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Morphological variability of the fibularis tertius tendon in human fetuses

P. Karauda et al., Fibularis tertius

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Abstract

Background: In adults, the fibularis tertius (FT) demonstrates great morphological variation. The present study classifies the types of FT insertion in human fetuses and compares their prevalence to the prevailing classification among adults.

Materials and methods: Fifty spontaneously-aborted human fetuses (19 male, 31 female, 100 upper limbs in total) aged 18-38 weeks of gestation at death were examined. The fetuses were obtained from spontaneous abortion after parental consent. The study was performed in accordance with the legal procedures in force in Poland and with the Donation Corpse program for both adults and fetuses.

Results: The most common type of FT found was Type VI (32%), characterized by a bifurcated distal attachment: a main tendon inserting onto the base of the fourth metatarsal bone, and accessory bands inserting onto the fourth interosseous space. Five other types were observed: Type IV (20%), with a single tendon inserting distally to the fascia covering the fourth interosseous space; Type I (18%), with a single tendon inserting distally onto the shaft

of the fifth metatarsal bone; Type V (14%), with a bifurcated arrangement comprising a main tendon characterized by a very wide insertion onto the base of the fifth metatarsal bone and an accessory band inserting onto the base of the fourth metatarsal bone; and Type III (12%) with a single tendon inserting distally onto the shaft of the fourth metatarsal bone and fascia covering the fourth interosseous space. Finally, Type II (4%) was characterized by a single tendon inserting onto the base of the fifth metatarsal bone via a very wide distal insertion.

Conclusions: The fibularis tertius demonstrates high morphological variability, with the most common configuration found in adults — a single insertion onto metatarsal 5 — being actually uncommonly found in fetuses.

Keywords: fibularis tertius, fibularis tertius tendon, anatomical variations, new classification, fetuses, variations, development

INTRODUCTION

The anterior compartment of the leg contains four muscles: the tibialis anterior, the extensor hallucis longus, extensor digitorum longus and the fibularis tertius muscle (FTM). Of this group of muscles, the FTM is the most superficial; it usually originates from the distal third or half of the fibula and of the intermuscular septum. The fibers of the muscle belly pass vertically downward until the muscle belly becomes the fibularis tertius tendon (FTT). After passing under the superior extensor retinaculum and inferior extensor retinaculum of the foot in the same canal as the extensor digitorum longus, the FTT inserts into the dorsal surface of the base of the fifth metatarsal bone [19]

In adults, the fibular muscle is characterized by frequent morphological variations, which mainly involve the presence of additional bands or muscles such as the fibularis digiti quinti and fibularis quartus [4, 5, 24, 25, 27–29, 33, 37]. The fibularis longus, fibularis brevis and fibularis tertius often demonstrate additional bands; this criterion also forms the basis of the adult classification by Olewnik et al. [24, 25, 27]. Earlier studies on fetal volatility of morphological variation in FTM are based on proximal attachment [11].

The FTM is used as a reference for the anterolateral aspect/portal during ankle arthroscopy [37]. The fibularis brevis and FTT insert at the fifth metatarsal; this implies that

they can place torsional stress on areas where Jones fractures and stress fractures occur [35]. The FTM can be used in tendoplasty, tendon transfer, or resection surgeries on the foot.

The goal of our present work was to classify the types of FT insertion in human fetuses and compare the results with those observed in the prevailing classification among adults. It will establish the first such classification for human fetuses.

MATERIALS AND METHODS

Permission for the study was granted by the Local Bioethics Commission (agreement no RNN/130/20/KE). Fifty spontaneously-aborted human fetuses (19 male, 31 female, 100 lower limbs) aged 18-38 weeks of gestation at death were examined. The fetuses were obtained from spontaneous abortion after parental consent. The study was performed in accordance with the legal procedures in force in Poland and in accordance with the Donation Corpse program for both adults and fetuses. Their ages were determined on the basis of cranio-sacral and head measurements [26].

The leg and foot area was dissected as described previously [21–23, 25]. The procedure began with the removal of the skin and superficial fascia of the leg up to the crural fascia. The skin and subcutaneous tissue of the foot were then removed, and then as much of the crural fascia as possible was removed without tearing the muscle bellies (starting proximal to the retinaculum). The bellies and muscle tendons were then cleaned from the medial to the lateral side. The tendon was carefully dissected to the bone attachment itself. The course of each tendon was recorded.

Upon dissection, the following features of the FT were recorded:

- The type of FT insertion;
- FT morphometric measurements.

Measurements were taken using an electronic digital caliper (Mitutoyo Corporation, Kawasaki-shi, Kanagawa, Japan) with an accuracy of up to 0.1 mm. Two measurements were taken in each case and the mean values were recorded.

Ethical approval and consent to participate

The cadavers belonged to the Department of Anatomical Dissection and Donation, Medical University of Lodz.

Statistical analysis

Differences in tendon types between genders and bodysides were tested using the Chi² test. The normality of the continuous data was tested using the Shapiro-Wilk test. As the data was not normally distributed, non-parametrical tests were used. Morphological measurements between two groups were compared using the Mann-Whitney test, and measurements between EHL types were compared using the Kruskal-Wallis test by ranks with dedicated *post hoc* test.

All statistical analyses were performed using Statistica 13 software (StatSoft Polska, Cracow, Poland). A p-value lower than 0.05 was considered significant, with Bonferroni correction for multiple testing. The results are presented as mean and standard deviation unless otherwise stated.

RESULTS

The fibularis tertius muscle was present in 50 cases (31 females and 19 males, $p=0.0278$; 26 right and 24 left limbs, $p=0.8415$). It occurred significantly more often in specimens with shorter lower legs (56.2 ± 7.2 mm vs. 88.0 ± 18.9 mm, $p<0.0001$) but with greater cranio-sacral length (247.2 ± 33.05 mm vs. 226.76 ± 39.90 mm, $p<0.0172$).

It was classified according to the following types, based on type of distal insertion:

- Type I — single distal attachment. The tendon inserts into the shaft of the fifth metatarsal bone – Fig. 1. This type was found in nine cases.
- Type II — single distal attachment. The tendon is characterized by a very wide insertion into the base of the fifth metatarsal bone. This type was observed in two cases – Fig. 1.
- Type III — single distal attachment. The tendon inserts into the shaft of the fourth metatarsal bone and fascia covering the fourth interosseous space. This type was found in six cases – Fig. 1.
- Type IV — single distal attachment. The tendon inserts to the fascia covering the fourth interosseous space. This type was found in 10 limbs – Fig. 1.
- Type V — bifurcated distal attachment. The main tendon is characterized by a very wide insertion into the base of the fifth metatarsal bone, and the accessory band inserts into the base of the four metatarsal bone. This type was observed in seven lower limbs – Fig. 1.

— Type VI — bifurcated distal attachment. The main tendon inserts into the base of the fourth metatarsal bone, and the accessory bands inserts into the fourth interosseous space. This type was found in 16 cases – Fig. 1.

All types are also shown in the diagram - Fig. 7.

Table 1 presents the morphological parameters for the whole group and according to the above types.

Where possible, the type of insertion morphology was classified as band-shaped (18 cases in general) or fan-shaped (27 cases in general). The distribution of these types is presented in Table 2.

Table 1. Morphological parameters according to type of insertion.

Parameter	General	Insertion type						P
		I	II	III	IV	V	VI	
Muscle length	12.99 (4.29)	13.63 (2.44)	11.32 (1.01)	10.78 (0.93)	11.65 (0.96)	15.35 (4.71)	14.02 (6.39)	0.2080
Tendon width MTJ	0.85 (1.51)	0.61 (0.33)	0.62 (0.08)	0.21* (0.03)	0.26* (0.07)	1.01* (0.22)	1.56* (2.52)	0.0002*
Tendon thickness MTJ	0.18 (0.16)	0.13 (0.08)	0.22 (0.01)	0.19 (0.24)	0.09 (0.05)	0.18 (0.08)	0.26 (0.21)	0.0163
Tendon length	11.40 (3.12)	11.14 (2.01)	12.09 (1.36)	11.60 (0.58)	13.58* (1.85)	9.64* (3.84)	10.79 (4.04)	0.0050*
Acc. tendon length	9.30 (2.95)					5.61 (0.23)	11.15 (0.92)	0.1051
Distance from ExP	3.57 (1.12)	2.54 (0.62)	3.31 (1.00)	4.63 (0.28)		3.38 (1.45)	3.75 (0.95)	0.0179
ExP width	1.05 (0.39)	0.77 (0.15)	1.09 (0.01)	1.35 (0.15)		1.03 (0.56)	1.06 (0.39)	0.0537
ExP thickness	0.28 (0.84)	0.12 (0.05)	0.10 (0.01)	0.13 (0.08)		0.83 (1.74)	0.11 (0.06)	0.2262
ExP width	2.12 (0.64)	1.69 (0.68)	1.94 (1.05)	2.51 (0.16)		2.54 (0.57)	1.90 (0.58)	0.0718
ExP	0.22	0.14	0.61	0.14		0.28	0.18	0.5020

thickness	(0.21)	(0.06)	(0.73)	(0.06)		(0.21)	(0.07)	
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MTJ – Musculo-tendinous junction; Acc – accessory, Significant P according to Bonferroni Correction was 0.005.

Table 2. Shape of distal tendon insertion according to insertion type.

Insertion type	Insertion shape [n (%)]	
	Fan	Band
I	5 (18.5)	3 (16.7)
II	1 (3.7)	0 (0.0)
III	6 (22.2)	0 (0.0)
IV	0 (0.0)	10 (55.6)
V	7 (25.9)	0 (0.0)
VI	8 (29.6)	5 (27.8)

DISCUSSION

The present study has two key values. It presents the first systematic classification of FT insertion, and highlights its variability, classifying it as band-shaped or fan-shaped in human fetuses. Earlier studies did not describe such a large morphological variability of FT insertion in human fetuses.

To understand the potential morphological variation of the FTM, it is important to explain embryological basis. The common extensor mass of the foot is connected with the peroneal mass in the early stages of development, but these diverge in a 14-mm embryo: the extensor mass has differentiated into the tibialis anterior muscle, extensor digitorum longus, and extensor hallucis longus. The tibialis anterior muscle demonstrates a broad tendon reaching the cuneiforme primum bone. It demonstrates adult attachments in a 20-mm. embryo. The extensor digitorum longus is differentiated from the central portion of the muscle mass and is relatively more on the fibular side than in the adult. At first it ends distally in a broad flat plate which later, in a 20-mm. embryo, gives off the broad tendons to the digits. The FTM is early distinct from the extensor digitorum longus.

The FTM varies in its development and the nature of its origin and insertion. The FTM is topographically very closely related to the extensor digitorum longus, and there is every evidence that it is formed as a secondary attachment of the deep extensor stratum, which has

migrated in an upward direction and has separated from the extensor digitorum brevis. In this sense, it may represent a missing tendon for the fifth toe, which became an independent muscle following migration in response to the specialized functional requirements of the human foot [14]. Therefore, it, like the foot to which it belongs, the FTM must be an idiosyncratic feature that evolved early in human phylogenetic development [11]: it is very rare in the great apes but is found in about 29.6% of gorillas (terrestrial apes). Its overwhelming presence in both humans and gorillas, and its lack or rarity in the great apes, would indicate an evolutionary acquisition related to *bipedalism* [37][6–10]. Hence, from an evolutionary point of view, FTM most likely serves a very important function when walking. Therefore, any morphological changes in insertion may indicate that they have not yet reached the final evolutionary stage; the FTM has been found to have a range of insertion types, and to display accessory bands [24].

Among adults, the presence or absence of the FTM depends on the population studied. The widest range in its prevalence has so far been observed in Asian populations, ranging from 38.5% to 95.5% [1, 13, 14, 20, 32]. In North Africa, it was present in 52.8% of an Egyptian population and 67.7% of a Tunisian population [32]. In South America, it was present in 49.1%, 100% [30] and 93.8% of Brazilian populations [18], and interestingly, in 100% of a studied Bolivian population [16, 18, 30]. European population ranked between 38.2% and 92.9% [3, 15, 17, 24, 31, 36].

In the fetus, the FTM was found to be present in only 83.16% of cases in a Polish population [11]. Interestingly, our present findings, also obtained from Polish fetuses, found it to be present in only 50%.

Many FT classifications have been described [12, 14, 31, 34]. However, the most recent classification was the six-fold classification (I-VI) proposed by Olewnik [24]. Briefly, Type I (45%), i.e. a single distal attachment inserting into the shaft of the V metatarsal bone [24], was observed in 18% of cases in the present study; Type II (22%), with a single, broad distal attachment insertion to the base of the V metatarsal bone [24], was present in 4%. Type III (16.5%), characterized by a single, very wide distal attachment to the base of the V metatarsal bone, and to the base and shaft of the IV metatarsal bone, and to the fascia covering the fourth interosseous space [24], was not observed in the current study. It is possible that it appears at a later date - tendon dehiscence can occur postnatally. In addition, Type IV (8.8%), characterized by a bifurcated distal attachment into the base of the fifth metatarsal bone, and the accessory band inserts to the shaft of the V metatarsal bone, was not observed. Type V (5.5%), characterized by a bifurcated distal attachment, the main tendon

having a very wide insertion to the base of the V metatarsal bone, and the accessory band inserting to the base of the IV metatarsal bone[24]. In addition, Type VI, characterized by fusion with fibularis brevis tendon, was not observed by us either.

Interestingly, of the tendon types proposed in the present study, Type III, with a single distal attachment into the shaft of the fourth metatarsal bone and fascia covering the fourth interosseous space, was not observed in studies on adults, nor in fetal studies [11]. Similarly, Type IV, characterized by single distal attachment and tendon inserts to the fascia covering the fourth interosseous space, was not recorded by either Olewnik [24] in adults or Domagała et al. [11] in fetuses. Type V, with a bifurcated distal attachment where the main tendon has a very wide insertion into the base of the fifth metatarsal bone, and the accessory band inserts into the base of the four-metatarsal bone, was not found previously. Interestingly, Type VI has not been observed in other studies, despite being the most frequent type (32%); this was characterized by a bifurcated distal attachment where the main tendon inserts into the base of the fourth metatarsal bone, and the accessory bands inserts into the fourth interosseous space. Albay et al. [2] also did not describe the morphological variability of fibularis tertius tendon, focusing only on the assessment of the incidence of additional fibular muscles.

Albay et al. [2] performed morphometric measurements of FT depending on trimesters. In the second trimester, the average muscle belly length was 19.18 mm, and the tendons were 12.13 mm. In the third trimester, the muscle belly was 30.26 mm, and the tendon was 15.68 mm. Our research focused on morphometric measurements depending on the type of insertion. And the longest muscle belly was type V (15.35 mm) and the shortest was type III (10.78 mm). The tendon length was the longest in type IV (13.59 mm), and the smallest in type V (9.64 mm).

A second feature in our proposed classification is insertion type. Both band-shaped and fan-shaped types were observed. Interestingly, although the presence of a band-shaped or fan-shaped type was closely correlated with the corresponding type of insertion in adults [24], no such a correlation was observed in the present study. This might be an important consideration when stripping tendons during surgery.

CONCLUSIONS

We propose a six-fold classification that can be used to elucidate the appearance of accessory tendon bands. The fibularis tertius demonstrates high morphological variability, with the most common configuration found in adults - a single insertion onto metatarsal 5 - being actually uncommonly found in fetuses.

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Figure 1. Types of the fibularis tertius tendon, I Type I of the fibularis tertius tendon.

Right leg. *FT* fibularis tertius *EDL* extensor *VCB* fifth metatarsal bone *IVCB* fourth metatarsal bone **II Type II of the fibularis tertius tendon.** **Left leg.** *FT* fibularis tertius *EDL* extensor digitorum longus *VCB* fifth metatarsal bone *IVCB* fourth metatarsal bone **III Type III of the fibularis tertius tendon.** **Right leg.** *FT* fibularis tertius *EDL* extensor digitorum longus *VCB* fifth metatarsal bone *IVCB* fourth metatarsal bone **IV Type IV of the fibularis tertius tendon.** **Right leg.** *FT* fibularis tertius *EDLM* extensor digitorum longus muscle *EDL* extensor digitorum longus tendon *VCB* fifth metatarsal bone *IVCB* fourth metatarsal bone **V Type V of the fibularis tertius tendon.** **Left leg.** *FT* fibularis tertius *EDL* extensor digitorum longus *VCB* fifth metatarsal bone *FBT* fibularis brevis tendon. *FLT* fibularis longus tendon *FTM* fibularis tertius muscle **VI Type VI of the fibularis tertius tendon.** **Right leg.** *FT* fibularis tertius *EDL* extensor digitorum longus *VCB* fifth metatarsal bone *IVCB* fourth metatarsal bone *IIICB* third metatarsal bone

Figure 2. Scheme of all types. **Left leg.** *EDL* extensor digitorum longus; *VCB* fifth metatarsal bone; *FT* fibularis tertius



