VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 70, No. 3, pp. 180–184
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ISSN 0015–5659
www.fm.viamedica.pl

Morphological study of the calcaneofibular ligament in cadavers

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[Received 22 March 2011; Accepted 16 May 2011]

The aim of the present study was to investigate the anatomical and morphological characteristics and the maximum elongation of the calcaneofibular ligament (CFL) in cadavers.

In a sample of 72 cadaveric lower limbs the mean values of length, width, thickness, and angle with the sagittal plane were recorded for the CFL.

The mean ligament's length was 31.8 mm, and the mean width and thickness were 4.4 mm and 1.5 mm respectively. The mean angle with the sagittal plane was 51.11°. In 72.2% of the lower limbs studied, the ligament presented one band, while 22.2% and 5.6% of them were two-banded and three-banded respectively. A common origin with the anterior talofibular ligament (TFL) was found in 24 of the feet (33%). There were also 4 cases in which the anterior TFL was absent. Finally, we measured the maximal elongation of the ligament during extreme inversion and simultaneous dorsal flexion and found it to be 2.88 mm on average. We noticed and statistically verified that women presented a greater elongation compared to men.

A precise knowledge of the origin, insertion, direction, and morphology of CFL is critical for ligament injuries in ankle sprains and during ankle reconstruction. Ligament elasticity plays an important role in the range of ankle motion and ligament shearing. Male and female ankle joints differ in several anthropometric characteristics and thus the genre differences in ligament elongation are of great interest. (Folia Morphol 2011; 70, 3: 180–184)

Key words: calcaneofibular ligament, cadaveric, ligament elongation

INTRODUCTION

Peri-ankle ligaments play a critical role in ankle motion control though their relative contribution to the articular surfaces is not understood enough. Ankle injuries account for 10% of practitioners' admissions [30], and lateral ankle ligaments are involved in 85% of ankle sprains [26]. The lateral collateral ligament consists of the anterior talofibular ligament, the posterior talofibular ligament (TFL), and the calcaneofibular ligament (CFL). These ligaments are torn during supination and simultaneous adduction to the ankle joint [1], leading to functional instability, chronic pain, and recurrent sprains [8].

The calcaneofibular ligament is strong and important to joint motion and is involved in 50–75% of acute lateral ankle sprains [10]. It appears to limit talar tilting in dorsiflexion and talocalcaneal adduction while the CFL and the tibiocalcaneal ligament fibres along with the relevant bones guide the ankle motion, being isometric during passive flexion [24]. Several au-

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thors have studied the morphology of the CFL in living subjects [2] using magnetic resonance imaging (MRI) [26], stress-tenogram [8], or arthrography [25]. It is described as a cord-like or flat structure related to the deep surface of the peroneal sheath and separate from the anterolateral capsule in 68% of cases [31]. Its anatomy presents numerous variations in attachment points, orientation, the number of bands, and the morphology between the two genres [14, 29, 22]. The ligament's maximal elongation during inversion and dorsal flexion was previously measured by Asla et al. [2] using MRI while there is a lack of cadaveric studies concerning its elongation.

Regarding the functional, clinical, and surgical significance of the CFL as well as the ligament's anatomical variations, our aim was to determine and describe the precise anatomy, morphology, and elongation during extreme inversion and dorsal flexion of the ligament in a large number of Greek subjects. Additionally, we looked for a relationship between the gender and CFL elongation examining 28 female and 44 male cadaveric ankle joints. The hypothesis was that no statistically significant difference existed between the compared groups. To our knowledge this is the first study conducted on a Greek population.

MATERIAL AND METHODS

For the purposes of our study we prepared 72 embalmed human cadaveric ankles used for educational purposes in the Department of Anatomy-Histology-Embryology in the Medical School of the University of Ioannina. Of these, 28 belonged to women and 44 to men. The specimens were derived from legs cut through the distal portion of the tibia and fibula. Each specimen was thawed at room temperature for 24 hours before being examined.

No obvious ligament injuries, contractures, previous surgeries or deformities were noticed.

The ankle area was dissected free of soft tissue removing the superficial muscles, tendons, and fascia and exposing but the lateral ankle ligaments. In particular, we prepared and demonstrated the origin, insertion, and number of bands of the CFL and recorded our findings. With the foot in neutral position, we measured the width, length and thickness in the midway of each CFL using a flexible ruler and a vernier caliper. Direct anatomical measurement of ligament morphology rather than the radiological one has been suggested in previous studies [18]. The ligament length was measured from the one insertion point to the other using the free borders. A goniometer also revealed the angle of the ligament's course with the sagittal plane, perpendicular to the horizontal plane. The angle formed by the CFL depends on the motion of the ankle and the subtalar joint [32]; thus it is important to measure it in the neutral position [24]. Finally, we manually repeated twice a combination of extreme inversion and dorsal flexion of each foot until the CFL was taut and resisted any further motion as referred elsewhere [11, 28]. The tibia was stabilised with one hand as the heel was moved to forced supination. In this way we estimated CFL laxity and integrity, as suggested in previous studies [5, 7, 10, 19]. The elongation of the ligament was measured using a flexible ruler.

All our measurements were recorded on tables and the mean values were calculated. Using the Kolmogorov-Smirnov test of normality and the Mann--Whitney test, we compared maximal elongation between men and women. A p-value of less than 0.05 was considered to represent a statistically significant difference and the confidence interval was 95%.

Our aim was to present the morphological and anatomical characteristics of the CFL in a large Greek population as well as the probable correlation of ligament elongation with gender. We also took representative photographs including the rare cases of common origin with the anterior TFL and the absence of the anterior TFL.

RESULTS

The preparation of 72 embalmed human ankles determined the anatomy of the CFL. The calcaneofibular ligament originates from the lower segment of the anterior border of the lateral malleolus and after a posterior, inferior, and medial course inserts on a small tubercle of the lateral calcaneal surface. The ligament is extracapsular and cord-like (Fig. 1).

There were 52 subjects presenting one band forming the CFL, 16 with two bands and 4 with three bands. We recorded the presence of 24 ankles where the CFL had a common origin with the anterior talofibular one (Fig. 2). There were also 4 cases where the anterior TFL was absent (Fig. 3).

The mean measured length of the CFL was 31.83 mm, the mean width 4.42 mm, and the thickness was 1.58 mm on average.

The mean angle formed in relation to the sagittal plane was 52.11°.

The maximal elongation of the CFL during pronation was 2.88 mm on average concerning both sexes. Women presented 3.28 mm elongation of CFL on average during maximum inversion and dorsiflexion while in men it was 2.63 mm (Table 1). The elongation of CFL

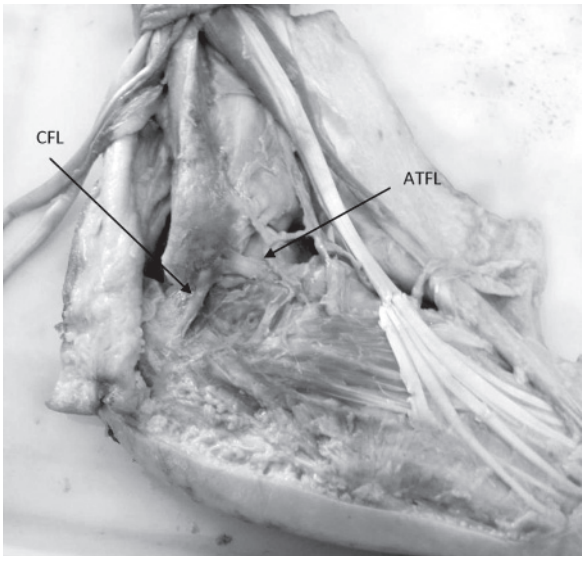

Figure 1. Anterior talofibular (ATFL) and calcaneofibular ligament (CFL).

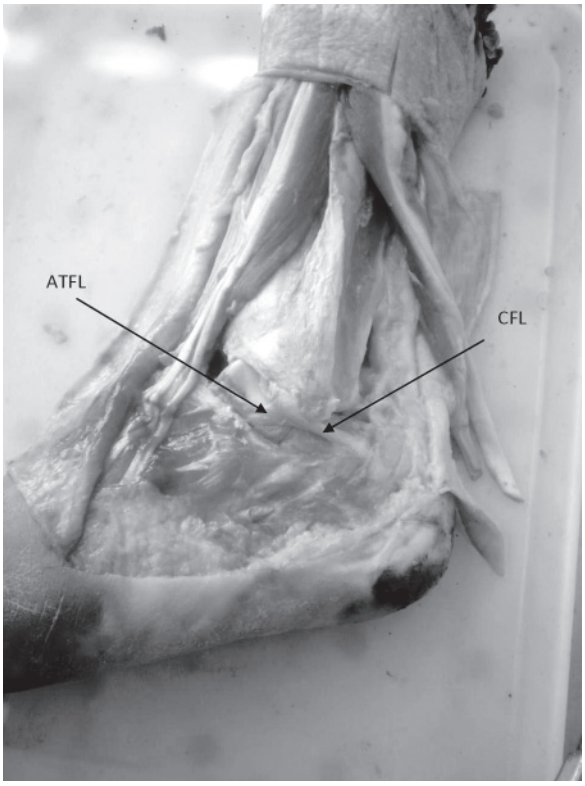

Figure 2. Common origin of anterior talofibular (ATFL) and calcaneofibular ligament (CFL).

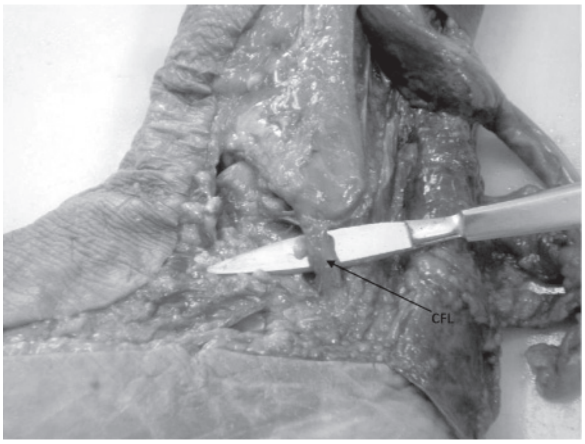

Figure 3. Anatomical variation: absence of anterior talofibular ligament; CFL — calcaneofibular ligament.

Table 1. Group statistics — elongation

Sex	N	Mean	SD	SE mean
Women	28	0.3286	0.07127	0.01347
Men	44	0.2636	0.06503	0.00980

Group statistics of men's and women's elongation of the calcaneofibular ligament; SD — standard deviation; SE — standard error

in women and men was not normally distributed according to the Kolmogorov-Smirnov test of normality of results; thus we employed a Mann-Whitney test to assess probable statistically significant differences between the two sexes (Table 2). The Mann-Whitney test revealed that women had a statistically significant difference in ligament elongation compared to men ($p = 0.000 < 0.05$); thus women had a greater elongation of CFL during maximal pronation (Table 3).

DISCUSSION

The ankle's articular surfaces and the relevant ligaments control the joint's motion. The clinical role of ankle ligaments is significant as they impede extreme ankle positions, mainly during gait [28]. The calcaneofibular ligament, along with the tibiocalcaneal ligament, are regarded as the principal structures controlling ankle motion [16]; thus a thorough knowledge of their anatomy is crucial. Additionally, the CFL is the ligament that varies most among lateral ankle ligaments, particularly in size, shape, orientation, and capsular formation [31].

In our 72 specimens we found that 44 of the CFL had typical attachment sites, but 24 of them had a common origin with the anterior TFL, while there were 4 rare cases in which the anterior talofibular was absent. Given that calcaneofibular rupture is usually seen in combination with anterior TFL tearing [25], our findings are of great interest.

The number of bands forming the CFL plays an important role in the ligament's function. In a pre-

Table 2. Tests of normality — elongation

Sex	Kolmogorov-Smirnov*			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Woman	0.270	28	0.000	0.784	28	0.000
Man	0.291	44	0.000	0.761	44	0.000

*Lilliefors significance correction; Kolmogorov-Smirnov test of normality, signifying that the distribution of the measurements in men and women is not normal

Table 3. Test statistics*

	Elongation
Mann-Whitney U	328.000
Wilcoxon W	1318.000
Z	–3.578
Asymp. sig. (2-tailed)	0.000

*Grouping Variable: sex; statistically significant difference ($p = 0.000 < 0.05$) of calcaneofibular ligament elongation between men and women

vious study, Muhle et al. [18] found no multiple fascicles in six cadaveric specimens using MRI depiction. In our study, we found 52 cases with only one band, 16 with two bands, and 3 that were three-banded CFLs.

The ligament length is the most critical factor affecting talar tilt and ankle joint instability after an injury [8]. The examination of our 72 cadaveric lower limbs revealed a CFL mean length of 31.83 mm, which is in accordance with previous cadaveric studies reporting mean lengths of 31.94 mm [26], 27.69 mm [23], 19.5 mm [17], and 30–40 mm [21, 27]. Burks et al. [4] did not measure the free length of the ligament from the one insertion point to the other and thus found a higher ligament mean length of 35.8 mm [4]. Two of the above measured the distance between the ligament attachment sites and thus the values acquired were lower [23, 17].

We found a mean width of CFL of 4.42 mm, which is lower than previous studies that measured it to be 4.68 mm [26], 5.5 mm [17], 5.3 mm [4], 5.4 mm [21], and 4–5 mm [27]. In all the aforementioned studies, the CFL width was measured at its middle. The difference found in our specimens could be a characteristic of the Greek population, but no previous studies exist with which to compare our findings.

The mean thickness of CFL recorded in our specimens was 1.58 mm. In a previous MRI study, CFL thickness was found to be 2.13 ± 0.5 mm [6].

The obliquity and angles of the ligament with the sagittal plane varies: the ligament may be oblique, horizontal, vertical or fan-shaped [20]. We found that the ligament angle in relation to the sagittal plane was 52.11°, which is close to previous cadaveric studies that describe the CFL as an oval one whose angle with the sagittal plane was 32–60° (mean angle of 51°) [26]. Knowledge of ligament orientation is critical for the detection of ankle ligament injuries via arthrography, arthroscopy, stress radiographs, and MRI [26].

Calcaneofibular ligament elongation is critical for the stabilisation of the subtalar and ankle joint during ankle sprains [25, 28, 32]. Its elongation during extreme inversion and dorsal flexion in our specimens was found to be 2.89 mm. The measurement of this elongation was done according to previously published studies suggesting that the CFL is taut in the maximal dorsal flexion and inversion [2, 28, 30]. Although we applied maximal force to the above directions until the ligament could not elongate any further, it has been described that even 25–30° of dorsal flexion is enough for calcaneofibular tautness [16, 28]. The only previous study measuring CFL elongation was conducted by Asla et al. [2], who found via MRI that the CFL was elongated from the neutral to 29.9 mm and 31.0 mm on average at maximal dorsiflexion and pronation, respectively. It has been proven that section of the CFL increases 11–13.8% of the anteroposterior mobility of the subtalar joint [11, 13] and 21.5% of the grades of inversion range of motion [12]. In total, damaging the CFL augments by 57% the inversion and eversion of the ankle joint [15]. We also found that women presented a statistically significantly greater elongation than did men (3.32 mm and 2.63 mm, respectively), which could be explained by the fact that women have differences in foot anatomy and are expected to have more lax ankle joints [9, 22]. It is known that tendons contain oestrogen receptors and thus can be affected by female hormones, although the results of several studies are controversial [3].

Our study has several limitations. First, the study was performed in previously deep frozen cadavers that may affect tissue elasticity. Second, the living history of the subjects with respect to sporting, occupational, and social pursuits was unknown.

The calcaneofibular ligament is frequently involved in ankle ligament sprains and chronic lateral and subtalar instability. Tearing the CFL is related to the ligament's elasticity and thus its elongation. A good knowledge of ankle anatomy is required for diagnosing injuries and during reconstructive surgeries to maintain normal joint biomechanics and function.

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