



## Original Research

# Ultrasound evaluation of extrinsic foot muscles in patients with chronic non-insertional Achilles tendinopathy: A case-control study

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## ABSTRACT

**Aim:** The purpose of the present study was to compare and quantify with ultrasound imaging (USI) the extensor digitorum longus (EDL), tibialis anterior (TA) and peroneus muscles (PER) muscle thickness and cross-sectional area (CSA) between chronic non-insertional Achilles tendinopathy (AT) and healthy subjects.

**Methods:** a sample of 143 individuals was recruited and divided in two groups: chronic non-insertional AT group (n = 71) and a healthy group (n = 72). The thickness and CSA were assessment by USI for EDL, TA and PER muscles in both groups.

**Results:** The thickness evaluation for the TA muscle increased showing statistically significant differences (P = 0.018) as well as for the thickness of the PER muscles significant differences (P = 0.001) were observed in favor of the tendinopathy group. The CSA measurements showed statistically significant differences for a decrease in EDL (P = 0.000), TA (P = 0.001) and PER muscles (P = 0.011) for the tendinopathy group with respect to the control group.

**Conclusions:** The CSA of the EDL, TA and PER muscles is reduced in participants with chronic non-insertional AT. The thickness for TA muscle is increased as well as a decrease of PER muscles thickness is presented for the AT group with respect to the control group.

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## 1. Introduction

Achilles tendinopathy (AT) is one of the most common ankle and foot disease, identify by the combination of pain, swelling and lack of functionality in the lower limb (Jarvinen et al., 2001). The incidence rate of AT was estimated in 2.35–2.16 per 1000 in the current population (Albers, Zwerver, Diercks, Dekker, & Van den Akker-Scheek, 2016). The etiology of AT is multifactorial, for example recent histopathologic studies have found changes in the tendon thickness and cross-sectional area (CSA) in response to load adaptations and degenerative mechanisms (Cook & Purdam, 2009).

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Hon-Yun and Ying-Hui (Li & Hua, 2016) reported two main classifications of AT according to the locations: insertional (at the calcaneus enthesis) and non-insertional (2–6 cm proximal to the Achilles tendon at the calcaneus). Degeneration is very prevalent in non-insertional individuals with AT (van Dijk, van Sterkenburg, Wiegerinck, Karlsson, & Maffulli, 2011), due to a decrease of the blood flow in this area (Chen et al., 2009).

Achilles tendon is the key for ankle mobility and functionality, and therefore, of human locomotion (Lorimer & Hume, 2014). Nevertheless, the Achilles tendon does not work in isolation. It is related to the gastrocnemius and soleus joint movements of the ankle (Maganaris, Narici, & Maffulli, 2008) and foot (Hintermann, Nigg, & Sommer, 1994). Despite the mechanisms of Achilles tendinopathy still unclear, several authors showed that adaptations of the tendon and surrounding muscles are very common in patients with AT in response to load requirements (Chiquet, 1999; Galloway,

Lalley, & Shearn, 2013). Those adaptations involve changes in the extrinsic foot muscles morphology, such as the thickness and CSA.

The extrinsic foot muscles including extensor digitorum longus (EDL), tibialis anterior (TA) and peroneus muscles have been an important role in the ankle biomechanics. For example, EDL and TA acts in early stances allowing and controlling the gradual plantar-flexion of the foot (Angin, Crofts, Mickle, & Nester, 2014). Murley et al. (Murley, Menz, & Landorf, 2009) reported that peroneus longus and brevis (PER) muscles developed and important role in the ankle joint acting as a plantar-flexor muscles and stabilizers of the subtalar joint. In addition, a primary function of the PER muscles is to provide the eversion required to balances the opposing inversion actions (Otis, Deland, Lee, & Gordon, 2004).

Ultrasound imaging (USI) has been used to evaluate the thickness and CSA of numerous muscles related with musculoskeletal conditions. Considering the lower limb, Lobo et al. (Lobo, Morales, et al., 2016) reported a reduced peroneus longus CSA in subjects with ankle sprains. Abductor hallucis and flexor hallucis brevis were examined by USI showing a reduction in the thickness and CSA in individuals with hallux valgus (Lobo, Marin, et al., 2016). In addition, thickness of the vastus medialis muscle was reduced in subjects with knee osteoarthritis (Taniguchi et al., 2015). Concerning other areas, USI has been useful to evaluate the CSA of intrinsic hand muscles in individuals with nerve injuries (Mohseny et al., 2015). Moreover, Strini et al. (Strini, Strini, Barbosa, & Gavião, 2013) found by USI the masseter, temporalis and sternocleidomastoid muscles may present USI changes related with temporomandibular disorders. Javanshir et al. (Javanshir, Amiri, Mohseni Bandpei, Penas, & Rezasoltani, 2015) reported that observation of USI deep cervical muscles may be developed during exercise programs for subjects with neck pain. In the trunk region, the morphology of the abdominal wall muscles has been described by Whittaker et al. (Whittaker, Warner, & Stokes, 2013) and related with lumbopelvic pain (Kiesel et al., 2007). Several authors considering USI as safe, non-invasive and a rapid method to assess the musculoskeletal and soft tissues disorders (Romero-Morales et al., 2018; Whittaker et al., 2013). For the Achilles tendon, USI measures have focused on tendon thickness and CSA in patients with and without pathology. However, prior studies have limited measures of the structures surrounding the ankle joint and the extrinsic foot muscles.

The purpose of the present study was to compare and quantify with USI the thickness and CSA of the EDL, TA and PER muscles in subjects with and without AT. We hypothesized that in existence of tendinopathy, the thickness and CSA of the extrinsic foot muscles were decreased.

## 2. Materials and methods

### 2.1. Study design

An observational study has been developed from January to December 2017, according to the Strengthening the Reporting of Observational Studies in Epidemiology Statement (STROBE) guidelines (Welch et al., 2015).

### 2.2. Ethics

The Research and Ethics Committee of La Princesa Hospital (Madrid, Spain; record number: 2828 A) approved the study. Consent informs were signed by the participants before the beginning of the investigation. The Declaration of Helsinki was respected throughout the study.

### 2.3. Sample

A sample of 143 subjects from 18 to 55 years was included in the study. Two groups were constituted: chronic non-insertional AT group ( $n = 71$ ) and a control group ( $n = 72$ ). The enrollment of the participants was carried out by a specialized medical doctor with more than 10 years of experience in sport medicine. For the tendinopathy group, participants were added if they presented: tendon pain of at least 3 out of 10 points in visual analogue scale (VAS), soreness and dysfunction in the body of the tendon at least 3 months, had no under pharmacological or physical treatments currently. The exclusion criteria were fractures, surgeries, sprains or any disease in the lower limb the last 12 months (Håkan Alfredson & Cook, 2007), plantar orthoses and skin disturbances (Alfredson, Pietila, Jonsson, & Lorentzon, 1998).

The sample size calculation was carried out with G\*Power software by the difference between tendinopathy and control group using the thickness of TA (mm) variable of a pilot study ( $n = 20$ ) divided in two groups (mean  $\pm$  SD), 10 individuals with chronic non-insertional AT ( $18.06 \pm 4.85$ ) and 10 subjects for the control group ( $20.58 \pm 2.43$ ). An  $\alpha$  error of 0.05, a power of 0.80, and effect size of 0.65 with 1 tailed hypothesis were used for the sample size calculation. Finally, a total sample of 60 subjects was calculated. However, we could recruit a sample of 143 individuals.

### 2.4. Ultrasound imaging

All USI images were performed by the same therapist (P.M.L) with 3 years of specialization and experience. A high-quality ultrasound system (LogiQ P7, GE Healthcare, UK) with a 4–13 MHz linear transducer (L6-12 RS type with 38-mm footprint) was used to carried out the B-Mode ultrasound recordings. All USI measurements were developed in supine position. TA was assessment “longitudinally at a 20% of the distance between fibular head and the inferior border of the lateral malleolus”, with the transducer in a longitudinal view for the thickness and in a transversal view for the CSA (Crofts, Angin, Mickle, Hill, & Nester, 2014). (Figs. 1A and 2A) PER were evaluated exactly at the midpoint between fibular head and the lateral malleolus. The transducer was placed in a longitudinal and transversal view for the thickness and CSA, respectively (Crofts et al., 2014). (Figs. 1C and 2C) EDL was examined following the TA principles, placed the transducer laterally to the TA muscle at the midpoint between the origin and the insertion of the muscle. Longitudinal and transversal views were recorded for the thickness and CSA captures (Figs. 1B and 2B). No previous studies were found for the EDL evaluations, thus the intra-class correlation coefficient (ICC) test was carried out for the intra-rater reliability. In addition, the same protocol was carried out after 1 h in order to repeat the USI evaluations in all 71 tendinopathy patients included in the study. Skin marks were removed before new measurements were carried out (Lobo, Marin, et al., 2016).

### 2.5. Image measurement

The final measurements were obtained by the mean of 3 repeated values for each measurement. Image J software (v.2.0; Maryland, USA) was employed for evaluated all the images offline.

### 2.6. Data analysis

The statistical analysis was performed by the SPSS package v.22.0 (IBM, Armonk, NY: IBM Corp). First, Kolmogorov-Smirnov was carried out to assess the normality. Second, a descriptive analysis was employed for all the individuals and separately in the two groups. Finally, a comparative analysis between tendinopathy

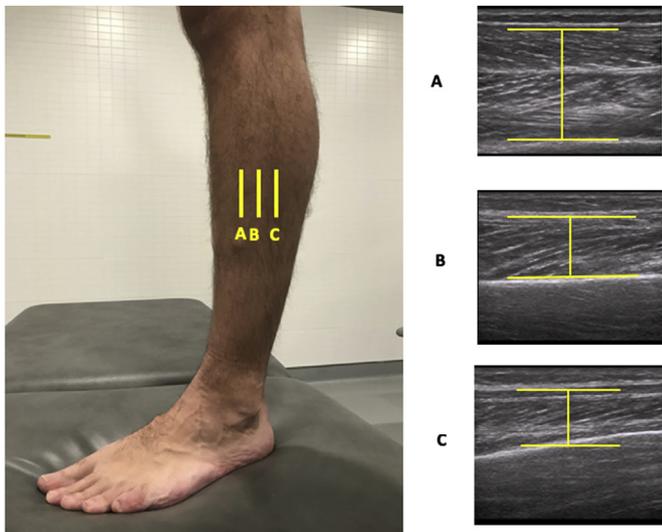


Fig. 1. Ultrasound imaging thickness for the TA, EDL and PER muscles in longitudinal view.

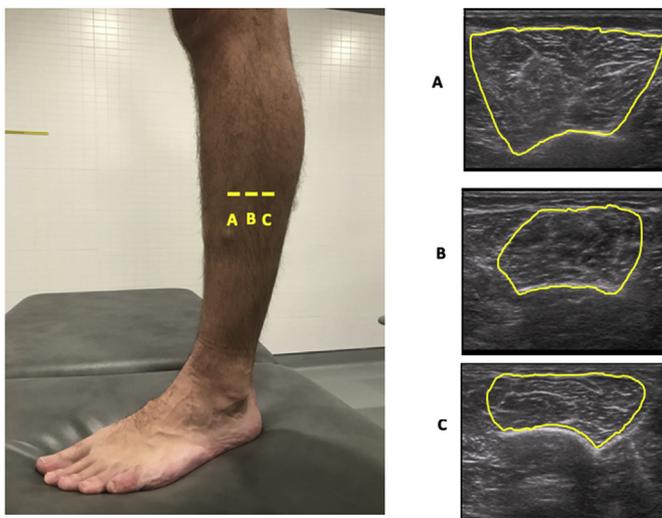


Fig. 2. Ultrasound imaging CSA for the TA, EDL and PER muscles in transversal view.

and control group was performed. Mean, standard deviation (SD) with the Student's *t*-test and median, interquartile range (IR) with Mann-Whitney *U* test were carried out for parametric and non-parametric data, respectively. In addition, Levene's test was employed to assess the equality of variances. Moreover, the ICC was performed to evaluate the reliability of the EDL measurements.

### 3. Results

Considering Table 1, the body mass index (BMI) showed statistically significant differences ( $P < 0.05$ ) between groups and age, weight, height did not show statistically significant differences ( $P > 0.05$ ). Regarding Table 2, USI measurements of the EDL thickness did not show statistically significant differences ( $P = 0.676$ ). The thickness evaluation for the TA muscle increased showing statistically significant differences ( $P = 0.018$ ) as well as for the thickness of the PER muscles significant differences ( $P = 0.001$ ) were observed in favor the tendinopathy group. The CSA measurements showed statistically significant differences for a

decrease in EDL ( $P = 0.000$ ), TA ( $P = 0.001$ ) and PER muscles ( $P = 0.011$ ) for the tendinopathy group with respect to the control group. In addition, the ICC values for the thickness (ICC = 0.818;  $F = 20.72$ ,  $P = 0.000$ ) and CSA (ICC = 0.730;  $F = 14.55$ ,  $P = 0.000$ ) of the EDL muscle were considered excellent and good, respectively.

### 4. Discussion

The purpose of this study was to conclude if subjects with AT would demonstrate differences in the thickness and CSA in the extrinsic foot muscles compared with individuals without features of AT. These variables were of interest, extrinsic foot muscles are structures directly related with the Achilles tendon and its biomechanics.

Calhoun et al. (Calhoun, Li, Ledbetter, & Viegas, 1994) reported that an 83% of load is transmitted through the tibia and ankle structures as well as a 17% transmitted through the fibula. Therefore, the muscles directly related to this area, such TA, EDL and PER, are very susceptible to suffer changes in individuals with AT conditioning the ankle biomechanics. Excessive pronation was considered as a risk factor to predispose AT (Maffulli & Kader, 2002), compensatory changes in ankle biomechanics in subjects with AT producing a high mechanical stress on the soft tissues structures, such as TA muscles (Williams, Zambardino, & Banning, 2008). Those findings were related with a thickness increase in TA muscle in response to excessive loads requirements found in our study in individuals with AT. Williams et al. (Williams et al., 2008) indicated that tibial rotations were related with the rotation of the Achilles tendon. For example, an increase of tibial internal rotation could be produce a decrease in Achilles mid-portion blood flow (Clement, Taunton, & Smart, 1984). Therefore, changes in biomechanics of the joints directly related with the Achilles tendon affects to demands of muscles, such EDL and TA, modifying the pronation of the rearfoot, which could be result in the development of pathology. In addition, Angin et al. (Angin et al., 2014) observed a greater thickness and CSA of the extrinsic foot muscles in patients with pes planus. Moreover, several authors reported tissue and tendon changes of the thickness and CSA of the Achilles tendon in response to exercise (Neves, Johnson, Hunter, & Myrer, 2014; Ohberg, Lorentzon, & Alfredson, 2004) and in presence of pathology (Arya & Kulig, 2010; Cook & Purdam, 2009).

PER muscles thickness and CSA with and without pathology can be evaluated and monitored with USI. Lobo et al. (Lobo, Morales, et al., 2016) reported a reduced CSA in peroneus longus in individuals who suffered from ankle sprains. In addition, Murley et al. (Murley et al., 2009) observed a reduced peroneal muscle tissue in patients with pes planus. Authors suggest that in presence of pathology the ankle supinator muscles increase their activity to the detriment of PER muscles (Murley et al., 2009). In the present study both thickness and CSA were reduced in patients with AT, so it should be considered an important variable for the diagnosis and treatment in individuals with AT.

With respect to the reliability of the USI measures for EDL muscle, our findings suggest that the thickness and CSA were valid to evaluate the EDL morphology, presenting similar results to authors who study the extrinsic foot muscles with USI (Angin et al., 2014; Crofts et al., 2014).

The results of the present study do not provide a cause explanation or management for the AT. Authors indicated that the etiology of the tendinopathy is multifactorial and pretends to offer an interesting approach assessing and quantifying the surrounding musculoskeletal structures of the Achilles tendon by USI, such as extrinsic foot muscles. Several studies reported the importance of a complete diagnosis of the AT based on the clinician interpretations of the symptoms added to complementary imaging assessments,

**Table 1**  
Sociodemographic data, pain scores and VISA-A scale of the sample.

Data	Tendinopathy (n = 71)	Controls (n = 70)	P-value Cases vs Controls
Age, y	45.11 ± 12.75 <sup>a</sup>	37.61 ± 11.91 <sup>a</sup>	.200 <sup>b</sup>
Weight, kg	76.00 ± 12.00 <sup>c</sup>	75.00 ± 18.50 <sup>c</sup>	.412 <sup>d</sup>
Height, m	1.76 ± 0.11 <sup>c</sup>	1.76 ± 0.12 <sup>c</sup>	.566 <sup>d</sup>
BMI, kg/m <sup>2</sup>	24.81 ± 2.13 <sup>c</sup>	23.88 ± 3.67 <sup>c</sup>	.012 <sup>d</sup>
VAS	2.00 ± 3.00 <sup>c</sup>	N/A	N/A
VISA-A	56.00 ± 14.00 <sup>c</sup>	N/A	N/A

Abbreviations: VAS, visual analogue scale.

<sup>a</sup> Mean ± standard deviation (SD) was applied.<sup>b</sup> Student's *t*-test for independent samples was performed.<sup>c</sup> Median ± interquartile range (IR) was used.<sup>d</sup> Mann-Whitney *U* test was utilized.**Table 2**  
Ultrasound imaging measurements.

Measurement	Tendinopathy (n = 71)	Controls (n = 72)	P-value
EDL thickness (mm)	15.91 ± 2.49 (10.29–22.63) <sup>a</sup>	16.09 ± 2.71 (9.99–22.93) <sup>c</sup>	0.676 <sup>b</sup>
EDL CSA (mm <sup>2</sup> )	388.55 ± 60.97 (223.47–502.63) <sup>c</sup>	452.56 ± 89.77 (260.35–680.49) <sup>c</sup>	0.000 <sup>d</sup>
TA thickness (mm)	210.91 ± 110.07 (109.81–527.90) <sup>a</sup>	134.53 ± 35.17 (87.41–206.62) <sup>c</sup>	0.018 <sup>b</sup>
TA CSA (mm <sup>2</sup> )	407.89 ± 62.61 (263.80–559.84) <sup>c</sup>	527.35 ± 179.02 (282.37–852.79) <sup>c</sup>	0.001 <sup>d</sup>
Peroneus thickness (mm)	17.60 ± 2.56 (13.38–26.89) <sup>a</sup>	18.71 ± 2.96 (10.72–24.07) <sup>c</sup>	0.001 <sup>b</sup>
Peroneus CSA (mm <sup>2</sup> )	354.01 ± 65.84 (212.75–443.37) <sup>c</sup>	375.58 ± 80.65 (207.01–543.10) <sup>a</sup>	0.011 <sup>d</sup>

Abbreviations: CSA, cross sectional area; EDL, extensor digitorum longus; TA, tibialis anterioris

<sup>a</sup> Mean ± standard deviation (SD) (minimum–maximum) was applied.<sup>b</sup> Student's *t*-test for independent samples was performed.<sup>c</sup> Median ± interquartile range (IR) (minimum–maximum) was used.<sup>d</sup> Mann-Whitney *U* test was utilized.

such as USI (Maffulli, Sharma, & Luscombe, 2004; Romero-Morales et al., 2019). In addition, the main findings in this paper pretends to improve and help in the diagnosis and management of the AT. Furthermore, due to the observational and cross-sectional study design, our study only support evidence to determine an association, but not for conclude if our findings may be caused by or may be a cause to AT. Further longitudinal cohort studies are necessary in order to determine this cause-effect relationship.

#### 4.1. Limitations

One of the main limitations was the impossibility of developing an inter-rater test for the EDL variable. The BMI was calculated with the Quetelet's formula showing statistically differences between groups that could influence the results (Garro & Webster, 1985). In addition, the differences between groups for the BMI could be explained due to the Quetelet's index calculation. Despite height and weight did not show differences between groups separately, the different distribution of the height and weight between both groups showed statistically significant differences between both groups (Foley et al., 2000). At last, color elastography could be useful for the study of extrinsic foot muscles.

#### 4.2. Future studies

Additional studies will be needed to enhance our knowledge about the role played by the extrinsic foot muscles in AT. Electromyography and pressure platforms studies may help to clarify the clinical relevance of the association between foot muscle activation, posture and foot and ankle disorders, such AT.

### 5. Conclusions

The CSA of the EDL, TA and PER muscles is reduced in participants with chronic non-insertional AT. The thickness for TA muscle

is increased as well as a decrease of PER muscles thickness is presented for the AT group with respect to the control group.

### 6. Conflicts of interest and Source of Funding

There are no conflicts of interest or Source of Funding.

#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ptsp.2019.02.006>.

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