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ORIGINAL ARTICLE

The relationship between femoral cartilage thickness and muscle strength in knee osteoarthritis

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Abstract To explore whether femoral cartilage thickness is related (and changes) with muscle strength in subjects with knee osteoarthritis (OA). Forty patients (27 F, 13 M) with knee OA—who were under quadriceps muscle strengthening program—were enrolled in the study. Isokinetic/isometric knee muscle strength measurements (at 30–60° angles and 60–180° velocity) were performed at baseline, end of the muscle strengthening program, and third month control visit using a biodex dynamometer. Femoral cartilage thicknesses (at medial/lateral condyle and intercondylar area) were measured using ultrasonography. Seventy-nine knees of 40 patients (27 F, 13 M) aged 52.03 ± 11.72 years (range, 26–71) were analyzed. Mean VAS scores on the first and third months were significantly lower than the initial values ($p < 0.001$, $p = 0.049$). Isometric peak torque and total work values at 180 °/s were significantly higher than the baseline measurements at first and third month controls (all $p < 0.05$). Cartilage thicknesses (at three sites) were significantly higher than the baseline measurements (all $p < 0.05$) on the third month but not on the first month (all $p > 0.05$). Femoral cartilage thicknesses were positively correlated with isometric strength values at baseline and third month. We propose that femoral cartilage thicknesses increase on the third month of strengthening therapy. Since this late-phase thickening parallels the earlier increase in muscle strength (starting, on the first month), we speculate that regeneration rather than edema might be the primary underlying cause.

Keywords Cartilage · Isokinetic · Knee · Osteoarthritis · Ultrasound

Introduction

Osteoarthritis (OA) is a chronic inflammatory disease which is characterized by loss of articular cartilage and one of the most common diseases of the elderly population [1, 2]. Knee OA is the most common type and it is associated with decreased knee muscle strength [3, 4].

In the literature, it has been reported that femoral cartilage thickness changed in various diseases that might cause muscle weakness e.g. hemiparetic stroke, spinal cord injury, systemic sclerosis, and systemic lupus erythematosus [5–8]. Herewith, to the best knowledge of the authors, the relationship between the femoral cartilage thickness and the knee muscle strength has not been reported until now. Accordingly, in this study, we aimed to explore whether femoral cartilage thickness is related (and changes) with muscle strength in subjects with knee OA. Similar to the previous studies, we used ultrasound (US) imaging which has been shown to be a reliable method for assesing distal femoral cartilage [9, 10].

Patients and methods

Subjects with knee OA—who were under quadriceps muscle strengthening program—were consecutively recruited. They fulfilled the American College of Rheumatology criteria for knee OA [11]. Subjects who had inflammatory rheumatic disease, meniscal lesions, cruciate ligament lesion, recent knee

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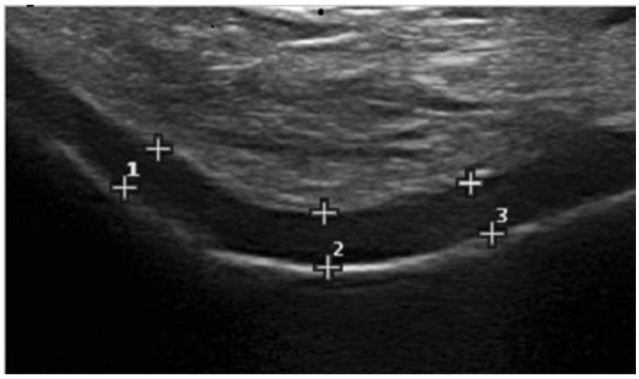

Fig. 1 Ultrasound image (suprapatellar axial view) shows the femoral cartilage thickness measurements. *1* medial femoral condyle, *2* intercondylar area, *3* lateral femoral condyle

trauma, and any disease causing muscle weakness were excluded. Overall, 40 patients (27 F, 13 M) were enrolled in the study. Subjects were informed about the study procedure and they consented to participate. The local ethics committee approved the study protocol.

Demographic characteristics (age, profession, height, weight) of the subjects were noted. Pain and functional status were evaluated using VAS and WOMAC (Turkish version), respectively [12–14].

Bilateral quadriceps and hamstring muscle strengths were measured with an isokinetic dynamometer (Cybex NORM 6000). Patients were seated upright and fixed with pelvic and distal thigh belts. They were allowed to hold on both sides of the chair with their hands. Isokinetic muscle strength was measured concentrically at two angular velocities; 5 repetitions at 60 °/s and 10 repetitions at 180 °/s. Isometric muscle strength was measured at 30 and 60° of knee flexion. Subjects performed trial repetitions before each set and a 20 s resting interval was provided between the sets. Vocal encouragement was kept constant during the testing procedure.

Patients were then enrolled in an isokinetic strengthening program, i.e., 10 repetitions at 30 °/s, 10 repetitions at 60 °/s, 10 repetitions at 90 °/s, 10 repetitions at 180 °/s, one times a day. Then, patients were given a home based exercise regimen which comprised quadriceps isometric and hamstring stretching exercises.

Femoral cartilage thicknesses were measured while subjects lied supine on the examination bed with maximum knee flexion. Ultrasound imaging was done using suprapatellar axial view and measurements were taken from the midpoints of the medial femoral cartilage, intercondylar area, and lateral femoral cartilage. The same sonographer (ST) performed all the measurements which were substantially evaluated by the expert sonographer (LÖ) (Fig. 1). Cartilage and strength measurements were performed at baseline, at the end of the muscle strengthening program (first month) and third month control visits. US and cybex measurements were done by different persons, i.e., one sonographer and one technician. The sonographer was blinded to the cybex measurements.

Statistical analyses were done using SPSS 20.0. Friedman test were used for comparisons between the repeated three measures. Bonferroni-Dunn procedure was used for comparing the pairs of repeated measurements. Pearson or Spearman coefficients were used for correlation analysis. *P* values less than 0.05 were considered statistically significant.

Results

Seventy-nine knees of 40 patients (27 F, 13 M) aged 52.03 ± 11.72 years (ranged 26–71) with knee OA were analyzed. The average body mass index (BMI) of patients was 28.22 ± 5.37 (range 18.42–39.61).

The mean VAS scores on the first and third months were significantly lower than the initial values ($p < 0.001$, $p = 0.049$, respectively). WOMAC scores were similar between the evaluations (Table 1).

Flexion and extension peak torque values at 30 and 60°, and total work values at 180 °/s were significantly higher than the baseline measurements at first and third month controls (all $p < 0.05$).

Cartilage thicknesses (at three sites) were significantly higher than the baseline measurements (all $p < 0.05$) on the third month but not on the first month. Measurements pertaining to the first and third months were similar (all $p > 0.05$) (Table 2).

Correlation analyses are given in Table 3. In the baseline evaluations, femoral cartilage thicknesses were positively

Table 1 Baseline, first, and third month scores of VAS and WOMAC

	Baseline (Mean ± Std)	First month (Mean ± Std)	Third month (Mean ± Std)	p (friedman)	p (Bonferroni-Dunn procedure)		
					Baseline–first month	First–third month	Baseline–third month
VAS	5.67 ± 2.96	4.76 ± 2.70	5.40 ± 2.77	*0.001**	*0.001**	0.386	*0.049**
WOMAC (pain)	12.98 ± 4.96	13.02 ± 5.31	13.15 ± 5.27	0.910	–	–	–
WOMAC (strength)	4.66 ± 2.01	4.86 ± 2.28	4.73 ± 2.33	0.305	–	–	–
WOMAC (function)	45.34 ± 17.06	44.81 ± 18.12	43.98 ± 16.03	0.067	–	–	–

*$P < 0.05$

Table 2 Baseline, first, and third month values of femoral cartilage thickness and knee muscle strengths

	Baseline (Mean ± Std)	First month (Mean ± Std)	Third month (Mean ± Std)	*p* (Friedman)	*p* (Bonferroni-Dunn procedure)		
					Baseline–first month	first–3rd month	Baseline–3rd month
LFC	19.25 ± 3.10	19.95 ± 3.06	20.71 ± 3.34	*0.001**	0.317	0.168	*0.001**
ICA	20.63 ± 4.74	21.64 ± 4.59	21.73 ± 4.56	*0.015**	0.209	1.000	*0.028**
MFC	19.24 ± 3.98	20.31 ± 4.06	20.44 ± 4.14	*0.018**	0.118	1.000	*0.037**
exisomet30pt	93.63 ± 52.23	105.82 ± 55.92	97.85 ± 59.60	*0.001**	*0.002**	1.000	*0.028**
flxisomet30pt	87.18 ± 42.78	98.53 ± 48.61	91.23 ± 53.97	*0.001**	*0.001**	0.778	*0.028**
exisomet60pt	133.97 ± 76.04	148.65 ± 77.35	148.71 ± 74.79	*0.001**	*0.001**	0.307	*0.018**
flxisomet60pt	72.32 ± 63.07	72.51 ± 41.06	70.76 ± 41.82	*0.001**	*0.001**	1.000	*0.003**
exisokin60pt	74.27 ± 52.48	102.30 ± 63.84	86.26 ± 62.54	*0.001**	*0.001**	0.286	*0.001**
flxisokin60pt	53.23 ± 34.27	76.13 ± 43.26	67.08 ± 59.43	*0.001**	*0.001**	*0.037**	*0.001**
exisokin180 work	33.23 ± 32.59	52.62 ± 37.68	47.79 ± 40.75	*0.001**	*0.001**	0.066	*0.001**
flxisokin180 work	35.42 ± 28.64	53.98 ± 33.15	47.83 ± 33.08	*0.001**	*0.001**	*0.007**	*0.002**

LFC lateral femoral condyle, *ICA* intercondylar area, *MFC* medial femoral condyle, *exisomet30pt* at 30°, isometric extensor peak torque values, *flxisomet30pt* at 30°, isometric flexor peak torque values, *exisomet60pt* at 60°, isometric extensor peak torque values, *flxisomet60pt* at 60°, isometric flexor peak torque values, *exisokin60pt* at 60 °/s, isokinetic extensor peak torque values, *flxisokin60pt* at 60 °/s, isokinetic flexor peak torque values, *exisokin180 work* at 180 °/s, isokinetic extensor work values, *flxisokin180 work* at 180 °/s, isokinetic flexor work values

*$P < 0.05$

correlated with isometric strength values at 30° and isokinetic work values at 180 °/s. While no correlations were detected on the first month measurements; similar to the baseline evaluations, femoral cartilage thicknesses were positively correlated with isokinetic strength values at 60 °/s and isokinetic work values at 180 °/s on the third month measurements.

Discussion

In this study, we aimed to explore whether/how femoral cartilage thickness might change with knee muscle strengthening. Our results have shown that while the knee muscle strength starts to increase on the first month, a parallel/positive change in the femoral cartilage thickness starts to be seen on the third month of exercise therapy.

Although there are no studies in the literature that have examined directly the relationship between cartilage thickness and knee muscle strength; it has been reported that femoral cartilage thickness decreases in conditions where there is immobilization and a generalized decrease in muscle strength [7, 15, 16]. Likewise, in some rheumatic diseases that may cause muscle weakness, femoral cartilage thickness was found to be thinner [8, 17]. Taking into account the parallelism between

Table 3 The correlation between femoral cartilage thickness and knee muscle strengths

	Baseline			first month			3rd month		
	LFC	ICA	MFC	LFC	ICA	MFC	LFC	ICA	MFC
exisomet30pt	**$r = 0.244$**	**$r = 0.283$**	**$r = 0.299$**	NC	NC	NC	NC	NC	NC
flxisomet30pt	**$r = 0.254$**	NC	NC	NC	NC	NC	NC	NC	NC
exisomet60pt	NC	NC	NC	NC	NC	NC	NC	NC	$r = 0.321$
flxisomet60pt	NC	NC	NC	NC	NC	NC	NC	NC	**$r = 0.390$**
exisokin60pt	NC	NC	NC	NC	NC	NC	$r = 0.415$	NC	**$r = 0.493$**
flxisokin60pt	NC	NC	NC	NC	NC	NC	$r = 0.454$	$r = 0.280$	**$r = 0.465$**
exisokin180work	**$r = 0.251$**	**$r = 0.312$**	**$r = 0.276$**	NC	NC	NC	**$r = 0.399$**	NC	**$r = 0.419$**
flxisokin180work	**$r = 0.250$**	**$r = 0.317$**	**$r = 0.293$**	NC	NC	NC	**$r = 0.384$**	NC	**$r = 0.400$**

The data in boldface shows that there is a correlation between the data

r correlation coefficient, *NC* non-correlate, *LFC* lateral femoral condyle, *ICA* intercondylar area, *MFC* medial femoral condyle, *exisomet30pt* at 30°, isometric extensor peak torque values, *flxisomet30pt* at 30°, isometric flexor peak torque values, *exisomet60pt* at 60°, isometric extensor peak torque values, *flxisomet60pt* at 60°, isometric flexor peak torque values, *exisokin60pt* at 60 °/s, isokinetic extensor peak torque values, *flxisokin60pt* at 60 °/s, isokinetic flexor peak torque values, *exisokin180 work* at 180 °/s, isokinetic extensor work values, *flxisokin180 work* at 180 °/s, isokinetic flexor work values

knee muscle strength and femoral cartilage thickness in our study, the findings of the aforementioned studies might be considered to noteworthy as regards the parallelism in the reverse direction.

In an animal study by Maldonado et al. [18], rats were evaluated in four—control, immobilized, exercised, and exercised and then immobilized—groups. While cartilage thicknesses decreased significantly in the immobilized group, they were unaffected in the exercised and then immobilized group, and significantly increased in the exercised group. Their findings seem to be in line with our results of increased cartilage thicknesses on the third month controls. Herewith, although we were not able to exclude the possibility of cartilage edema (actually causing the increased thickness), we considered it to be less likely since increased thickness was significant on the third month but not in the early phase of exercise therapy. Further, it is well-known that as the periarticular muscle strength increases, mechanical load is shifted from the joint to the muscle compartment (i.e., the main goal of exercise therapy) [19]. Therefore, we imply that the increased cartilage thickness in the late phase might be more likely associated with cartilage regeneration as the muscles have already started to mechanically support the joint (load) after the first month.

The lack of a histological examination seems to be major drawback of our study. Yet, our discussion as regards increased cartilage thickness (edema vs. regeneration) would have been readily clarified in that sense.

To conclude, in the light of our first and preliminary findings, we propose that femoral cartilage thicknesses increase on the third month of exercise therapy. Since this late-phase thickening parallels the earlier increase in muscle strength (starting on the first month), we speculate that the regeneration rather than the edema might be the primary underlying cause. Further studies with longer follow up and histological evaluations are definitely warranted to explore the exact mechanism(s) and the long term maintenance of increased cartilage thickness.

Compliance with ethical standards Subjects were informed about the study procedure and they consented to participate. The local ethics committee approved the study protocol.

Disclosures None.

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