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Ultrasonographic Measurement of the Distal Femoral Cartilage and Quadriceps Muscle Thickness in Hemiparetic Patients After Stroke and the Associations with Functional Status

İnme Sonrası Hemiparetik Hastalarda Distal Femoral Kıkırdak ve Kuadriseps Kas Kalınlığının Ultrasonografik Ölçümü ve Fonksiyonel Durumla İlişkisi

Aysel Çınar SEYHAN[a], Mustafa Aziz YILDIRIM[a], Kadriye ÖNEŞ[a], Mustafa ÇORUM[a]

[a]Clinic of Physical Medicine and Rehabilitation, İstanbul Physical Medicine Rehabilitation Training and Research Hospital, İstanbul, TURKEY

ABSTRACT Objective: To compare the femoral cartilage and quadriceps muscle thickness on both the hemiplegic and intact sides using ultrasonography (USG) and examine the relationship between these measurements and functional parameters in stroke patients. **Material and Methods:** Sixty-five patients who were under follow-up for stroke were included in this study. Femoral cartilage and quadriceps muscle [rectus femoris (RF)+vastus intermedius (VI)] thicknesses in both knees were measured using USG; Brunnstrom and Fugl-Meyer test were used for motor evaluation. Barthel Index (BI) and Functional Ambulation Classification (FAC) were used for functional evaluation. **Results:** The bilateral femoral cartilage thickness on medial, intercondylar and lateral regions values were not significantly different between the intact and hemiplegic sides. The RF+VI value was significantly lower on the hemiplegic side than on the intact side ($p<0.05$). There were significant positive correlations between the RF+VI value and the BI and FAC scores. **Conclusion:** The measurement of the femoral cartilage thickness in stroke patients did not differ significantly between the hemiplegic side and the intact side, whereas the quadriceps muscle thickness measurements were significantly lower on the hemiplegic side than on the intact side. Quadriceps muscle thickness values affect the functional status in stroke patients.

Keywords: Musculoskeletal system; cartilage; hemiplegia; stroke; ultrasonography

ÖZET Amaç: İnme hastalarında hem hemiplejik hem de sağlam taraf femoral kıkırdak ve kuadriseps kas kalınlığını ultrasonografi (USG) kullanarak karşılaştırmak ve bu ölçümler ile fonksiyonel parametreler arasındaki ilişkiyi incelemek. **Gereç ve Yöntemler:** Bu çalışmaya, inme nedeniyle takip edilen 65 hasta dâhil edildi. Her 2 dizdeki femoral kıkırdak ve kuadriseps kası [rektus femoris (RF)+vastus intermedius (VI)] kalınlığı USG ile ölçüldü; motor değerlendirme için Brunnstrom ve Fugl-Meyer testi kullanıldı. Fonksiyonel değerlendirmede ise Barthel İndeksi [Barthel Index (BI)] ve Fonksiyonel Ambulasyon Sınıflandırması (FAS) kullanıldı. **Bulgular:** Mediyal, interkondiler ve lateral bölgelerdeki femoral kıkırdak kalınlığı değerleri sağlam ve hemiplejik taraflar arasında anlamlı olarak farklı değildi. RF+VI değeri sağlam tarafa göre hemiplejik tarafta anlamlı olarak daha düşüktü ($p<0,05$). RF+VI değeri ile BI ve FAS skorları arasında anlamlı pozitif korelasyonlar vardı. **Sonuç:** İnme hastalarında femoral kıkırdak kalınlığının ölçümü hemiplejik taraf ile sağlam taraf arasında önemli ölçüde farklılık göstermezken, kuadriseps kas kalınlığı ölçümleri sağlam tarafa göre hemiplejik tarafta anlamlı ölçüde daha düşüktü. Kuadriseps kas kalınlığı değerleri inmeli hastalarda fonksiyonel durumu etkileyebilmektedir.

Anahtar Kelimeler: Kas-iskelet sistemi; kıkırdak; hemipleji; inme; ultrasonografi

Stroke is a clinical syndrome characterized by acute neurological deficits arising from focal impairment of brain blood flow. Hemiparesis is the most common neurological condition observed after a stroke.[1] Immobilization may develop in hemiparetic patients owing to motor weakness. Further, stroke is

Correspondence: Mustafa ÇORUM
Clinic of Physical Medicine and Rehabilitation, İstanbul Physical Medicine Rehabilitation Training and Research Hospital, İstanbul, TURKEY/TÜRKİYE
E-mail: mustafacorum@gmail.com

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one of the most important causes of immobilization in the lower extremities. Together with other risk factors, immobilization negatively impacts many systems after a stroke. Some of these negative impacts on the musculoskeletal system include articular cartilage degeneration and thinning, muscle atrophy, osteopenia, and osteoporosis.[2] Considering the incidence, immobilization may be one of the major causes of cartilage degeneration.[3] Immobilization after stroke caused reduced proteoglycan content and synthesis, decreased articular cartilage thickness. Furthermore, stroke and accompanying disorders in muscle physiopathology may lead to atrophy of the lower extremity muscles. Immobilization after stroke results in reduced muscle mass and function as a result of decreased neuromuscular activation and muscle unloading. Immobilization results with altered fiber type proportions, including selective fast-twitch myosin heavy chain (MHC) fiber atrophy and specific loss of slow-twitch MHC fibers in hemiparetic limbs of stroke patients.[4] Cartilage tissue is vital for maintaining normal knee joint function.[5] Quadriceps muscle is fundamental for ambulation because it is the most important extensor of the knee joint as well as an antigravity muscle.[6] Hence, the development of an effective and noninvasive method for the evaluation of cartilage and muscles has been one of the goals of musculoskeletal system radiology. Many studies have demonstrated muscle atrophy after stroke through measurements in different muscles of the lower and upper extremities performed using various methods [computed tomography (CT), dual-energy x-ray absorptiometry (DEXA)].[7-13] A decrease in femoral cartilage thickness after stroke has also been demonstrated in the literature through measurements performed using ultrasonography (USG). Over the past 20 years, musculoskeletal USG has gained importance in the diagnosis of diseases. Using USG, it is possible to evaluate changes in knee muscles, articular cartilage, and soft tissue.[14]

This study aimed to compare the femoral cartilage and quadriceps muscle thickness measured by USG between the hemiplegic and intact sides in stroke patients, examine the relationship within these measurements and functional parameters.

MATERIAL AND METHODS

This is a cross-sectional study. The age, sex, educational status, marital status, working status, hemiplegic sides, dominant hand, stroke duration, medical history, and stroke etiology of the patients included in the study were questioned and recorded. All participants provided written informed consent at the beginning of the study after full information about its procedures and purposes. Bakırköy Sadi Konuk Training and Research Hospital's Ethics Committee approved the study (no: 2018/258, date: 23.07.2018).

Sixty-five inpatients (mean age 66.6±12.9, mean time after stroke 8.34±6.9) who were under follow-up for stroke were included in this study. The inclusion criteria were the presence of a history of ischemic or hemorrhagic stroke [based on CT and/or magnetic resonance imaging (MRI) report]. Furthermore, the patients had to have less than 2 years since the date of the incident and aged between 18 and 90 years.

Patients were excluded, if they presented with any of the following diagnoses: history of multiple strokes, more than 2 years since the stroke incident, inflammatory arthritis or any other rheumatic disease, history of trauma in the knee (trauma to the cruciate ligament or meniscus), previous knee surgery, neurological gait disability before stroke, knee contracture.

All ultrasonographic measurements were performed by the same assessor using a diagnostic USG device (MyLab 60, Esaote, Genova, Italy) and a 6-18-MHz linear probe. Femoral cartilage and quadriceps muscle [rectus femoris (RF)+vastus intermedius (VI)] thickness in both knees were measured using USG. Horizontal imaging was performed from the suprapatellar region while the patient was in the supine position with the knees at maximum flexion. Femoral cartilage thickness was measured at three different positions: medial, intercondylar, and lateral (Figure 1).[15] For bilateral examination of the musculus VI and musculus RF muscle layer thickness, horizontal imaging was performed from the midpoint of the line between the anterior superior iliac protrusion and the upper part of the patella while the patients were in supine position with the knees in full extension; the average of three measurements was recorded as the muscle thickness (Figure 2).[16]

FIGURE 1: Ultrasonographic measurements of femoral cartilage thickness (medial, intercondylar, lateral).

The Fugl-Meyer lower extremity scale, which is the first tool to have been developed for quantitatively assessing sensorimotor recovery after a stroke and was prepared on the basis of Twitchell and Brunnstrom's motor recovery stages, was used to evaluate the following parameters of patients' motor function: reflex activity, whether consecutive movements were performed synergistically or voluntarily (in terms of tremor speed and time), unsupported sitting, protective reactions on the intact and affected sides, ability to stand without support, ability to stand on the intact leg, and ability to stand on the affected leg. Scoring was performed by assigning 0 points if the action could not be performed, 1 point if the action could be partially performed, and 2 points if the action could be completely performed. The highest score that could be obtained on the scale was 46.[17]

The Barthel Index (BI) and Functional Ambulation Classification (FAC) were used for functional evaluation. BI has been adapted to Turkish and contains 10 items that evaluate daily living activities and mobility. It evaluates feeding, bathing, dressing, self-care, bowel and bladder care, toilet use, transfer from wheelchair to bed, walking on a leveled surface, and climbing up and down the stairs. It also indicates how much help is received during daily activities. Scores between 0-20 indicate that the individual is fully dependent; 21-61, that the individual is highly dependent; 62-90, that the individual is moderately dependent; 91-99, that the individual is slightly dependent; and 100, that the individual is completely independent.[18]

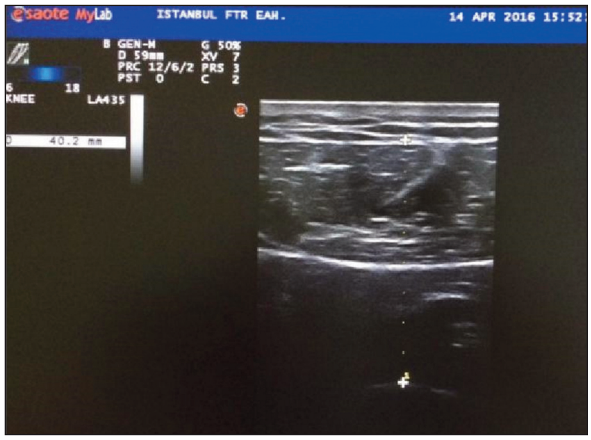

FIGURE 2: Ultrasonographic measurements of quadriceps (rectus femoris+vastus intermedius) muscle thickness with horizontal imaging.

FAC scale evaluates the ambulation capacity of patients and is divided into six categories (0-5; FAC 0: no ambulation, FAC 1-2: cannot walk without support, and FAC 3-5: can walk 6 meters on their own). FAC is important for ambulatory development in stroke patients and is a valid and reliable scale.[19]

STATISTICAL ANALYSIS

Descriptive statistics were presented in terms of mean, standard deviation, median, minimum, maximum, frequency, and percentage. Normality was evaluated using the Shapiro-Wilk's test. Paired samples t-test and Wilcoxon test were used to analyze dependent quantitative data. Pearson and Spearman

TABLE 1: Demographic characteristics of patients.

		Minimum-Maximum	Median	Mean±SD/n-%	
Age (years)		33.0-90.0	67.0	66.6±12.9	
Time after stroke (months)		1.0-24.0	6.0	8.34	6.9
Gender	Female			33	50.8
	Male			32	49.2
Marital status	Married			57	87.7
	Widowed			8	12.3
Education	Illiterate			12	18.5
	Literate			12	18.5
	Primary			30	46.2
	Secondary			3	4.6
	High school			3	4.6
	University			5	7.7

SD: Standard deviation.

correlation analyses were used to assess correlations. The significance level was identified as $p<0.05$. Statistical Package for the Social Sciences (SPSS 22.0) software was used for all statistical analyses.

RESULTS

The demographic and clinical characteristics of the patients are shown in Table 1. The mean age of the patients was 66.6±12.9 years. The mean time after stroke for these patients was 8.34±6.9 months. The results of the Brunnstrom motor stage, Fugl-Meyer lower extremity scale, FAC, and BI are presented in Tables 2. The bilateral femoral cartilage thickness on medial, intercondylar and lateral regions were not significantly different between the intact and hemiplegic sides of the 65 patients included in the study ($p=0.228$, $p=0.393$, $p=0.460$; respectively) (Table 3). The RF+VI value was significantly lower on the hemiplegic side than on the intact side ($p<0.001$) (Table 3).

There was no significant correlation between the hemiplegic side bilateral femoral cartilage thickness on medial, intercondylar and lateral regions values and the Brunnstrom, Fugl-Meyer, BI and FAC scores. There were no significant correlations between the hemiplegic side RF+VI value and the Brunnstrom, Fugl-Meyer ($r=0.124$, $p=0.325$; $r=0.219$, $p=0.080$; respectively). There were significant positive correlations between the hemiplegic side RF+VI value and the BI, and FAC scores ($r=0.427$, $p<0.001$; $r=0.311$, $p=0.012$; respectively) (Table 4). There were no significant correlations between the hemiplegic side RF+VI value and the medial condyle ($r=0.241$, $p=0.053$) and intercondylar region values ($r=0.200$, $p=0.110$). A significant positive correlation was found between the hemiplegic side RF+VI value and the lateral condyle value ($r=0.313$, $p=0.011$) (Table 5).

TABLE 2: Functional evaluation features.

	Minimum-Maximum	Median
Etyology	Ischemia	
	Hemorrhage	
Fugl-Meyer	3.0-43.0	23.0
Barthel index	0.0-100.0	20.0
FAC score	0.0-5.0	1.0
Brunnstrom lower	1.0-6.0	3.0

FAC: Functional Ambulation Classification.

DISCUSSION

Based on the results of our study, compared with the healthy side, in the hemiplegic side, no statistically significant decrease was observed in the femoral cartilage thickness measurements of stroke patients; however, the quadriceps muscle thickness measurements were significantly lower in the hemiplegic side than in the healthy side.

TABLE 3: Femoral cartilage thickness and quadriceps muscle thickness measurements and comparison of intact side and hemiplegic side.

	Minimum-Maximum	Median	Mean±SD	p value
Bilateral femoral cartilage thickness				
Medial condyle				
Hemiplegic side	1.3-3.1	2.1	2.1±0.4	0.228[p]
Intact side	1.3-2.8	2.1	2.0±0.3	
Intercondylar region				
Hemiplegic side	1.2-3.3	2.0	2.0±0.5	0.393[w]
Intact side	1.1-3.3	1.9	2.0± 0.4	
Lateral condyle				
Hemiplegic side	1.3-3.1	2.0	2.0±0.4	0.460[w]
Intact side	1.1-3.0	2.0	1.9±0.4	
Quadriceps muscle thickness				
Hemiplegic side	4.0-34.3	14.0	15.3±7.4	**< 0.001**[w]
Intact side	4.2-37.8	16.9	17.6±7.7	

[p]Paired samples t-test; [w]Wilcoxon test; SD: Standard deviation.

TABLE 4: Comparison of functional evaluation parameters of hemiplegic side bilateral femoral cartilage thickness and quadriceps muscle thickness measurements.

		Brunnstrom	Fugl-Meyer	Barthel	FAC
Bilateral femoral cartilage thickness					
Medial condyle	r value	0.184	0.226	0.196	-0.222
	p value	0.142	0.070	0.118	0.076
Intercondylar region	r value	0.041	-0.018	0.058	-0.066
	p value	0.748	0.890	0.644	0.601
Lateral condyle	r value	0.033	0.017	0.151	-0.154
	p value	0.794	0.891	0.229	0.221
Quadriceps muscle thickness					
Rectus femoris + Vastus intermedius	r value	0.124	0.219	0.427	0.311
	p value	0.325	0.080	**< 0.000**	**0.012**

Spearman correlation; FAC: Functional Ambulation Classification.

TABLE 5: Correlation of hemiplegic side femoral cartilage thickness and quadriceps muscle thickness measurements.

		Medial condyle	Intercondylar region	Lateral condyle
Rectus femoris + Vastus intermedius	r value	0.241	0.200	0.313
	p value	0.053	0.110	**0.011**

Spearman correlation.

Our literature research revealed highly contradictory results regarding the effects of immobilization on articular cartilage.[20] A review examining the effects of loading in various animal models reported that immobilization causes increases, decreases, as well as no changes in the thickness of articular cartilage; the increasing, decreasing, and unchanging articular cartilage thickness in the different animal models may have resulted from different immobilization positions or from different measurement areas. In other words, different cartilage plates or knee layers may have been measured in these studies. In a rat model, O'Connor et al. studied the knee cartilage after loading with non-rigid immobilization in flexion.[21] They found no change in the cartilage thickness in the posterior regions after four weeks, whereas the thickness increased by 15-22% in the anterior femoral region and by 10% in the anterior tibial regions. In our study, we prevented this by measuring the cartilage thickness exactly over the patella with maximum knee flexion. In a study that was designed similarly to the current study, Tunç et al. evaluated 87 stroke patients and found that particularly the lateral femoral condyle measurements on the hemiplegic side were significantly thinner compared with those on the intact side.[14] This may be attributed to the longer mean incident duration in that study compared with the current study (mean incident duration in the said study: 12.3 months; mean incident duration in the current study: 6.29 months). In contrast, when patients were grouped according to the incident duration in a manner similar to that in the study of Tunç et al., lateral condyle measurements revealed that patients who were in the 1-2 year period had lower cartilage thickness on the hemiplegic side than on the intact side. However, there was no statistically significant difference.[14]

One of the reasons why no significant difference were found in the femoral cartilage thickness measurements between the hemiplegic and intact sides of stroke patients in the current study might have been the lack of mechanical stress in both knees in non-ambulated patients because these patients are unable to place a load on either knee. The high number of nonambulated patients in the current study (FAC0+FAC1+FAC2=73.8%) may have affected the results in such a way. Joint movement and the degree of mechanical stress applied on the joint are extremely important for maintaining articular cartilage integrity. Intermittent stress caused by load bearing and movement determines the thickness of cartilage. Even when a low contact stress is applied, cartilage thickness has been shown to be greater in the contact areas. In other words, cartilage thickens when exposed to moderate activity.[22]

In a previous study that was designed similarly to the present one, Nozoe et al. measured quadriceps (RF+VI) muscle thickness using USG on the hemiplegic and intact sides of 16 non-ambulated stroke patients.[23] The decrease on the paretic side was found to be more pronounced at the third week. In the current study, we evaluated the patients cross-sectionally according to their status at a moment. Similar to other studies, the current study also demonstrated muscle atrophy. Many studies have reported on muscle atrophy in the chronic stage of stroke.[7,9-11] In stroke, adaptive structural changes in muscle tissue may begin as early as 4 hours after cerebral ischemia. This might be related to the disruption of the synaptic transmissions of the motor neurons that innervate muscles. This, in turn, leads to a decrease in the number of motor units.[7] One week later, muscle weakness develops on the unaffected side as well.[8] In the current study, we showed significant muscle atrophy on the affected side compared with the unaffected side. We also examined the correlation between the quadriceps muscle thickness and functional evaluation parameters. There were no significant correlations between the RF+VI values and the Brunnstrom motor stage and Fugl-Meyer motor rating scale ($p>0.05$). There were significant positive correlations between the RF+VI value and the FAC, BI scores ($p<0.05$). In agreement with the present study, Metoki et al. reported that the mean muscle volume was significantly lower on the hemiplegic side than on the intact side.[11] Muscle volume on the hemiplegic and intact side was positively correlated with the BI and negatively correlated with patient age. In the present study, we found that the functional ambulation score was correlated with the quadriceps muscle thickness measurements. In another study, Hayashida et al. examined the correlation of muscle strength and mass with gait speed in 318 elderly Japanese individuals.[24] The study found a positive correlation between knee extensor muscle strength and gait speed.

In the present study, we also assessed the correlation between the femoral cartilage and quadriceps muscle thickness on the affected side of stroke patients. We found that the lateral condyle region of the femoral cartilage was associated with the quadriceps muscle measurement. This result may be attributed to the increase in mechanical stress on the joint caused by the increasing muscle thickness.

The main limitation of our study is that the sample size was small. Another limitation is that the patients age range was very wide. Furthermore stroke patients, were in acute subacute and chronic period.

CONCLUSION

In stroke patients, it is possible to measure femoral cartilage and quadriceps muscle thickness using USG and determine the association of these parameters on the functional status. The measurement of the femoral cartilage thickness in stroke patients did not differ significantly between the hemiplegic side and the intact side, whereas the quadriceps muscle thickness measurements were significantly lower on the hemiplegic side than on the intact side. Performing these measurements may be beneficial to clinicians when preparing a rehabilitation plan. To evaluate all the factors affecting femoral cartilage and quadriceps muscle thickness, it will be necessary to perform advanced and comprehensive studies that include large patient groups with different demographic characteristics and investigate all parameters affecting the periarticular tissue (denervation, non-use, hormonal disorders, etc.).

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

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