Original Communication

PREVALENCE OF FIBULARIS TERTIUS IN A SCOTTISH POPULATION: A DISSECTION STUDY

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ABSTRACT

Fibularis tertius (FT) is a muscle of the anterior compartment of the leg that is considered inconstant, whose reported prevalence varies widely among populations. The current work aims to determine the prevalence of FT in a Scottish population. Forty-four caucasian cadavers of Scottish origin (88 lower limbs; 19 females, 25 males; age at death: 81.8 ± 11.2 years), preserved using the Thiel soft-fix embalming method were analyzed. The absence of FT was observed in 5 of the cadavers studied (11.4%). In four male cadavers the absence was verified unilaterally; in one female cadaver the absence was verified bilaterally. Taking into account the total number of lower limbs, FT was absent from 6.8% of cases, determining a total prevalence of 93.2%. There were no significant differences in the presence or absence of FT when comparing lower limbs of female vs male cadavers (p = 0.614). In three of the four cadavers in whom the unilateral absence of FT was verified, an accessory tendon in that side of the body was observed, in all cases with origin in the tendon of the extensor digitorum longus to the 5th toe. The present study confirms, for the Scottish population, the high prevalence of FT. These findings, in conjunction with its anatomical characteristics and its potential functional importance during gait in humans, would lead to considering FT as constant, being its absence a variation.

Key words: *peroneus tertius; Thiel-embalmed cadavers; Scottish population; inconstant muscle.*

RESUMEN

Fibularis tertius (FT) es un músculo del compartimiento anterior de la pierna considerado inconstante, cuya prevalencia reportada varía ampliamente entre distintas poblaciones. El propósito del presente trabajo es determinar la prevalencia de FT en una población escocesa. Se analizaron 44 cadáveres caucásicos de origen escocés (88 miembros inferiores; 19 mujeres, 25 hombres; edad al fallecimiento: 81.8 ± 11.2 años), preservados utilizando la técnica de embalsamiento de Thiel. La ausencia de FT se constató en 5 de los cadáveres estudiados (11.4%), en forma unilateral en cuatro cadáveres masculinos, y en forma bilateral en un cadáver femenino. Considerando el número total de miembros inferiores analizados, la ausencia de FT se observó en 6.8% de los casos, determinando una prevalencia total de 93.2%. No hubo diferencias significativas en la presencia o ausencia de FT al comparar los miembros inferiores de cadáveres masculinos vs femeninos (p = 0.614). En tres de los cuatro cadáveres con ausencia unilateral de FT, se observó un tendón accesorio con origen ipsilateral en el tendón del músculo extensor digitorum longus hacia el quinto dedo. El presente estudio confirma, para la población escocesa, la alta prevalencia de FT. Estos hallazgos, aunados a sus características anatómicas y su potencial importancia para la marcha en humanos, deberían llevar a considerar a FT como un músculo constante, siendo su ausencia una variante.

Palabras clave: *músculo peroneus tertius; cadáveres conservados con Thiel; población escocesa; músculo inconstante.*

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INTRODUCTION

Fibularis tertius (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 (Das et al., 2009; Moore et al., 2018). From this insertion, its fibers run distally and anteriorly. Its tendon, running obliquely and laterally to the more lateral tendon of extensor digitorum longus (EDL), inserts distally into the dorsal tubercle and shaft edge of the 5th metatarsal bone and, frequently, into the fascia covering the 4th interosseous space (Eliot and Jungers, 2000; Ercikti et al., 2016).

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 12.2% (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 fibers 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.

FT is characterized 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). In addition, 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) (Table 1). 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).

No previous published work analyzing the prevalence of FT in a Scottish population has been found. Taking this into consideration, the current study aims to determine the prevalence of FT in a Scottish sample of Thiel embalmed adult cadavers of both sexes. The information obtained is of academic and clinical interest, and allows comparison with similar studies carried out on samples from other countries.

MATERIALS AND METHODS

This project was conducted at the Centre for Anatomy and Human Identification (CAHID), University of Dundee, Scotland, and complied with the Human Tissue Act Scotland (2006; updated 2019) regulations. Data collection was completed between March and May 2021

Subjects: The research involved the dissection and analysis of 44 caucasian cadavers (88 lower limbs) (19 females, 25 males; age at death: 81.8 ± 11.2 years) of Scottish origin, preserved using the Thiel soft-fix embalming method. The cause of death was in all cases not related to the leg and foot anatomical structures. All limbs were free of any damage that could potentially affect the presence or absence of FT.

Procedures: The cadavers had previously been used in anatomical dissection classes. Notwith-standing 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. In case of absence, it was

recorded whether it was unilateral or bilateral, as well as the sex of the corresponding cadaver.

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 prevalence of FT and sex. In all cases, a p-value ≤ 0.05 was considered significant. Quantitative variables are presented as mean ± SD.

Author/s	Population	Lower limbs	Type of Study	Prevalence
Adachi (1909)	Japanese	938	Cadaver dissection	95.5
Afroze et al. (2020)	Indian	66	Cadaver dissection	100
Bertelli and Khoury (1991)	French	44	Cadaver dissection	90.9
Chatyingmongkol et al.	Thai	247	Cadaver dissection	95.55
de Gusmão et al. (2013)	Brazilian	64	Cadaver dissection	96.9
Jadhav et al. (2015)	Indian	100 (100M)	Cadaver dissection	87
Joshi et al. (2006)	Indian	220	Cadaver dissection	89.55
Nakano (1923)	Chinese	84 (12F; 72M)	Cadaver dissection	89.3
Nayak (2017; 2021)	Eastern Indian	100	Cadaver dissection	100
Olewnik (2019)	Caucasian	106 (55F; 51M)	Cadaver dissection	85.8
Olumide et al. (2013)	Nigerian	200 (106F; 94M)	Palpation	63.0
Palomo-López et al. (2019)	Spanish	962 (736F;	Palpation	38.25
Ramirez et al. (2010)	Chileans	336 (200F;	Palpation	49.11
Rourke et al. (2007)	British	82 (38F; 44M)	Cadaver dissection	92.7
Salem et al. (2018)	Bahraini	439 (280F;	Palpation	42.0
Salem et al. (2018)	Saudi	208 (109F; 99M)	Palpation	38.5
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;	Palpation	52.8
Stevens et al. (1993)	British (East	40 (20F; 20M)	Cadaver dissection	95.0
Verma and Seema (2015)	Indian	60 (4F; 54M)	Cadaver dissection	100
Vieira et al. (2018)	Brazilian	32 (6F; 26M)	Cadaver dissection	93.75
Witvrouw et al. (2006)	Belgian	200 (100F;	Palpation	81.5

Table 1-. Prevalence of FT in different adult populations. Abbreviations: FT = fibularis tertius; F = female; M = male

RESULTS

An absence of FT (in at least one of both lower limbs) was observed in 5 out of the 44 cadavers studied (11.4%). 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 (Fig. 1). Taking into account the total number of lower limbs dissected, FT was absent from 6.8% of cases, therefore determining a total prevalence of 93.2%. 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 2).

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 had its distal insertion in the head of the 5th metatarsal bone. In the second case, the tendon was directed towards the fascia between the 4th and 5th metatarsal bones. In the third case, the accessory tendon was distally inserted at the base of the 1st phalanx of the 5th toe (Fig. 2). 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.

Figure 1- 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.

Presence of FT	Sex		
	Male	Female	Total
Present	46	36	82
Absent	4	2	6
Total	50	38	88
p-value	0.614		

Table 2- *Presence of FT according to sex Abbreviations:* FT = *fibularis tertius*. Test applied: contingency tables with the Chi^2 test

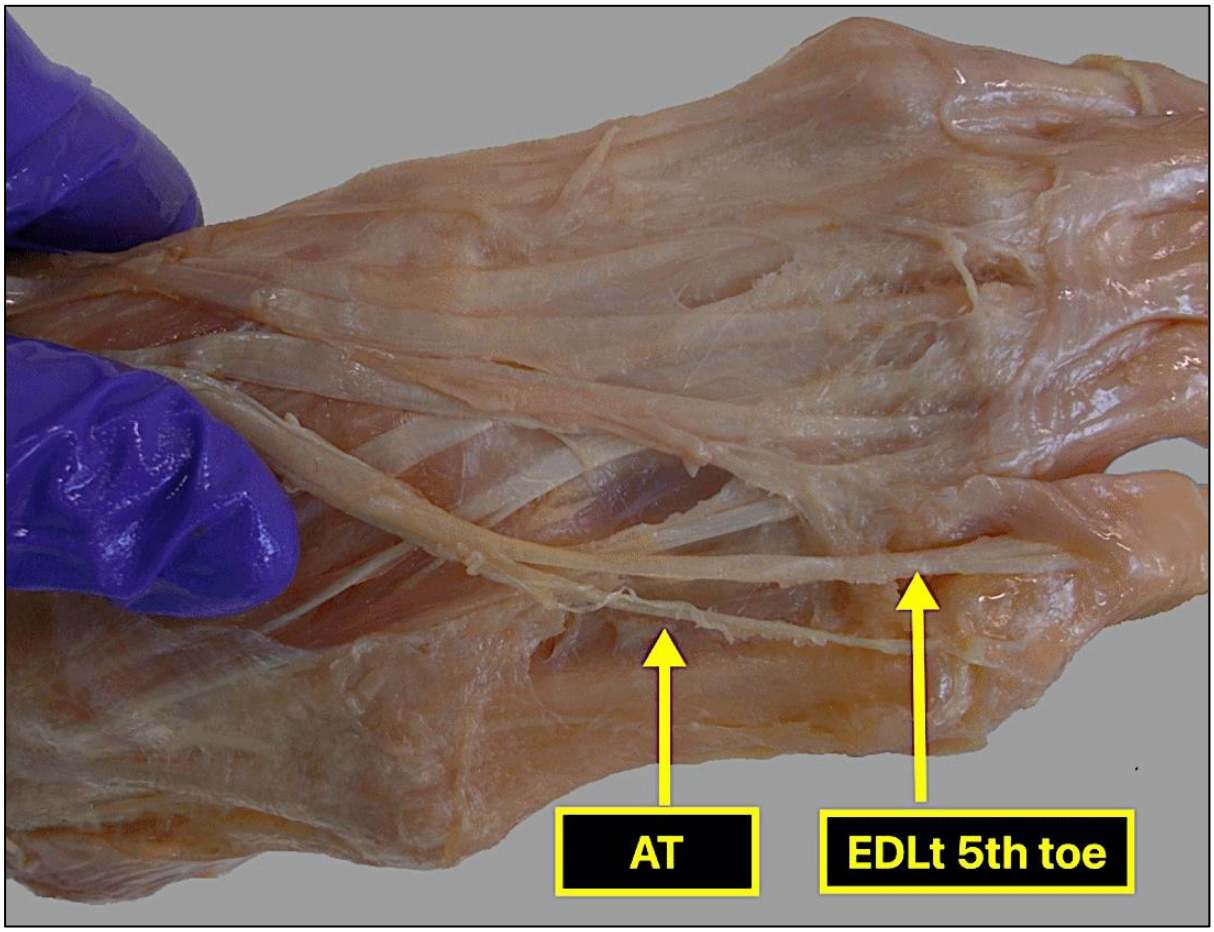

Figure 2- Accessory tendon of EDL. In this specimen the *fibularis tertius* muscle is absent; from the tendon of the extensor digitorum longus to 5th toe arises an accessory tendon, directed to the base of the proximal phalanx of the same toe, with a band-shaped insertion. Right lower limb of a male individual. Abbreviations: AT = accessory tendon; EDLt = tendon of the extensor digitorum longus muscle to 5th toe.

DISCUSSION

In the present study, the prevalence of FT was analyzed in a sample of adult cadavers of Scottish origin. No other similar works realized in this population and using Thiel-embalmed corpses were found in the scientific literature, providing a novel aspect to the present study. Furthermore, there are scarce anatomical dissection works addressing FT where both extremities of the same cadaver have been analyzed, since most of the observations were performed only on isolated lower extremities (Rourke et al., 2007).

Considering the total sample of lower limbs, 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 analyzed a very similar number of cadavers (41 vs 44, respectively). This result indicates that, for the population studied, FT is present in the vast majority of subjects; although in a minority of cases it may be completely absent, bilaterally or unilaterally.

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. Although some currently used anatomy textbooks consider this muscle as inconstant (Latarjet and Ruiz-Liard, 2019; Moore et al., 2018; Rouvière and Delmas, 2005), some academics suggest that it is more appropriate to consider it a constant muscle, with its missing being a variation (Marin et al., 2006; Krammer et al., 1979). Nevertheless, 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).

Table 1 compares the prevalence found in the current study with other studies carried out in adults of different populations. As can be noticed, the prevalence reported when the method used was anatomical dissection is systematically higher than that reported in studies where the method of determination was in vivo palpation technique. 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 is also in agreement with Yammine and Erić (2017), who in a meta-analysis work found an average prevalence of 80% vs 93% when the technique used was in vivo palpation or dissection, respectively. According to these authors, the difference could be due to the difficulty, by palpation, of separating the fibularis tertius tendon (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% accuracy 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).

The prevalence found in the current study was also higher than that reported in studies that analyzed human fetuses (Table 3). 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 analyzed more developed specimens.

Author/s	Population	Lower limbs	Age of gestation (weeks)	Prevalence (%)
Albay and Candan (2017)	Turkish	200 (92F; 108M)	13 - 40	80
Domagała et al. (2006)	Poland	386 (194F; 192M)	12 - 36	83.16
Karauda et al. (2022); Ruzik et al. (2022)	Poland	100 (62F; 38M)	18 - 38	50
Sokołowska-Pituchowa et al. (1979)	Poland	84	Crown-rump length between 112 and 236 mm	78.6

Table 3- Prevalence of FT in human fetuses Abbreviations: FT = fibularis tertius; F = female; M = male

Interestingly, 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 it bilaterally in 1 case (20%) and unilaterally in the rest of the individuals (80%).

On the other hand, in the study conducted by Chatyingmongkol et al. (2004) in Thai population, 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. It should be mentioned that the percentage of bilateral absence could be even higher, given that only one of the lower limbs was dissected in 41 of the 144 cadavers studied. While this could indicate a possible difference between the Thai and other populations, the results should be carefully considered, given the limited number of lower limbs in which the absence of FT was ascertained.

According to Spinner et al. (2020) 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.

Regarding the prevalence of FT in relation to sex, in the present work, and in line with the findings reported by Palomo-López et al. (2019), there was no significant difference 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.

There is no consensus among authors on the functional importance of FT; concomitantly, the potential detrimental effect on the functionality of the ankle and foot joints caused by its absence, has not been fully elucidated. Some 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 (Bourdon and Petitdant, 2012; Oyedun et al., 2014; 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).

The present study confirms, for the Scottish population, the high prevalence of FT. Its almost constant presence and morphological characteristics would lead to considering FT as a constant muscle, being its absence a variation. In addition, its near exclusivity to the human species could indicate, from an evolutionary point of view, the functional importance of this muscle for humans. This last issue has not been fully elucidated, and further studies in this area seem to be necessary.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Ethical Approval

The dissections on variations in the *fibularis tertius* muscle that form part of the current work

were carried out in full compliance with local Scottish legislation – the Anatomy Act 1984 and the Human Tissue (Scotland) Act 2006. All donors bequeathed their bodies for medical education and research, under the auspices of Scottish anatomical legislation

Informed Consent
It does not correspond.

Contributions
A.P.: project design, data collection, statistical analysis and manuscript redaction. C.L.: project design and manuscript redaction.

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