administered to both the anterior and posterior thigh regions. The ultrasound image was considered to be optimized when the transducer and skin were separated by a slender layer of gel, indicating the absence of any external pressure on the muscle. Once an optimal image was obtained, a static image was captured and the thickness of the muscle was measured using caliper-based tools integrated into the software of the ultrasound machine. To ensure data reliability, three scans were performed on each site during a single session, and the average of the two closest measurements was used for subsequent analysis. The total thickness of quadriceps muscles was determined by adding the thickness measurements of the RF, VL, VM, and VI muscles, while the total thickness of the hamstrings was calculated by summing the thickness measurements of the BF, ST, and SM muscles.

Tibia length measurement: The measurement was obtained by determining the linear distance between the superior border of the medial tibial condyle and the inferior border of the medial malleolus. The subjects' knee and ankle were positioned at a precise 90-degree angle during the measurement procedure.

Data analysis

Data are presented as mean ± SD. The normality of the data was assessed using the Shapiro-Wilk test, and it was determined that the data had a normal distribution. Paired sample t-tests was used to analyze the differences in strength and size of the quadriceps and hamstring muscles. Bivariate relationships between the dependent variables (muscle strength, size, tibia length, H:Q ratios) were evaluated using Pearson product-moment correlations. Correlations were categorized as very weak, weak, moderate, strong, or very strong based on their values falling within specific ranges: 0.00-0.19, 0.20-0.39, 0.40-0.59, 0.60-0.79, and 0.80-1.00, respectively (Papageorgiou, 2022; Weisscher, 2007). The significance level was established at $p < 0.05$, and all statistical analyses were conducted using IBM SPSS 22 (IBM Corporation, Armonk, NY).

RESULTS

Table 1. Participants characteristics, muscle strength and muscle size parameters (N=47)

Variables	Mean±SD (%95 CI)
Age (year)	21.06±1.52 (20.51-20.62)
Weight (kg)	77.18±10.51 (75.10-80.27)
Height (cm)	179.47±6.21 (177.64-181.29)
BMI (kg/m^2)	23.96±2.97 (23.08-24.82)
RF Muscle Thickness (mm)	23.27±2.53 (22.52-24.00)
VI Muscle Thickness (mm)	17.16±2.79 (16.34-17.98)
VM Muscle Thickness (mm)	19.07±1.82 (18.53-19.60)
VL Muscle Thickness (mm)	24.17±3.24 (23.21-25.12)
BF Short Head Muscle Thickness (mm)	11.36±1.84 (10.81-11.90)
BF Long Head Muscle Thickness (mm)	25.17±4.44 (23.87-26.48)
Semitendinosus Muscle Thickness (mm)	27.98±3.80 (26.86-29.10)
Semimembranosus Muscle Thickness (mm)	29.09±3.77 (27.99-30.20)
Hamstring Muscles Thickness Total (mm)	93.60±9.99 (90.67-96.53)
Quadriceps Muscles Thickness Total (mm)	83.66±8.40 (81.20-86.13)
Hamstring Muscle Isokinetic Strength (t)	150.97±20.02 (145.09-156.85)
Quadriceps Muscle Isokinetic Strength (t)	227.30±32.27 (217.82-236.78)
H/Q Strength Ratio	0.67±0.67 (0.65-0.68)
H/Q Muscle Thickness Ratio	1.12±0.14 (1.08-1.17)
Tibia Length (cm)	39.66±1.51 (39.22-40.10)

BMI: Body mass index; RF: Rectus femoris; VI: Vastus intermedius; VM: Vastus medialis; VL: Vastus lateralis; BF: Biceps Femoris; H/Q: Hamstrings/Quadriceps; t: torque.

Relationships between muscle size, strength and H:Q ratio

The results indicate a lack of significant correlation between the H: Q strength and size ratio and between the size and strength of the quadriceps and hamstrings muscles ($p>0.05$). As expected, a statistically significant, strong positive correlation was observed between the strength of the quadriceps and hamstrings muscles ($r = 0.753$; $p<0.05$). A statistically significant, weak positive correlation was observed between the strength of the quadriceps, hamstrings muscles and tibia length ($r = 0.338$, $r = 0.341$ respectively; $p<0.05$). H:Q strength ratio was negatively and moderately correlated with quadriceps muscle strength ($r = -0.439$; $p<0.05$), H:Q muscle size ratio was negatively and moderately correlated with quadriceps size ratio ($r= -0.592$; $p<0.05$). A significant, strong positive correlation was found between H:Q size ratio and hamstring muscle size ($r = 0.641$; $p<0.05$). An unexpected correlation was also found between quadriceps muscle size and hamstring muscle strength ($r = 0.341$; $p<0.05$). The existing body of literature needs more knowledge regarding the potential association between the size of an antagonist's muscle and the corresponding strength of its agonist's muscle.

Descriptive data for muscle size and strength

The paired sample t-tests revealed that the total thickness of the hamstring muscles was significantly greater than that of the quadriceps muscles ($t = 5.922$; $p <0.001$). Furthermore, the isokinetic strength of the quadriceps muscles was significantly greater than that of the hamstring muscles ($t = 24.150$; $p <0.001$). Consequently, due to the higher total muscle thickness of the hamstrings and greater isokinetic strength of the quadriceps, the H:Q muscle size ratio was significantly higher than the H:Q muscle strength ratio ($t = 20.838$; $p < 0.001$).

Table 2. Pearson correlations for isokinetic hamstring and quadriceps strength and muscle size, tibia length, H:Q muscle strength and size ratio (N=47)

Variables		Quadriceps Muscle Isokinetic Strength (t)	Total Quadriceps Muscle Size (mm)	Hamstring Muscle Isokinetic Strength (t)	Total Hamstring Muscle Size (mm)	Tibia Length (cm)	H:Q Muscle Size Ratio	H:Q Isokinetic Strength Ratio
Quadriceps Muscle Isokinetic Strength (t)	r	–	0.279	**0.753**	0.063	**0.338**	-0.172	**-0.439**
	p		0.057	**0.001**	0.674	**0.020**	0.248	**0.002**
Total Quadriceps Muscle Size (mm)	r	0.279	–	**0.341**	0.226	-0.224	**-0.592**	0.018
	p	0.057		**0.019**	0.127	0.129	**0.001**	0.904
Hamstring Muscle Isokinetic Strength (t)	r	**0.753**	**0.341**	–	0.166	**0.341**	-0.105	0.252
	p	**0.001**	**0.019**		0.265	**0.019**	0.482	0.087
Total Hamstring Muscle Size (mm)	r	0.063	0.226	0.166	–	-0.151	**0.641**	0.119
	p	0.674	0.127	0.265		0.311	**0.001**	0.424
Tibia Length (cm)	r	**0.338**	-0.224	**0.341**	-0.151	–	0.029	-0.026
	p	**0.020**	0.129	**0.019**	0.311		0.848	0.860
H:Q Muscle Size Ratio	r	-0.172	**-0.592**	-0.105	**0.641**	0.029	–	0.129
	p	0.248	**0.001**	0.482	**0.001**	0.848		0.388

t: Torque; cm: Centimeter; mm: Milimeter

Table 3. Comparison of isokinetic strength and size of quadriceps and hamstring muscles, H:Q muscle size and strength ratio (N=47)

Variables	Mean±SD	Mean Difference±SD	95% CI of the Difference		t	p
			Lower	Upper		
Total Hamstring Muscle Size (mm)	93.60±9.99	9.94±11.50	6.56	13.31	5.922	0.001
Total Quadriceps Muscle Size (mm)	83.66±8.40					
Quadriceps Muscle Isokinetic Strength (t)	227.30±32.27	76.33±21.67	69.97	82.69	24.150	0.001
Hamstring Muscle Isokinetic Strength (t)	150.97±20.02					
H:Q Muscle Size Ratio	1.13±0.14	0.46±0.15	0.41	0.50	20.838	0.001
H:Q Isokinetic Strength Ratio	0.67±0.07					

t: Torque; cm: Centimeter; mm: Milimeter; CI: Confidence Interval

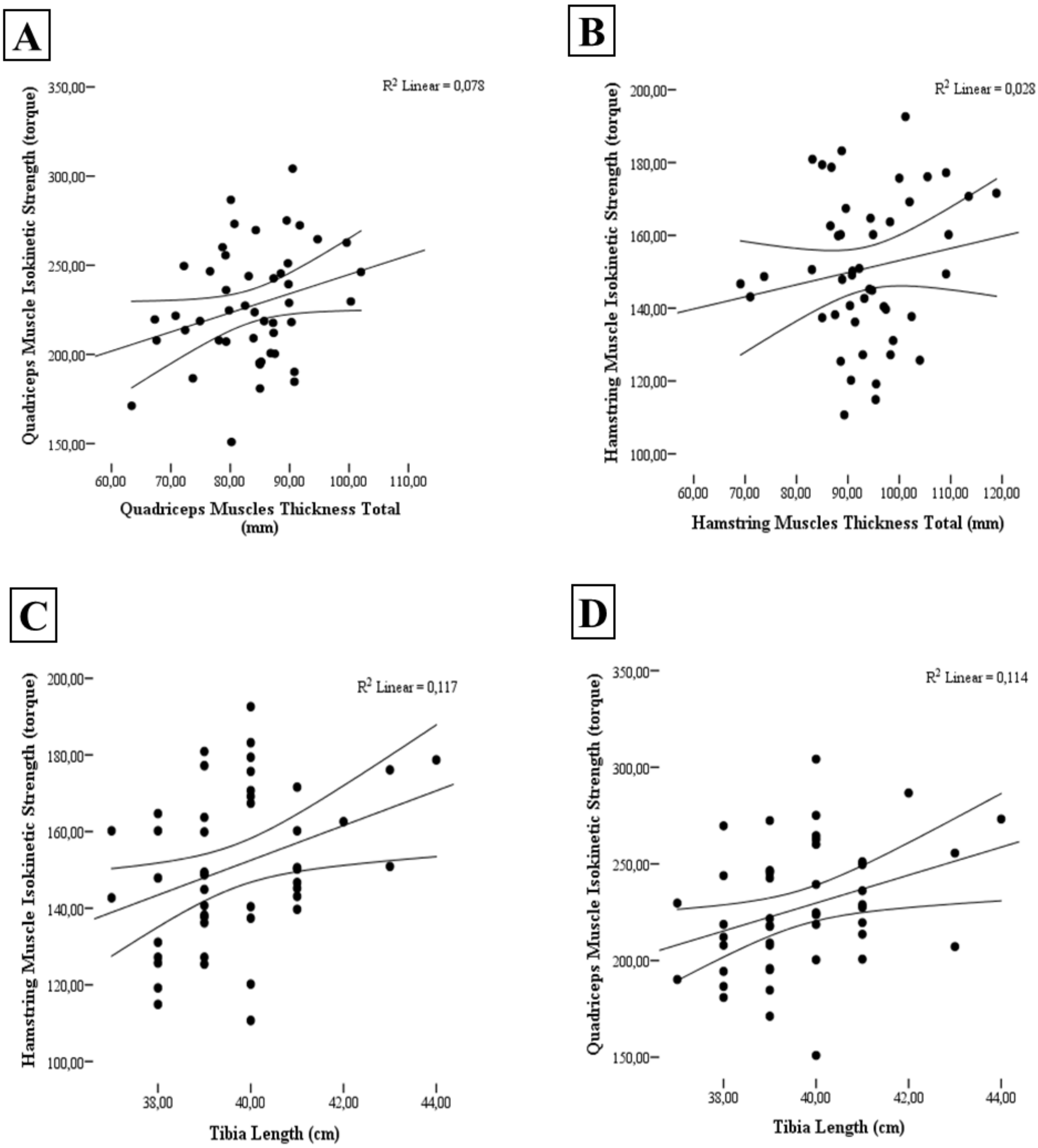

Figure 1. A: Relationship between quadriceps muscle size and strength; B: Relationship between hamstring muscle size and strength; C: Relationship between hamstring muscle strength and tibia length; D: Relationship between quadriceps muscle strength and tibia length.

DISCUSSION AND CONCLUSION

The present research aimed to explore the relationship between the size of the knee extensor and flexor muscle groups, investigate how the size of these muscle groups is linked to their capacity to generate strength and examine whether the muscle size ratio correlates with the strength ratio of the hamstrings-to-quadriceps (H:Q). Additionally, we examined the impact of tibia length on the isokinetic strength of both the quadriceps and hamstring muscles. Unexpectedly, our findings did not reveal a significant association between muscle size and strength. However, a positive correlation was observed between isokinetic muscle strength and tibia length. Specifically, tibia length accounted for 11% of the variance in isokinetic strength of both the quadriceps and hamstring muscles ($r^2 = 0.114$). The results showed a positive correlation between the isokinetic strength of the quadriceps and hamstrings, indicating that these two muscle groups tend to exhibit concurrent increases in strength. Similar to the lack of correlation observed between muscle strength and size, our investigation did not reveal a significant relationship between the H:Q strength ratio and the size ratio of these muscle groups.

The risk of suffering from hamstring strain injury is higher when there is an imbalance in strength around the knee joint, as indicated by a low hamstring-to-quadriceps (H:Q) strength ratio (Croisier et al., 2008; Ruas et al., 2019). Nonetheless, there needs to be more exploration of the determinants of this ratio. Given the pivotal role of muscle size in influencing strength capacity, it is reasonable to surmise that the ratio of muscle size between opposing muscles may likewise influence their strength ratio (Bamman et al., 2000). Similarly, it is expected that the size of opposing muscles would exhibit a correlation. The present investigation yielded an unexpected finding, as the size of the quadriceps muscle was not found to be correlated with that of the hamstring muscle. This discrepancy may be explained by the previous assertion of Loenneke et al. (2021) that the relationship between muscle strength and size may differ between baseline and resistance training conditions. Specifically, while such a correlation may exist at baseline, it may not be present after resistance training. The predominance of athletic individuals within our student cohort may have contributed to the absence of a discernible correlation between muscle size and strength. This could be explained by Loenneke et al. (2021), proposition that exercise-induced muscle growth does not necessarily translate into concurrent changes in exercise-induced strength. Also, the role of both neural and morphological factors in facilitating improvements in strength has been acknowledged for a considerable time (Folland & Balshaw., 2021). In their comprehensive review, Reggiani & Schiaffino (2020) assert that the relationship between muscle strength and mass is complex and not easily discernible. They highlight that one possible reason for the absence of a strong correlation between mass gain and strength increase is the involvement of neural adaptations. Specifically, they posit that training entails the acquisition of the motor unit recruitment and firing rate and the concurrent deactivation of opposing muscle groups. Our study's results were consistent with those of Denadai et al. (2014) who observed a lack of association between the ratio of knee extensor and flexor muscle cross-sectional area (ACSA) and concentric strength ratio. This similarity in results may be elucidated by the composition of their study cohort, comprising professional football players. The study conducted by Akagi et al. (2014) revealed that the ratio of muscle size between knee extensors and knee flexors did not significantly affect the strength ratio. Our findings similarly suggest that muscle size may not be a primary factor determining muscle strength. However, caution should be exercised when comparing studies, given the potential differences in various experimental aspects, including but not limited to the level of experience of participants (professional versus collegiate soccer players), the method employed in measuring muscle size (cross-sectional area [CSA] versus muscle volume), and the conditions under which strength was measured (isokinetic versus isometric). In contrast to our findings, Masuda et al. (2003) observed a significant positive correlation between the peak torque of knee extensors and knee flexors and the cross-sectional area (CSA) of quadriceps ($r = 0.54$ and 0.59, respectively) and hamstrings ($r = 0.57$ and 0.64, respectively). In their study, Sekir et al. (2022) utilized regression analysis to examine the relationship between quadriceps muscle thickness and cross-sectional area during rest and contraction and the ability to predict both isometric and isokinetic muscle strength in the quadriceps. The results indicated that these anatomical factors may be predictors of quadriceps strength in both muscle contractions. Evangelidis et al. (2016) also found that the muscle size of knee extensors (quadriceps) and flexors (hamstrings) demonstrated significant correlations with their respective isometric strength ($r = 0.62$-0.84, $P < 0.001$). Notably, while hamstrings muscle volume was strongly associated with knee flexor strength across all velocities and contraction modes, quadriceps size was only moderately associated with knee extensor concentric strength ($r = 0.55$-0.56, $P < 0.01$) and exhibited no association with eccentric strength ($r = 0.27$-0.33, $P > 0.05$). The muscle volume ratio between the hamstrings and quadriceps (H:Q) exhibited correlations with both isometric and functional strength ratios. The dissimilarity observed between the results of the present study and the previous study may be attributed to the variances in the methodological approaches utilized for the measurement of muscle size and strength. Specifically, the prior study utilized magnetic resonance imaging to determine muscle cross-sectional area, while our study utilized ultrasonography to assess muscle thickness. Furthermore, the prior study evaluated isometric and isokinetic strength at 50º and 350º/s, whereas we conducted strength testing at 60º/s. These differences in methodological procedures may have contributed to the observed discrepancies between the two studies.

The results of the study indicate that there exists a significant positive weak correlation between tibia length and quadriceps and hamstring muscle isokinetic strength, as evidenced by correlation coefficients of 0.338 ($p < 0.05$) and 0.341 ($p < 0.05$), respectively. Dean et al. (2022) found no significant relationship between quadriceps muscle strength and tibia length, which contrasts with the results obtained in our study. Bolz et al. (1984) observed that the limb with shorter length exhibited consistent weakness in terms of knee flexion and extension strength. Additionally, a pilot study conducted by Hamzat (2001) demonstrated a significant association between patient height and quadriceps strength in healthy individuals. In their study, Qazi et al. (2017) identified a significant weak correlation between tibia and femur length and leg extension strength. Chevidikunnan & Khan (2020) conducted an analysis that corroborated this finding, demonstrating the presence of a weak positive correlation between femoral length and isokinetic peak torque of the knee flexors and extensors. The current body of literature examining the relationship between limb length and knee muscle strength is limited and has utilized varying methodological approaches. Thus, additional studies are necessary to elucidate this subject further and better understand the potential association.

The present study provides evidence that the H:Q muscle size ratio is not significantly correlated with the H:Q muscle strength ratio. Furthermore, our findings demonstrate that muscle strength does not exhibit a linear relationship with size, suggesting that muscle size alone is not a reliable predictor of muscle strength. These results underscore the importance of considering other relevant parameters, such as pennation angle, muscle fiber type, fascicle length, fascicle angle, and muscle length, in evaluating and understanding muscle strength. The potential influence of limb length on muscle strength warrants further investigation, as the existing literature on this topic is limited. When a comparison of isokinetic torque between individuals is necessary, accounting for individual differences in limb length may be advantageous in accurately interpreting and comparing muscle strength measurements. Moreover, studies examining alterations in muscle architecture resulting from resistance training are essential for understanding the relationship between muscle strength and architectural parameters.

GENİŞLETİLMİŞ ÖZET

GİRİŞ

Uzun yıllardır, kas kütlesinin, iligili kasın üretebileceği maksimum kuvvet veya torkun en etkili belirleyicisi olduğu genel olarak kabul edilmektedir. Daha büyük kaslar, daha fazla sayıda sarkomer ve aktin-miyozin çapraz köprüleri barındırdığından, daha büyük kasılma kuvveti üretebilirler (Powell, 1984). Kas gücü, sportif performans ve günlük fonksiyonel aktivitelerde önemli bir rol oynar, hem de kas yaralanmaları için bir risk faktörüdür ve eklem dejenerasyonunun gelişimini ve ilerlemesini etkileyebilir. Kas kütlesinin, kuvvet ile pozitif bir ilişkisinin bulunduğu yaygın olarak kabul edilen bir durum olsa da kas kütlesindeki artışın direkt olarak kas gücünde bir artış sağlayıp sağlamadığı veya kas kütlesi artmadan da kas gücünde gelişim elde edilebileceği konusu henüz net değildir (Bamman ve ark., 2000; Abe ve ark., 2007). Hamstring: Quadriceps (H:Q) kas kuvveti oranı, kas asimetrisini belirlemek diz eklem stabilitesini takip etmek, kas gücü özelliklerini ve işlevselliğini belirlemek ve alt ekstremite yaralanmalarının önlenmesi ve rehabilitasyonunda kritik bir parametre olarak kullanılmaktadır (Coombs & Garbutt, 2002; Ruas ve ark., 2015; Kulas ve ark., 2018). Ayrıca düşük bir H:Q oranının, hamstring yaralanması geçirme olasılığını önemli ölçüde artırdığına dair bulgular mevcuttur (Croisier ve ark., 2008). H:Q kuvvet oranı, kuvvet dengesizliklerini değerlendirmede ve hamstring yaralanmaları için potansiyel risk faktörlerini belirlemede değerli bir araç olmasına rağmen, literatürde bu oranı etkileyen faktörler hakkında sınırlı bilgi bulunmaktadır. Karşıt kas gruplarının büyüklüğü, ilgili kasların işlevselliğini etkileyebilir. Ayrıca, bir agonist kasın kütlesi ile antagonist kas kütlesi arasındaki ilişki tam olarak bilinmemektedir (Evangelidis ve ark., 2015). Dolayısı ile bu araştırmada hamstring kas kütlesi ile kuadriceps kas kütlesi arasındaki ilişkinin incelenmesi ve bu ilişkinin kuvvet oranına etkisinin incelenmesi amaçlanmıştır.

YÖNTEM

Bu araştırma ilişkisel bir model ile tasarlanmış olup, araştırmaya rekratif düzeyde aktif 47 spor bilimleri fakültesi öğrencisi gönüllü olarak katılmıştır. Alt ekstremiteye ilişkin ciddi sakatlık geçiren veya cerrahi operasyon geçmişi olan gönüllüler araştırma dışında tutulmuştur. Hamstring ve kuardiceps kas kütlesinin belirlenebilmesi için, tecrübeli bir uzman tarafından ultrasonografi işlemi gerçekleştirilmiştir. Ultrasonografi katılıcımları supin pozisyonda, bacak tam ekstansiyonda iken, en kalın nokta olarak kabul edilen kas uzunluğunun %50'sinden gerçekleştirilmiştir. Her bir kas için 3 ölçüm yapılmış ve en yakın 2 değerini ortalaması kaydedilmiştir. Hamstring ve kuadriceps izokinet kas kuvveti, Isomed 2000 marka dinamometre ile 60º/s açısal hızda ölçülmüştür. 5 tekrardan oluşan ekstansiyon ve fleksiyon döngüsünden sonra, her hareket için elde edilen ortalama zirve değer (fleksiyon, ekstansiyon) kaydedilmiştir. Hem ultrason hem de izokinetik kuvvet ölçümleri dominant taraftan gerçekleştirilmiştir. Elde edilen verilerin istatitiksel analizinde, pearson korelasyon testinden ve bağımlı gruplar için t-testinden faydalanılmıştır. Tüm istatistiki işlemler SPSS 22.0 paket program aracılığı ile gerçekleştirilmiştir.

BULGULAR

Araştırma bulguları, hamstring ve kuadriceps kas kütlesi ile ilgili kaslar tarafından üretilen zirve tork değerleri arasında herhangi bir yönde ilişki olmadığını göstermektedir. Ayrıca, H:Q kas kütle oranının H:Q kas kuvvet oranı ile ilişkili olmadığı görülmüştür. Hamstring kas kütlesi ile kuadriceps kas kütlesi arasında bir ilişki tespit edilemezken, hamstring izokinetik kas kuvveti ile kuadriceps izokinetik kas kuvveti arasında pozitif yönlü, güçlü ve anlamlı bir ilişki tespit edilmiştir.

SONUÇ

Sonuç olarak, kuadriceps ve hamstring kas kütlesinin izokinetik diz ekstansiyon ve fleksiyon kuvvetini belirlemede geçerli bir parametre olmayabileceği ancak ilgili kaslar tarafından üretilen kuvvetin karşılıklı olarak paralel bir artış gösterdiği söylenebilir. Tibia uzunluğu, kuadriceps ve hamstring kaslarının ürettiği tork değerini etkileyebilir, bireyler arası diz eklemi özelinde izokinetik kuvvet karşılaştırmaları yapılırken, relatif tork değerlerinin yanı sıra, tibia uzunluğunun da değerlendirmede göz önünde tutulması önerilebilir.

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Tartışma ve Yorum *Discussion and Commentary*	Elde edilen bulguların değerlendirilmesi *Evaluation of the obtained finding*	Kadir KESKİN Feride Nur GÖĞÜŞ

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