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The ultrasound elastography findings in lateral epicondylitis in comparison with healthy individuals

Bilge İpek Torun[1], Serhan Eren[2], Mehtap Balaban[3]

[1]*Department of Anatomy, Faculty of Medicine, Ankara Yıldırım Beyazıt University, Ankara, Türkiye*
[2]*Department of Radiology, Batman Kozluk State Hospital, Batman, Türkiye*
[3]*Department of Radiology, Faculty of Medicine, Ankara Yıldırım Beyazıt University, Ankara, Türkiye*

Abstract

Objectives: To evaluate the ability of strain sonoelastography (SEL) in diagnosing lateral epicondylitis (LE) and to asses clinical and diagnostic efficacy of strain SEL in patients with clinically confirmed LE and in healthy volunteers.

Methods: Strain SEL was performed on 110 patients with clinical symptoms of LE and on 56 healthy participants. The common extensor tendon (CET) was evaluated with gray-scale and color Doppler ultrasonography (CDUS). The stiffness and the elasticity of the CET was divided into 2 main types and 2 subtypes as a spectrum ranging from hard for 1a to soft for 2b.

Results: The thickness of the CET in patients with LE (6.3±1.06 mm) were remarkably thicker than in healthy participants (3.8±0.62 mm) (p<0.001). There were negative significant correlations between the thickness of the CET and lower and mean strain ratios (SR) (rs= [–0.666], p<0.001 for lower SR and rs= [–0.358], p<0.001 for mean SR). Thickness of the CET varied between the groups of elastographic patterns (p<0.001). The SR of tendon in patients with LE (6.68±2.49 mm) were remarkably lower than in healthy participants (11.16±4.88 mm) (p<0.001). The SR of tendon in patients with LE also varied significantly between the groups of elastographic patterns (p<0.001).

Conclusion: Strain SEL is a promising sonographic technique for musculoskeletal imaging to differentiate thickening and softening of CET in LE. SR and SEL pattern findings are compatible with gray scale ultrasound and CDUS findings.

Keywords: common extensor tendon; imaging; radiologic anatomy; tendon thickness

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Introduction

Tendons are the ligaments that provide movement and transmit the power produced by the muscle contraction to the bones and joints.[1] The common extensor tendon is composed of tendinous portions of the extensors carpi radialis brevis and longus, extensor digitorum, extensor digiti minimi and extensor carpi ulnaris muscles, and serve as the upper attachment for posterior extensor muscles of forearm. It originates from the lateral epicondyle of humerus.[2] Lateral epicondylitis (LE), also called as “tennis elbow”, is a pathological condition of CET that causes pain in lateral aspect of the elbow due to repetitive stress and overuse of the CET in labor and sports activities as well as age-related degeneration. Pain, burning and swelling of the lateral aspect of the elbow are the most common symptoms of LE. Estimated prevalence of LE is 1–3% in the general population.[3] The diagnosis of LE is made primarily by using typical clinical manifestations and physical examination.[4] Furthermore, a wide variety of radiologic methods are used to diagnose LE, including conventional muscle sonography and color Doppler ultrasonography (CDUS), elastography and, magnetic resonance imaging (MRI).[5,6]

Ultrasound elastography imaging is ultrasound-based imaging method that provides information on the elasticity and stiffness properties of tissues.[7] There are two main different techniques of ultrasound elasticity imaging: compression based strain sonoelastography (SEL) and shear-wave SEL.[8] Strain SEL is based on difference of stiffness and elasticity between one tissue or lesion to another by applying probe compression. Numerous clinical SEL applications and studies were found to evaluate diagnosis and assessment of changes in tissue stiffness and elasticity in pathological conditions.[9–14] However, clinical utility of elastography has been infrequently studied in LE and has not been evaluated with tendon thickness.

The main purpose of this study was to assess clinical and diagnostic efficacy of strain SEL in patients with clinically confirmed LE and in healthy volunteers.

Materials and Methods

This study was approved by the institutional review board, and informed consent was obtained from all participants. From January 2019 to January 2022, a retrospective analysis with strain SEL was performed on total of 110 patients with clinical symptoms of LE and 56 healthy participants (103 women and 63 men, age range: 20–81 years, mean age 42.95 years). The inclusion criteria of this study were pain and discomfort of lateral aspect of humerus that compatible with LE. A clinical history of surgery, fracture, or other diseases that affect musculoskeletal system such as rheumatoid arthritis and osteoarthritis were excluded from the study. The inclusion criteria for the healthy participants were asymptomatic elbows, no previous trauma or surgery at the elbow, and no history of systemic inflammatory disorders.

The healthy participants and patients with LE were examined with gray scale and CDUS, and real-time strain based SEL (LOGIQ S7 Expert, GE Medical Systems) using a 5–11 MHz linear-array transducer by two radiologists (one radiologist with 18 years of experience and one radiologist with 5 years of experience on musculoskeletal system). In the beginning of the study, ten cases were examined together for sample consistency. All participants in our study were examined in comfortable position. All participants' arms were supported by a pillow and elbows were semi-flexed. 5–11 MHz linear array transducer was positioned parallel to the lateral epicondyle with semi-flexed elbow to investigate the CET. The CET was evaluated with gray-scale and CDUS for swelling, tendinosis, partial tear, calcification, tendon thickness, hyperemia and inflammatory changes. The thickness of the CET was measured from the longitudinal view from the antero-posterior direction. Also strain SEL images of the CET were acquired from longitudinal view of the elbow due to avoid artifacts of gray scale sonography and elastography. Strain images were obtained by freehand technique with compression and decompression. The optimal strain was adjusted according to the visual indicator of compression. The visual indicator had six levels and strain and compressions of four or more were considered valuable. Results of the tissue elasticity distribution were showed a color map together with the B-mode image. Stiffness and elasticity of the CET were represented by the color spectrum, which was blue and green for hard, yellow for intermediate and red for soft tissue. The stiffness and elasticity of the CET was divided into 2 main types and 2 subtypes as a spectrum ranging from hard for 1a to soft for 2b: type 1a, blue predominance; type 1b, green predominance; type 2a, small yellow and red areas within green predominance; and type 2b, green areas within yellow and red predominance.

All statistical analyses were performed with SPSS software (version 28.0, IBM SPSS, IBM Corp., Armonk, NY, USA) Median and range for continuous variables were used to define feature of participants. Counts and percentages for the categorical variables were used to define feature of participants. The variables were examined with Kolmogorov-Smirnov normality test whether distributed normally or not. Continuous variables were analyzed between healthy participants and patients by using Mann-Whitney U and Kruskal-Wallis tests. Categorical variables were analyzed between healthy participants and patients by using chi-square test and Fisher exact test. The correlation between continuous variables as thickness of the CET, strain ratio (SR) and symptom duration were performed with Spearman's non-parametric correlation analysis. A p value <0.05 was considered statistically significant.

Results

Baseline characteristics of participants were summarized in **Table 1** and imaging findings of the patients are summarized in **Table 2**. There was no difference between patients and healthy participants for age (p=0.345).

Ultrasound examination revealed that the CET at the lateral epicondyle thickened with decreased fibrillar echogenicity, intratendinous calcification, and increased fluid in its vicinity (**Figure 1**). Intratendinous vascularization increased in CDUS (**Figure 2**). The SEL examination in the tendon showed green-weighted yellow and red coding areas consistent with soft coding (**Figure 3**).

The thickness of the CET in patients with LE (6.3±1.06 mm) were remarkably thicker than in healthy participants (3.8±0.62 mm) (p<0.001). In addition, the thickness of the CET was thicker in patients with tendinosis, partial tear, hyperemia and calcific tendinopathy than in healthy participants (p<0.001) (**Figure 4**). The thickness of CET increased with age (p<0.001). There

Table 1

Characteristics of the patients.

		Lateral epicondylitis	Control
Sex	Men	41	22
	Women	69	3428
Involvement	Right	63	28
	Left	47	52
Hand dominance	Right	99	4
	Left	11	
Age (range)		49.55±12.2 (20–81)	29.96±8.88 (20–53)

Table 2

Imaging findings of the patients.

	Lateral epicondylitis (n=110)	Control (n=56)	P-value
Gray scale findings			
Tendinosis	108	16	<0.001
Calcification	41	0	<0.001
Intrasubstance tear	68	0	<0.001
Epicondyle degeneration	35	0	<0.001
Doppler findings			
Hyperemia	50	0	<0.001
Elastographic findings			
1a	5	41	
1b	18	14	<0.001
2a	46	1	
2b	41	0	

were negative significant correlations between the thickness of the CET and lower and mean SR (rs= [–0.666]; p<0.001 for lower SR and rs= [–0.358]; p<0.001 for mean SR). The thickness of the CET also varied significantly between the groups of elastographic patterns (p<0.001) (**Figure 5**). But there was no difference between the thickness of the CET of 2a and 2b elastographic patterns (p=0.927).

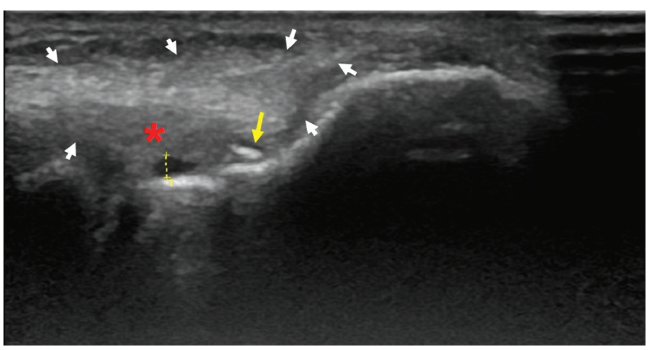

Figure 1. B-mode ultrasonography. Thickening on right common extensor tendon (**white arrow heads**), decrease in fibrillar echogenicity (**red asterisk**), adjacent anechoic fluid increase (**dashed yellow line**) and intratendinous calcification (**yellow arrow**).

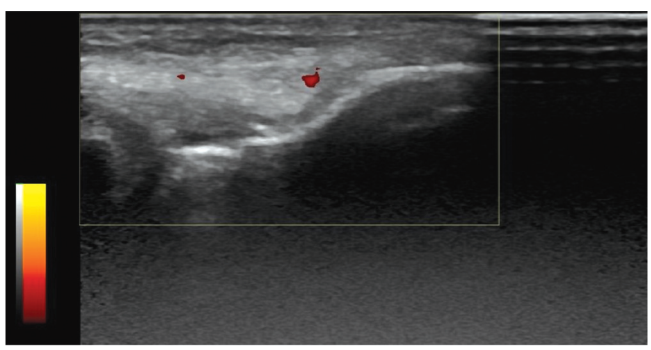

Figure 2. Increased intratendinous vascularization in the common extensor tendon.

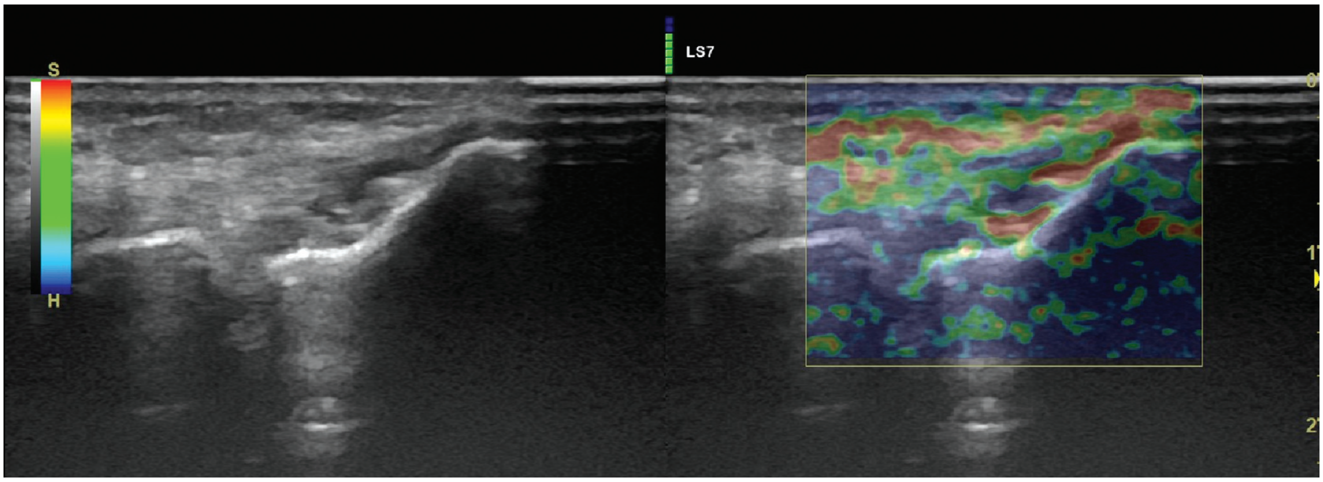

Figure 3. Green-weighted red soft coding in SEL imaging.

In 110 patients with clinical confirmed LE, right elbow involvement was 63 and left elbow involvement was 47. Intrasubstance tear was found in 68/110 (61.8%) of the patients. Calcification was present in 41/110 (37.3%) tendons. Hyperemia in the CET was found in 50/110 (45.5%) of the patients. Tendinosis of the CET was detected in 108/110 (98.2%) of the patients. Degeneration of the lateral epicondyle was found 35/110 (31.8%) of the patients.

In 56 healthy participants, tendinosis of the CET was detected in 16/56 (28%) of participants. Other B mode and CDUS findings were normal. Calcification and degenerative changes in lateral epicondyle were not involved in healthy participants.

From gray-scale ultrasonography and CDUS, intrasubstance tear (**Figure 6a**), calcification (**Figure 6b**), hyperemia, tendinosis of the CET and degeneration of the lateral epicondyle were showed statistically significant differences between healthy participants and patients with LE (p<0.001).

Of 166 participants, 46 (27%) showed elastographic pattern of type 1a, 32 (19%) showed elastographic pattern of type 1b, 47 (28%) showed elastographic pattern of type 2a, and 41 (24%) showed elastographic pattern of type 2b.

The SR of the tendon in patients with LE (mean: 6.68 ±2.49 mm, min: 1.70 – max: 16.1) were remarkably lower than in healthy participants (mean: 11.16±4.88 mm, min: 2.80 and max: 25.1) (p<0.001) (**Figures 7** and **8**). The SR of the tendon in patients with LE decreased with age. There was negative significant correlation between the mean SR of tendon and age (rs=[–0.261]; p<0.001). The

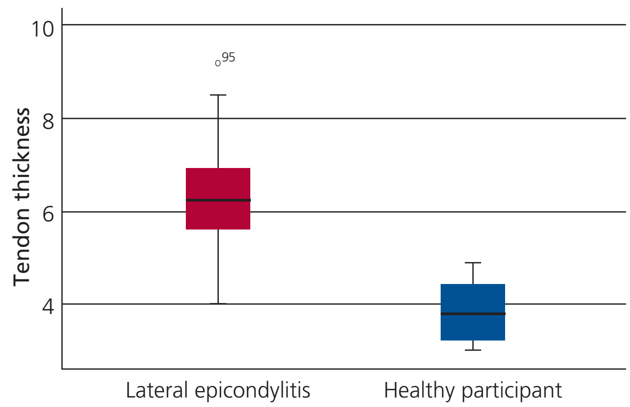

Figure 4. Plot of tendon thickness in patients with lateral epicondylitis and healthy individuals.

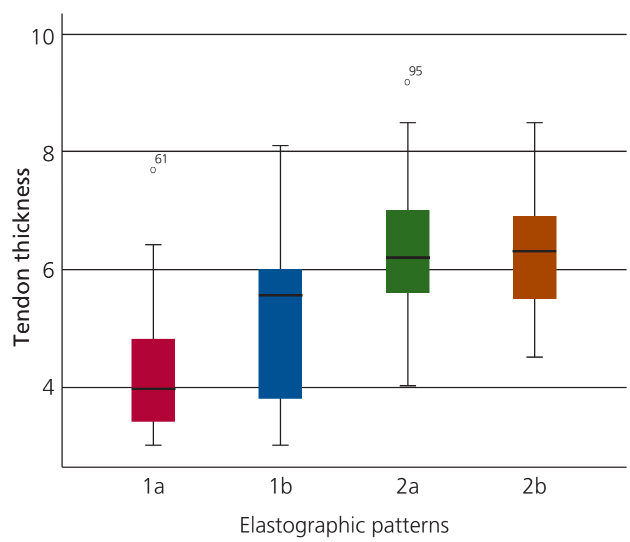

Figure 5. Elastographic patterns – tendon thickness plot.

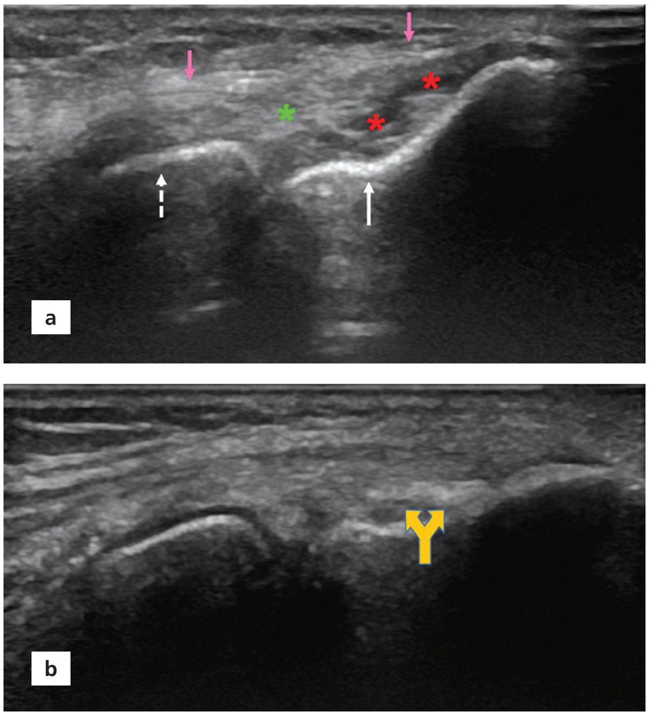

Figure 6. B-mode ultrasonography of lateral epicondyle (**white arrow**), distal radius (**dashed white arrow**), common extensor tendon (**green asterisk**) and upper border of the tendon (**pink arrows**). (**a**) intratendinous partial rupture (**red asterisks**) (**b**) intratendinous calcification (**double-headed arrow**).

SR of the tendon in patients with LE also varied significantly between the groups of elastographic patterns (p<0.001) (**Table 3**) (**Figures 9** and **10**). But there was no significant difference between the mean SR of the tendon in patients with LE of 1a and 1b elastographic patterns (p=0.403).

The SR of the tendon in patients with tendinosis (mean: 7.1±3.07, min: 1.7 – max: 16) were remarkably lower

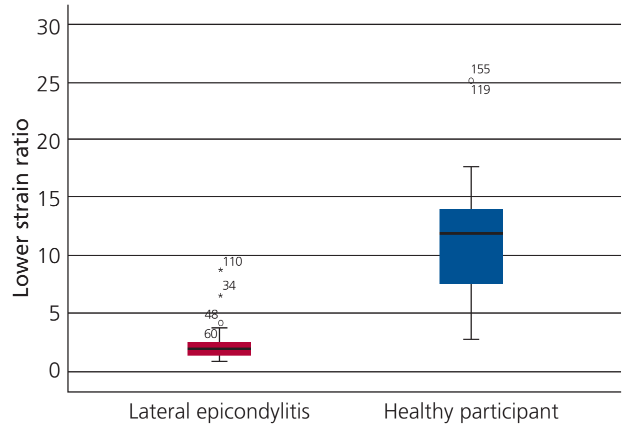

Figure 7. Plot of lower strain ratio in patients with lateral epicondylitis and healthy individuals.

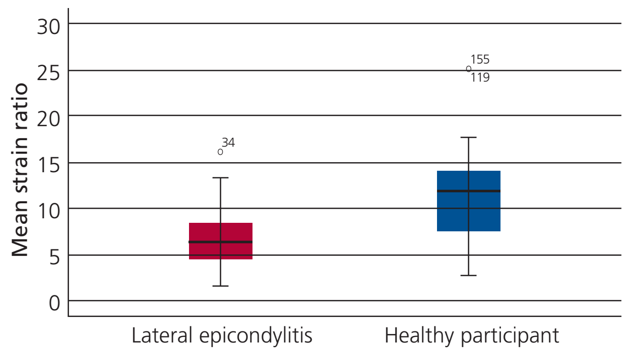

Figure 8. Plot of mean strain ratio in patients with lateral epicondylitis and healthy individuals.

than in healthy participants (mean: 11.2±5.07, min: 2.8 and max: 25.1) (p<0.001). The SR of tendon in patients with intrasubstance tear (mean: 6.5±2.3 mm, min: 2.5 – max: 12) were remarkably lower than in healthy partici-

Table 3
Lower and mean strain ratios of elastographic patterns.

	Elastographic patterns	Lower strain ratio	Mean strain ratio
1a	Patient	4.1±2.7	9.5±2.6
	Control	13.3±3.7	13.3±3.7
1b	Patient	3.3±1.1	8.9±2.2
	Control	5.3±1.7	5.3±1.7
2a	Patient	2.2±0.56	6.79±2.08
	Control	3.6	4.2
2b	Patient	1.3±0.3	5.2±2.01
	Control	-	-

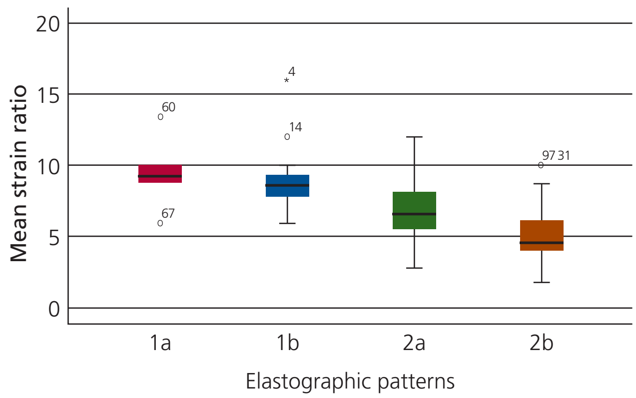

Figure 9. Elastographic patterns – mean strain ratio plot

pants (mean: 9.3±4.6, min: 1.7 and max: 25.1) (p<0.001). The SR of the tendon in patients with calcification (mean: 6.9±2.7, min: 1.7 – max: 16.1) were remarkably lower than in healthy participants (mean: 8.5±4.3, min: 2.5 and max: 25.1) (p=0.096). The SR of the tendon in patients with hyperemia (mean: 6.7±2.25, min: 2.7 – max: 13.4) were remarkably lower than in healthy participants (mean: 8.8±4.5, min: 1.7 and max: 25.1) (p=0.016). There was no significant difference between the mean SR of the tendon in patients with lateral epicondyle degeneration (mean: 6.9±2.63, min: 2.7 – max: 16.1) and in healthy participants (mean: 8.5±4.3, min: 1.7 and max: 25.1) (p=0.129).

Discussion

The mechanism of the CET injury is repetitive stress of forearm and wrist during movement of dorsiflexion and supination. Furthermore, patient characteristics, habits and activity level also affect the common extensor

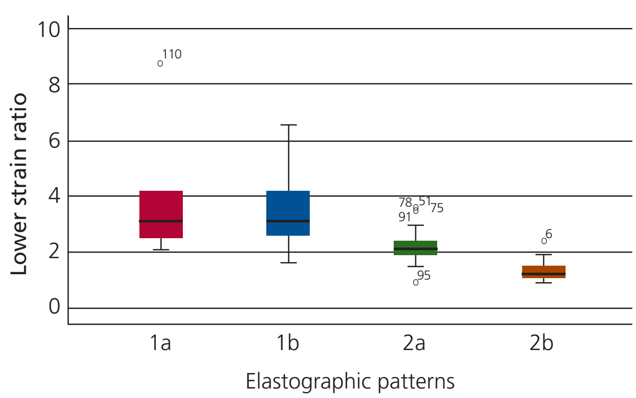

Figure 10. Elastographic patterns – lower strain ratio plot

tendinopathy.[15,16] The diagnosis of LE is made primarily by using typical clinical manifestations and physical examination. Furthermore, a wide variety of radiologic methods is used to diagnose LE, including conventional muscle sonography, CDUS, and magnetic resonance imaging.[16–18]

SEL provides elasticity and stiffness of tissue or lesions such as breast, liver, thyroid and tendons. In recent studies, strain SEL and shear-wave SEL have been investigated in diagnosis of LE. Gray scale and CDUS findings of LE are low echogenicity, increased thickness, intrasubstance tear, calcification and inflammation of lateral collateral ligament of elbow.[19] Tendinosis and low echogenicity is the most common sonographic finding of LE.[20] In our study, most grayscale findings of the patients with clinically confirmed LE was also tendinosis and intrinsic low echogenicity. The thickness of the CET significantly increased in LE compared to the healthy participants, which in consistent with Ahn et al.[21] and Zhu et al.[22] In addition, thickness of the CET varied significantly between the groups of elastographic patterns, and increased with age. It was seen that the thickness of the CET increased significantly as tendon getting softer.

Khoury et al.[23] showed that increased tendon compressibility indicative of tendon softening was a new sign of tendinopathy. De Zordo et al.[24] showed that real-time SEL was valuable in the detection of the intratendinous and peritendinous alterations of LE. Real-time SEL images showed hard tendon structures in 96% of tendon in healthy volunteers, and softening of different grades in 67% in patients with LE, which was considered a statistically significant difference in relation to the findings. Also, Ahn et al.[21] revealed that patients with LE had significantly lower SRs in their CET origins. In our study it was seen that the mean and lower SRs of the tendon in patients with LE were significantly lower compared to healthy participants. Furthermore, mean and lower SRs of the CET varied significantly between the groups of elastographic patterns.

Several limitations needed to be mentioned in this study. Ultrasonography and SEL imaging is highly operator dependent imaging modalities.[25] Additionally, we did not study interobserver and intraobserver variability. To avoid of sample error, we calculated both mean and lower SRs of the CET. One sample for lower SR were taken from red color scale of tendon and second sample for mean SR were taken from all part of the CET. Another limitation is semi-quantitative calculation of SR.[26]

Conclusion

We suggest that strain SEL is a promising sonographic technique for musculoskeletal imaging to differentiate variable etiologies that cause thickening and softening of the CET in LE. SR and SEL pattern findings are compatible with gray scale and CDUS findings. SEL findings are also compatible with degree of degeneration of the CET. Further longitudinal studies may support this consideration.

Conflict of Interest

No conflict of interest was declared by the authors.

Author Contributions

BİT: project development, collecting the clinical data, manuscript writing, editing the manuscript; SE: collecting the clinical data, manuscript writing, editing the manuscript; MB: project development, collecting the clinical data, manuscript writing, editing the manuscript. The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Ethics Approval

This study was approved by the institutional review board (No: E2-20-76, date: 16.12.2021) and informed consent was obtained from all participants. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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ORCID ID:
B. İ. Torun 0000-0002-0155-7447;
S. Eren 0000-0002-6935-4267;
M. Balaban 0000-0002-6752-6838

deomed

Correspondence to: Mehtap Balaban, MD
Department of Radiology, Faculty of Medicine,
Yıldırım Beyazıt University, Ankara, Türkiye
Phone: +90 312 906 20 00
e-mail: mehtapbalaban40@hotmail.com

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