

# Sonoelastography of the distal third of the Achilles tendon in asymptomatic volunteers: correlation with anthropometric data, ultrasound findings and reproducibility of the method

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## Abstract

**Objective** Evaluating prospectively elastosonography (EUS) findings of distal third of Achilles tendon in asymptomatic volunteers and correlating with subject characteristics and ultrasound (US) findings and, subsequently, calculating reproducibility of method.

**Materials and methods** 70 consecutive Achilles tendons were examined with US and EUS in 35 asymptomatic volunteers. Mean age 42.3 years ( $\pm 7.6$ ), 22 were female (mean age 41  $\pm 8.7$ ) and 13 were male (mean age 42.5  $\pm 11.4$ ). Information about population was collected (anthropometric data, sport activity, taken therapy and associated conditions/pathologies).

**Results** Statistically significant correlation was found between BMI and EUS findings ( $p = 0.007$ ) and between EUS aspect and US diagnosis ( $p = 0.039$ ) both to the right tendon. Possible influence of smoking ( $p = 0.063$  to right) and associated conditions ( $p = 0.059$  to left), has been found. The multivariate analysis showed that EUS results are correlated only with BMI (high BMI corresponds to the best EUS results), independently from smoke and associated conditions on right side. No correlations have emerged for the left tendon. The 22.8 % of the volunteers took on chronic therapies, none statistically significant correlation. In the past, 80 % of subjects played sports (7.4 % agonistic and 92.6 % non-agonistic). The 22.9 % of volunteers played sporadic or no activity. The 60 % of volunteers has

played sports that may lead overload of the Achilles tendon. The 61.5 % of subjects with BMI  $\geq 25$  was active little or nothing; 63.6 % of the subjects with BMI  $< 25$  is playing sports. US examination showed 57.1 % normal tendons and 42.9 % tendinosis. Rate of tendinosis was similar in both left and right (40 and 45.7 %, respectively). Statistically significant correlation was found between EUS aspect and US diagnosis on the right tendon but not on the left. Correlation between thickness and EUS aspect was calculated: no correlation was found. Interoperator correlation was excellent ( $k = 0.89$  for left tendon and  $k = 0.91$  for right tendon).

**Conclusions** The EUS is an interesting and useful technique, characterised by a high reproducibility. Its results are related to BMI and US appearance of the tendon, and they are probably influenced by the smoke and associated conditions. However, the flexed ankle position, needed to properly examine the distal third by US, alters the elasticity of the tendon and causes false negative results to EUS. Then, for the EUS study of the distal third, it would be appropriate the relaxed position, with a gel pad to optimise the probe adhesion.

**Keywords** Achilles tendon · Elastosonography · Ultrasound

## Introduction

Achilles tendon is the largest and strongest tendon in the human body, which originates from the gastrocnemius and soleus muscles. According to its anatomy, Achilles tendon can be divided into three third: proximal third or musculotendinous junction, middle third 2–6 cm from calcaneal

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insertion, and distal third at the insertion at the calcaneus [1].

Tendon alterations can result from the level of sports activities [2, 3], from the use of corticosteroids, fluoroquinolones and oestrogen medications [4, 5]. Tendinopathy is frequently associated to systemic diseases, like immunes [6]. Also tendon elasticity decrease with increasing age [7].

Proximal third pain is not very common [8]; middle third is commonly affected by tendon ruptures, particularly in athletes, but also in non-active individuals. Distal third alterations depends on the overload and they are influenced by the type of used footwear [9, 10]; also, condition is more complex compared to middle third, since tendon, bursae and bone (and combination of these) can be involved [3]. A prominent posterior angle of the calcaneal bone may cause “impingement” on the tendon [11].

For tendon investigation, the ultrasound (US) is an accurately and non-invasively method, to assess the morphological and dynamic aspects of tendon structure [2]. To support the diagnosis, a method for evaluating the tissues elasticity: the ultrasound elastography or sonoelastography (EUS) in recent years has been joined to the US investigation [12, 13]. The principle of EUS is that tissue compression produces a displacement within the tissue, and this strain is less in hard tissue than in soft tissue [13]. This technique was first described by Ophir et al. and Pesavento et al., in 90s [1, 14]. Recently, it was applied to muscle-skeletal system [1, 12, 15–17].

There are several EUS techniques [15]: one of these is axial strain elastography, in which the compression is applied manually. Real-time axial-strain EUS is the simplest technique allowing direct visualisation of the elastogram superimposed on the B-mode image [12].

The aim of this study is to evaluate EUS findings of distal third of Achilles tendon in asymptomatic volunteers and to correlate with subject characteristics and US findings. Successively, we want to calculate the inter-observer concordance for reproducibility of method.

## Materials and methods

### Study population

In this prospective study, from January to May 2012, 80 consecutives Achilles tendons were examined with US and EUS in 40 consenting asymptomatic volunteers.

Volunteers were asymptomatic at the examination time; they were questioned both about tendon injury, inflammation, surgery, or painful and about traumas on the lower limbs in general. We don't find subjects with a history of tendon rupture.

Information was collected about associated conditions that may determine a change in the load on the distal third of the tendon (e.g., congenital or post-traumatic limb dysmetria) or pathologies that may involve the tendons (e.g., rheumatological diseases, collagen abnormalities, infectious diseases, neurological conditions) [4]. Five volunteers were excluded by the presence of autoimmune diseases.

The remaining 35 subjects have mean age years ( $42.3 \pm 7.6$ ), 22 were female (mean age  $41 \pm 8.7$ ) and 13 were male (mean age  $42.5 \pm 11.4$ ).

Information was collected about therapies taken chronically and/or in the previous 15 days. Body Mass Index (BMI) was calculated for all subjects. We considered left or right predominance, smoking, current and previous sporting activities. Sporting activity was classified intense if performed four or more times/week, moderate if about three times/week and mild if one or two times/week. Potential sports overload was also considered.

### Examination protocol

Two radiologists, specialised in muscle-skeletal imaging (with 10 and 4 years of experience), independently performed US and real-time axial-strain EUS using the same ultrasound system (Hi Vision Preirus, Hitachi Medical) and the same linear transducer at a frequency range of 13–15 MHz.

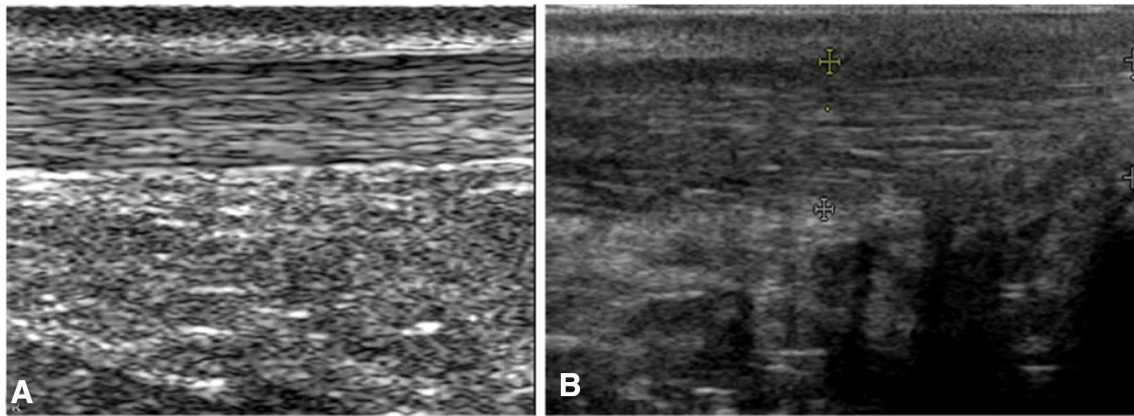
Subject was placed in prone position with the feet hanging free below the foot-end of the examination table with the ankle flexed to  $90^\circ$  to allow a correct visualisation of the distal third of the tendon.

The insertional third was examined in longitudinal scanning, measuring the anteroposterior diameter and analysing the echogenicity and echotexture in longitudinal and transverse view. Transducer was positioned perpendicular to the tendon to avoid anisotropy.

The tendon measure in anteroposterior view has been considered normal for thickness up to 5–7 mm [18]. In our sample, we take measures classically at 2 cm proximal to insertion and, in addition, at calcaneal insertion to have a further point of reference.

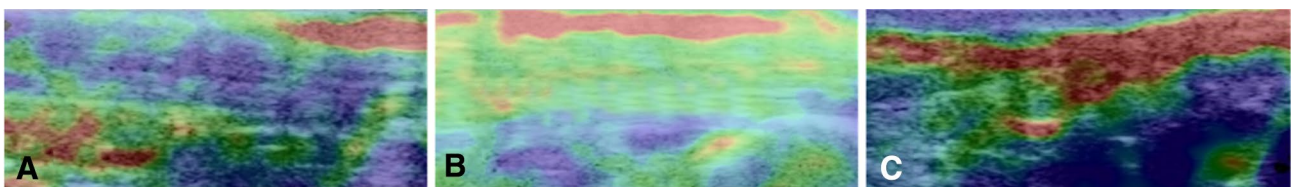
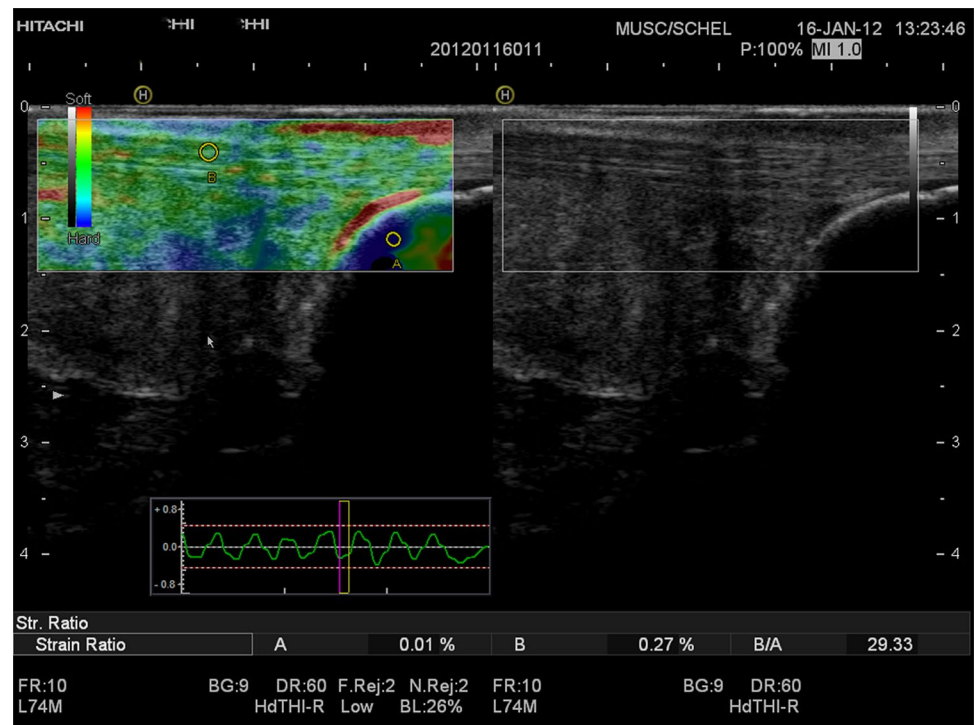
Based on US appearance, tendon was defined normal, tendinosis (when fusiform hypoechoic swelling of the tendon without fibres disruption was found), with partial-tear (when tendon was enlarged up 1 cm with hypo/anechoic cleft) or full-thickness tears (when complete fibre disruption with tendon retraction was found) [6] (Fig. 1).

The EUS evaluation was performed in sagittal plane, applying repetitive compression with the transducer over the region of interest. Correct compression was verified and appropriately adjusted according to the visual indicator seen on the video screen (Fig. 2).



**Fig. 1** US of Achilles tendon in longitudinal view. **a** normal tendon; **b** tendinotic tendon, characterised by fusiform hypoechoogenicity and increased thickness

**Fig. 2** The elastogram is visible on the *left side* of screen, and the conventional B-mode on the *right side*. It is possible to evaluate stiffness using *colour scale* or using the software (in this case the ROI *A* and *B* are positioned and machine calculates the strain ratio *B/A*)



**Fig. 3** EUS appearance of tendon according to the qualitative method. **a** hard tendon, characterised by *blue* or *blue-green* colour. **b** intermediate tendon, characterised by *green-yellow* colour. **c** soft tendon, characterised by *red* colour

**Table 1** Population characteristics and correlation with EUS results to the left (L) and to the right (R) tendon

	Total <sup>a</sup>	Female <sup>a</sup>	Male <sup>a</sup>	<i>p</i> (L)	<i>p</i> (R)
Population <sup>b</sup>	35	22	13	0.789	0.468
Mean Age <sup>c</sup> (years) ± sd	42.3 ± 7.6	41 ± 8.7	42.5 ± 11.4	0.231	0.511
Mean weight <sup>c</sup> (Kg) ± sd	68.7 ± 4.8	65.7 ± 6.3	77.2 ± 12.5	0.895	0.132
Mean height <sup>c</sup> (m) ± sd	1.69 ± 6.8	1.66 ± 5.6	1.76 ± 0.08	0.640	0.136
Mean BMI <sup>c</sup> (value) ± sd	24 ± 4	22 ± 3	25 ± 4	0.871	<b>0.007</b>
Smoke <sup>b</sup>	12	8	4	0.886	0.063
Associated conditions <sup>b</sup>	10	6	4	0.059	0.892
Chronic therapy <sup>b</sup>	8	5	3	0.243	0.871
Therapy 15 days ago <sup>b</sup>	7	5	2	0.635	0.856
Previous sport activity <sup>b</sup>	28	18	10	0.697	0.382
Previous overload <sup>b</sup>	21	13	8	0.613	0.896
Actual sport activity <sup>b</sup>	19	9	10	0.221	0.189
Actual overload <sup>b</sup>	9	3	6	0.275	0.484
Left traumas/inflammatory facts <sup>b</sup>	9	3	6	0.759	0.137
Right traumas/inflammatory facts <sup>b</sup>	4	2	2	0.232	0.354

Bold value is statistically significant

<sup>a</sup> Unless otherwise specified, data are number of cases

<sup>b</sup> Parameters analysed by Chi squared test

<sup>c</sup> Parameters analysed by Mann–Whitney *U* test

The elastogram appeared superimposed on the B-mode image with a scale of colours, according to the elasticity features: blue and blue-green represent hard tissue, green and yellow, intermediate thickness and red, soft tissue (Fig. 3).

The radiologists did not consider the borders of scans in their grading (for artefacts presence, because of inhomogeneous application of pressure) [1].

Correlation inter-operator was calculated.

### Statistical analysis

Statistical analysis was performed with SPSS software release 20.0. Standard descriptive statistic was used to summarise characteristics of volunteers (mean ± standard deviation for continuous variables and percentage for categorical variables). Multivariate binary logistic analysis and correlation coefficient (*r*) were used. The Mann–Whitney *U* test was performed to analyse continuous variables; the Chi squared test was performed to analyse categorical variables. A value of *p* < 0.05 was considered statistically significant. For statistics, we considered examinations carried out by the most experienced radiologist as reference standard. Reproducibility of the method was calculated using k-Cohen coefficient: poor concordance if *k* = 0, slight between 0.01 and 0.20, fair between 0.21 and 0.40, moderate between 0.41 and 0.60, good between 0.61 and 0.80 and excellent between 0.81 and 1.00 [19].

### Results

Characteristics of population are summarised in Table 1; each parameter was correlated with the EUS results (Table 1).

According to the colour scale, the tendons were found to be hard in 51.4 % and intermediate in 48.6 %; no soft tendons were found.

All volunteers have right predominance, so this has not been considered for statistical analysis.

Statistically significant correlation was found between BMI and EUS findings on right tendon: subjects with hard pattern had higher BMI (*p* = 0.007). This association resulted independent by the age (*r* = 0.094 and *p* = 0.613).

The 34.3 % of subjects is smoker (8 F and 4 M); nearly statistically significant correlation within smoke and EUS findings was found for right tendon (*p* = 0.063); no correlation for the left tendon (*p* = 0.886).

Associated pathologies/conditions were found in 28.6 % (6 F e 4 M); nearly statistically significant correlation was found for the left tendon (*p* = 0.059); no correlation for the right tendon (*p* = 0.892). We found: previous neoplasm (2F, 1 M), arterial hypertension (5F, 4 M), gastric ulcer (1 M), anemy (2F).

The multivariate analysis showed that EUS results are correlated only with BMI (high BMI corresponds to the best EUS results), independently from smoke and associated conditions on right side. No correlations have emerged for the left tendon (Table 2).

**Table 2** Results of multivariate binary analysis of EUS findings and BMI, associated conditions, smoke for right and left tendon

	<i>B</i>	E.S.	Wald	df	Sig.	Exp (B)
<b>Right</b>						
BMI	−0.247	0.129	3.687	1	<b>0.052</b>	0.771
Associated conditions	0.289	0.786	0.131	1	0.705	1.329
Smoke	1.056	0.851	1.538	1	0.204	2.891
Constant	4.827	3.105	2.185	1	0.126	129.027
<b>Left</b>						
BMI	−0.032	0.094	0.132	1	0.701	0.958
Associated conditions	1.068	0.722	2.176	1	0.132	2.916
Smoke	0.012	0.759	0.011	1	0.979	1.009
Constant	0.170	2.571	0.009	1	0.938	1.184

Bold value is statistically significant

**Table 3** US diagnosis and subdivision into intermediate and hard according with EUS aspect

US	EUS		<i>p</i> value
	Intermediate	Hard	
<b>Left</b>			
Tendinosic	8 (45 %)	6 (35 %)	0.854
Normal	10 (55 %)	11 (65 %)	
Total	18 (100 %)	17 (100 %)	
<b>Right</b>			
Tendinosic	4 (25 %)	12 (62 %)	<b>0.028</b>
Normal	12 (75 %)	7 (38 %)	
Total	16 (100 %)	19 (100 %)	

Correlation between US and EUS aspect was calculated using Chi squared test

Bold value is statistically significant

The 22.8 % of the volunteers took on chronic therapies; in particular, 72 % of them took hormone therapy (estrogenic and progestin), the remaining 28 % other therapies (mainly antihypertensive drugs).

Within 15 days before the examination, 20 % of subjects had taken FANS for a mean of 4.3 days (min 1, max 15) for conditions not related to the lower limbs, especially the Achilles tendon. No one had taken corticosteroids or fluoroquinolones.

In the past, 80 % of subjects played sports (7.4 % agonistic and 92.6 % non-agonistic): intense activity has been practised in 14 % of these, moderate in 55.6 % and mild in 30.4 %. The 22.9 % of volunteers played sporadic or no activity. The 60 % of volunteers has played sports that may lead overload of the Achilles tendon (52.6 running %, dance 4.9 %, football 40.5 %, other 2 %).

At the examination time, 54.3 % of subjects practising non-agonistic sports: intense activity was performed 10.5 % of these, moderate in 21.1 % and mild in 68.4 %. The 45.7 % of volunteers carried out sporadic or no activity. The 25.7 % of volunteers practised sports that may lead

**Table 4** Mean average of the tendon calculated to insertion and from 2 cm by the calcaneal insertion, to the left (L) and to the right (R) tendon

	Mean thickness	<i>p</i> value
<b>Left</b>		
Insertion	4.5 (±1.1) cm	0.398
To 2 cm from insertion	4.2 (±0.9) cm	0.621
<b>Right</b>		
Insertion	4.2 (±0.8) cm	0.472
To 2 cm from insertion	3.9 (±0.8) cm	0.527

Correlation was calculated by Chi squared test

overload of the Achilles tendon. The 61.5 % of subjects with BMI ≥ 25 was active little or nothing; 63.6 % of the subjects with BMI < 25 are playing sports.

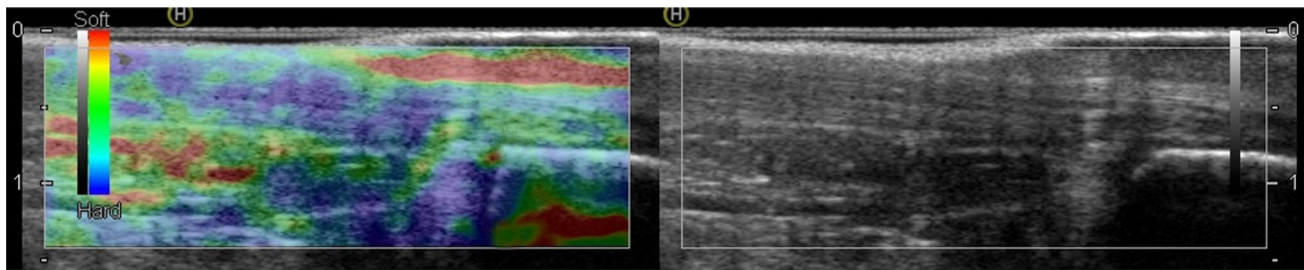
Previous ankle traumas or inflammatory facts to the tendons were detected in 10 % of examined ankles. None of the subjects had previous tendon ruptures.

US examination showed 57.1 % normal tendons and 42.9 % tendinosic. Rate of tendinosic tendons was similar in both left and right (40 and 45.7 %, respectively). Neither full- nor partial- thickness tears have been found. The 35.3 % of volunteers had bilateral tendinopathy. Statistically significant correlation was found between EUS aspect and US diagnosis on the right tendon but not on the left (Table 3). Correlation between thickness and EUS aspect was calculated: no correlation was found (Table 4).

Interoperator correlation was excellent (*k* = 0.89 for left tendon and *k* = 0.91 for right tendon).

### Discussion

Sonoelastography has been recently introduced to assess muscle and tendons elasticity [2, 13]. There are relatively few studies about technique, outcome, and indications for EUS applied to the muscles and tendons [13, 20]. Achilles



**Fig. 4** This is an example of the conflict between the US and EUS findings. **a** EUS shows *blue-green* colour, so the tendon is classified as hard. **b** US shows areas of fusiform hypoechoogenicity, so the tendon is tendinosis

tendon is the most studied structure since it is a simple target to examine [1, 12, 13, 18, 21, 22]. In literature there are some studies dividing Achilles tendon into three thirds [1, 13]. Most studies have focused on the middle third because it is commonly affected by ruptures [3, 12]. Distal third pain is also common but it has a different aetiology: mainly depends on the overload [3]. In literature, there is no work about only the distal third, so we decided to examine it.

Some parameters are known to be related to various alterations of the Achilles tendon: age, sports, sex, dominant-side, inflammatory and autoimmune conditions, medications [4]. So we tried to correlate those data to the EUS appearance. Furthermore, EUS findings are not found to be significantly correlated with age, sex, height, weight and level of present and past physical activity. According to Turan et al. [23], the Achilles tendon is remarkably stiffer in elderly subjects compared to young subjects in all parts of the tendon examination and this condition might explain the increased incidence of tendon ruptures in the elderly population.

Our study shown that BMI only influences EUS aspect of the tendon on the right side ( $p = 0.007$ ) but not on the left. A possible correlation also exists between EUS aspect on right tendon and smoke ( $p = 0.063$ ).

These findings to the right tendon, and not to the left, may depend on the reduced number of enrolled volunteers. A greater number of subjects could highlight significance to the left tendon too. Moreover, this could be linked to the right predominance of study population; it is necessary to enrol a population with higher rate of left predominance to demonstrate it. In our opinion, the association between higher BMI and EUS best results could be due to a greater influence of the sports overload on the health of the tendon, with respect to the overload linked to a higher BMI. Although statistically significant correlation between activity and EUS appearance has not been found, the relationship between sport and degeneration of the tendon is known, in fact, in our sample, 61.5 % of patients with  $\text{BMI} \geq 25$  did not practise sports, while 63.6 % of the volunteers with  $\text{BMI} < 25$  was sportingly active.

Regarding the smoke: in some works, a significant correlation between smoking and thickness/degeneration of the tendons has not been demonstrated [24, 25]. In others, significant correlation was found but the Authors consider the data not conclusive [26]. In absence of definitive data in literature, our results are difficult to interpret, probably also because of the relatively small number of subjects.

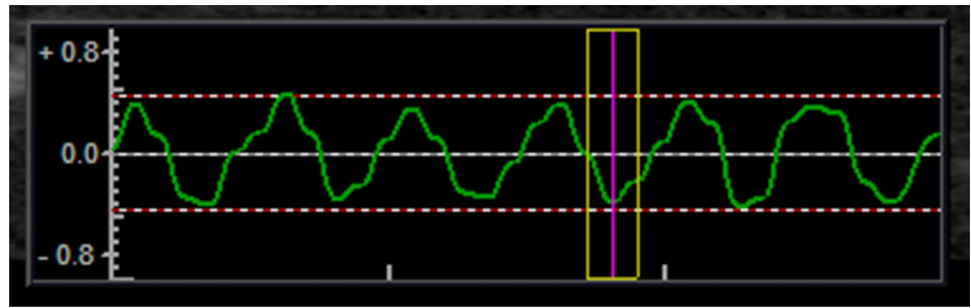
In our sample, related conditions and pathologies have nearly statistically significant correlation ( $p = 0.059$  on left). This suggests an influence of some conditions, but heterogeneity of population does not allow neither to obtain statistical significance nor to understand which conditions affect the data. A greater number of subjects per group of pathologies would allow a precise correlation.

Our study showed a significant correlation between US and EUS aspect on the right tendon ( $p = 0.028$ ) but contrary to what would be expected [16], most of the tendinosis to US were found to be hard to EUS (Fig. 4). In our opinion, these data is influenced by examination position of ankle ( $90^\circ$  of flexion): in fact when the Achilles tendon is maximally stretched, elasticity increases [27]. A major part of works use the relaxed position [1, 12] and we found only one study in literature comparing elasticity at different levels of flexion [27].

Therefore, position alters the elasticity of the tendon and causes false negative results (tendon might be “harder”). To avoid this problem, it would be appropriate to carry out the EUS study of the distal third in relaxed position, perhaps using a gel pad to ensure the probe adhesion. Some authors have used the gel pad in their work [1]. However, the US examination should be performed with strained tendon: we wonder if the different position used for the two tests can somehow alter the results comparison. A study would be useful to examine these aspects.

For EUS diagnosis we have considered the colour scale, which is qualitative method (Fig. 2). It is also possible to use the semiquantitative method provided by the machine software but the qualitative interpretation may be more useful in clinical practise [12]; it is more immediate and reduces the examination time. Furthermore, literature

**Fig. 5** A visual indicator on the screen gives an optimal dynamic range of pressure: it is necessary that the graph of compressions remains within the minimum and maximum lines to get the right pressure



shows that reproducibility of EUS is excellent when performed qualitatively and poor when semi-quantitatively evaluation (strain ratio) was used [15].

A possible limit of the method is that the application of pressure to the probe is relatively operator dependent [13] and there is “significant differences in both the maximum and the mean value of the elastic modulus of the muscles and tendons when different transducer pressure were applied” [23]. Since EUS is an echographic technique, it is certainly operator dependent but the presence of a visual indicator on the screen (Fig. 5) gives an optimal dynamic range of pressure [14]; this decreases interobserver variability and facilitates image acquisition [1].

In our sample, we have obtained an excellent reproducibility, in agreement with other works that use the qualitative method [12, 21].

## Conclusions

The EUS is an interesting and useful technique, characterised by a high reproducibility.

Its results are related to BMI and US appearance of the tendons, and they are probably influenced by the smoke and associated conditions. However, the flexed ankle position, needed to properly examine the distal third by US, alters the elasticity of the tendon and causes false negative results to EUS. Then for the EUS study of the distal third, it would be appropriate the relaxed position, with a gel pad to optimise the probe adhesion.

In conclusion: this study provides many opportunities to improve the routine use of EUS. Further studies would be needed to investigate aspects highlighted by our study.

## Compliance with ethical standards

**Conflict of interest** The authors declare that she has no conflict of interest.

**Funding** None funding have this study.

**Ethical approval** All procedures performed in the 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.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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