Analysis of fibularis tertius muscle in terms of frequency, morphology and morphometry in a Scottish population

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I declare that this dissertation entitled 'Analysis of Fibularis Tertius muscle in terms of frequency, morphology and morphometry in Scottish population' has been composed solely by me, and that it has not been submitted, in whole or in part, in any previous application for a degree. The work contained here is entirely mine except where it explicitly states otherwise by reference or acknowledgement in the text.

Signed: ....

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LIST OF ABBREVIATIONS

AT = accessory tendon

EDL = extensor digitorum longus muscle

EDLt = tendon of the extensor digitorum longus muscle to 5th toe

FT = fibularis tertius muscle

FTT = tendon of fibularis tertius muscle

MB = metatarsal bone

MRI = Magnetic Resonance Imaging

SD = standard deviation

ABSTRACT

Fibularis tertius (FT) is a muscle of medical and academic interest, characterised by its great variability. Despite its importance, there are no publications related to its anatomical features in Scottish people. The current work aims to investigate the morphological characteristics of FT in the aforementioned population. Forty-four Thiel-embalmed cadavers (19 females, 25 males; age at death: 81.8 ± 11.2 years) of Scottish origin were dissected. For each cadaver, its presence or absence was determined and if present, its origin, insertion and morphometric measurements were assessed.

This muscle was found to be absent in 6.8% of the lower limbs, with no difference between sexes. In 80% of cases, the absence was unilateral. Regarding the origin, in 95.1% of the cases there was no clear separation between the muscle bellies of FT and the extensor digitorum longus. In 88.6% of the lower limbs the origin was in the distal third of the fibula, while in 11.4% of the cases the insertion extended to the lower half of this bone. The length and width of the origin averaged 72.8mm and 23.3mm respectively, with no differences between sexes or sides of the body. Tendon length and width averaged 70.4mm and 3.2mm respectively, with no differences between sexes or sides of the body.

The insertion of the tendon showed substantial inter- and intra-individual variations, in both type and morphological variants. Contrary to what is mentioned in currently used anatomy textbooks, in 67% of the cases some kind of insertion was found at the level of the 4th metatarsal bone, in addition to the insertion at the 5th metatarsal bone usually described. Almost half of the cadavers (48.7%) had different insertion sites when comparing the two sides of the body. The fan-shaped insertion variant was observed in the majority of cases (83%).

In the present study, the significant variability of the anatomical characteristics of FT, outlined in the scientific literature, was confirmed for the Scottish population. In addition, several variations were identified that are not mentioned in current anatomy textbooks, something that should be taken into account in anatomy and surgical training courses. Further studies of Scottish and other populations are required.

1. INTRODUCTION

The fibularis tertius muscle (FT), also referred to as peroneus tertius or anterior fibularis, is a comparatively small muscle localised in the anterior compartment of the leg, which functions as a dorsiflexor and eversor of the foot (Mehta *et al*., 2011). It is thought to be relevant to the mechanics of this anatomical region during bipedal gait in humans, although its true importance in this respect has not yet been fully understood (Yammine and Erić, 2017).

In addition to its classic textbook description, several studies report relevant morphological variability, with size ranging from being as voluminous as the extensor digitorum longus (EDL) to its complete absence (Lambert, 2016). Such variability includes, apart from its possible absence, at least three types of origin, presence of an accessory FT, additional slips with origin in EDL, and at least six different distal insertion patterns (Olewnik, 2019; Ughame and Kardile, 2018).

Despite being a muscle that have been considered by some authors to be of little or no functional importance (Stevens *et al.*, 1993), it is of academic, clinical and surgical interest. Its variations have been related to diagnoses of chronic ankle pain, as well as with different types of fractures of the 5th metatarsal bone (MB) (Ercikti *et al*., 2016). Additionally, the FT tendon (FTT) has been extensively used, among others, in tendinoplasty and resection of the foot (Yammine and Erić, 2017). An understanding of its variations is therefore necessary when planning surgical interventions in the area.

Anatomical dissection studies have been conducted to determine FT characteristics and morphological variations in various populations, including samples from Europe, Asia, Africa, and South America (Olewnik, 2019). However, to the author's knowledge no such studies have been conducted in the Scottish population. In addition, no work reviewed has used Thiel embalmed cadavers, a process that allows excellent flexibility and tissue quality compared to the classical techniques (which generally involve the use of 10% formaldehyde) (Jaung *et al*., 2011). Despite its many advantages, the tendons of Thiel-embalmed cadavers present a partial denaturation caused mainly by the boric acid, and therefore do not provide a realistic representation of the biomechanical characteristics of the fresh body (Fessel *et al*., 2011). For this reason, biomechanical analysis of FTT were not included in the present work.

This experimental, descriptive and cross-sectional research study aims to determine the prevalence, morphological characteristics and variations of FT in a Scottish sample of Thiel embalmed adult cadavers of both sexes, donated to the Centre for Anatomy and Human

Identification (CAHID), University of Dundee, Scotland. The information obtained is not only of academic and medical interest, given the aforementioned clinical and surgical applications of this muscle; it also represents a novel contribution by allowing comparison of the characteristics of FT within and between subjects for this specific population, as well as allowing comparison with similar studies carried out on samples from other countries.

2. BACKGROUND

The region of the leg is divided into anterior, lateral and posterior fascial compartments, bounded by an anterior and posterior intermuscular septum, the interosseous membrane, and the bones of the leg (tibia and fibula) (Rouvière and Delmas, 2005). The anterior compartment (also called dorsiflexor or extensor compartment) is situated anterior to the interosseous membrane; it contains four muscles, which from medial to lateral are: tibialis anterior, extensor hallucis longus, EDL and FT. All four muscles are dorsiflexors of the ankle joint, meaning that their contraction raises the forefoot while lowering the heel (Moore *et al*., 2018).

The FT, called the "ninth muscle" or "nonus pedem moventium" by the author considered the father of modern anatomy, Andreas Vesalius (Brussels, 1514 – Greece, 1564), acquired its current name from the physician and anatomist Bernhard Siegfried Albinus (Germany, 1697 – Leyden, 1770), who assigned it to the peroneus group (Wood Jones, 1943).

2.1. Anatomical characteristics

FT is a semi-pennate, small and very thin muscle, which occupies the lower and outer part of the anterior compartment of the leg, being the most superficial muscle of it (Yammine and Erić, 2017). Its origin is described on the anterior aspect of the lower half or third of the fibula, at the interosseous membrane and in the anterior intermuscular crural septum (Moore *et al*., 2018; Das *et al*, 2009). The latter, topographically separates FT from the muscles of the external compartment (fibularis longus and fibularis brevis); although according to Krammer *et al*. (1979) from a functional point of view it would imply a connection rather than a separation, thus acting as an intermuscular aponeurosis. From this insertion, its fibres run distally and anteriorly, ending with its muscle belly proximal to the inferior extensor retinaculum (Sammarco and Henning, 2007). Its tendon, running obliquely and laterally to the more lateral tendon of EDL, inserts distally into the dorsal tubercle and shaft edge of the 5th MB and, frequently, into the fascia covering the 4th interosseous space (Ercikti *et al*., 2016; Eliot and Jungers, 2000; Testut and Latarjet, 1984). This insertion presents morphology that has been described as a "hockey stick appearance" (Mabit *et al*., 1996).

In contrast to the other peroneal muscles (innervated by the superficial fibular nerve), FT innervation is provided by a small branch of the deep fibular nerve (L4, L5), which branches next to the origin of EDL, runs parallel between this muscle and extensor hallucis longus, and then pierces the FT. It is supplied by one or two perforating branches of the anterior tibial artery, which also supplies the other muscles of the anterior compartment (Iyer, 2020; Moore *et al.*, 2018; Rourke *et al.,* 2007). At the level of the foot it also receives another supply from the arcuate artery and the 4th dorsal metatarsal artery (Spinner *et al*., 2020).

The muscle belly of FT is located immediately adjacent to the EDL, with which it has an intimate connection at its most proximal origin. The two are usually joined completely (Lauth, 1798) so that, on occasions, it is not possible to determine with certainty the separation between the two (Marin *et al.*, 2006). In fact, not only their muscle bellies but also their tendons are difficult to separate (Bertelli and Khoury, 1991). Intercrossing fibers may be present at the proximal insertion level, particularly with the fascicles that will give rise to the tendons for the 4th and 5th toes (de Gusmão *et al*., 2013; Krammer *et al*., 1979). The tendons of both muscles fused or linked by intertendinous connections (Koshi, 2017; Stevens *et al*., 1993), with the FT tendon being the widest and most laterally located (Krammer *et al*., 1979).

This led some classical authors to consider FT as a division of EDL, regarding the former as the "fifth tendon" of the latter (Spinner *et al*., 2020) or an "appendage" to it, without a defined anatomical identity (Testut and Latarjet, 1959). Consistent with this, the tendons of these two muscles share a common synovial sheath, which extends from the lower part of the superior extensor retinaculum to the middle of the dorsum of the foot. Therefore, both tendons run together underneath the superior and inferior extensor retinacula (Stevens *et al*., 1993). The latter forms a loop around both tendons completely encircling them (Koshi, 2017).

Given this characteristic, it was not until the 19th century that renowned anatomists such as Jakob Henle (Fürth, 1809 - Göttingen, 1885) and Josef Hyrtl (Austria, 1810 – Austria, 1894) revalidated Vesalius' description of FT as an entity separate from the others (Yammine and Erić, 2017). Vesalius, in his classic book *De corporis humani fabrica* (1555) describes it as "*nonus proprius per se musculus*", indicating its existence as independent of that of the EDL (Krammer *et al*., 1979). In support of this, FT syntopy analysis has shown that its fibres have a completely different orientation from the fibers of EDL, each diverging towards its own tendon and forming an acute angle between the respective clusters of muscle fibres (de Gusmão *et al*., 2013). Furthermore, as found by Marin *et al*. (2006), in most cases there would be an obvious anatomical separation between the two. In the same way, Jadhav *et al*. (2015) found a completely formed independent belly of FT, clearly distinguishable from EDL, in 80.45% (70 out of 87) of the legs analysed. Thus, FT would not be part of the EDL muscle, but the "missing" part of the extensor digitorum brevis muscle at the 5th toe, which in the course of evolution migrated proximally at its origin (Witvrouw *et al*., 2006), or it could be the representative of the extensor digiti minimi muscle, whose insertion moved to the base of the 5th MB (Nayak, 2017).

2.2. Comparative anatomy

FT has been considered exclusive to humans due to the particular form of bipedal locomotion of our species, and according to some authors it would not be found in other mammals. Because of this, their presence has been considered an evolutionary feature that separates humans from other "less evolved" animals (Morton, 1924; Keith, 1923).

Notwithstanding this, there have been infrequent reports of its existence in some non-human primate species. Kimura and Takahashi (1985), studying crab-eating monkeys (Macaca fascicularis) found this muscle in 5 lower limbs of male specimens, in a total of 174 legs (2.9%). A research study on orangutans reported a prevalence of 6.6% (1 in 15 individuals) (Loth, 1931). Hecker (1922) also mentions finding this muscle in a chimpanzee, while Wells (1935) verified its existence in the right leg of a specimen of Chacma baboon (Papio porcarius). It is worth mentioning that, particularly in the latter two studies, the small sample sizes dictate the need for caution when drawing conclusions.

In addition, it has been suggested that its prevalence reaches up to 30% in gorillas, which would represent a parallelism determined by the similarity in the functionality of the foot between this species and humans (Yammine and Erić, 2017). In a review, Straus (1930) found that FT was present in 6 out of 18 (33.3%) specimens of Highland Gorilla (Gorilla beringei). Morton (1924) also reports finding FT in two gorilla specimens analysed.

This is the only primate species (apart from Homo sapiens) with almost exclusively terrestrial locomotion, compared to the arboreal locomotion present in its ancestors (Yammine and Erić, 2017). Although the posture of such animals is not fully erect, their feet are plantigrade, supporting a greater proportion of their body weight compared to other quadrupeds (Morton, 1924). The different prevalence of this muscle between gorillas and humans could be explained by the fact that, in evolutionary terms, the latter have had a much longer terrestrial existence (Johnson, 1973). Apart from this, there are no reported examples of the presence of FT in other mammalian species, including lesser apes such as Rhesus monkeys and Strepsirrhini (Stevens *et* *al*., 1993; Kaneff, 1980; Okuda, 1953). In these animals, there is no muscle to counteract the movement of inversion when the foot is dorsiflexed (Boyer, 1935).

2.3. Functional aspects

The human foot is a complex anatomical structure, modified to enable orthograde bipedal posture and locomotion (Spinner *et al*., 2020). Being an integral part of this structure, FT has a weak function as a dorsiflexor of the ankle joint (Iyer, 2020). Despite its small size, the fact that it passes some distance in front of the axis of this joint gives it a good mechanical advantage for this movement (Raheja *et al*., 2005). At the same time, its insertion at the lateral edge of the foot allows it to evert it, at the level of the subtalar and transverse tarsal joints (Snell, 2012). Its insertion in the 5th MB, in conjunction with its expansion at that level, allows it a much more stable anchorage, and consequently a more powerful pronation effect (Reimann, 1981). This action implies that FT, together with the rest of the peroneal muscles, is involved in complex actions such as skating and dancing (Raheja *et al*., 2005), also fulfilling a protective function against supination trauma (Valerius *et al*., 2011).

Additionally, it has been suggested that it acts primarily as a sling that supports the medial longitudinal arch of the foot (the highest and most important of the three arches of the foot) as well as stabilising the lateral longitudinal arch (Chatyingmongkol *et al*., 2004), functioning in a similar way to an overhead support of a segmental arched bridge (Jana and Roy, 2011). The appearance of FT would thus be a phylogenetic change that would ensure the stability of the plantar arch (Jana and Roy, 2011). It has also been suggested that it acts by maintaining the sole in a transversely parallel plane to the ground (Stevens *et al*., 1993); as well as transferring the centre of pressure of the foot medially in the direction of the first metatarsal head and the first toe (hallux), which would help to maintain balance during the stance phase of gait (Hicks, 1956).

This is however contradicted by Jungers *et al*. (1993) who, using telemetered electromyography to study leg muscle activity during gait in humans, verified a lack of FT activity during the support-phase. In this study, the sample consisted of only three adult males; despite the small sample size, there was a very close similarity in muscle recruitment patterns in these three individuals, and that leads the authors to suggest that it was adequate for the purposes of the study.

They concluded that FT acts in conjunction with EDL and tibialis anterior as a swing-phase muscle to level the foot prior to the next touchdown, and assist the toes to lift off the ground, thus improving the efficiency and economy of standing gait. Additionally, they propose that the eversion force caused by FT would help to counteract the effect of inversion generated by the tibialis anterior muscle, allowing dorsiflexion of the foot without this concomitant movement. This action may be necessary to allow a maximal weight-bearing area, as well as adaptation of the sole (particularly at the level of the forefoot) to uneven surfaces during walking and standing (Krammer *et al*., 1979).

In this sense, it has been determined that when FT is absent, greater activation of the peroneus longus and peroneus brevis muscles is necessary to evert the foot. Considering that both muscles are plantar flexors, their activation at the moment of gait when dorsiflexion is necessary determines a lower energy efficiency (Eliot and Jungers, 2000).

Under these circumstances, FT would have an important role in the plantigrade use of the foot during walking or running (Olewnik, 2019). This fact is supported by its high prevalence, its wide insertion at the lateral border of the mid-foot, and the presence of similar substitute muscles when absent. Moreover, the consistency between different ethnicities leads to the hypothesis that FT is not in an ongoing process of phylogenetic degeneration (as has been suggested for the palmaris longus), but may imply a function that the muscle must necessarily perform (Yammine and Erić, 2017).

Some authors claim that its action as a foot evertor would represent a mechanism to avoid excessive inversion injuries (Salem *et al*., 2018). In this respect, it has been suggested that it could have a particular proprioceptive role, contracting reflexively in response to a sudden inversion of the foot, protecting it from the sprain of the anterior tibiofibular ligament (the most commonly sprained ligament of the body) (Moore *et al*., 2018). Other authors suggest that the function of FT is not so much related to the application of force in dorsiflexion and eversion, but in the fine tuning of the foot position during the swing phase of walking (Witvrouw *et al*., 2006).

From an evolutionary point of view, this muscle would have been primitively restricted to the dorsum of the foot as an integral part of the extensor digitorum brevis. The functional demands of standing and plantigrade foot gait would have determined the migration of its belly towards the proximal anterior region of the leg, transforming it into an extrinsic foot muscle (Joshi *et al*., 2006). Additionally, FT could have played an essential role during the phylogenic development of bipedal posture in humans, being the eversion of the foot characteristic of the movement in our species (Krammer *et al*., 1979). This would be in agreement with that reported by Joshi *et al*. (2006), who verified in subjects of Indian origin that the FT insertion tendon was very thick in

12.18% (24 out of 197) of the lower limbs studied, even as thick or thicker than the EDL tendon. According to these authors, this would indicate an important component of eversion during normal human foot function. This is also supported by the study of Chatyingmongkol *et al*. (2004) who, working with a sample of 236 legs of subjects from Thailand, report a large proportion of FT width in comparison to the common fibres of EDL at the level of the ankle joint (mean ratio: 34.77% right; 39.55% left), which would indicate the functional significance of the former.

On the contrary, other authors do not consider FT a functionally important muscle, suggesting that the integrated actions of peroneus longus, peroneus brevis and EDL could supplant its action on the foot (Stevens *et al*., 1993). Some researchers have found that the absence of FT is not accompanied by a statistically significant increase in the risk of ankle ligament injuries, nor is it accompanied by a loss of strength in dorsiflexion and eversion of the foot (Oyedun *et al*., 2014; Bourdon and Petitdant, 2012; Witvrouw *et al*., 2006).

Regarding the former, in a study involving a sample of 100 male and female physical education students, a slight, non-significant increase in the relative risk of this type of injury was observed among subjects without FT (ascertained by palpation) compared to subjects with its presence (relative risk 1.47 vs. 0.93, respectively). The lack of significant difference could be explained by the presence of other numerous intrinsic risk factors, which combined with the absence of FT would lead to an increased risk of ankle injury. In relation to the latter, this could be related to the relatively small size of FT which would determine its inability to generate high levels of force. Additionally, the fact that the absence of FT is congenital, could imply that compensatory hypertrophy of other muscles with actions on the foot (peroneus longus, peroneus brevis and tibialis anterior) would be sufficient to counterbalance this absence (Witvrouw *et al*., 2006).

These statements should however be taken with caution, since FTTs not identified during palpation could have led to inaccurate conclusions. What is more, an almost constant presence of accessory peroneal muscles has been described that would substitute the function of FT when it is not present (Yammine and Erić, 2017).

2.4. Clinical and surgical aspects

Despite the debate on the role of FT, it has clinical and surgical importance, so preoperative assessment of this muscle is imperative before undertaking any surgical procedure (Mehta *et al*., 2011). It can be used in myocutaneous flaps to repair injuries in the lower third of the leg and dorsum of the foot, without impairing motor function and with little aesthetic impairment. This muscle is one of the few options available to generate these kind of flaps (Verma and Seema, 2015). Its high prevalence, the length and width of its muscle belly and its easy access through a longitudinal incision on the anterior-lateral side of the leg, make it suitable for this procedure. In addition, the fact that its fibres become flatter as they approach their insertion also favours this technique, as it allows the use of greater muscle thickness in the reconstructive treatment of complex lower limb wounds (de Gusmão *et al*., 2013; Verma and Seema, 2015).

By supplementing a dead space with vascularised muscle such as FT, it is possible to improve the delivery of oxygen, nutrients and immune system components necessary for tissue recovery (Yildiz and Yalcin, 2012). Other muscles have been reported to be used for such a surgical procedure, including soleus, gastrocnemius, tibialis anterior and EDL; however, the use of these may be detrimental to the motor function of the foot, as well as the patient's quality of life (de Gusmão *et al*., 2013).

Split anterior tibialis tendon transfer (SPLATT) to FT has also been used to treat equinovarus foot deformity in children with cerebral palsy, proving to be a safe surgical alternative with good functional results (Sarıkaya *et al*., 2020). Other authors have reported the use of FT in ligamentoplasty procedures to treat cases of lateral ankle laxity (Mehta *et al*., 2011). Its use as a local muscle flap in the treatment of lower limb osteomyelitis, as well as to treat claw foot deformity by modifying the distal insertion of this muscle, has also been described (Arnold *et al.*, 1999; Brody and Grumbine, 1984).

FT also constitutes a landmark for the anterolateral portal during ankle arthroscopies, being used for the placement of the inflow cannula to avoid inadvertent neuromuscular injuries (Yammine and Erić, 2017; Mehta *et al*., 2011). Additionally, it has also been observed that FT has a similar sensitivity and a higher specificity than the abductor hallucis in the needle electromyography for the diagnosis of mild length-dependent peripheral neuropathy, in particular when the proximal muscle is not yet involved (Boon and Harper, 2009).

The FTT, given its biomechanical characteristics (stronger than the medial and lateral ankle ligament) has been used as graft material (tendinous autografts and allografts) for ankle ligament reconstruction (Zwirner *et al*., 2021). The use of FTT graft to reconstruct a ruptured tendon of the tibialis anterior muscle has been reported (Gaulrapp and Heimkes, 1997); following such intervention, the authors claim to have found no additional loss of function related to it. The FTT has also been used in transplantation surgeries; the transfer of the tibialis posterior muscle tendon to the anterior compartment of the leg, anastomosing it to the tendons of the muscles present in this compartment (including the FTT) has been used in cases of persistent foot drop (Ozkan *et al*., 2009; Ozkan *et al*., 2007).

On the other hand, its variations beyond normal can lead to more evertor activities as well as be responsible for deformities and foot-related symptoms (Abhinitha *et al*., 2014). Its insertion has been considered a contributing factor to stress, Jones and avulsion fractures of the 5th MB, being detrimental in the recovery phase of these injuries, due to the causation of torsional stresses exerted on the base of this bone (Vertullo *et al*., 2004). The risk of avulsion fractures may be increased in cases where some fascicles of the FTT insert into the tuberosity of the 5th MB, creating an intertendinous connection between them and the tendon of fibularis brevis (Ercikti *et al*., 2016). Considering this, individuals with an absence of FT may be less vulnerable to this type of fracture (Das *et al*., 2009). On the other hand, the risk would increase in cases where this muscle is "bulky and large" (Abhinitha *et al*., 2014).

Other authors have determined that the impingement of FT may provoke a painful condition and a typical synovial cyst (Litt *et al*., 1989). Its hypertrophy and tendon sliding over the anterolateral talar dome have been further described as causes of atraumatic anterolateral ankle pain and snapping in a young adult male; in this case, myoplasty of the FT resulted in complete relief of symptoms (Sammarco and Henning, 2007).

In the same way, the FTT has been implicated as a rare cause of anterolateral ankle or rearfoot pain. Derrick *et al*. (2016) describe a case of ankle pain, burning sensation, and swelling in an adult female associated with longitudinal split tear of FTT. McGoldrick *et al*. (2017) describe a case of a paediatric patient with lateral ankle pain due to isolated tear of FTT. Taşer *et al*. (2009) argue that a possible cause of longitudinal tear in the tendon of the peroneus brevis muscle could be an abnormal FT, since its atypical origin and insertion points and muscle size might change the mechanism of ankle movement. This lesion may be a cause of chronic ankle pain and disability, so the authors state that this peculiarity should be considered in the clinical diagnosis of ankle pain.

In adding to this, Iceman *et al*. (2020) describe what they call *Peroneus Tertius Syndrome*, characterised by symptomatic FTT causing catching or locking on the anterolateral ankle or rearfoot with associated pain. The authors suggest that this syndrome should be taken into consideration as part of the differential diagnosis during the evaluation of anterolateral ankle or rearfoot pain.

2.5. Morphological variations

FT is characterised by frequent morphological variations, a feature it shares with the rest of the peroneal muscles (fibularis longus, fibularis brevis, fibularis quartus and fibularis digiti quinti, the latter two considered accessory muscles) (Olewnik, 2019). This may indicate that it has not yet reached its final evolutionary stage (Verma and Seema, 2015). According to Johnson (1973), in evolutionary terms the process of adaptation is a process of experimentation, and this also applies to terrestrial bipedalism. As a result, a significant amount of variation is expected to occur in FT, since its recent evolutionary history determines its involvement in a considerable degree of morphological experimentation.

In addition to its variability, FT is considered an inconstant muscle, with its absence usually being asymptomatic and verified as a chance finding in imaging studies or autopsies. (Iyer, 2010). Unlike other muscles with this feature, such as pyramidalis or palmaris longus, FT has a bony origin and insertion and a consistent muscle belly, characteristics that indicate a muscle with a defined function. Furthermore, its strong tendon insertion would not resemble the gracile tendons found in other inconstant muscles (Marin *et al*., 2006).

There is no consensus on the prevalence of FT among different populations. A very wide range is reported, from a minimum of 38.5% (Palomo-López *et al*., 2019) to studies reporting a presence of 100% (Nayak, 2017; Verma and Seema, 2015; Larico and Jordán, 2005), varying according to the population studied (Table 1). Macalister (1875) mentions that this muscle may be absent in approximately 1 in 10 subjects. In an 1894 report, Schwalbe and Pfitzner mentioned having examined 537 legs, finding its presence in 91.8% of the individuals analysed; this percentage was later reproduced in generations of classic anatomy textbooks (Krammer *et al*., 1979). According to Testut and Latarjet (1984) it would be present in 86 cases out of 100 in populations of African descent, and 92 to 93 out of 100 in most European populations. The latter coincides with Adachi (1909) who reports the presence of FT in 719 out of 777 lower limbs (92.5%) in European populations. On the other hand, Karauda *et al.* (2021), Albay and Candan (2017), Domagała *et al*. (2006), and Sokołowska-Pituchowa *et al*. (1979) found a prevalence of 50%, 80%, 83.16% and 78.6%, in a sample of 100, 100, 193 and 42 human foetuses, respectively.

Other authors report a higher prevalence. Wood Jones (1943) argues that this muscle may be absent in 1% of cases, while Ercikti *et al*. (2016) found its absence in only one cadaver, bilaterally, out of a total of 44 lower extremities analysed. Overall, the highest frequencies were found in studies conducted in Japanese and South American populations (95.5% and 97.4% respectively), while the lowest frequencies were reported in studies of African, Indian and Chinese communities (90.2%, 90.8% and 89.3% respectively) (Yammine and Erić, 2017).

The low frequency of FT absence reported by most authors has led to the proposition that it should be considered the exception rather than the rule. Some authors (Marin *et al*., 2006; Krammer *et al*., 1979) suggest that it is more appropriate to consider it a constant muscle, with its missing being a variation. However, its potential absence in some subjects determines the need to assess for its existence prior to performing any surgery on the foot (Das *et al*., 2009).

There is also no consensus on the description of the origin and insertion of FT. A summary of some of these studies can be found in Table 1. The differences observed among populations could be determined by a genetic basis; which would also explain the slightly greater tendency for it to be present in males compared to females (Yammine and Erić, 2017).

Notwithstanding this, the review of the scientific literature leads to the suggestion that the prevalence of FT is not systematically higher in one sex compared to the other: while some authors observed equal or very similar values between sexes (Witvrouw *et al*., 2006) (81.4% female, 81.6% male), other studies found higher prevalence in either females (Palomo-López *et al.*, 2019) (38.6% vs. 37.2%) or males (Olumide *et al.*, 2013; Ramirez *et al.*, 2010) (66.0% vs. 54.9%; 56.6% vs. 44.0%, respectively). In this regard, Salem *et al.* (2018) found a higher prevalence in females in the Bahraini, Kuwaiti and Tunisian populations (52.1% vs. 30.2%; 31.6% vs. 22.3%; 54.7% vs. 47.2%, respectively), while on the contrary they found a higher prevalence in males in the Saudi and Egyptian populations (39.9% vs. 28.9%; 51.79% vs. 39.13%, respectively).

Table 1. *Prevalence, origin and insertion of FT in different populations*

Author/s	**Population**	**Lower limbs**	**Type of Study**	**Prevalence (%)**	**Origin (% of presence)**	**Insertion (% of presence)**
Adachi (1909)	Japanese	938	Cadaver dissection	95.5	-	-
Afroze *et al.* (2020)	Indian	66	Cadaver dissection	100	97% distal 1/3 of fibula; 1.5% accessory FT; 1.5% duplication of FT	86,4% type II; 1.5% type IV; 1.5% type V; 10.6% type VI.
Bertelli and Khoury (1991)	French	44	Cadaver dissection	90.9	14cm from the lateral malleolus	80% proximal 3rd of 5th MB; 10% distal 3rd of 5th MB; 10% on the tendon of the extensor digitorum longus
Chatyingmongkol *et al*. (2004)	Thai	247	Cadaver dissection	95.55	-	-
de Gusmão *et al. (*2013)	Brazilian	64	Cadaver dissection	96.9	51.62% distal third of fibula; 45.16% distal and medial thirds of fibula; 3.22% Distal, medial and proximal thirds of fibula	77.4% 5th MB; 22.6% 5th MB and base and proximal third of 4th MB
Jadhav *et al.* (2015)	Indian	100 (100M)	Cadaver dissection	87	-	44.82% only dorsum of VMB; 26.41% medial and lateral slip to 4th and 5th MBs; 22.98% only dorsum of 4th MB; 5.79% others
Joshi *et al*. (2006)	Indian	220	Cadaver dissection	89.55	18.3% lower ¾ of fibula; 30.5% lower ½ of fibula; 51.2% distal 1/3 of extensor surface of fibula	50.2% Base of 5th MB; 12.2% base and shaft of 5th MB; 18.3% Base and shaft of 5th MB + fourth interosseous space; 19.3% others

Table 1. *Prevalence, origin and insertion of FT in different populations*

Nakano (1923)	Chinese	84 (12F; 72M)	Cadaver dissection	89.3	-	-
Nayak (2017)	Eastern Indian	100	Cadaver dissection	100	100% lower one fourth of medial surface of shaft of fibula	94% base of 5th MB; 4% dorsum of 5th MB; 2% base of 4th MB
Olewnik (2019)	Caucasian (Polish)	106 (55F; 51M)	Cadaver dissection	85.8	67% distal half of fibula; 22% distal third of fibula; 11% muscle belly absent, independent tendon originated from EDL	45% type I; 22% type II; 16.5% type III; 8.8% type IV; 5.5% type V; 2.2% type VI
Olumide *et al.* (2013)	Nigerian	200 (106F; 94M)	Palpation	63.0	-	-
Palomo-López *et al.* (2019)	Spanish	962 (736F; 226M)	Palpation	38.25	-	-
Ramirez *et al.* (2010)	Chileans	336 (200F; 136M)	Palpation	49.11	-	-
Rourke *et al*. (2007)	British	82 (38F; 44M)	Cadaver dissection	92.7	Distal shaft of the fibula (mean: 28.4% on the fibula)	100% dorsal surface of the shafts of the 4th and 5th MBs
Salem *et al.* (2018)	Bahraini	439 (280F; 159M)	Palpation	42.0	-	-
Salem *et al.* (2018)	Saudi	208 (109F; 99M)	Palpation	38.5	-	-

Table 1. *Prevalence, origin and insertion of FT in different populations*

Salem *et al.* (2018)	Kuwaiti	153 (106F; 47M)	Palpation	41.2	-	-
Salem *et al. (*2018)	Tunisian	198 (127F; 71M)	Palpation	67.6	-	-
Salem *et al.* (2018)	Egyptian	250 (138F; 112M)	Palpation	52.8	-	-
Stevens *et al*. (1993)	British (East Anglia)	40 (20F; 20M)	Cadaver dissection	95.0	92.1% centered around the lower middle quarter of the fibula	100% base of 5th MB (97.4% single tendon; 2.6% double tendon).
Verma and Seema (2015)	Indian	60 (4F; 54M)	Cadaver dissection	100	100% distal half of anterior border of the fibula	98.34% base of 5th MB; 1.66% whole shaft of 5th MB
Vieira *et al.* (2018)	Brazilian	32 (6F; 26M)	Cadaver dissection	93.75	46.66% distal third of fibula; 46.66% middle third of fibula; 6.68 proximal third of fibula	70% 5th MB; 30% between the 4th and 5th MBs
Witvrouw *et al.* *(*2006)	Belgian	200 (100F; 100M)	Palpation	81.5	-	-

Abbreviations: FT = muscle Fibularis Tertius; EDL = muscle Extensor Digitorum Longus; MB = metatarsal bone; F = female; M = male

As shown in Table 1, the studies that determined the presence of FT *in vivo* using palpation techniques resulted in lower frequencies than those studies performed using anatomical dissection. This is in agreement with that mentioned by Yammine and Erić (2017), who in a meta-analysis work found an average prevalence of 80% vs 93% respectively. According to these authors, the difference could be due to the difficulty, by palpation, of separating the FTT from the lateral slip of EDL, in addition to the thinness verified in some cases in the former. Other authors add that the aponeurosis that covers it makes its clinical identification difficult, which may lead to underestimation of its prevalence (Palomo-López *et al*., 2019).

This does not seem to correspond with what was found in a pilot study carried out by Witvrouw *et al.* (2006), where the authors determined 100% accurancy when comparing a palpation technique vs MRI to determine the presence of FT. This could be due to the fact that the sample was composed of young athletes with considerable muscle development, which consequently facilitated the identification by palpation of the FTT (Ramirez *et al*., 2010).

3. MATERIALS AND METHODS

This project was conducted in the laboratory of Anatomy of the Centre for Anatomy and Human Identification (CAHID) at the University of Dundee, Scotland, and complied with the Human Tissue Act Scotland (2006; updated 2019) regulations. Data collection was carried out between March and May 2021. All data were uniquely collected by the author of the current study.

3.1. Subjects

The research involved the dissection and analysis of 44 cadavers (88 lower limbs) (19 females, 25 males; age at death: 81.8 ± 11.2 years) donated to CAHID, and preserved using the Thiel soft-fix embalming method. This procedure, developed by Walter Thiel in 1992, differs from other commonly used preservation techniques (such as the use of 10% formalin) in that it retains the body's natural colour, texture, plasticity and flexibility, which makes it advantageous for research on the morphology of anatomical structures (Ottone *et al*., 2016).

All subjects were caucasian adults from the Scottish population. The cause of death in all cases was unrelated to the structures of leg and foot, and in no case affected the morphology of FT. All limbs were free of any damage, fracture or pathology that could affect the anatomical structures analysed.

3.2. Procedures

The cadavers had previously been used in anatomical dissection classes. Notwithstanding this, in most cases the leg and foot region was partially or completely undissected. Using a combination of sharp and blunt dissection, the anterior compartment and dorsum of the leg and foot of each lower extremity was dissected, and the presence or absence of FT was determined. Where present, it was meticulously dissected and cleaned. After this procedure, the following were determined for this muscle: a) type of origin; b) insertion type; c) insertion morphology; d) morphometric measurements. Additionally, in all cadavers (regardless of the presence or absence of FT) the length of the leg (measured as the distance between the uppermost part of the head of the fibula and the lowermost part of the external malleolus) and the width of the EDL tendon directed to the 5th toe, were estimated. For the latter, the distance from the separation of this tendon from the common tendon of EDL and its insertion at the level of the distal phalanx of the 5th toe was determined, taking the measurement at the halfway point. In case of absence of FT, the possible presence of an accessory tendon was determined, in which case its width was measured halfway between its origin and insertion.

3.2.1 Determination of the type of origin

To describe the origin of FT, the classification described by Joshi *et al*. (2006) was used, and the origins were divided into the following three types:

a) Very extensive (lower ¾ of the fibula)

b) Extensive (lower ½ of the fibula)

c) Normal (distal third of the fibula)

3.2.2 Morphometrics measurements

The length and width of both the FT belly and the FTT were measured as described by Rourke *et al*. (2007) (Figure 1). The length of the belly was determined by considering only the insertion at the level of the fibula; the width was measured from the fibula to the tendon, once the middle of the muscle belly had been calibrated. In those cases where the boundary between the muscle bellies of FT and EDL muscles was not unambiguously defined, the FTT was identified, and the direction and insertion of the muscle fibres was carefully analysed. The most proximal muscle fibres heading towards the tendon marked the end of the EDL and the beginning of the FT muscle bellies (Figure 2).

To determine the FTT length, the starting point was taken as the most proximal portion of the tendon completely deprived of muscle fibre insertions; the end point was taken as its distal insertion. The FTT width was determined halfway of the length of the tendon.

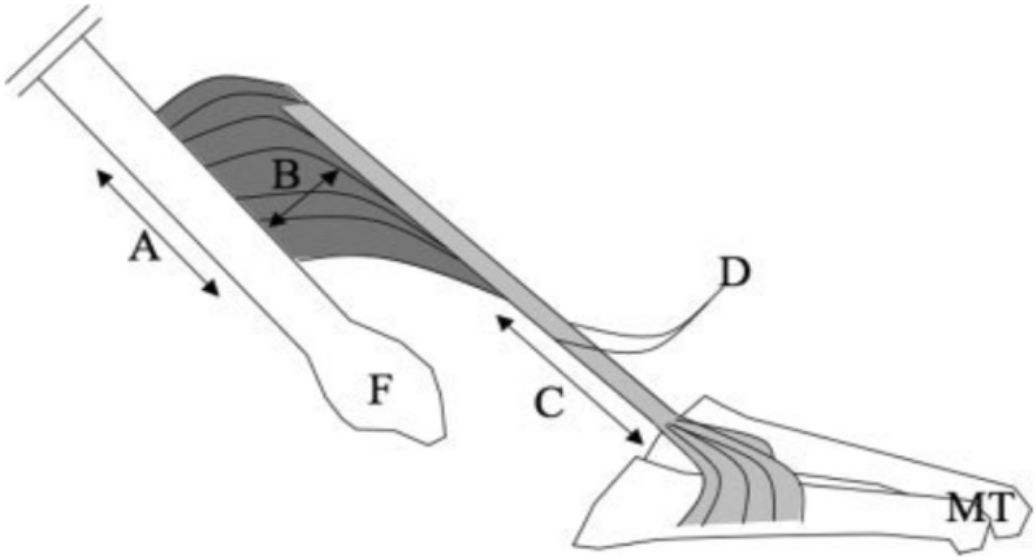

Figure 1: Measurements taken on the muscle belly and tendon of FT. Abbreviations: F = fibula; MT = lateral metatarsals; A = length of muscle belly; B = muscle belly width; C = length of tendon devoid of muscle fibres; D = width of tendon at its midpoint. Taken from: Rourke *et al*. (2007).

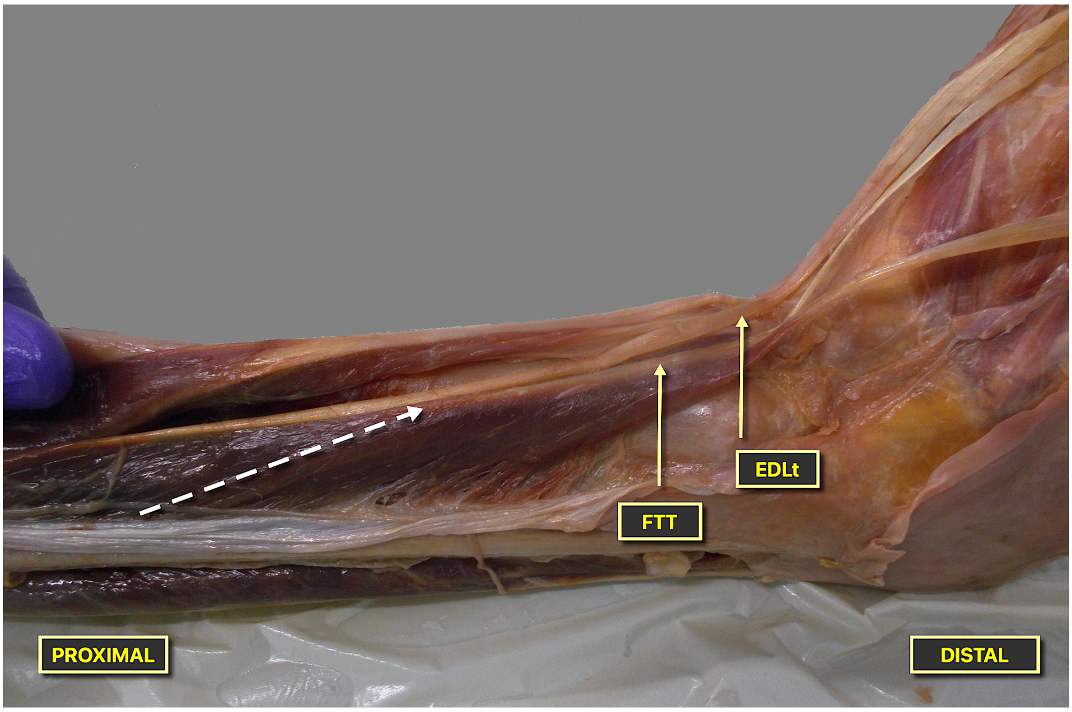

Figure 2: Determination of the limits of FT. The most proximal muscle fibres considered to be clearly directed towards the fibularis tertius tendon were considered to be the proximal limit of this muscle (dashed white arrow). Image of the right lower limb of a female individual. Abbreviations: FTT = fibularis tertius muscle tendon; EDLt = extensor digitorum longus muscle tendon.

3.2.3. Determination of the insertion type and morphology

The type of FTT insertion was established according to the classification described by Olewnik (2019) (Table 2; Figure 3).

Table 2. *Classification of FTT insertion.* Description made by Olewnik (2019)

Insertion type	**Defining characteristics**
Type I	Single distal attachment. FTT inserts into the shaft of the 5^{th} MB
Type II	Single distal attachment. Very wide insertion of FTT into the base of the 5^{th} MB
Type III	Single distal attachment. Very wide insertion of FTT into the base of the 5^{th} MB, the base and shaft of the 4^{th} MB, and the fascia covering the 4^{th} interosseous space
Type IV	Bifurcated distal attachment. The main tendon inserts into the base of the 5^{th} MB, and the accessory band inserts into its shaft
Type V	Bifurcated distal attachment. Very wide insertion of the main tendon into the base of the 5^{th} MB; the accessory band inserts into the base of the 4^{th} MB
Type VI	Fusion with an additional band of the fibularis brevis tendon

Abbreviations: FTT = Fibularis Tertius Tendon; MB = metatarsal bone

The insertion morphology was determined, as described by the same author, as: a) *band shaped* (insertion less than twice the width of the tendon above) or b) *fan shaped* (insertion at least twice the width of the tendon above) (Figure 4).

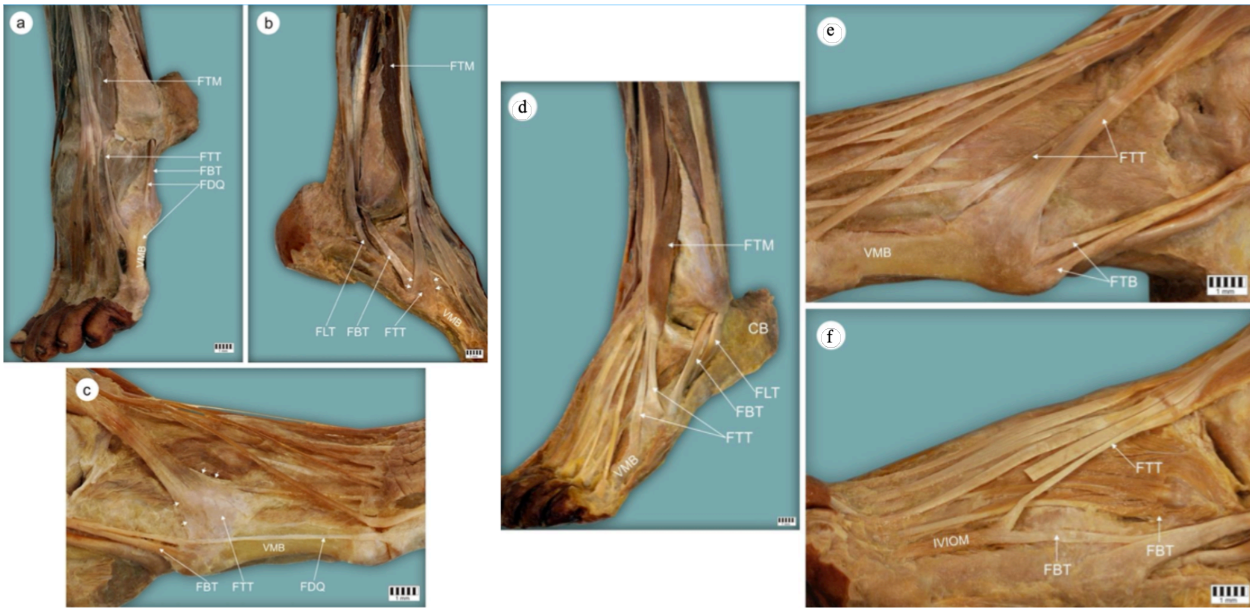

Figure 3: Classification of FTT insertion types: a) type I; b) type II; c) type III; d) type IV; e) tipe V; f) type VI. Abbreviations: FTM = Fibularis Tertius Muscle; FLT = fibularis longus tendon; FBT= fibularis brevis tendon; FTT = fibularis tertius tendon; VMB = 5th metatarsal bone; FDQ = fibularis digiti quant; CB = calcaneal bone; IVIOM = fourth interosseous muscle. The white arrowheads show the extent of the tendon. Taken from: Olewnik (2019).

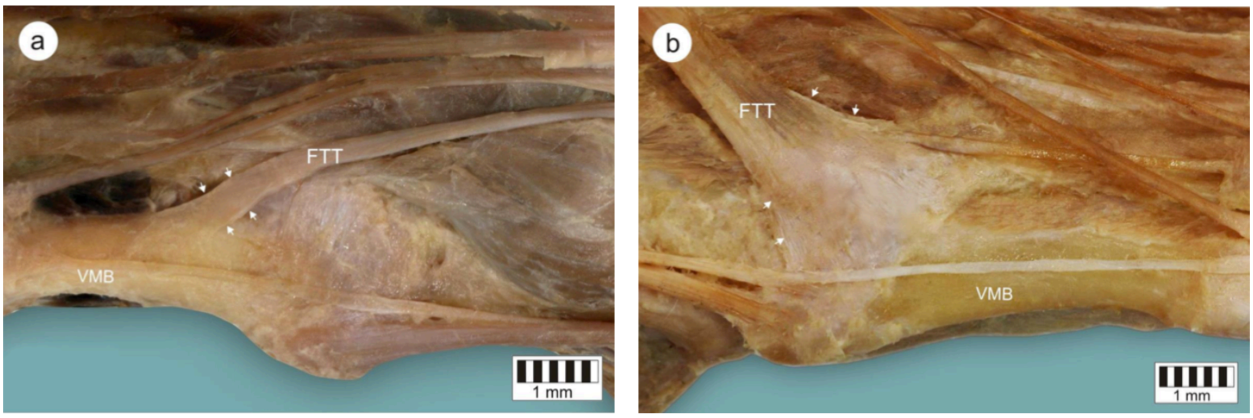

Figure 4: Variants of insertion of FTT. a) Band-shaped; b) Fan-shaped. Abbreviations: FTT = fibularis tertius tendon, VMB = 5th metatarsal bone. Taken from: Olewnik (2019).

3.2.4 Instruments and data collection

Muscle measurements were performed using a digital electronic caliper (RS PRO Digital Caliper; resolution: 0.01mm, accuracy: 0.03mm); values (in mm) were rounded to the 1st decimal place. The length of the fibula was determined using an inextensible tape measure (Forge Steel Tape

Measure); values (in cm) were rounded to the 1st decimal place. Measurements on 43 of the 44 bodies were taken in triplicate, on three non-consecutive days. For quantitative data, where two values were equal, this was taken for the purposes of this work. In cases where the three values were dissimilar, if there was no more than a 20% difference between the most dissimilar values, the median was taken as valid data. In cases where the difference was greater than 20%, a fourth measurement was carried out on another day, taking the median of the two intermediate data as valid for the purposes of this research. For qualitative data (type of origin, type of insertion morphology, type of insertion), it was considered valid when at least 2 were equal to each other. It was not the case that those data were all different from each other when comparing the 3 measurements made.

One of the bodies, due to availability issues, could only be examined during one day. In this case, for the quantitative data, each measurement was taken in duplicate, and the average of the two values was taken as valid.

For quantitative variables, the average absolute and relative error was calculated, using the formula described by Peterson and Smith (2013). Since only one researcher carried out all measurements, it was not possible to estimate inter-observer error.

3.3. Statistical analysis

All statistical analyses were performed using the free software JASP (University of Amsterdam). The Chi^2 test with contingency tables was used to evaluate the relationship between presence, type of origin and type of insertion of FT and sex. It was also used to determine possible differences in the type of insertion according to the side of the body.

Continuous data were checked for homogeneity of variance, and for normality of distribution using the Shapiro - Wilk test. Where these two criteria were met, morphological measurements were compared using Student's t-test for independent data. In the opposite case, the non-parametric Mann-Whitney test was used. If a statistically significant difference between two groups was found, in cases where parametric statistics were used the effect size was calculated using Cohen's d, with values equal to or less than 0.20 considered as no effect, between 0.21 and 0.49 as small effect, between 0.50 and 0.79 as moderate effect and equal to or greater than 0.80 as large effect (Caycho *et al*., 2016). In cases where non-parametric statistics were used, the effect size was determined using Rank Biserial Correlation. In accordance with Goss-Sampson

(2019), the interpretation was carried out in a similar way to Pearson's r correlation statistic, and consequently values from $r_{rb} = 0.10$ to $r_{rb} = 0.30$ were established as weak effect size; $r_{rb} = 0.40$ to $r_{rb} = 0.60$ as moderate effect size; and $r_{rb} = 0.70$ to $r_{rb} = 1$ as large effect size (Dancey and Reidy, 2006).

In all cases, a p-value lower than 0.05 was considered significant. Quantitative variables are presented as mean ± SD.

4. RESULTS

4.1. FT prevalence

Of the 44 bodies studied, the absence of FT (in at least one of both lower limbs) was determined in 5 bodies (11.4%) (Figure 5). Of these, in 4 male cadavers the absence was verified unilaterally, two times for the left leg and two times for the right leg. In one female cadaver the absence was verified bilaterally. Considering the total number of lower limbs analysed, the FT was absent from 6.8% of cases. There were no significant differences in the presence or absence of FT when comparing lower limbs of female vs. male cadavers (p = 0.614) (Table 3).

Figure 5: Absence of FT. Image of the left lower limb of a female cadaver. In this individual the absence was verified bilaterally. Abbreviations: EDL = Extensor Digitorum Longus muscle.

Table 3. *Presence of FT according to sex*

Presence of FT	Sex		
	Male	**Female**	**Total**
Yes	46	36	82
No	4	2	6
Total	50	38	88
p-value	0.614		

Abbreviations: FT = fibularis tertius. Test Applied: contingency tables with the Chi^2 test

In 75% (3 in 4) of the cadavers in whom the unilateral absence of FT was verified, the existence of an accessory tendon in that side of the body was observed, in all cases with origin in the tendon of the EDL to the 5th toe. In one case, this tendon, with a width of 0.8mm, had its distal insertion in the head of the 5th MB. In the second case, the tendon was 1.0mm thick, and was directed towards the fascia between the 4th and 5th MBs. In the third case, the accessory tendon, with a width of 1.4mm, was distally inserted at the base of the 1st phalanx of the 5th toe (Figure 6). In the latter, a similar accessory tendon was also verified in the other foot of the cadaver, with similar origin and insertion but with a greater thickness (1.8mm).

4.2. FT origin

In 4 cases (4.9%) a clearly defined separation between FT and EDL muscle bellies was verified (Figure 7); in the remaining cadavers the muscle bellies of both muscles did not present an evident solution of continuity, so the division between them was determined using the procedure explained previously (Figure 2). In 72 lower limbs (88.6%) the origin was determined to be of normal type (lower 1/3 of fibula), while in 10 lower limbs (11.4%) the origin was extensive (lower 1/2 of fibula). In the latter case, the attachment of the EDL muscle was reduced to upper half of the anterior surface of the fibula. There was no evidence of FT with a very extensive origin.

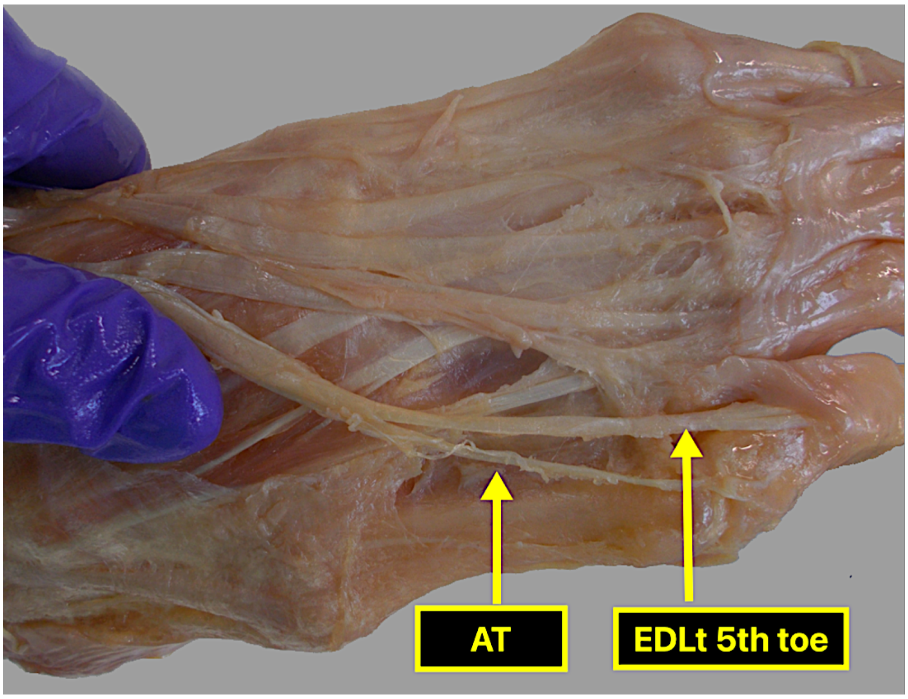

Figure 6: Accessory tendon of EDL. In this specimen the fibularis tertius muscle is absent; from the tendon of the extensor digitorum longus to 5th toe arises an accessory tendon, directed to the base of the proximal phalanx of the same toe, with a band-shaped insertion. Right lower limb of a male individual. Abbreviations: AT = accessory tendon; EDLt = tendon of the extensor digitorum longus muscle to 5th toe.

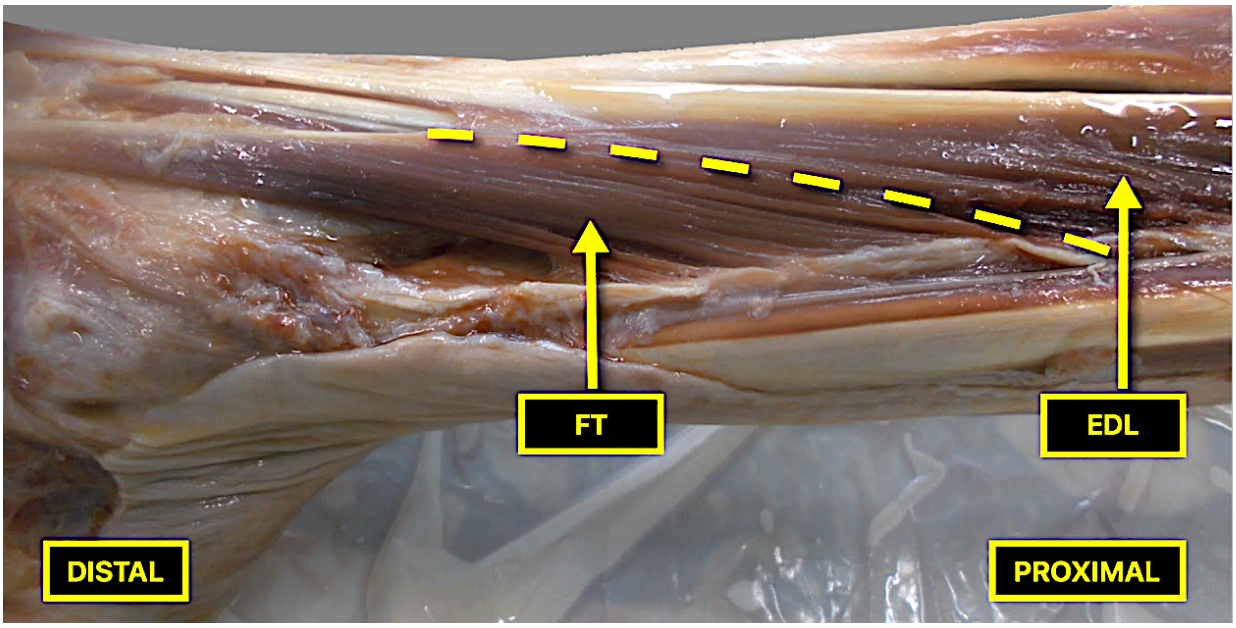

Figure 7: Division between EDL and FT muscle bellies. In this specimen a defined separation between the muscle bellies of the FT and EDL muscles can be appreciated (dashed yellow line). Left lower limb of a female cadaver. Abbreviations: FT = fibularis tertius muscle; EDL = extensor digitorum longus muscle.

In four of the cadavers with FT present bilaterally (10.3%), differences were confirmed in the type of origin between both lower limbs; on three occasions, the origin of FT was extensive on the right and normal on the left, while on one occasion it was extensive on the left and normal on the right. In the remaining subjects with bilateral FT, the type of origin was similar between both sides. There were no differences in the type of origin of FT in relation to the sex of the cadavers analysed (p = 0.855) (Table 4).

Table 4. *Type of origin of FT according to sex*

Types of origin	**Sex**		
	Male	**Female**	**Total**
Normal	40	32	72
Extensive	6	4	10
Very Extensive	0	0	0
Total	46	36	82
p-value	0.855		

Abbreviations: FT = fibularis tertius. Test Applied: contingency tables with the Chi^2 test

4.3. FTT insertion type

The FTT insertion was type III in 28 lower limbs (34.1%) (Figure 8); type I in 18 lower limbs (22.0%) (Figure 9); type IV in 5 lower limbs (6.1%) (Figure 10); type II in 4 lower limbs (4.9%) (Figure 11); in one instance (1.2%) the insertion was type V. No insertions with the description corresponding to type VI were identified. It should be noted that, in 44.4% (8 out of 18) of type I insertion, in 40% (2 out of 5) of type IV insertions and in 75% (3 out of 4) of type II insertions, was also observed an extension of some fascicles of the FTT towards the fascia covering the 4^{th} intermetatarsal space.

Finally, in 26 lower extremities (31.7%) it was found that the type of FTT insertion did not have a clear correspondence to any of the 6 types described by Olewnik (2019). Of these, on 20 limbs

(24.4% of the total sample) it was observed the insertion in the shaft of the 5th MB, shaft of the 4th MB and fascia in between; on one occasion (1.2%) the insertion was directed to the shaft of the 5th MB, and to the base and shaft of the 4th MB; on 3 occasions (3.7%) the insertion was to the base and shaft of the 5th MB and to the base of the 4th MB; once (1.2%) the insertion was to the shaft of the 4th MB as well as to the fascia separating the 4th and 5th MBs; finally, once (1.2%) the tendon was bifurcated, with the main tendon going to the shaft of the 5th MB and the accessory tendon to the shaft of the 4th MB.

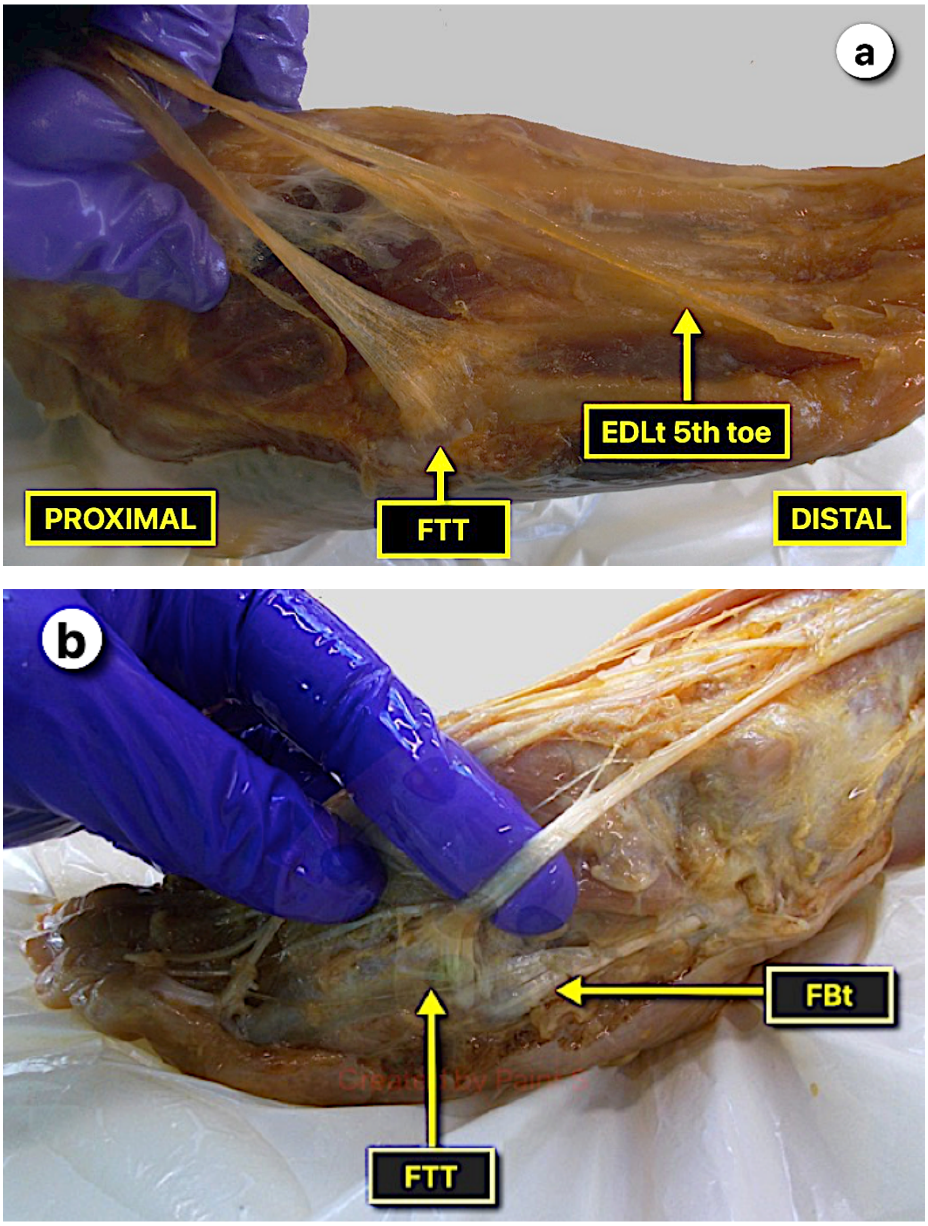

Figure 8: Type III FTT insertion. a) Right lower limb of a male cadaver; b) left lower limb of a female cadaver; in specimen b, some fibres of the FT and fibularis brevis tendons appear to fuse at the level of the base of the 5th MB. Abbreviations: FTT = fibularis tertius muscle tendon; FBt = fibularis brevis muscle tendon.

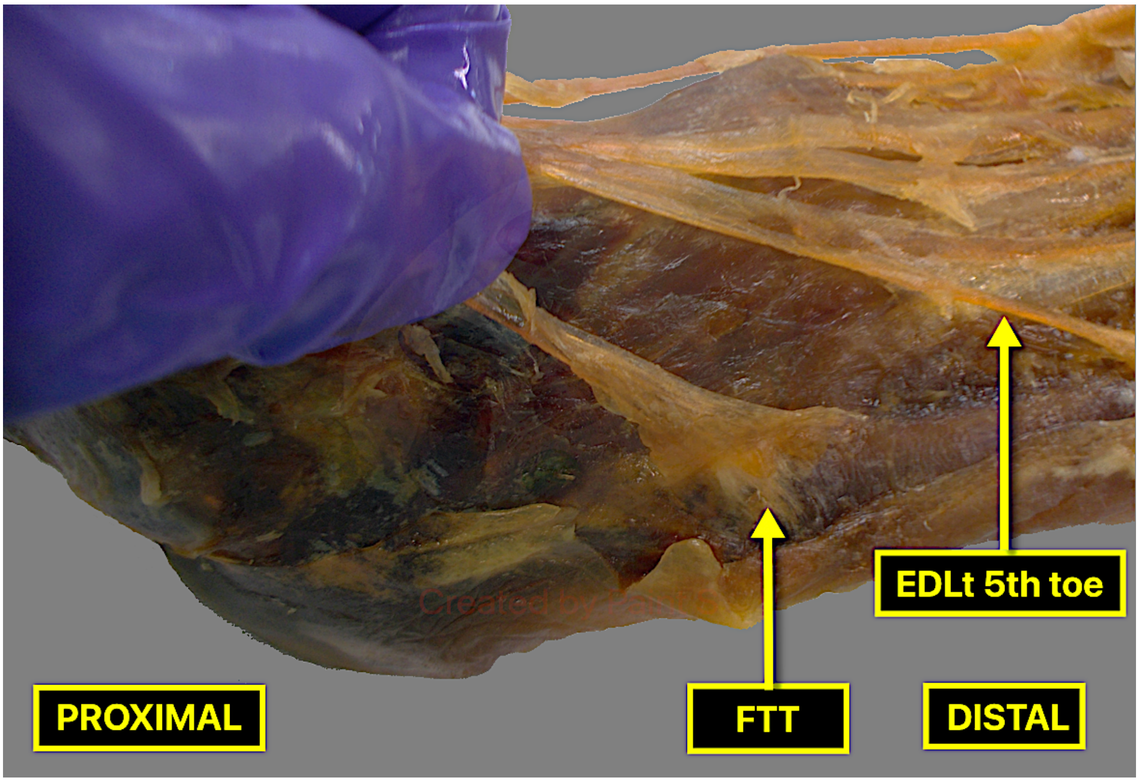

Figure 9: Type I FTT insertion. The insertion is fan-shaped, extending into the fascia covering the 4th intermetatarsal space. In this specimen, the very wide insertion and the proximity of some tendon fibres to the base of the MB make it difficult to differentiate from a type II. Image of the right lower limb of a male cadaver. Abbreviations: FTT = tendon of the fibularis tertius muscle; EDL 5th toe = tendon of the extensor digitorum longus muscle directed to the 5th toe.

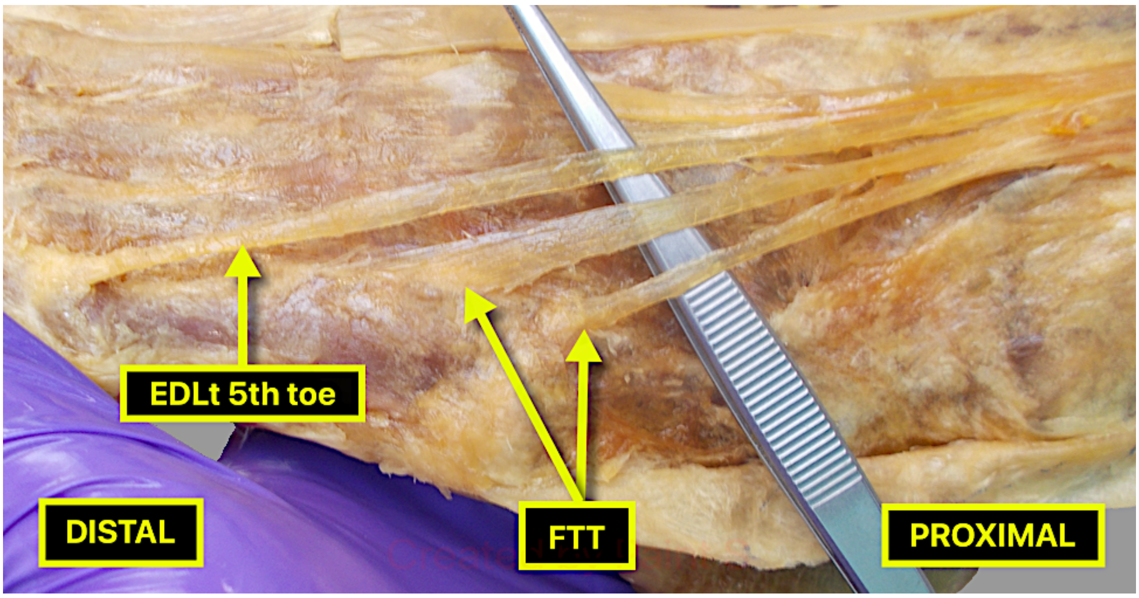

Figure 10: Type IV FTT insertion. Left lower limb of a male cadaver. Abbreviations: FTT = tendon of the fibularis tertius muscle; EDLt 5th toe = tendon of the extensor digitorum longus muscle directed to the 5th toe.

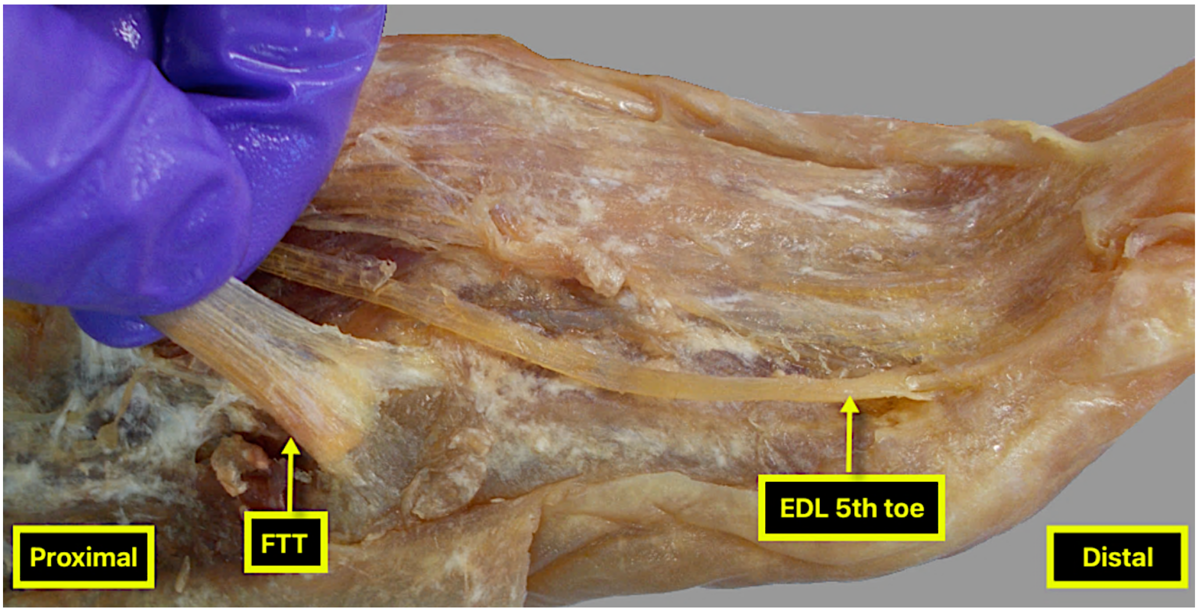

Figure 11: Type II FTT insertion. In this specimen, some fibres of the FTT took insertion at the fascia covering the 4th intermetatarsal space. Right lower limb of a female cadaver. Abbreviations: FTT = tendon of the fibularis tertius muscle; EDLt 5th toe = tendon of the extensor digitorum longus muscle directed to the 5th toe.

Of the 39 bodies with bilateral presence of FT analysed, in 19 cases (48.7%) we found that the type of distal insertion of the FTT was dissimilar when comparing right and left lower limbs; while in the remaining 20 cadavers (51.3%) the type of insertion was similar between both lower extremities. Considering the totality of the sample, there were no significant differences in the type of insertion in relation to the corresponding sex ($p = 0.575$) (Table 5), nor in the type of insertion in relation to the corresponding side of the body ($p = 0.558$) (Table 6).

4.4. FTT morphological variants of insertion

In 68 cases (83%) the FTT insertion was fan-shaped, while the remaining 14 insertions (17%) were band-shaped. Comparing sides of the same cadaver, in only one of the cadavers with bilateral presence of FT, a band-shaped variant was verified for both lower limbs; in the rest, the insertions were fan-shaped bilaterally (n=30), or band-shaped in one side and fan-shaped in the other (n=8). In subjects with unilateral presence of FT, in 75% of the cases (3 out of 4) the tendon of this muscle was band-shaped. In subjects with accessory tendons (n=3), 100% of them had a band-shaped insertion.

Table 5. *Type of insertion of FT according to sex*

Sex	Type of Insertion						
	I	II	III	IV	V	Others	Total
Female	7	3	13	1	0	12	36
Male	11	1	15	4	1	14	46
Total	18 (22.0%)	4 (4.9%)	28 (34.1%)	5 (6.1%)	1 (1.2%)	26 (31.7%)	82 (100%)
p-value	0.575						

Abbreviations: FT = fibularis tertius. Test Applied: contingency tables with the Chi^2 test. The type of insertion was established according to the classification of Olewnik (2019).

Table 6. *Type of insertion of FT according to body side*

Side	Type of Insertion						
	I	II	III	IV	V	Others	Total
Right	9	3	15	1	0	13	41
Left	9	1	13	4	1	13	41
Total	18 (22.0%)	4 (4.9%)	28 (34.1%)	5 (6.1%)	1 (1.2%)	26 (31.7%)	82 (100%)
p-value	0.558						

Abbreviations: FT = fibularis tertius. Test Applied: contingency tables with the Chi^2 test. The type of insertion was established according to the classification of Olewnik (2019).

4.5. FT morphometric measurements

The absolute and relative intra-observer morphometric measurement errors for the variables measured can be seen in Table 7. The FT morphometric measurements for the whole sample, as well as separated by sex, can be seen in Table 8.

For all the variables analysed, with the exception of the width of the EDL tendon to the 5th toe, there was no significant difference ($p > 0.05$) between males and females. For this latter variable, a significant difference in favour of males was identified, with an effect size of $r_{rb} = 0.53$, corresponding to a moderate effect ($r_{rb} \leq 0.60$). In cases where FT was absent, the width of the EDL tendon to the 5th digit was 3.8 ± 0.6mm. This value is higher than the average found for this same tendon when FT was present, or for the totality of subjects (3.3 ± 0.6mm in both cases). This difference is significant ($p = 0.04$), with an effect size of $r_{rb} = 0.5$, corresponding to moderate ($r_{rb} \leq 0.60$).

Table 7. *Average absolute and relative intra-observer morphometric measurement errors* (for FT, otherwise specified)

Parameter	Absolute error (mm)	Relative error (%)
Belly length	8.5	11.7%
Belly width	1.6	6.7%
Malleolus length	2.2	0.6%
Tendon length	3.0	4.3%
Tendon width	0.3	8.1%
Tendon width of EDL to 5th toe	0.2	5.7%

Abbreviations: FT = muscle fibularis tertius; EDL = muscle extensor digitorum longus.

Table 8. *Morphometric measurements* (for FT, otherwise specified). Data expressed as mean values ± SD

Parameter	All limbs (n = 82)	Female (n = 36)	Male (n = 46)	p-value
Belly length (mm)	72.8 ± 22.8	69.1 ± 18,3	75.6 ± 25,5	0.300 (+)
Belly width (mm)	23.3 ± 3.9	23.6 ± 3.5	23.1 ± 4.2	0.548 (*)
% of the fibula occupied by origin	20.0 ± 6.1	19.8 ± 4.7	20.0 ± 7.1	0.617 (+)
Tendon length (mm)	70.4 ± 11,7	69.5 ± 11,8	71.1 ± 11.6	0.531(*)
Tendon width (mm)	3.2 ± 1.0	3.1 ± 0.8	3.3 ± 1.1	0.432 (+)
Tendon width of EDL to 5th toe (mm) (FT present)	3.3 ± 0.6	3.0 ± 0.4	3.6 ± 0.6	<.001 (+)
Tendon width of EDL to 5th toe (mm) (FT absent)	3.8 ± 0.6 (n = 6)	4.4 ± 0.4 (n = 2)	3.6 ± 0.6 (n = 4)	-

Abbreviations: FT = muscle fibularis tertius; EDL = muscle extensor digitorum longus. p- value = according to sex comparison. Test Applied: when the assumption of normality and homogeneity of variance were met, Student's t-test was used for independent data (*); otherwise, Mann - Whitney (+) was used.

Table 9 shows the morphometric measurements of FT according to body side. For all variables, with the exception of the width of the EDL tendon to the 5th toe, there was no significant difference ($p > 0.05$) between the left and right lower extremities. For the latter variable, a significant difference in favour of the left side was determined. The effect size was $d = 0.49$, corresponding to a small effect ($d \leq 0.49$).

Table 9. *Morphometric measurements according to side* (for FT, otherwise specified). Data expressed as mean values ± SD

Parameter	**Left limb (n = 41)**	**Right limb (n = 41)**	**p-value**
Belly length (mm)	74.6 ± 26,2	68,8 ± 21,8	0.519 (+)
Belly width (mm)	22,7 ± 4,0	23,9 ± 3,8	0,164 (*)
% of the fibula occupied by origin	19,8 ± 7,6	19,5 ± 6,7	0,876 (+)
Tendon length (mm)	68,9 ± 13,4	71,9 ± 9,6	0,100 (+)
Tendon width (mm)	3,4 ± 1,1	3,1 ± 0,8	0.393 (+)
Tendon width of EDL to 5th toe (mm) (FT present)	3,4 ± 0,7	3,2 ± 0,5	0.031 (+)
Tendon width of EDL to 5th toe (mm) (FT absent)	4.0 ± 0.9 (n = 3)	3.7 ± 0.4 (n = 3)	0.667 (*)

Abbreviations: FT = muscle fibularis tertius; EDL = muscle extensor digitorum longus. Test Applied: when the assumption of normality and homogeneity of variance were met, it was used Student's t-test for independent data (*); otherwise, Mann - Whitney (+) was applied.

Table 10 shows the mean and SD of the differences between left and right lower limb for each of the cadavers, considering the whole sample as well as differentiated by sex. In none of the variables a significant difference was found when comparing males to females ($p > 0.05$).

Table 10. *Differences in Morphometric measurements comparing sides of the same cadaver* (for FT, otherwise specified). Data expressed as mean values ± SD

Parameter	**All limbs (n = 82)**	**Female (n = 36)**	**Male (n = 46)**	**p-value**
Belly length (mm)	18,7 ± 18,2	19,2 ± 18,5	18,3 ± 18,4	0,844 (+)
Belly width (mm)	3,9 ± 2,8	3,4 ± 2,8	4,3 ± 2,9	0,351 (*)
% of the fibula occupied by origin	5,1 ± 4,9	5,3 ± 5,0	4,9 ± 4,9	0,899 (+)
Tendon length (mm)	8,0 ± 6,4	9,6 ± 7,0	6,7 ± 5,5	0,190 (+)
Tendon width (mm)	0,8 ± 0,6	0,6 ± 0,4	0,9 ± 0,7	0,153 (*)
Tendon width of EDL to 5th toe (FT present bilaterally) (mm)	0,4 ± 0,4	0,4 ± 0,4	0,4 ± 0,4	0,369 (+)
Tendon width of EDL to 5th toe (mm) (FT absent unilaterally)	0.8 ± 0.8 (n = 4)	-	0.8 ± 0.8 (n = 4)	-
Tendon width of EDL to 5th toe (mm) (FT absent bilaterally)	0.5 (n = 1)	0.5 (n = 1)	-	-

Abbreviations: FT = muscle fibularis tertius; EDL = muscle extensor digitorum longus. p- value = according to sex comparison. Test Applied: when the assumption of normality and homogeneity of variance were met, it was used Student's t-test for independent data (*); otherwise, Mann - Whitney (+) was applied.

5. DISCUSSION

No other similar studies conducted both in a Scottish population and using Thiel-embalmed cadavers, were found in the scientific literature. To the best of the author's knowledge, this would be the first work with these characteristics, providing a novel aspect to the present study. In addition, there are few anatomical dissection papers addressing FT in which both limbs of the same cadaver were examined, as most of the research was carried out on isolated lower limbs only (Rourke *et al.*, 2007).

The findings of the current study confirm that FT is a muscle with highly variable origin, insertion and morphology, which in a minority of cases may be completely absent (Sirasanagnadla *et al.*, 2014). A close relationship was also verified between the bellies of FT and EDL muscles, their separation not being evident in more than 95% of the cases. This contrasts with Jungers *et al.* (1993), who claim that it is usually possible to separate both muscles at the level of their origins, and also with the findings of Marin *et al.* (2006) who verified an evident anatomical separation between both muscles in 60% of the lower limbs studied. In the same direction, Jadhav *et al*. (2015) found a completely formed and independent belly of FT, clearly distinct from EDL, in 80.45% of the cases.

Krammer *et al.* (1979) maintain that, despite the intimate contact between both muscles, there is a very thin layer of connective tissue between them, which allows their separation without disrupting the continuity of muscle fibers or tendons. In the current work, as mentioned above, it was not possible to verify this fact in the vast majority of cadavers.

The fibres of FT were arranged at an oblique angle, inserted entirely on one side of the tendon, thus confirming their unipennate muscle character. In addition, the presence of morphological characteristics that are not included in commonly used anatomy textbooks was observed. Along the same lines as Krammer *et al*. (1979), it could be suggested that the characteristics of FT commonly described corresponds more to a variation than to a standard structure.

5.1. Prevalence

Considering the total sample, the prevalence of FT reached 93.2%. This value is similar to that described by other studies that used anatomical dissection to determine its presence/absence, and is the same percentage found by Yammine and Erić (2017) as weighted true prevalence, in their meta-analysis work from 25 other studies that included 3628 lower limbs. Expectedly, in the current work the prevalence proved to be similar to that reported for the British population (92.7%) as described by Rourke *et al*. (2007), who also analysed a very similar number of cadavers (41 vs 44, respectively).

On the other hand, this value is higher than that reported by *in vivo* research using the palpation technique as the method of determination (Table 1). This is consistent with Lambert (2016), who posit that FT is present in approximately 91.3% of specimens as described in anatomical dissection works, while the prevalence in studies using surface palpation techniques is between 49.1% and 81.5%, depending on the population.

This value was also higher than that reported in fetal studies (Karauda *et al.*, 2021; Albay and Candan, 2017; Domagała *et al*., 2006; Sokołowska-Pituchowa *et al*., 1979). In disagreement with Yammine and Erić (2017), this could not be satisfactorily explained by the frequent absence of FT in foetuses less than 10 weeks, as the above-mentioned studies analysed more developed specimens.

In agreement with what has been found by Palomo-López *et al.* (2019), there was no significant difference in the prevalence of FT when lower limbs from female to male subjects were compared. This contrasts with Wood (1868) who found the absence of FT in 5 of 68 male cadavers (7.4%) vs. 5 of 34 female cadavers (14.7%). Ramirez *et al*. (2010), also verified a lower prevalence in lower limbs of female to male specimens (43% vs 57%, respectively); given that these authors used the palpation technique, in this case it could be speculated that in the female sex the presence of FT could have been underestimated due to a lower average muscle development in this population.

5.1.1. Comparison between sides of the same cadaver

Interestingly, in the current study it was observed that, where FT was absent, in the majority of cases (4 of 5 subjects, 80%) it happened unilaterally, with only one subject with bilateral absence. This percentage is similar to that reported by Wood (1868) who, in 10 subjects (5 females, 5 males), found that FT was absent bilaterally in 2 cases (1 female, 1 male) and unilaterally in the remaining 80% of the cadavers. It also agrees with the findings of Johnson (1973), who in 5 cadavers with absence of FT, found that bilaterally in 1 case (20%) and unilaterally in the rest of the individuals (80%). On the other hand, in the study by Chatyingmongkol *et al*. (2004) the authors found different percentages: in 57.1% (4 of 7) of the cadavers with absence of FT, it was bilateral; in 28.6% (2 of 7) of the cases the absence was unilateral on the left side; and in the remaining case (14.3%) the absence was unilateral on the right side.

According to Spinner *et al*. (2021) the EDL tendon to the 5th toe is sometimes duplicated. In the current work it was found such an accessory tendon in 50% (3 of the 6) of lower limbs in which the absence of FT was verified. This could represent a rudimentary analogue of the absent muscle, as a similar accessory tendon was only found in one of the remaining 82 limbs in which FT was present. This percentage, however, is much lower than that shown in the study by Yammine and Erić (2017), who determined that in more than 95% of cases where FT is absent, the presence of an additional fibular muscle or a tendinous slip from EDL is ascertained.

5.2. Characteristics of the muscle belly

In the current work the origin of FT in relation to the fibula, as well as the length and width of its belly, proved to be highly variable between cadavers. As mentioned *ut supra*, in most cases (95.1%) it was not observed a clear separation between the muscular bellies of FT and EDL. For this reason, and in line with what Bertelli *et al.* state, the separation between the two muscle bellies was difficult. This could explain the higher average relative measurement error found in this variable compared to the other variables considered (Table 7).

5.2.1. Origin of FT in relation to the fibula

Yildiz and Yalcin (2012) argue that variations in the origin of FT are not frequent, which is in agreement with the work of Jadhav *et al*. (2015) who claim not to have observed any variation in it in 100 lower extremities examined. In contrasting with this, in the present study variations in origin of FT were found between subjects.

Considering the percentage of the fibula occupied by the origin of FT, a very wide range was found, between 10.7% as minimum and 49.0% as maximum. The average value (20.0%), however, was much lower than the 30.2% reported by Stevens *et al*. (1993), who stated maximum values of this variable of 26cm (vs 18cm in the current work); and also lower than the average value described by Rourke *et al*. (2007), which is 28.4%. Considering both legs of the same subject, in the present study the maximum variability observed was 21.1%. With respect to this, no differences were found between sexes.

In the majority of cases (88.6%) the origin was in the distal third of the fibula, while in 11.4% of cases the insertion extended to the lower half of this bone. This is in accordance with Afroze *et al*. (2020) who also found the former type of origin in the majority (97%) of the specimens; this is also the origin commonly described in current anatomy textbooks (Spinner *et al*., 2020; Moore *et al*., 2018; Rouvière and Delmas, 2005). Nayak (2017) mentions having found its origin in the most distal portion of the fibula in 100% of the specimens studied; in this case, the author describes it as being inserted in the lower one fourth of the medial surface, but it should be noted that this author refers only to the shaft, and not to the whole length of this bone.

In contrast, Joshi *et al*. (2006) verified the origin of FT in the distal third of the fibula only in approximately 50% of the lower limbs studied, similar to that reported by Vieira *et al*. (2018) who found it only in 46.66% of the specimens analysed. It is also not in line with what is stated by Olewnik (2019), who found that in most cases (67%) the origin was in the distal half of the fibula, while in only 22% of cases the origin was verified in the distal third of this bone. In the same sense, Krammer *et al.* (1979) argue that FT usually originates in the lower 2/3 or lower half of the anterior margin of the fibula. This is in agreement with that described in the classic treatise on anatomy by Testut and Latarjet (1984), who describe its insertion in the inferior half of this bone.

The findings in the present study also differ from those reported by Stevens *et al.* (1993) who observed that, in 92.1% (35 of 38) of the lower limbs studied, the origin was centred around the lower middle quarter of the fibula, rather than the distal lower third of it, and by Marin *et al.* (2006) who found that in 70% of cases the origin was in the middle third of this bone.

Joshi *et al.* (2006) verified very extensive origin of FT (occupying distal, medial and proximal thirds of the shaft of the fibula) in 18.2% of the lower limbs observed. de Gusmão *et al*. (2013) also reported finding FT muscle bellies with very extensive origin, although only in 3.2% of the lower limbs studied. In the current work, none of the cadavers studied presented this type of origin.

5.2.2. Length of the muscle belly

Regarding the length of the origin of FT at the fibula, values in the current study were found to range from 37.8mm minimum (female, left limb) to 180.2mm maximum (male, left limb), with an average of 72.8mm. This is similar to that reported by Rourke *et al.* (2007), who verified values ranging from 38mm minimum to 193mm maximum. Verma and Seema (2015) state an average length of the belly length of FT of 21cm, much higher than that found in the current study. This difference would be given, however, by the fact that these authors measured the length "from origin up to extent of muscle fibers", while in the present work it was considered only its bony insertion at the level of the fibula.

In this study this variable was, on average, longer in males than in females (75.6mm vs 59.1mm, respectively) and longer in the left leg than in the right leg (74.6mm vs 68.8mm, respectively) although for both cases the differences were not significant.

5.2.2.1. Comparison between sides of the same cadaver

There were significant variations in this variable between both legs of the same cadaver: in some cases the lengths between the two sides were the same or very similar, while in others there were significant differences. The maximum absolute difference was 78.4mm (180.2mm left, 101.8mm right), found in a male cadaver. The maximum relative difference was 74.6% (99.1mm right, 45.3mm left) found in a female cadaver. Comparing between sexes, there were no significant differences ($p > 0.05$) in the length of the origin of FT.

5.2.3. Width of the muscle belly

Considering all lower limbs, muscle belly width data ranging from a minimum of 14.6mm (male, left limb) to a maximum of 34.1 mm (male, left limb) were found, the average being 23.3mm. The values for both sexes and both sides showed no significant differences ($p > 0.05$). These values are larger than those found by Chatyingmongkol *et al*. (2004), who reported a maximum width for FT of 11.2mm and a minimum width of 1.0mm, with an average of 3.75mm and 4.41mm on the left and right leg respectively. The difference can be explained, however, by the different criteria used to measure it: while these authors took measurements at the level of the ankle joint, in the current study it was done at the middle of the bony insertion of the muscle belly.

The present work also found higher average values than those reported in the papers by Verma and Seema (2015) (23.3mm vs 19mm, respectively) and Rourke *et al.* (2007) (23.3mm vs 19.4mm, respectively). As mentioned above, in the current study the same measurement criteria were used as the latter authors; in the case of the former, they do not clarify in their work which criteria they used to measure this variable.

5.2.3.1. Comparison between sides of the same cadaver

In the current study it was verified an important intra-individual variation when comparing both lower limbs: while in some cadavers there were practically no differences between the left and right leg, in the case where the greatest difference was observed it was in absolute terms of 9.3mm and in relative terms of 44.2% (25.7mm on the right and 16.4mm on the left), in the same male subject. Taking into account the average differences between both sides, no significant differences were found ($p > 0.05$) between sexes.

5.3. Characteristic of the tendon

To the author's knowledge, relatively few studies have determined the characteristics of FTT. The scientific literature describes its great variability, being able to be "thick and broad or quite slender and diaphanous" (Johnson, 1973; p.18). This was verified in the results of the current study.

5.3.1. Tendon length

Considering all the lower limbs analysed, the average length (70.4mm) was very similar to that found by Olewnik (2019) (73.9mm) and by Rourke *et al.* (2007) (69.6mm), although greater than that verified by Nayak (2017) (5cm). Strikingly, de Gusmão *et al.* (2013) report a mean FTT length without muscle fibres of only 1.2cm.

As for other variables measured in this muscle, a large variability was verified in the length of the FTT (or the main tendon, in case of the presence of an accessory one). The minimum and maximum values observed were 49.8mm and 101.5mm respectively, in both cases found in the left lower limb of 2 male cadavers. This represents a percentage difference of 68.3%, which accounts for the aforementioned variability. This data is comparable to that reported by Nayak (2017), who also verified a large variability, with values in the range of 4.1cm to 9.8cm (although in this case the percentage difference is smaller: 41.0%).

5.3.1.1. Comparison between body sides of the same cadaver

Regarding the intra-individual values, it was found right to left absolute differences ranging from 0mm to a maximum of 21.9mm (93mm right vs. 71.1mm left); in relative terms, the largest difference between sides was 28.0% (71.8mm right vs. 54.2mm left), in both cases in female cadavers. These differences are somewhat larger than those found in the data reported by Verma and Seema (2015), where maximum differences between sides of up to 2cm were observed in three male cadavers. In relative terms, the maximum difference recorded in this research was 28.6% (8cm right vs 6cm left), similar to that found in the current study.

On average, FTT length was slightly longer in males than in females, similar to the findings of Rourke *et al*. (2007). Additionally, this variable was greater in the right side compared to the left side; in both cases the difference was not statistically significant ($p > 0.05$). Although in average terms the difference in the length of FTT between sides of the body proved to be larger in females than in males, again there was no statistically significant difference ($p > 0.05$).

5.3.2. Tendon width

In relation to the width of FTT it was found a minimum value of 1.3mm (male, right limb) and a maximum of 6.6mm (male, left limb). The average (3.2mm) was very similar to that found by Ercikti *et al*. (2016) in a study involving 44 lower extremities, where they report a mean of 3.11mm and 3.32mm on the right and left sides respectively, with a minimum of 1.66mm and a maximum of 7.11mm. On the other hand, this data is lower than that reported by Nayak (2017) and Verma and Seema (2015), who found mean values of 4mm and 5mm respectively, in both cases with a maximum of 8mm. In these studies, the authors do not mention at what level the tendon width was measured. Additionally, in the current study FTT was wider in males than in females (3.3mm vs 3.1mm respectively) although the difference was not significant ($p > 0.05$).

In lower limbs where FT was absent, the average width of the EDL tendon to the 5th toe was significantly greater than in specimens where FT was present (3.8mm vs 3.3mm respectively; $p = 0.044$), with an effect size of $r_{rb} = 0.5$, corresponding to moderate ($r_{rb} \leq 0.60$). In relation to this, the average width proved to be greater in lower limbs belonging to females compared to males (4.4mm vs 3.6mm, respectively). Given that FT has been considered by some authors as the migrated part of the extensor digitorum brevis to the 5th toe, it could be expected that the tendon of the EDL is thickened as a replacement for this absence, thus representing a functional adaptation (Ramirez *et al*., 2010; Das *et al*., 2009). It should be mentioned that, in the current study, the small number of cadavers in which this muscle was absent ($n = 5$) implies that the results obtained should be interpreted with caution.

5.3.2.1. Comparison between sides of the same cadaver

With respect to intra-subject variability, there were again appreciable differences among individuals. While in 4 cadavers it was equal or very similar on the right and left sides (difference of 0.0 or 0.1mm), in the others there were greater differences, up to a maximum of 3mm (6.6mm on the left vs. 3.6mm on the right side; percentage difference of 58.9%), found in 1 male cadaver. This again contrasts with the work of Verma and Seema (2015); from the data provided by these authors it is possible to verify maximum differences on the right and left sides of 1mm (0.1cm) in absolute terms, and 18.2% (0.5cm vs 0.6cm) in relative terms.

In the present study, it was in males that the greatest average difference was observed comparing both sides, although there was not a significant difference between sexes ($p > 0.05$).

Despite what might be expected, in the four subjects where FT was unilaterally absent the average width of the EDL tendon to the 5th toe was greater in the side where FT was present compared to the side where FT was absent (4.0mm vs 3.6mm respectively).

5.3.3. Tendon width in relation to the EDL tendon to the 5th toe

On average, the width of the FTT was slightly less than the average width of the EDL tendon to the 5th toe (3.2mm vs 3.3mm, respectively). It is noteworthy that there was a significant difference ($p < .001$) in the average thickness of the latter tendon in favour of males over females (3.6mm vs 3.0mm respectively), which may reflect a greater degree of hypertrophy in this population.

Despite this, in 41.5% of the lower limbs with FT present (19 females, 15 males), the FTT was wider than the EDL tendon to the 5th toe, with the largest difference verified in absolute terms of 3.5mm (6.6mm vs 3.1mm respectively) and in relative terms of 72.2%, found in the left lower limb of the same male cadaver. This fact could be related to the possible functional importance of FT as pronator of the foot (Witvrouw *et al*., 2006).

These values contrast with those reported by Joshi *et al*. (2006) who found the FTT wider than the EDL tendon to the 5th toe (something they called a "quite thick tendon") in only 12.18% of the 187 cases in which the muscle was present. According to these authors, the presence of such a thick FTT could be beneficial for certain surgical procedures, including the treatment of lateral laxity of ankle or tendon transplant in the replacement of damaged dorsiflexor (e.g. paralysed anterior tibial muscle). Mabit *et al*. (1996) stated that in 60% of cases the FTT width is greater than 4mm, which makes the tendon biomechanically reliable for this type of procedure. In contrast to this, in the present work it was found a FTT width equal to or greater than 4.0mm in only 17% (14 out of 82) of the lower limbs measured; which could be implying that, in many subjects, the FTT thickness does not reach the ideal value required in this type of procedure.

In contrast to the findings of the present work, Saxena *et al.* (2013), Sawant *et al.* (2012) and Das *et al*. (2009) did not verify the absence of FT accompanied by an apparent thickening of the EDL tendon to the 5th toe. It should be noted that the three papers mentioned are not population-based studies but are case reports.

5.4. Characteristic of the Insertion

The insertion of the FT main tendon showed inter- and intra-individual variations, both in type and in morphological variants of insertion. These differences are in some cases not consistent with what is usually described in the scientific literature.

5.4.1. Variations in the insertion type

Regarding the type of insertion, several textbooks mention only the most proximal portion or the dorsal surface of the base of the 5th MB (Iyer, 2020; Spinner *et al.*, 2020; Moore *et al.*, 2018; Chaurasia, 2006; Rouvière and Delmas, 2005; Van de Graaf, 2002). This is in agreement with that reported by Nayak (2017), who verified the insertion of FT onto the base of the 5th MB in 94 out of 100 lower limbs analysed. Vieira *et al*. (2018) also reported insertion only in the 5th MB in 70% of lower limbs.

Other authors, however, found that this type of insertion was only present in approximately 50% of the specimens analysed (Jadhav *et al.*, 2015; Joshi *et al.*, 2006). Numerous variations have also been reported, including its insertion into the EDL tendon to 5th toe, its insertion at the level of the 4th MB, or even its insertion at the level of the 3rd MB (Bhadkamkar and Mysorekar, 1961). In the current study, it was found all the insertion types described in the classification made by Olewnik (2019), with the exception of type VI. According to this author, this last type has a very low prevalence, having been found in only 2 of 91 (2.2%) lower limbs analysed; although in the work of Afroze *et al*. (2020) the authors report this type of insertion in 10.6% of the lower extremities.

Interestingly, in the present work it was also found a significant percentage of lower limbs (31.7%) with types of insertion whose description would not be neatly included in any of the 6 categories described by the aforementioned author. In a similar way, Afroze *et al*. (2020) also found, although in a much lower percentage (3.0%), FTT features that did not correspond to the 6 categories mentioned, proposing the inclusion of two additional categories (Type IIa: a very slender tendon much less than standard tendon width; and Type Va: lateral slip inserted into the dorsal surface of the base of the 5th MB, and medial slip interacting with the tendon of extensor digitorum brevis of the 3rd toe).

Unlike what is argued in the previously mentioned textbooks and papers, in the present study in 67% of the lower limbs some kind of insertion was found at the level of the 4th MB. These values are very similar to those reported by Werneck (1957) who, in a study involving 45 cadavers, found the insertion of the FTT at the level of both the 4th and 5th MBs in 64% of cases. This could also be related to Bryce (1923), who maintains that this muscle frequently ends partially or totally at the level of the 4th MB, and Macalister (1875) who stated that the FTT can send a tendinous slip or even go entirely into this bone.

Following the same argument, Krammer *et al*. (1979) suggest that the distal insertion of the FTT has a constant projection to the 4th MB, although lateral mobilisation of this tendon is necessary to appreciate it. This projection would, according to these authors, have functional importance in linking both 4th and 5th MBs. In addition, the arrangement of the FTT fibres would be such that they would cause tension during inversion of the foot, as well as relaxation during the opposite movement of eversion.

The author of the current study further found differences in the predominant insertion type in relation to the work of Olewnik (2019): while the latter observed that the most common was type I (45%), the current work found that the most predominant insertion was type III (34.1%). This also differs from that reported by Afroze *et al*. (2020) who observed that in the majority of the specimens (84.8%) the insertion corresponded to type II, with neither type I nor type III insertion found in any of the 66 lower limbs analysed.

In addition, in the present study it was observed no significant differences comparing the type of insertion with respect to sex ($p > 0.05$); nor were differences found when comparing the type of insertion with respect to body sides ($p > 0.05$).

5.4.2. Comparison between sides of the same cadaver

Almost half of the cadavers analysed (48.7%) had different insertion sites comparing both sides. To the author's knowledge, there are no studies in the scientific literature that have carried out this kind of analysis in other populations. Interestingly, it was also found that in 75% (3 out of 4) of the subjects with unilateral presence of FT, the FTT presented a band-shaped morphology variant. Again, the small sample size means that these results should not be considered conclusive.

5.4.3. Variations in morphological variants of insertion of the main tendon

In the present study it was found that the majority (83%) of the main tendons of the FT presented a fan-shaped morphological variant. The larger insertion area of this type would be related to the functional relevance of this muscle as pronator of the foot (Reimann, 1981). This fact, however, differs from the data presented by Olewnik (2019). In that work, without considering type VI insertions (fused with an additional band of the fibularis brevis tendon) it was stated that in 46% of the cases (41 out of 89 tendons) the insertion was of the band-shaped type. Interestingly, in the latter study all the tendons with this morphology were associated with a type I insertion.

5.5. Limitations of the study

The current work has limitations, which determine that the results should be taken with caution. Among them, the characteristics of FT make it difficult to measure some variables accurately and precisely (e.g.: determination of the separation between the muscle belly of FT and EDL; determination of the exact point where the muscle fibres stop inserting into the FTT).

During the data collection period, restrictions imposed by the COVID-19 pandemic made group work difficult, which determined that the data collection was carried out by a single researcher. For this reason, it was not possible to establish an inter-observer measurement error, which could represent an additional limitation.

Furthermore, taking into account that the number of citizens of Scotland is approximately 5.463.300 people (Office for National Statistics, 2019), a sample of at least 385 subjects would be necessary to be representative of that population, assuming a confidence level of 95% and a margin of error of 5%. This leads to the suggestion that more similar studies of the Scottish population are needed.

6. FUTURE WORK

The author of the present study considers it necessary to carry out similar works using a larger sample of subjects. In addition, it could be necessary to carry out similar studies with a sample of fresh cadavers, not affected by any kind of embalming procedures; this would avoid possible effects on the morphology of the structures analysed, and would also allow the inclusion of biomechanical studies, as the tissues would not be affected by chemical processes.

7. CONCLUSIONS

In the present work, it was verified for the Scottish population the great variability described in the scientific literature with respect to the anatomical characteristics of FT. In agreement with other authors, several variations were identified that are not mentioned in current textbooks. This is particularly true with regard to its insertion: in the current analysis it was found a relevant amount of them that the author could not categorize according to the classification described by Olewnik (2019). This could be indicating the necessity to introduce more categories or subclassifications. Given the clinical and surgical importance of this muscle, the author believes it is necessary that the aforementioned variations are taught and taken into consideration during human anatomy and surgical training courses. Additionally, more studies involving the use of fresh cadavers and biomechanical measurements are needed.

REFERENCES

Abhinitha, P., Mohandas, K. G., Rao, A. S., Satheesha, B., Shetty, S. (2014). Anomalous pattern of tendinous slips of peroneus tertius and extensor digitorum longus muscles in the foot. A clinically important variation. *Gulhane Medical Journal* 56(3): 179–181.

Adachi, B. (1909). Beiträge zur Anatomie der Japaner. XII. Die Statistik der Muskelvarietäten. *Zeitschrift Für Morphologie Und Anthropologie* 2: 216–312.

Afroze, K., Muralidharan, S., Ebenezer, J. L., Muthusamy, S. (2020). Morphological variations of peroneus tertius: A cadaveric study with anatomical and clinical consideration. *Medeniyet Medical Journal* 35(4): 324–329.

Albay, S., Candan, B. (2017). Evaluation of fibular muscles and prevalence of accessory fibular muscles on fetal cadavers. *Surgical and Radiologic Anatomy* 39(12): 1337–1341.

Arnold, P., Yugueros, P., Hanssen, A. (1999). Muscle flaps in osteomyelitis of the lower extremity: a 20-year account. *Plastic Reconstructive Surgery* 104(1): 107–110.

Bertelli, J., Khoury, Z. (1991). The peroneus tertius island muscle flap. *Surgical and Radiologic Anatomy* 13(3): 243–244.

Bhadkamkar, A., Mysorekar, V. (1961). Anomalous peroneus tertius and extensor digitorum longus muscles. *Journal of the Anatomical Society of India* 10: 37–38.

Boon, A. J., Harper, C. M. (2009). Electromyographic sensitivity of peroneus tertius relative to abductor hallucis in assessment of peripheral neuropathy. *Muscle and Nerve* 40(4): 629–632.

Bourdon, B., Petitdant, B. (2012). The peroneus tertius muscle (third fibular). *Kinesitherapie* 12(130): 32–37.

Boyer, E. (1935). The musculature of the inferior extremity of the Orangutan Simia satyrus. *American Journal of Anatomy* 56: 193–256.

Brody, P., Grumbine, N. (1984). Peroneus tertius reconstruction for flexible clawtoes associated with cavus deformity: a preliminary report. *Journal of Foot Surgery* 23(5): 357–361.

Bryce, T. (1923). *Myology: Muscles of Anterior Region of Leg and Dorsum of Foot*. London: Longmans, Green and Co.

Caycho, T., Ventura-León, J., Castillo-Blanco, R. (2016). Magnitud del efecto para la diferencia de dos grupos en ciencias de la salud. *Anales Del Sistema Sanitario de Navarra* 39(3): 459–461.

Chatyingmongkol, K., Roongruangchai, J., Rojanavanichkit, W. (2004). The presence of the peroneus tertius muscle in Thai people. *Siriraj Medical Journal* 56: 216–221.

Chaurasia, B. (2006). *BD Chaurasia's Human Anatomy. Regional and Applied. Dissection and Clinical*. 4th ed. New Delhi: CBS Publishers and Distributors Pvt Ltd.

Dancey, C., Reidy, J. (2006). *Estatística Sem Matemática para Psicologia: Usando SPSS para Windows*. Porto Alegre: Artmed.

Das, S., Suhaimi, F., Latiff, A., Hlaing, K., Ghafar, N., Othman, F. (2009). Absence of the peroneus tertius muscle: Cadaveric study with clinical considerations. *Romanian Journal of Morphology and Embryology* 50(3): 509–511.

de Gusmão, L., Lima, J., Duarte, F., Souto, A., Gonçalves de Farias, A., Couto, B. (2013). Anatomical basis for the use of the fibularis tertius muscle in myocutaneous flaps. *Brazilian Journal of Plastic Surgery* 28(2): 191–195.

Derrick, E., Flores, M., Scherer, K., Bancroft, L. (2016). Peroneus Tertius Tendon Tear: A Rare Cause of Lateral Ankle Pain. *Cureus* 8(4): 1–7.

Domagała, Z., Gworys, B., Kreczyńska, B., Mogbel, S. (2006). A contribution to the discussion concerning the variability of the third peroneal muscle: An anatomical analysis on the basis of foetal material. *Folia Morphologica* 65(4): 329–336.

Eliot, D., Jungers, L. (2000). Fifth metatarsal morphology does not predict presence or absence of fibularis tertius muscle in hominids. *Journal of Human Evolution* 38(2): 333–342.

Ercikti, N., Apaydin, N., Kocabiyik, N., Yazar, F. (2016). Insertional Characteristics of the Peroneus Tertius Tendon: Revisiting the Anatomy of an Underestimated Muscle. *Journal of Foot and Ankle Surgery* 55(4): 709–713.

Fessel, G., Frey, K., Schweizer, A., Calcagni, M., Ullrich, O., Snedeker, J. (2011). Suitability of Thiel embalmed tendons for biomechanical investigation. *Annals of Anatomy* 193(3): 237–241.

Gaulrapp, H., Heimkes, B. (1997). Peronaeus-tertius-plastik nach veralteter traumatischer ruptur der tibialis-anteriorsehne (Kasuistik). *Unfallchirurg* 100(12): 979–983.

Goss-Sampson, M. (2019). *Análisis estadístico con JASP. Una guía para estudiantes*. Barcelona: FUOC.

Hecker, P. (1922). Formation du Péronier anterieur chez un chimpanzé. *Archives of Anatomy, Histology and Embryology* 1: 147–155.

Hicks, J. (1956). The mechanics of the foot, IV. *Acta Anatomica* 27: 180–192.

Iceman, K., Magnus, M., Thompson, M., Abicht, B. (2020). Peroneus Tertius Syndrome: A Rare Cause of Anterolateral Ankle and Rearfoot Pain. *Journal of Foot and Ankle Surgery* 59(1): 131–135.

Iyer, K. (2020). The Leg. In: Iyer, K. and Khan, W. (eds.) *Orthopedics of the Upper and Lower Limb*. 2nd ed. New York: Springer.

Iyer, P. (2010). Bilateral absence of fibularis tertius: clinical implications and phylogeny. *International Journal of Anatomical Variations* 3: 170–172.

Jadhav, D., Ambali, P., Patil, R., Doshi, A., Priya, R. (2015). Fibularis tertius muscle: Cadaveric study in Indians. *Journal of Krishna Institute of Medical Sciences University* 4(1): 64–69.

Jana, R., Roy, T. (2011). Variant Insertion of the Fibularis Tertius Muscle Is an Evidence of the Progressive Evolutionary Adaptation for the Bipedal Gait. *Clinics and Practice* 1(4): 169–171.

Jaung, R., Cook, P., Blyth, P. (2011). A comparison of embalming fluids for use in surgical workshops. *Clinical Anatomy* 24(2): 155–161.

Johnson, D. (1973). *Tendon Variations of the Peroneal Musculature in Man.* PhD Thesis. Yale University. https://elischolar.library.yale.edu/ymtdl/2/?no_redirect=true [Accessed 01 June 2021].

Joshi, S., Joshi, S., Athavale, S. (2006). Morphology of peroneus tertius muscle. *Clinical Anatomy* 19(7): 611–614.

Jungers, W., Meldrum, D., Stern, J. (1993). The functional and evolutionary significance of the human peroneus tertius muscle. *Journal of Human Evolution* 25(5): 377–386.

Kaneff, A. (1980). Organogenesis of the human extensor digitorum longus and the peroneus tertius evaluated from the viewpoint of evolutionary myology. *Anatomischer Anzeiger* 148(2): 152–167.

Karauda, P., Paulsen, F., Polguj, M., Diogo, R., Olewnik, Ł. (2021). Morphological variability of the fibularis tertius tendon in human fetuses. *Folia Morphologica* 4: 1-14.

Keith, A. (1923). The adaptational machinery concerned in the evolution of man's body. *Nature* 112(2807): 257–268.

Kimura, K., Takahashi, Y. (1985). The Peroneus Tertius Muscle in the Crab-eating Monkey (Macaca fascicularis). *Okajimas Folia Anatomica Japonica* 62(10): 173–185.

Koshi, R. (2017). *Cunningham's manual of practical anatomy*. 16th ed. Oxford: Oxford University Press.

Krammer, E. B., Lischka, M. F. Gruber, H. (1979). Gross anatomy and evolutionary significance of the human peroneus III. *Anatomy and Embryology* 155(3): 291–302.

Lambert, H. (2016). Leg muscles. In: R. Tubbs, M. Shoja, M. Lucas (Eds.), *Bergman's comprehensive encyclopedia of human anatomic variation*. New Jersey: Wiley Blackwell.

Larico, I., Jordán, L. (2005). Frecuencia del músculo peroneo tertius. *Revista de Investigación e Información En Salud* 1: 29–32.

Lauth, T. (1798). *Elemens De Myologie Et De Syndesmologie*. Vol 2. Paris: Bale.

Litt, R., Albassir, A., Willems, S., Debry, R. (1989). Pathology of the anterior peroneus tendon and that of the intermetatarsal bone. *Acta Orthopaedica Belgica* 55: 485–489.

Loth, E. (1931). *Anthropologie des parties molles (muscles, intestins, vaisseaux, nerfs peripheriques)*. Paris: Masson and Cie.

Mabit, C., Pecout, C., Arnaud, J. (1996). Ligamentoplasty using the peroneus tertius in the correction of lateral laxity of the ankle. Surgical technique. *Revue de Chirurgie Orthopedique et Reparatrice de L'appareil Moteur* 82(1): 70–75.

Macalister, A. (1875). Additional Observations on Muscular Anomalies in Human Anatomy. (Third Series) With a Catalogue of the Principal Muscular Variations Hitherto Published. *The Transactions of the Royal Irish Academy Science* 25: 1–134.

Marin, L., Barbosa, F., Andrade, O., Bazanelli, A., Ruiz, C., Pereira, L., Wafaea, N. (2006). Estudo anatômico do músculo fibular terceiro em humanos. *Arquivos Médicos do ABC* 31(1): 23–26.

McGoldrick, N. P., Bergin, D., Kearns, S. R. (2017). Peroneus Tertius Tendon Tear Causing Lateral Ankle Pain in a Child. *Journal of Foot and Ankle Surgery* 56(4): 854–856.

Mehta, V., Gupta, V., Nayyar, A., Arora, J., Loh, H., Suri, R. K., Rath, G. (2011). Chef musculaire accessoire du peroneus tertius de la jambe - une variété anatomique rare avec implication clinique - utilité dans les reconstructions. *Morphologie* 95: 23–25.

Moore, K., Dalley, A., Agur, A. (2018). *Clinically Oriented Anatomy*. 8th ed. Philadelphia: Wolters Kluwer.

Morton, D. (1924). The peroneus tertius muscle in gorillas. *Anatomical Record* 27: 323–329.

Nayak, G. (2017). A Morphometric Analysis of Fibularis Tertius Muscle in Eastern Indian Population. *International Journal of Anatomy, Radiology and* Surgery 6(4): 23–25.

Office for National Statistics. (2019). *Population estimates*. https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/annualmidyearpopulationestimates/mid2020 [Accessed 15 June 2021].

Okuda, S. (1953). Morphological studies on the muscles of the lower extremities in the Macaca Thesus. *Nihon University Journal of Medicine* 12: 435–447.

Olewnik, Ł. (2019). Fibularis Tertius: Anatomical Study and Review of the Literature. *Clinical Anatomy* 32(8): 1082–1093.

Olumide, J., Iretiolu, O., Adebayo, O., Okoliko, V., Adebo, M. (2013). Surface anatomy and prevalence of fibularis tertius muscle in a south-western Nigerian population. *Forensic Medicine and Anatomy Research* 1(2): 25–29.

Ottone, N. E., Vargas, C. A., Fuentes, R., Del Sol, M. (2016). Walter Thiel's embalming method. Review of solutions and applications in different fields of biomedical research. *International Journal of Morphology* 34(4): 1442–1454.

Oyedun, O., Kanu, L., Onatola, O., Zelibe, P. (2014). Does Peroneal tertius in absentia affect the range of motion of foot dorsiflexion and eversion? A kinesio-anatomical study. *Advances in Life Science and Technology* 21: 69–76.

Ozkan, T, Tuncer, S., Ozturk, K., Aydin, A., Ozkan, S. (2009). Tibialis posterior tendon transfer for persistent drop foot after peroneal nerve repair. *Journal of Reconstructive Microsurgery 25*(3): 157–164.

Ozkan, T., Tunçer, S., Oztürk, K., Aydin, A., Ozkan, S. (2007). Surgical restoration of drop foot deformity with tibialis posterior tendon transfer. *Acta Orthopaedica et Traumatologica Turcica* 41(4): 259–265.

Palomo-López, P., Losa-Iglesias, M. E., Calvo-Lobo, C., Rodríguez-Sanz, D., Navarro-Flores, E., Becerro-de-Bengoa-Vallejo, R., López-López, D. (2019). Fibularis tertius muscle in women and men: A surface anatomy cross-sectional study across countries. *PLoS ONE* 14(4): 1-10.

Peterson, J., Smith, R. (2013). *Introductory Technical Mathematics*. 6th ed. New York: Delmar.

Raheja, S., Choudhry, R., Singh, P., Tuli, A., Kumar, H. (2005). Morphological description of combined variation of distal attachments of fibularis in a foot. *Surgical and Radiologic Anatomy* 27(2): 158–160.

Ramirez, D., Gajardo, C., Caballero, P., Zavando, D., Cantín, M., Galdames, I. (2010). Evaluación clínica de la prevalencia del músculo fibular tercero. *International Journal of Morphology* 28(3): 759–764.

Reimann, R. (1981). Variable extensor apparatus of the small toe. Opposing muscle groups in competition for extensor function of the fifth involutional metacarpal ray of the lower extremity. *Gegenbaurs Morphologisches Jahrbuch* 127(2): 188–209.

Rourke, K., Dafydd, H., Parkin, I. (2007). Fibularis tertius: revisiting the anatomy. *Clinical Anatomy* 20(8): 946–949.

Rouvière, H., Delmas, A. (2005). *Anatomía Humana. Descriptiva, topográfica y funcional.* 11th ed. Paris: Masson.

Salem, A., Abdel, G., Almallah, A., Hussein, H., Abdel, A., Behbehani, N., Nedham, F., Nedham, A., Almarshad, R., Alshammari, M., Amer, H., Hasan, W., Alyaseen, F., and Mohammed, E. (2018). Variations of peroneus tertius muscle in five Arab populations: a clinical study. *Translational Research in Anatomy* 13, 1–6.

Sammarco, G., Henning, C. (2007). Peroneus tertius muscle as a cause of snapping and ankle pain: A case report. *American Journal of Sports Medicine* 35(8): 1377–1379.

Sarıkaya, I., Ertan, S., Şeker, A., Erdal, O., Görgün, B., Inan, M. (2020). The split transfer of tibialis anterior tendon to peroneus tertius tendon for equinovarus foot in children with cerebral palsy. *Acta Orthopaedica et Traumatologica Turcica* 54(3): 262–268.

Sawant, S., Shaikh, S., More, R. (2012). The absence of peroneus tertius muscle on the dorsum of the foot. *International Journal of Biological and Medical Research* 3(4): 2633–2635.

Saxena, A., Ray, B., Mishra, S., Perumal, V. (2013). A cadaveric report of unilateral fibularis tertius in absentia: a clinical perspective. *International Journal of Anatomical Variations* 6: 20–21.

Sirasanagnadla, S., Bhat, K., Nayak, S., Shetty, P., Thangarajan, R. (2014). A rare case of variant morphology of peroneus tertius muscle. *Journal of Clinical and Diagnostic Research* 8(10): 1–2.

Snell, R. (2012). *Clinical Anatomy by Regions*. 9th ed. Philadelphia: Lippincott Williams and Wilkins.

Sokołowska-Pituchowa, J., Miaśkiewicz, C., Skawina, A., Makoś, K., Gorczyca, J. (1979). The third peroneal muscle in human fetuses. *Folia Morphologica* 38: 489–498.

Spinner, R., Krych, A., Bernard, C. (2020). Knee and leg. In: Standring, S. (Ed.) *Anatomy. The anatomical Basis of Clinical Practice*. 42nd ed. Amsterdam: Elsevier.

Stevens, K., Platt, A., Ellis, H. (1993). A Cadaveric Study of the Peroneus Tertius Muscle. *Clinical Anatomy 110*(5): 106–110.

Straus, W. (1930). The foot musculature of the Highland Gorilla (Gorilla beringei). *The Quarterly Review of Biology 5*: 261–317.

Taşer, F., Shafiq, Q., Toker, S. (2009). Coexistence of anomalous m. peroneus tertius and longitudinal tear in the m. peroneus brevis tendon. *Eklem Hastaliklari ve Cerrahisi* 20(3): 165–168.

Testut, L., Latarjet, A. (1984). *Anatomía Humana*. 9th ed. Madrid: Salvat Editores.

Testut, L., Latarjet, A. (1959). *Compendio de anatomía descriptiva*. Madrid: Salvat Editores.

Ughame, J., Kardile, P. (2018). Anatomical study of Peroneus tertius. *Scholars Journal of Applied Medical Sciences* 6(10): 4100–4105.

Valerius, K., Frank, A., Kolster, B., Hamilton, C., Alejandre, E., Kreutzer, R. (2011). *The muscle book*. Berlin: Quintessence Publishing.

Van de Graaf, K. (2002). *Human Anatomy*. 6th ed. New York: McGraw-Hill.

Verma, P., Seema. (2015). Analysis of Fibularis Tertius in Terms of Frequency, Morphology, Morphometry and Clinical Significance in North Indian Cadavers. *International Journal of Anatomy and Research* 3(4): 1646–1650.

Vertullo, C., Glisson, R., Nunley, J. (2004). Torsional strains in the proximal fifth metatarsal: Implications for Jones and stress fracture management. *Foot and Ankle International* 25(9): 650–656.

Vieira, A., Monteiro, A., Nacur, F., Coutinho, R., Direito, T., Torres, D. (2018). Prevalence and Topography of the Peroneus tertius Muscle: A Study of Human Cadavers. *Journal of Morphological Sciences* 35(2): 106–109.

Wells, L. (1935). A Peroneus Tertius Muscle in a Chacma Baboon (Papio porcarius). *Journal of Anatomy* 69(4): 508–514.

Werneck, H. (1957). Contribuição para o estudo de alguns aspectos morfológicos do m. fibularis tertius em brancos, negros e mulatos, com pesquisa in vivo da presença de seu tendão. *Anais Da Faculdade de Medicina Da Universidade Federal de Minas Gerais* 17: 417–520.

Witvrouw, E., Vanden Borre, K., Willems, T., Huysmans, J., Broos, E., De Clercq, D. (2006). The significance of peroneus tertius muscle in ankle injuries: A prospective study. *American Journal of Sports Medicine* 34(7): 1159–1163.

Wood, J. (1868). Variations in Human Myology Observed during the Winter Session of 1867-68 at King's College, London. In *Proceedings of the Royal Society of London, 1867 – 1868.* Vol. 16. London: The Royal Society Publishing.

Wood Jones, F. (1943). *Structure and function as seen in the foot*. Paris: Baillière, Tindall and Cox.

Yammine, K., Erić, M. (2017). The Fibularis (Peroneus) Tertius Muscle in Humans: A Meta-Analysis of Anatomical Studies with Clinical and Evolutionary Implications. *Biomedical Research International* 2017: 1-12.

Yildiz, S., Yalcin, B. (2012). A unique variation of the peroneus tertius muscle. *Surgical and Radiologic Anatomy* 34(7): 661–663.

Zwirner, J., Koutp, A., Vidakovic, H., Ondruschka, B., Kieser, D. C., Hammer, N. (2021). Assessment of plantaris and peroneus tertius tendons as graft materials for ankle ligament reconstructions – A cadaveric biomechanical study. *Journal of the Mechanical Behavior of Biomedical Materials* 115: 1-8.