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Relationship Between Sarcopenia, Femoral Cartilage Thickness, and Knee Osteoarthritis: Case–Control Study

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ABSTRACT

Objective: This study aims to evaluate the association between femoral cartilage thickness (FCT) and knee osteoarthritis (KO) in individuals with sarcopenia and pre-sarcopenia, highlighting the potential role of FCT in the relationship between sarcopenia and KO.

Study Design: A cross-sectional study including 80 individuals (23 pre-sarcopenia, 21 sarcopenia, and 36 healthy controls) aged 40–75 years was conducted. Using ultrasound (US), FCT was measured, and KO prevalence was compared among the three groups. Logistic regression analyses were performed to determine the predictors of KO and sarcopenia, and ROC analysis was conducted to estimate sarcopenia from FCT measurements.

Results: The mean age of the 80 participants (55 females, 25 males) was 62.22 ± 7.56 years. The sarcopenia group had significantly lower medial and lateral FCT than the control group (all $p < 0.01$). Logistic regression analysis indicated that age and sarcopenia were significant predictors of KO (all $p < 0.01$). Multinomial logistic regression showed that KO and medial FCT were significant predictors of sarcopenia (all $p < 0.05$). ROC analysis demonstrated that medial FCT effectively predicted sarcopenia ($p = 0.001$, AUC = 0.736).

Conclusions: The results of this study showed that FCT was reduced, and KO prevalence was increased in sarcopenia patients. Additionally, age and sarcopenia were predictors for KO, while KO and decreased medial FCT were predictors of sarcopenia. These findings suggest that sarcopenia may influence FCT through mechanical effects related to muscle strength loss and potentially other mechanisms, making it a potential risk factor for KO.

1 | Introduction

Sarcopenia, a condition with prevalence increasing with age, is characterized by the loss of muscle mass and function, leading to diminished physical capability and reduced quality of life [1]. All body muscles can be affected by sarcopenia, but the lower extremity muscles are particularly prone to be impacted [2, 3].

Some studies have shown a relationship between quadriceps muscle strength, thickness, and Femoral Cartilage Thickness (FCT) [4–6]. A study investigating patients with knee osteoarthritis (KO) found a positive correlation between knee extensor muscle strength and FCT, showing that decreased muscle strength is associated with reduced FCT [5]. Additionally, it has been reported that FCT decreases in various conditions that could lead to muscle weakness [7, 8]. Furthermore, an

increased prevalence of KO, a disease associated with thinning of the femoral cartilage, has been demonstrated in sarcopenia patients [9–13].

Existing studies have primarily focused on the relationship between FCT and knee extensor muscle strength or the association between sarcopenia and KO. However, as far as we can tell, no study has examined the relationship between sarcopenia, FCT, and KO. Understanding these relationships is crucial to uncover potential common mechanisms underlying these conditions and improving clinical outcomes.

This study aims to investigate FCT differences between sarcopenia patients and healthy controls and to examine the relationship between sarcopenia, FCT, and KO. Additionally, it explores the potential of FCT as a predictive marker for sarcopenia and evaluates the association between sarcopenia and KO, focusing on the role of FCT in this relationship. In this study, the aim was to contribute to understanding potential risk factors for KO in sarcopenia patients and to guide early interventions for the prevention or management of KO.

2 | Materials and Methods

2.1 | Study Population

This cross-sectional study included a total of 80 individuals.

2.1.1 | Inclusion Criteria

Individuals

- presenting to the Physical Medicine and Rehabilitation Clinic of the university hospital between February and May 2021.
- aged 40–75 years.
- 23 pre-sarcopenia, 21 sarcopenia patients, and 36 healthy controls.
- equal number of control subjects selected based on similar characteristics in age, gender, and BMI.

2.1.2 | Exclusion Criteria

Individuals

- With knee surgery, joint deformities that may affect knee function.
- With any inflammatory rheumatic diseases, malignancies, neurological diseases, and diseases that may cause muscle weakness.
- Using medications that could impact muscle strength or function (e.g., steroids).
- With cognitive impairments or conditions that affect the ability to provide informed consent.
- With uncontrolled chronic conditions, such as diabetes or cardiovascular diseases.
- Who declined to participate in the study.

2.2 | Measurements

HGS was measured using a Jamar hand dynamometer (Lafayette, IN, USA). HGS was calculated as the average of two measurements obtained from the dominant hand. Bioelectrical impedance analysis (BIA) was evaluated using the Body Composition Analyzer, model BC-418 (Tanita Corp, Tokyo, Japan). Appendicular Skeletal Muscle Mass (ASMM) is calculated as the total muscle mass of all four extremities. The diagnoses of pre-sarcopenia and sarcopenia were made according to the updated diagnostic criteria set by the European Working Group on Sarcopenia in the Elderly (EWGSOP2) [14]. Pre-sarcopenia was defined as HGS values of $< 16\,N$ for women and $< 27\,N$ for men. Sarcopenia was identified with HGS values of $< 16\,N$ and ASMM values of < 15 kg for women and HGS values of $< 27\,N$ and ASMM values of < 20 kg for men.

The same ultrasound specialist performed FCT measurements on all individuals using a B-mode ultrasound with a linear transducer at a frequency range of 6–18 MHz (e-soate, My Lab 70) while they were lying supine with their knees flexed at a 90° angle. FCT measurements were taken twice from the medial femoral condyle, intercondylar area, and lateral femoral condyle in both knees, and the average was calculated. The specialist was blinded to the groups (Figure S1).*FCT;*

- L-IFC, Left İntercondylar Femoral Cartilage thicknesses.
- L-LFC, Left Lateral Femoral Cartilage Thicknesses.
- L-MFC, Left Medial Femoral Cartilage thicknesses.
- Mean-IFC, Right and Left İntercondylar Femoral Cartilage thicknesses mean.
- Mean-LFC, Right and Left Lateral Femoral Cartilage thicknesses mean.
- Mean-MFC, Right and Left Medial Femoral Cartilage thicknesses mean.
- R-IFC, Right İntercondylar Femoral Cartilage thicknesses.
- R-LFC, Right Lateral Femoral Cartilage thicknesses.
- R-MFC, Right Medial Femoral Cartilage thicknesses.

All participants were diagnosed with clinical or radiological OA according to the ACR diagnostic criteria [15], based on history, physical examination, and knee X-ray imaging from their medical records. Knee X-rays of patients with radiological OA were staged according to the Kellgren-Lawrence (KL) grading system (0–5 grading).

2.3 | Statistical Analysis

The effect size was calculated using the G Power 3.1 [16] software program for the difference between FCT (left medial condylar

area) in the paired t test, which was 0.65 (Cohen's $d = 0.38$) [11]. Considering a margin of error of 0.05 ($\alpha = 0.05$) and a power of 0.80, the minimum required sample size was 72. A total of 80 participants were included in this study.

Statistical analyses were conducted using SPSS Statistics version 21, released in 2012 by IBM, and Jamovi version 2.2, released in 2021 by Jamovi Project. ANOVA was used for normally distributed data comparisons between the three groups, with homogeneity checked using Levene's test. In contrast, the Kruskal–Wallis test was applied for non-normally distributed values. The post hoc Tukey test was used for pairwise group comparisons.

A logistic regression model was created to predict KO using group, age, gender, BMI, and medial FCT as predictors (EPV = 60/4 = 15).

Multinomial Logistic Regression analysis was conducted to predict Pre-Sarcopenia and Sarcopenia using KO, age, gender, BMI, and FCT (EPV = 42/7 = 6). Subsequently, a second model was created by removing non-significant variables, retaining only KO and FCT (EPV = 42/4 = 10.5). These EPV values surpass the recommended minimum of 10, indicating that the sample size and model design are adequate for this logistic regression analysis.

Receiver Operating Characteristic (ROC) analysis was conducted to assess the performance of FCT models in predicting the diagnosis of pre-sarcopenia and sarcopenia.

2.4 | Ethics Statement

This study protocol was reviewed and approved by the ethics committee of Akdeniz University Faculty of Medicine (KAEK-60, 27.01.2021). It was conducted according to the ethical standards of the 2000 Declaration of Helsinki. All subjects were informed about the study and obtained their written informed consent.

We used the STROBE case–control checklist when writing our report [17].

3 | Results

The mean age of the 80 individuals (55 females and 25 males) between 40 and 75 was 62.22 ± 7.56 years (Table 1). Medial Femoral Cartilage (MFC) and Lateral Femoral Cartilage (LFC) thicknesses, KO prevalence, and KL grading values were found to be different between the groups ($p < 0.05$) (Table 2) (Figure 1).

No significant difference was found between females and males in FCT values and pre-sarcopenia and sarcopenia prevalences (all $p \geq 0.05$).

A weak positive correlation was found between MFC thickness and BMI, ASMM, and HGS (respectively, $p = 0.037$/Spearman $r = 0.233$, $p = 0.027$/Spearman $r = 0.248$, $p = 0.003$/Spearman $r = 0.333$).

TABLE 1 | Demographic and clinical characteristics of all individuals.

	N	%	Mean ± SD
Age			62.22 ± 7.56
BMI			27.29 ± 3.70
Sex *n* (%)			
Female	55	68.8%	
Male	25	31.3%	
Group			
Healty	36	45%	
Pre-sarcopenia	23	28.7%	
Sarcopenia	21	26.3%	
KO			
No	20	25%	
Present			
Clinical KO	29	36.3%	
Radiological KO	31	38.8%	
Total	60	75%	
HGS			21.62 ± 8.28
ASMM			20.19 ± 4.69
R-MFC			1.50 ± 0.23
L-MFC			1.52 ± 0.25
Mean-MFC			1.51 ± 0.22
R-IFC			2.0 ± 0.32
L-IFC			1.99 ± 0.3
Mean-IFC			2.0 ± 0.28
R-LFC			1.70 ± 0.22
L-LFC			1.71 ± 0.20
Mean-LFC			1.70 ± 0.20

Note: KO, According to the ACR diagnostic criteria, clinical or radiological knee osteoarthritis.
Abbreviations: ASMM, Appendicular Skeletal Muscle Mass; BMI, Body Mass Index; HGS, Hand Grip Strength; L-IFC, Left İntercondylar Femoral Cartilage thicknesses; L-LFC, Left Lateral Femoral Cartilage Thicknesses; L-MFC, Left Medial Femoral Cartilage thicknesses; Mean-IFC, Right and Left İntercondylar Femoral Cartilage thicknesses mean; Mean-LFC, Right and Left Lateral Femoral Cartilage thicknesses mean; Mean-MFC, Right and Left Medial Femoral Cartilage thicknesses mean; R-IFC, Right İntercondylar Femoral Cartilage thicknesses; R-LFC, Right Lateral Femoral Cartilage thicknesses; R-MFC, Right Medial Femoral Cartilage thicknesses.

In the logistic regression analysis conducted for KO prediction, age and sarcopenia were found to be significant (all $p < 0.01$, odds ratio 0.276 for age, 3.248 for sarcopenia) (Table 3) (Figure S2).

In the multinomial logistic regression analysis for predicting pre-sarcopenia and sarcopenia, KO and MFC thickness were significant for sarcopenia ($p < 0.05$). In contrast, LFC thickness was significant for pre-sarcopenia ($p < 0.05$) (Table 4).

TABLE 2 | Demographic and clinical characteristics of the pre-sarcopenia, sarcopenia, and control groups.

	Healty control (36) (Mean ± SD) (0)	Pre-sarcopenia (23) (Mean ± SD) (1)	Sarcopenia (21) (Mean ± SD) (2)	*p*	*F*	95% CI (Lower/Upper) (0–1) (0–2) (1–2)	η^2 (Effect size)
Age	60.44 ± 7.12	64.30 ± 6.62	63.00 ± 8.80	0.138	2.032	(−8619/0.9) (−7451/2340) (−4077/6686)	
BMI	27.96 ± 3.95	27.75 ± 3.02	25.56 ± 3.65	0.057	2.975	(−2091/2520) (−0.058/4685) (−0.507/4706)	
Sex *n* (%)							
Female	23 (41.8%)	16 (29.1%)	16 (29.1%)	0.624			
Male	13 (52.0%)	7 (28.0%)	5 (20.0%)				
KO							
No	14 (38.9%)a	5 (21.7%)ab	1 (4.8%)b	No	0.015*		
Present	22 (61.1%) ab	18 (78.3%) abc	20 (95.2%) bc				
KL Grading	1.42 ± 0.9 a	2.36 ± 0.92 bc	2.38 ± 1.06 bc	0.023*			
R-MFC	1.57 ± 0.24 ab	1.49 ± 0.21 abc	1.38 ± 0.19 bc	0.007**	5.352	(−0.056/0.223) (0.053/0.340) (−0.045/0.271)	0.122
L-MFC	1.61 ± 0.23 ab	1.51 ± 0.22 abc	1.38 ± 0.23 bc	0.002**	6.802	(−0.047/0.247) (0.0817/0.383) (−0.033/0.298)	0.150
Mean-MFC	1.59 ± 0.21 ab	1.50 ± 0.21 abc	1.38 ± 0.20 bc	0.002**	7.057	(−0.041/0.224) (0.078/0.3513) (−0.027/0.273)	0.155 (Large effect)
R-IFC	2.06 ± 0.31	1.95 ± 0.35	1.94 ± 0.32	0.252	1.402	(−0.090/0.321) (−0.086/0.337) (−0.222/0.242)	0.035
L-IFC	2.06 ± 0.32	1.94 ± 0.32	1.94 ± 0.26	0.217	1.558	(−0.074/0.312) (−0.078/0.318) (−0.217/0.219)	0.039
Mean-IFC	2.06 ± 0.26	1.94 ± 0.33	1.94 ± 0.26	0.165	1.845	(−0.061/0.295) (−0.060/0.306) (−0.197/0.206)	0.046 (Small effect)
R-LFC	1.77 ± 0.25 ac	1.62 ± 0.14 bc	1.67 ± 0.21 abc	0.022*	4.035	(0.019/0.291) (−0.035/0.246) (−0.203/0.105)	0.095
L-LFC	1.79 ± 0.22 a	1.66 ± 0.17 bc	1.63 ± 0.17 bc	0.005**	5.744	(0.009/0.256) (0.034/0.287) (−0.111/0.167)	0.130
Mean-LFC	1.78 ± 0.22 a	1.64 ± 0.14 bc	1.65 ± 0.16 bc	0.004**	5.516	(0.0255/0.262) (0.011/0.255) (−0.145/0.123)	0.125 (Medium-Large effect)

Note: a.b,c: Post hoc test subgroups.
Abbreviations: KL Grading, Kellgren-Lawrence Grading; KO, Knee Osteoarthritis; L-IFC, Left İntercondylar Femoral Cartilage thicknesses; L-LFC, Left Lateral Femoral Cartilage Thicknesses; L-MFC, Left Medial Femoral Cartilage thicknesses; Mean-IFC, Right and Left İntercondylar Femoral Cartilage thicknesses mean; Mean-LFC, Right and Left Lateral Femoral Cartilage thicknesses mean; Mean-MFC, Right and Left Medial Femoral Cartilage thicknesses mean; R-IFC, Right İntercondylar Femoral Cartilage thicknesses; R-LFC, Right Lateral Femoral Cartilage thicknesses; R-MFC, Right Medial Femoral Cartilage thicknesses.
*$p < 0.05$.
**$p < 0.01$.

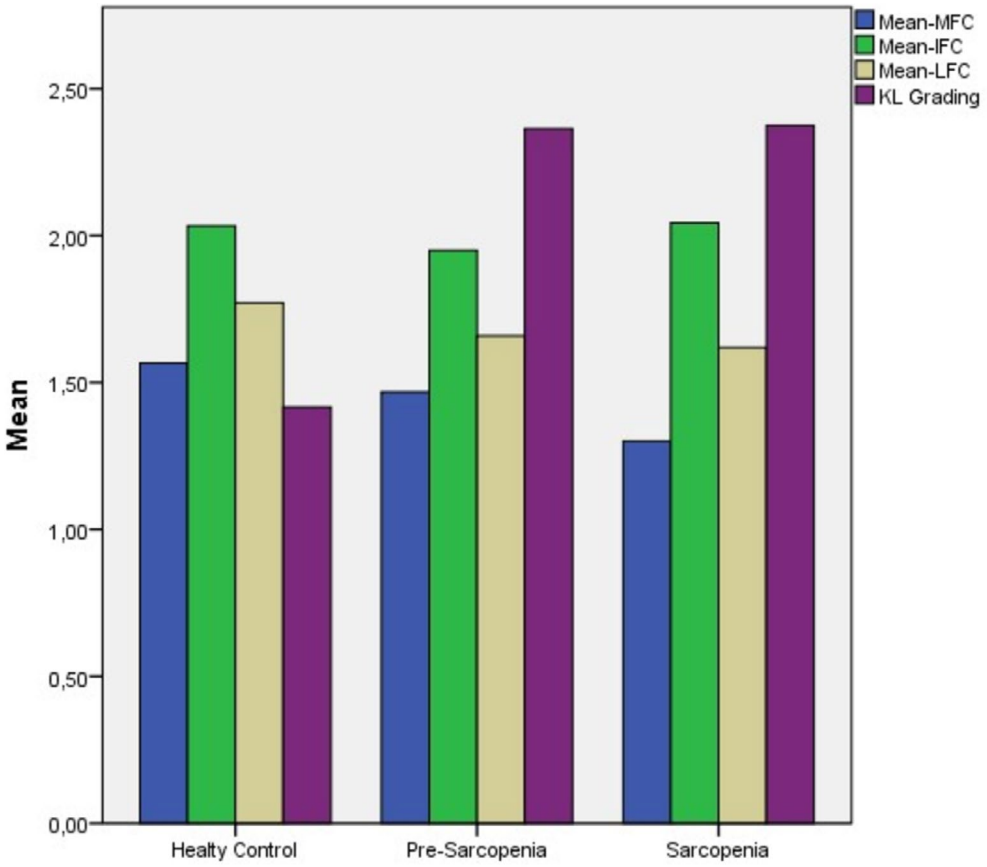

FIGURE 1 | Femoral Cartilage Thicknesses and Kellgren-Lawrence (KL) grading of the groups.

ROC analysis demonstrated the ability of FCT to discriminate between pre-sarcopenia and sarcopenia. MFC thickness was statistically significant for sarcopenia ($p = 0.001$, AUC = 0.736), while MFC, LFC, and intercondylar femoral cartilage thickness (IFC) were significant for pre-sarcopenia (all $p < 0.05$) (Figures S3 and S4) (Table 5).

For Predicting Pre-Sarcopenia;

- Mean-IFC model, Accuracy = 62.5%, F1 = 69.41%, AIC = −198.986.
- Mean-LFC model, Accuracy = 72.5%, F1 = 72.3%, AIC = −196.822.
- Mean-MFC model, Accuracy = 65%, F1 = 71.4%, AIC = −210.768.
- For predicting pre-sarcopenia, the mean LFC model is the best.

For Predicting Sarcopenia;

- Mean-IFC model, Accuracy = 48.75%, F1 = 47.6%.
- Mean-LFC model, Accuracy = 66.25%, F1 = 55.3%.
- Mean-MFC model, Accuracy = 52.5%, F1 = 51.1%.
- For predicting sarcopenia, the mean MFC model is the best.

4 | Discussion

This study's findings, which investigated the relationship between sarcopenia and KO and the role of FCT in this context, showed a decrease in medial and lateral FCT and an increase in KO prevalence in both pre-sarcopenia and sarcopenia patients compared to healthy controls. The decrease in FCT was shown to be a predictor of sarcopenia, while the presence of sarcopenia was also a predictor of KO. These findings support the idea that the reduction in FCT in sarcopenia may predispose individuals to KO and that sarcopenia may contribute to the coexistence of KO.

In the literature, studies have shown a positive correlation between quadriceps muscle strength and FCT, as well as a reduction in FCT in diseases accompanied by muscle weakness [5, 7, 8]. Based on this information, a decrease in FCT is a plausible outcome in sarcopenia, and our study results support this theory by showing a decrease in FCT in sarcopenia patients.

The literature has extensively studied the coexistence of sarcopenia and KO, and the relationship between these two conditions has been demonstrated in numerous studies [12, 13, 18–21]. Consistent with the literature, our study found an increased prevalence of KO in sarcopenia patients. Furthermore, the study demonstrated that sarcopenia may be an indicator of KO, and KO may be an indicator of sarcopenia.

TABLE 3 | Logistic regression models for predicting knee osteoarthritis (KO).

Predictor	Estimate	SE	*Z*	*p*	Odds ratio	95% confidence interval		Model fit
						Lower	Upper	
Model 1								
Intercept	−152.510	57.815	−26.379	0.008**	2.38e-7	2.85e-12	0.020	AIC = 68.5
Age	0.286	0.080	35.934	0.001**	13.310	113.881	15.557	R^2McF = 0.394
Sex (1 = Male)	−0.1693	0.755	−0.224	0.823	0.844	0.19234	37.060	R^2CS = 0.358
BMI	0.0930	0.100	0.926	0.354	10.974	0.90144	13.360	R^2N = 0.530
Mean-MFC	−0.1049	16.378	−0.064	0.949	0.900	0.03634	223.104	1.02 ≤ VİF ≤ 1.13
Group (2–0)	34.943	13.354	26.167	0.009**	32.926	24.037	451.026	AUC = 0.901
Group (1–0)	0.0267	0.8042	0.033	0.974	1.027	0.2123	496.733	
Model 2								
Intercept	−15.779	4.372	−3.609	0.001**	1.40e-7	2.66e-11	7.40e-4	AIC = 63.5
Age	0.276	0.075	3.657	0.001**	1.318	1.137	1.53	R^2McF = 0.383
Group (2–0)	3.248	1.231	2.639	0.008**	25.749	2.308	287.33	R^2CS = 0.350
Group (1–0)	−0.002	0.786	−0.003	0.998	0.998	0.214	4.65	R^2N = 0.518
								1.05 ≤ VİF ≤ 1.11
								AUC = 0.898

Note: Groupe: 0 = Control, 1 = Pre-Sarcopenia, 2 = Sarcopenia. Estimates represent the log odds of "KOA present = 1" versus "KOA no = 0".
Abbreviation: Mean-MFC, Right and Left Medial Femoral Cartilage thicknesses mean.
**$p < 0.01$.

Aging, obesity, diabetes, and vitamin D deficiency have been reported as common risk factors for both sarcopenia and KO. Reduced muscle strength, pro-inflammatory cytokines, and irisin are believed to play roles in their pathogenesis [22]. However, a definitive conclusion has not been reached regarding a cause-and-effect relationship. The notion of a vicious cycle between the two conditions is widely accepted [21, 23].

A decrease in knee extensor muscle strength and FCT in patients with KO has been demonstrated in some studies [5, 9–11]. The relationship between quadriceps muscle strength and FCT could be one of the mechanisms explaining the association between sarcopenia and KO. However, the cause-and-effect relationship between muscle strength and cartilage damage is unclear. In an animal experiment to investigate whether cartilage damage occurs due to muscle weakness or if it emerges first, rabbits' quadriceps muscles were weakened by injecting Botulinum toxin type A into the muscles. After 4 weeks, significant changes were observed in the patellofemoral region.

The results indicated that the initial signs of joint cartilage deterioration appeared with muscle weakness, suggesting that muscle weakness may be a risk factor for cartilage damage and osteoarthritis [24]. Another study investigating the relationship between knee muscle strength and cartilage thickness in individuals with KO found a positive correlation, and after a 1 month quadriceps strengthening program, an increase in quadriceps strength was correlated with an increase in cartilage thickness. This led to the interpretation that cartilage thinning might be attributed to muscle strength loss [5].

It is an accepted concept that a decrease in knee muscle strength leads to increased load on the knee and destabilization, causing cartilage damage. However, it has been reported that mechanical effects alone cannot solely explain this relationship. Muscle cells may play a significant role in cartilage homeostasis and regulating cartilage gene expression, indicating a more complex interplay beyond mechanical factors [23, 25].

The finding of reduced FCT in sarcopenia patients in this study is consistent with the literature. It indirectly supports the relationship between muscle strength and cartilage thickness and suggests that this relationship plays a role in the coexistence of sarcopenia and KO. Another finding of this study is that while a reduction in medial FCT indicates sarcopenia, it is not an indicator of KO. Instead, the significant association of sarcopenia presence with KO supports the view that sarcopenia may be a risk factor for KO.

The literature generally indicates a positive relationship between FCT and BMI [26–28]. However, one study has reported a positive correlation between FCT and muscle mass and a negative relationship with fat mass [29]. Consistent with the literature, this study found a weak positive correlation between BMI,

TABLE 4 | Multinomial logistic regression for predicting pre- sarcopenia and sarcopenia.

Predictor	*B*	SE	Wald	*p*	Exp (B)	95% CI Lower	95% CI Upper	Model fit
Model 1	Category = 2 (Sarcopenia Group), Referans = 0 (Healty Control)							Model 1
Intercept	11.0766	5.3282	2.079	**0.038***	64643.68478	1.88434	2.22e+9	AIC = 168
Age	−0.0173	0.0490	−0.353	0.724	0.98287	0.89290	1.082	R^2McF = 0.205
Sex (1 = Male)	−0.1913	0.7353	−0.260	0.795	0.82586	0.19546	3.489	R^2CS = 0.136
BMI	−0.1860	0.0993	−1.873	0.061	0.83024	0.68336	1.009	R^2N = 0.266
KOA (1–0)	2.8496	1.2804	2.226	**0.026***	17.28031	1.40496	212.539	
Mean-MFC	−4.6435	2.3418	−1.983	**0.047***	0.00962	9.77e-5	0.948	
Mean-IFC	1.4788	1.5987	0.925	0.355	4.38770	0.19116	100.711	
Mean-LFC	−2.3111	2.7845	−0.830	0.407	0.09916	4.23e-4	23.256	
	Category = 1 (Pre-Sarcopenia Group), Referans = 0 (Control Group)							
Intercept	4.5342	5.0728	0.894	0.371	93.15182	0.00448	1.94e+6	
Age	0.0378	0.0486	0.777	0.437	1.03851	0.94414	1.142	
Sex (1 = Male)	−0.1734	0.6255	−0.277	0.782	0.84081	0.24676	2.865	
BMI	−0.0131	0.0839	−0.156	0.876	0.98696	0.83735	1.163	
KOA (1–0)	0.6809	0.8172	0.833	0.405	1.97561	0.39818	9.802	
Mean-MFC	0.4558	1.9172	0.238	0.812	1.57742	0.03681	67.593	
Mean-IFC	0.7531	1.5322	0.491	0.623	2.12350	0.10540	42.782	
Mean-LFC	−5.6377	2.5910	−2.176	0.030	0.00356	2.22e-5	0.572	
Model 2.	Category = 2 (Sarcopenia Group), Referans = 0 (Control Group)							Model 2.
Intercept	8.632	3.362	2.568	**0.010***	5606.91299	7.71140	4.08e+6	AIC = 163
KOA (1–0)	−2.563	1.160	−2.210	**0.027***	0.07707	0.00794	0.748	R^2McF = 0.166
Mean-MFC	−4.558	2.248	−2.028	**0.043***	0.01048	1.28e-4	0.858	R^2CS = 0.111
Mean-IFC	0.865	1.507	0.574	0.566	2.37502	0.12394	45.513	R^2N = 0.218
Mean-LFC	−2.166	2.604	−0.832	0.405	0.11461	6.96e-4	18.869	
	Category = 1 (Pre-Sarcopenia Group), Referans = 0 (Control Group)							
Intercept	7.763	3.066	2.532	**0.011***	2351.79340	5.77862	957136.619	
KOA (1–0)	−1.040	0.670	−1.553	0.120	0.35329	0.09501	1.314	
Mean-MFC	0.518	1.901	0.272	0.785	1.67816	0.04041	69.694	
Mean-IFC	0.516	1.489	0.347	0.729	1.67591	0.09048	31.042	
Mean-LFC	−5.708	2.508	−2.276	**0.023***	0.00332	2.43e-5	0.453	

Note: KOA: 1 = Present, 2 = No.
Abbreviations: Mean-IFC, Right and Left İntercondylar Femoral Cartilage thicknesses mean; Mean-LFC, Right and Left Lateral Femoral Cartilage thicknesses mean; Mean-MFC, Right and Left Medial Femoral Cartilage thicknesses mean.
*$p < 0.05$ indicate bold values.

appendicular muscle mass, and HGS with FCT. This positive relationship suggests that muscle strength, muscle mass, and BMI influence FCT through mechanical factors and biochemical signals regulating cartilage metabolism.

Studies investigating the relationship between gender and FCT have indicated that FCT tends to be thinner in females compared to males [30]. Males' higher muscle strength can explain their thicker femoral cartilage. In this study, no difference in

TABLE 5 | ROC analysis of femoral cartilage thickness for predicting pre-sarcopenia and sarcopenia.

		AUC	SE	*p*	95% CI (Lower–Upper)	Cut off
Predicting pre-sarcopenia	Mean_MFC	0.698	0.059	0.002**	0.582-0.814	1.55
	Mean_IFC	0.636	0.062	0.037*	0.515-0.758	2.10
	Mean_LFC	0.696	0.062	0.003**	0.574-0.817	1.80
Predicting sarcopenia	Mean_MFC	0.736	0.06	0.001**	0.618-0.854	1.45
	Mean_IFC	0.566	0.071	0.370	0.427–0.705	2.03
	Mean_LFC	0.600	0.067	0.173	0.469–0.732	1.73

Abbreviations: Mean-IFC, Right and Left İntercondylar Femoral Cartilage thicknesses mean; Mean-LFC, Right and Left Lateral Femoral Cartilage thicknesses mean; Mean-MFC, Right and Left Medial Femoral Cartilage thicknesses mean.
*$p < 0.05$.
**$p < 0.01$.

FCT was found between females and males, which could be attributed to the similar rates of sarcopenia in both groups.

The limitations of this study include the small sample size for regression analyses, despite sufficient patient numbers and a large effect size (>0.14) for group comparisons, leading to wide confidence intervals in the regression models. Additionally, ethical and financial constraints prevented knee radiographs from being performed on all participants, requiring them to rely on knee radiographs retrieved from patient records instead. The study also did not evaluate factors such as obesity, exercise habits, and nutrition, which play a shared role in the pathogenesis of sarcopenia and KO. Another limitation of this study is its cross-sectional design, lack of prognostic insight, inability to establish causality, and reliance on binary outcomes, which may overlook important associations. Further prospective studies with larger patient populations and more comprehensive data are needed in this regard.

This study showed a decrease in FCT and an increase in the prevalence of KO in sarcopenia patients. It has been observed that a decrease in medial FCT may predict sarcopenia, while sarcopenia may also predict KO. Moreover, the reduction in FCT may play an important role in explaining the relationship between KO and sarcopenia.

A weak positive correlation was found between HGS and muscle mass with FCT, highlighting the importance of mechanical and biochemical factors affecting cartilage thickness. Sarcopenia may be a risk factor for KO, and these two conditions might share common pathophysiological mechanisms. Prospective studies with larger sample sizes could contribute to a better understanding of the relationship between sarcopenia, KO, and FCT.

Author Contributions

S.T., N.B., E.K. investigation, data curation, methodology, design, formal analysis, writing. S.T. performing an ultrasound. S.T., E.K., N.B. writing, supervision, review and editing. All authors have read and approved the final manuscript.

Ethics Statement

The ethics committee of Akdeniz University Faculty of Medicine (KAEK-60, 27.01.2021) reviewed and approved this study protocol. All subjects were informed about the study, and their written informed consent was obtained. Written and verbal consent was obtained from all participants.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.