Journal of Frailty, Sarcopenia and Falls

Original Article

The relationship between quadriceps femoris thickness measured by US and femoral cartilage thickness in knee osteoarthritis, its effect on radiographic stage and clinical parameters: comparison with healthy young population

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Abstract

Objective: In this study, we aimed to investigate the relationship between quadriceps muscle thickness and femoral cartilage thickness measured by ultrasonography (US) in knee osteoarthritis (OA), to correlate this relationship with radiographic stage and clinical parameters, and to compare these values with those in healthy young adults. **Methods**: A total of 71 patients with knee osteoarthritis and 31 healthy young adults were included in the study. Patients with knee osteoarthritis (Group 1) and healthy young adults (Group 2) were divided into two groups. Muscle thickness measurements of the quadriceps femoris muscle (M. vastus intermedius + M. rectus femoris) were performed by US. **Results**: Bilateral quadriceps muscle thickness and bilateral femoral cartilage thickness values were significantly lower in Group 1 than in Group 2. The 10-metre walk test score and Time Up and Go (TUG) test score were significantly higher in Group 1 than in Group 2. A strong positive correlation was found between bilateral quadriceps (RF+VI) muscle thickness and bilateral femoral cartilage thickness (medial, intercondylar, lateral) in Group 1. **Conclusions**: This study showed a strong positive correlation between quadriceps thickness and femoral cartilage thickness. According to these results, we conclude that US may have a place in the diagnosis of knee osteoarthritis.

Keywords: Cartilge thickness, Knee osteoarthritis, Quadriceps muscule thickness, US

Introduction

Osteoarthritis is one of the most important causes of pain and physical disability among adult population. It increases health expenditures and decreases the quality of life. Risk factors for osteoarthritis include age, gender, heredity, obesity, previous trauma, muscle weakness, and inflammatory joint diseases[1].

The quadriceps muscle is the main muscle that provides stability in the knee joint. The load on the knee joint is not only on the cartilages; the absorption of periarticular structures, especially the quadriceps muscle, is thought to be an important factor preventing the development of knee osteoarthritis. Therefore, a decrease in quadriceps muscle strength has been associated with the development of knee osteoarthritis and a programme to strengthen the surrounding muscles to increase stability is important in the conservative treatment of knee osteoarthritis[2,3]. It has been shown that the quadriceps muscle can be strengthened with isometric exercise in knee osteoarthritis, there is a significant relationship between muscle thickness and strengthening, and this strengthening provides pain and

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Edited by: *Yannis Dionyssiotis*
Accepted *23 June 2023*

Figure 1. Ultrasonographic measurement of femoral cartilage thickness (medial, intercondylar, lateral).

functional improvement[4-6]. However, quadriceps muscle thickness has not been used in the diagnosis, staging, and treatment follow-up of OA.

The use of ultrasonography (US) as a non-invasive, inexpensive, easily applicable and reliable diagnostic method in the diagnosis and follow-up of musculoskeletal system diseases has recently become widespread. It has been proven by many researchers that US is a good indicator in the measurement of quadriceps muscle thickness and femoral articular cartilage thickness[7].

In this study, it was aimed to determine the relationship between quadriceps muscle thickness measured by US and femoral cartilage thickness, radiographic stage and clinical parameters in knee osteoarthritis, and also to compare the values with those in healthy young adults.

Materials and Methods

This study was conducted on 71 patients with knee osteoarthritis who applied to the outpatient clinic of Istanbul Physical Medicine and Rehabilitation Training Hospital between May 2016 and October 2016, and 31 healthy young adults without knee problems who applied to the outpatient clinic for any other reason. OA was diagnosed clinically and radiologically according to the American College of Rheumatology (ACR) criteria Patients with knee osteoarthritis (group 1) and healthy young adults (group 2) were divided into two groups.

Inclusion Criteria

1. Diagnosis of knee OA (according to ACR criteria)
2. Patients aged 50-75 years
3. Presence of grade 2-4 gonarthrosis according to Kellgren-Lawrance (K-L) staging

Exclusion criteria

1. Those who had knee injections (PRP, hyaluronic acid, corticosteroid), oral glucosamine, chondroitin in the last 6 months
2. Those with neurological diseases that make walking difficult
3. Hip-knee operation, history of knee trauma
4. People who have performed quadriceps strengthening exercises in the last 6 months
5. Patients with Stage-1 knee OA according to K-L staging
6. Those who need an assistive device for mobilisation
7. People with rheumatic diseases (RA, AS, Gout, Pseudogout)

Evaluation Methods

Knee joints of all patients were evaluated by standing anteroposterior compression and lateral direct radiographs and knee joint US. Knees of young adults were evaluated only by US.

Roentgenographic Evaluation

Knee radiographs of the Group 1 were taken in the anteroposterior, standing and erect positions. Direct radiographs were evaluated according to the K-L classification.

Ultrasonographic Evaluation

All ultrasonographic measurements were performed by the same person using a diagnostic ultrasonography device (Esaote MyLab60) and a 6-18 MHz linear probe. Ultrasonographic quadriceps femoris (rectus femoris+vastus intermedius) thickness and femoral cartilage thickness measurement were performed blindly to direct radiographs (K-L classification).

Figure 2. Ultrasonographic quadriceps (RF+VI) muscle thickness measurement with horizontal imaging.

Femoral cartilage thickness assessment technique: Femoral cartilage thickness was measured in 3 different localisations: medial, intercondylar and lateral by horizontal imaging from the suprapatellar region with the patient in supine position and knees in maximum flexion (Figure 1).

Quadriceps femoris (rectus femoris+vastus intermedius) assessment technique: Muscle thickness measurements of the quadriceps femoris muscle (M. vastus intermedius and M. rectus femoris) were performed at specific points defined in previous studies[4,8,9].

In our study, patients were placed supine with their knees in full extension, horizontal imaging was performed at the midpoint of the line between the anterior superior iliac crest and the upper pole of the patella for quadriceps muscle thickness measurement, and the average of 3 measurements of M. vastus intermedius and M. rectus femoris was recorded as muscle thickness (Figure 2).

Pain Assessment

Pain was assessed by visual analogue scale (VAS) in rest, activity and night pain. For this purpose, a 10 centimetre (cm) long line was drawn and this line was numbered at 1 cm intervals. 0: No pain, 10: The most severe pain was explained and the patient was asked to mark the value corresponding to the pain on the scale.

Western Ontorio and McMaster Universities Osteoarthritis Index(WOMAC)

The index was used for functional assessment. In the WOMAC index, pain was assessed with 5 questions, stiffness with 2 questions and functional level with 17 questions. The questions were scored between 0-4 for each measurement and a total score was determined for each section.

Physical Function Tests

The following tests were used to evaluate the physical functional status of the patients[10].

Timed Up & Go test (TUG)

The time taken for the patient to get up from the chair, walk 3m and sit down again is recorded. The average of three tests is taken[11,12].

Ten meter walk test

The patient is asked to walk a distance of 10 meters as fast as possible, and the elapsed time is recorded[13].

Statistical analysis

In the descriptive statistics of the data, mean, standard deviation, median minimum, maximum, frequency and ratio values were used. The distribution of variables was measured by Kolmogorov-Smirnov test. Mann-Whitney u test and independent sample t test were used to analysis quantitative data. Chi-square test was used in the analysis of qualitative data, and Fischer test was used in cases where the conditions of chi-square test were not met. Spearman correlation analysis was used in the correlation analysis. SPSS 22.0 programme was used for impact level and cut-off value in the analyses.

Results

Group 1 consisted of 71 patients with knee osteoarthritis and Group 2 consisted of 31 healthy young adults.

The patients in Group 1 were aged between 50 and 75 years (mean age 61.4), while the healthy adults in Group 2 were aged between 23 and 40 years (mean age 32.8).

		Group 1		Group 2		p
		Mean±SD/n-%	Median(Min-Max)	Mean±SD/n-%	Median(Min-Max)	
Age		61,4 ± 7,7	50 -75	32,8 ± 5,8	23-40	0,000 ^{t}
Sex	Female	54 76,1%		18 58,1%		0,067 $^{x^2}$
	Male	17 23,9%		13 41,9%		
Weight (kg)		79,8 ± 11,5	80 58 -108	78,4 ± 12,1	76 54-95	0,125 ^{m}
Size (cm)		161,4 ± 7,4	160 146 -182	162,2 ± 8,9	167 150-190	0,098 ^{m}
BMI		30,4 ± 4,7	30 21 -44	29,8 ± 3,6	23 20-33	0,105 ^{m}
Education	Primary E.	45 63,4%		10 32,3%		0,095 $^{x^2}$
	HighSchool	5 7,0%		8 25,8%		
	University	4 5,6%		13 41,9%		
Marital Status	Married	47 66,2%		17 54,8%		0,221 $^{x^2}$
	Single	12 16,9%		10 32,3%		
	Widow	12 16,9%		4 12,9%		
Job	Unemployed	1 1,4%		3 9,7%		
	Employe	14 19,7%		13 41,9%		
	Officer	1 1,4%		12 38,7%		
	Student	0 0,0%		3 9,7%		
	Housewife	44 62,0%		0 0,0%		
	Retired	11 15,5%		0 0,0%		
Smoking	No	61 85,9%		22 71,0%		0,075 $^{x^2}$
	Yes	10 14,1%		9 29,0%		

^{m} Mann-whitney u test / ^{t} t test / $^{x^2}$ Ki-kare test.

Table 1. The relationship between the two groups according to the sociodemographic characteristics of the patients.

When the gender distribution between the two groups was compared, 17 (23,9%) of the 71 patients in group 1 were male and 54 (76,1%) were female. Of the 31 healthy individuals in group 2, 13 (41,9%) were male and 18 (58,1%) were female (Table 1). While gender distribution, weight, height, BMI value, educational status distribution, marital status distribution, smoking rate did not show a significant difference between the two groups (p>0,05), age showed a difference between the two groups (p=0,00).

In the radiographic evaluation of the patients, according to Kellgren-Lawrance (K-L) staging for the right knee; 25 patients stage 2, 30 patients stage 3, 16 patients stage 4 and for the left knee; 25 patients stage 2, 28 patients stage 3, 19 patients stage 4.

In pain assessment, right knee VAS mean; 5,8 left knee VAS mean; 5,7.

WOMAC mean; pain; 10,2, stiffness; 2,5, physical function; 34,7.

The mean right and left quadriceps (rectus femoris+vastus intermedius) muscle thickness was 23,7 mm in Group 1. In Group 2, right quadriceps (rectus femoris+vastus intermedius) muscle thickness was 36,6 mm and left quadriceps (rectus femoris+vastus intermedius) muscle thickness was 35,5 mm (Table 2, Figure 3).

Right quadriceps (rectus femoris+vastus intermedius) muscle thickness was significantly lower in Group 1 than in Group 2 (p<0,05). Left quadriceps (rectus femoris+vastus intermedius) muscle thickness was significantly lower in Group 1 than in Group 2 (p<0,05) (Table 2).

The 10-meter walking test score in Group 1 was significantly (p<0,05) higher than in Group 2. The TUG test score in Group 1 was significantly (p<0,05) higher than Group 2 (Table 3, Figure 4).

Right knee medial condyle, intercondylar region, and lateral condyle values were significantly lower in Group 1 compared to Group 2 (p<0,05). Left knee medial condyle, intercondylar region, and lateral condyle values were significantly lower in Group 1 compared to Group 2 (p<0,05). (Table 4, Figure 5).

In Group 1, a strong positive correlation was found between right quadriceps (RF+VI) muscle thickness and right femoral cartilage thickness (medial, intercondylar, lateral)

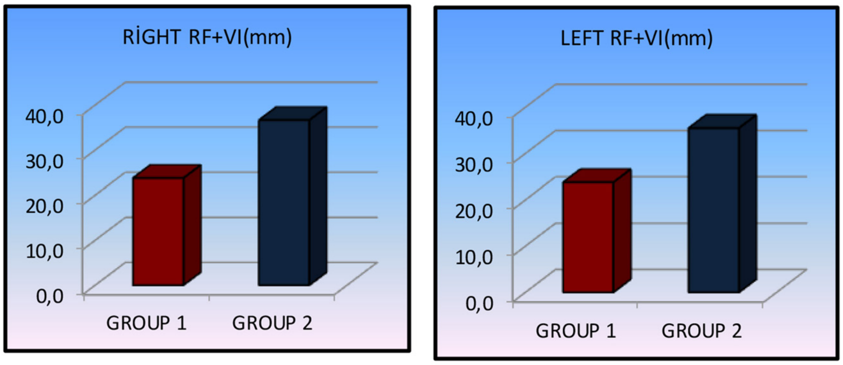

Figure 3. Quadriceps muscle (RF+VI) thicknesses.

	GROUP 1		GROUP 1		p
	Mean±SD	Median(Min-Max)	Mean±SD	Median(Min-Max)	
QUADRİCEPS Thickness(RF+VI) (mm)					
Right	23,7 ± 6,1	23 14-42	36,6 ± 3,5	36 28-43	***0,000*** m
Left	23,7 ± 5,8	23 14-40	35,5 ± 3,4	37 26-41	***0,000*** m
m *Mann-whitney u test*					

Table 2. Quadriceps muscle thicknesses.

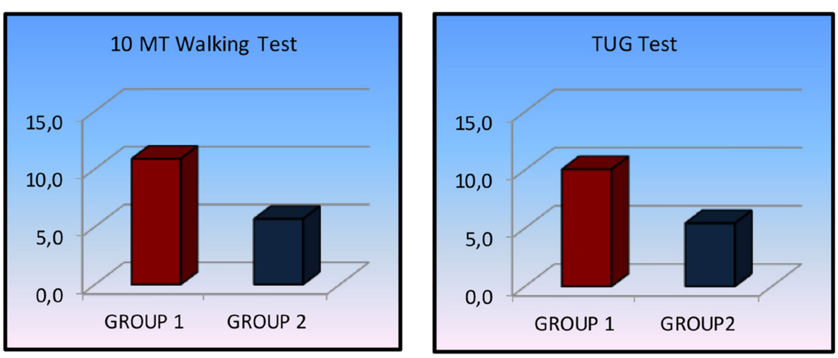

Figure 4. 10 meters walking and TUG tests.

	GROUP 1		GROUP 2		p
	Mean±SD	Median(Min-Max)	Mean±SD	Median(Min-Max)	
10MT walking test (second)	10,9 ± 2,5	11 5-16	5,7 ± 0,7	6 4-7	***0,000*** m
TUG Test(second)	10,1 ± 2,7	10 5-17	5,4 ± 0,5	5 4-6	***0,000*** m
m *Mann-whitney u test*					

Table 3. 10 meters walking and TUG tests.

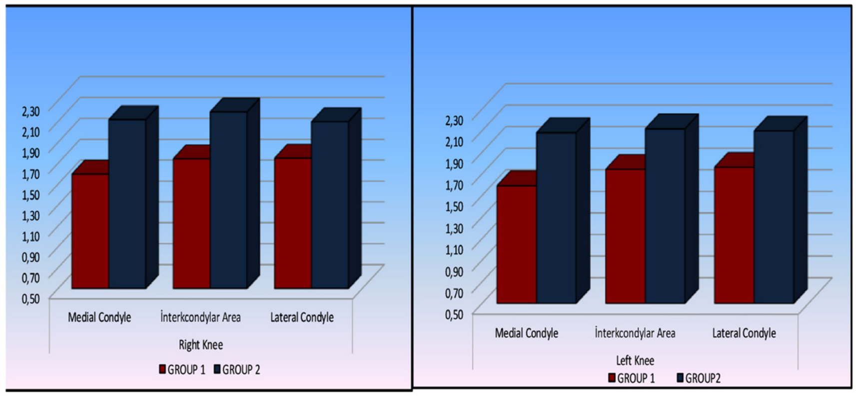

Figure 5. Femoral cartilage thickness values.

	GROUP 1		GROUP 2		p
	Mean±SD	Median(Min-Max)	Mean±SD	Median(Min-Max)	
Right Knee(mm)					
Medial Condyle	1,6 ± 0,3	1,5 1,0-2,5	2,1±0,2	2,1 1,6-2,4	***0,000*** m
İntercondylar Area	1,7 ± 0,3	1,8 1,1-2,6	2,2±0,2	2,2 1,8-2,8	***0,000*** m
Lateral Condyle	1,7 ± 0,3	1,7 1,1-2,6	2,1±0,2	2,1 1,6-2,6	***0,000*** m
Left Knee (mm)					
Medial Condyle	1,6 ± 0,3	1,6 1,0-2,4	2,1±0,2	2,1 1,7-2,5	***0,000*** m
İntercondylar Area	1,7 ± 0,3	1,8 1,0-2,6	2,1±0,3	2,1 1,6-2,8	***0,000*** m
Lateral Condyle	1,8 ± 0,3	1,8 1,1-2,6	2,1±0,2	2,1 1,5-2,6	***0,000*** m
m Mann-whitney u test					

Table 4. Femoral cartilage thickness values.

and between left quadriceps (RF+VI) muscle thickness and left femoral cartilage thickness (medial, intercondylar, lateral).

There was a significant (p<0,05) negative correlation between bilateral quadriceps muscle (RF+VI) thickness and K-L knee stage in patients with knee osteoarthritis (Group 1).

There was a significant (p<0,05) negative correlation between bilateral quadriceps muscle (RF+IV) thickness and WOMAC pain, WOMAC stiffness, WOMAC physical function, WOMAC total score. There was a significant (p<0,05) negative correlation between bilateral quadriceps muscle (RF+VI) thickness and TUG test score.

There was a significant (p<0,05) negative correlation between bilateral quadriceps muscle (RF+IV) thickness and VAS rest, night, movement, mean score.

There was a significant (p<0,05) negative correlation between bilateral quadriceps muscle (RF+IV) thickness and 10-meter walking test score.

Discussion

The incidence of OA increases with age. This increase in OA at older ages has been reported to be due to the following reasons such as insufficient muscle function and inadequate peripheral neurologic response, joint instability associated with increased ligament flexibility, decreased anabolic response to growth factors, loss of chondrocytes, and thinning of the cartilage plate[14].

Ageing affects both muscle and cartilage thickness and these changes play an important role in the development and progression of knee osteoarthritis. The gradual loss of muscle mass and strength, together with changes in muscle quality, can affect the health of articular cartilage by contributing to joint instability and abnormal loading. At the same time, age-related changes in cartilage thickness and composition reduce its ability to withstand mechanical stresses, making it more susceptible to damage.

The correlation between muscle and cartilage thickness is complex and non-linear. Although muscle thickness is often associated with joint stability and function, it does not necessarily correspond to cartilage thickness in a direct and predictable way. Genetic variations, age, gender, hormonal influences and overall body composition may contribute to the observed differences in the muscle-cartilage relationship. Moreover, although physical activity is beneficial for muscle growth, it does not always result in proportional cartilage thickness. Understanding the complex interaction between muscle and cartilage thickness can provide valuable insights into optimising musculoskeletal health and preventing injuries

In this study, we used the RF+VI value because it provides a clearer selection of the start and end point of the quadriceps muscle in the axial section with US and is more practical.

Evaluation of decreased performance during functional movements in knee OA is extremely important in order to see the effectiveness of treatment in activities of daily living.

In our study, we found a negative correlation between quadriceps muscle thickness and gait performance tests and pain in both groups. It is thought that quadriceps muscle thickness can be increased with quadriceps strengthening exercises and the reduction of pain experienced by patients, especially during activity, may lead to increased participation in functional activities and improved gait performance.

The cause-effect relationship between muscle weakness and knee osteoarthritis is thought to be bidirectional. The effect of quadriceps muscle strength in the osteoarthritic process may lead to functional limitation by negatively affecting the balance and walking abilities of patients[15].

The most commonly used method in the diagnosis of OA and in the evaluation of articular cartilage damage is to measure the width of the joint opening on direct radiography (K-L). When joint degeneration was first detected radiologically and OA was diagnosed, cartilage damage had progressed significantly at the molecular level[16,17]. In addition, computed tomography (CT) and magnetic resonance imaging (MR) are used in the diagnosis of OA[18].

The inclusion of quantitative cartilage thickness measurement in studies on OA and cartilage is a factor that adds strength to the study. It has been reported that the most sensitive method for the evaluation of knee joint cartilage is fat-printed 3D MRI[19].

In this study, we preferred US instead of MRI for cartilage thickness measurement because US is a method that can be performed instantaneously, is both easy and has been shown to be close to MRI in cartilage evaluation in cadaveric studies[20]. However, the point to be considered when evaluating knee cartilage with US is that the clearest image can be obtained when the knee is in maximum flexion. In our study, we found a significant relationship between quadriceps thickness, femoral cartilage thickness and knee OA stage by US.

Muscle ultrasound shows promise as a tool for early screening and diagnosis of knee OA by assessing muscle structure and function. Its non-invasive nature, cost-effectiveness and potential for monitoring treatment response make it an attractive modality for clinical applications. However, further research is needed to establish standardised protocols, validate diagnostic criteria and improve the interpretation of muscle ultrasound findings. Integrating muscle ultrasound into a comprehensive diagnostic approach, along with other imaging techniques and clinical assessments, has the potential to improve early detection and intervention strategies in knee joint injuries.

Our study has some limitations and these are that knee OA was assessed only by plain knee radiography, quadriceps muscle strength was not assessed and vastus medialis obliquus (VMO) thickness was not measured by US.

Conclusion

It has been shown that there is a significant relationship between quadriceps muscle thickness and femoral cartilage thickness, knee OA stage, pain scores and functional scores. In this framework, quadriceps and femoral cartilage thickness assessment by US may be promising as a practical, economical and reliable method in the diagnosis and follow-up of knee OA. However, further studies with larger patient groups with different demographic characteristics are needed to evaluate all factors that may affect quadriceps muscle thickness and femoral cartilage thickness.

Understanding the complex relationship between ageing, muscle thickness and cartilage thickness is crucial for developing targeted interventions to prevent or slow the progression of knee osteoarthritis.

Ethics approval

The study protocol was approved by the Ethics Committee of Dr. Sadi Konuk Hospital (2016/03/30, Date: 16 March 2016).

Consent to participate

All patients included in the study were informed about the study and their written consent was obtained.

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