Surgical and Radiologic Anatomy (2025) 47:143
https://doi.org/10.1007/s00276-025-03633-9

ANATOMIC VARIATIONS

A rare unilateral variation of extensor digitorum longus and fibularis tertius muscles

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Received: 11 February 2025 / Accepted: 7 April 2025 / Published online: 24 May 2025

Abstract

Purpose Both the extensor digitorum longus (EDL) and fibularis tertius (FT) muscles exhibit a wide range of morphological variations.

Methods A 70-year-old male cadaver was subjected to routine anatomical dissection for research and teaching purposes.

Results The EDL had a markedly smaller fleshy belly, whereas the FT appeared hypertrophic. The EDL tendon displayed an atypical elongation and bifurcated into only three distinct slips, which inserted into the dorsal digital expansions of the second, third, and fourth toes. In contrast, the FT tendon was remarkably well-developed and divided into two slips. The lateral slip attached to the dorsal aspect of the base of the fifth metatarsal, while the medial slip extended distally to integrate into the dorsal digital expansion of the fifth toe.

Conclusion In injuries involving tendon incisions, clinicians should consider EDL variations to ensure proper tendon restoration. The FT muscle flap and tendon grafts are commonly used to correct ankle joint laxity and foot drop. Understanding variations in the EDL and FT is crucial for surgical planning.

Keywords Cadaver · Extensor digitorum longus · Fibularis Tertius · Tendon · Variation

Introduction

The extensor digitorum longus (EDL) muscle forms an integral component of the anterior compartment of the leg. The EDL tendon typically bifurcates into two primary branches, each of which subsequently divides into two terminal slips, which then attach to the 2nd-5th toes [4]. The EDL plays a critical role in the gait cycle, particularly in dorsiflexion during the transition from pre-swing to initial contact, ensuring controlled stance phase. The EDL may give rise to accessory slips that insert into the base of the proximal phalanx of the 2nd toe, the anterior aspect of the 5th metatarsal bone, or the 1st dorsal interosseous muscle. Additionally, it may form a connecting slip to the extensor hallucis longus via its most medial tendon or contribute to the extensor digitorum brevis through a transverse band [7].

Typically, the fibularis tertius (FT) muscle originates from the distal fibular shaft and the adjacent interosseous membrane, although additional fibers may arise from the anterior intermuscular septum. The FT tendon is frequently presented as an extension or subdivision of the EDL muscle. The muscle courses laterally relative to the EDL and typically inserts on the medial side of the dorsal surface of the base of the 5th metatarsal [9]. The FT contributes to foot eversion and functions as a secondary dorsiflexor. The coordinated actions of inversion and eversion play a crucial role in maintaining postural stability, particularly when walking or standing on uneven terrain. Additionally, the FT enhances efficiency and biomechanical economy of movement during the swing phase of gait [8]. The FT muscle exhibits a notable degree of morphological variability, characterized by the presence of accessory tendinous structures. While variations in the origin of the FT muscle are rare, significant

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heterogeneity has been observed in its insertion. Olewnik made a classification based on the insertion of the PT muscle into six types [6].

A rare unilateral variation in the tendons of the EDL and FT is reported in this case, and its clinical significance is discussed.

Case presentation

During a routine educational dissection, an atypical morphological variation was identified in the tendons of the EDL and FT muscles in the dorsal region of the foot. This variation was observed in the right lower limb of a 70-year-old African-American male cadaver. While the proximal origins of both muscles appeared unremarkable, a significant discrepancy was noted in the size and structure of their muscle bellies.

Compared to the standard anatomical configuration, the EDL displayed a markedly smaller fleshy belly, whereas the FT exhibited a hypertrophic appearance. This anomaly was attributed to the muscle fibers of the EDL tendon slip to the 5th toe merging with the FT muscle fibers (Fig. 1).

The most pronounced deviation pertained to the tendon formation patterns of these muscles, which diverged significantly from the typical anatomical presentation. The EDL tendon exhibited an unusual elongation and bifurcated into only three distinct slips, which terminated at the dorsal digital expansions of the 2nd, 3rd, and 4th toes. The slips directed to the 2nd and 3rd toes originated from a common tendon, whereas the slip to the 4th toe arose from a separate tendon. In contrast, the FT tendon was notably robust and divided into two prominent slips. A special morphological variant of insertion was observed in our study which cannot be categorized Olewnik's classification [6]. The lateral slip anchored to the dorsal surface of the base of the 5th metatarsal, while the medial slip extended distally to contribute to the dorsal digital expansion of the 5th toe (Fig. 2).

Discussion

Due to bipedal locomotion, the musculature of the human lower limb has undergone significant modifications, with some muscles still evolving. The FT frequently exhibits variations in its attachment, particularly distally, suggesting that it has not yet reached its final evolutionary stage. The muscles of the lower limb develop from the hind limb bud (lumbar and sacral somites), whereas tendons originate from the somatopleuric mesoderm. Myogenic cells differentiate into myoblasts, which further divide and subdivide, eventually attaching to the developing lower limb bones to form the final musculature. Any disruption in the mechanisms governing these divisions may lead to morphological variations. To ensure arch stability, certain phylogenetic changes have emerged in the human foot, one of which is the appearance of the peroneus tertius muscle [2].

EDL variations are typically linked to anomalies in the somatopleural mesoderm of the limb bud during embryonic development. Such disruptions interfere with the reciprocal interactions between muscles and tendons, resulting in anatomical variations. Developmental irregularities affecting the EDL may sometimes present as asymptomatic disorders [4].

A literature review further suggests that the FT is considered either a detached portion of the EDL or a migrated segment of the extensor digitorum brevis [2].

Various bifurcation patterns and accessory tendon slips have been documented in the literature. In such cases, the bifurcated tendons and their respective slips typically insert onto their corresponding digits. Additionally, case report have described congenital absence of one or more EDL tendons, as well as instances of supernumerary tendon formations [7].

Several studies have reported that the EDL muscle may exhibit variations by giving off extra slips. Kamaşak et al. (2022) documented a rare anatomical variation of the EDL, characterized by a double tendon bifurcating into four

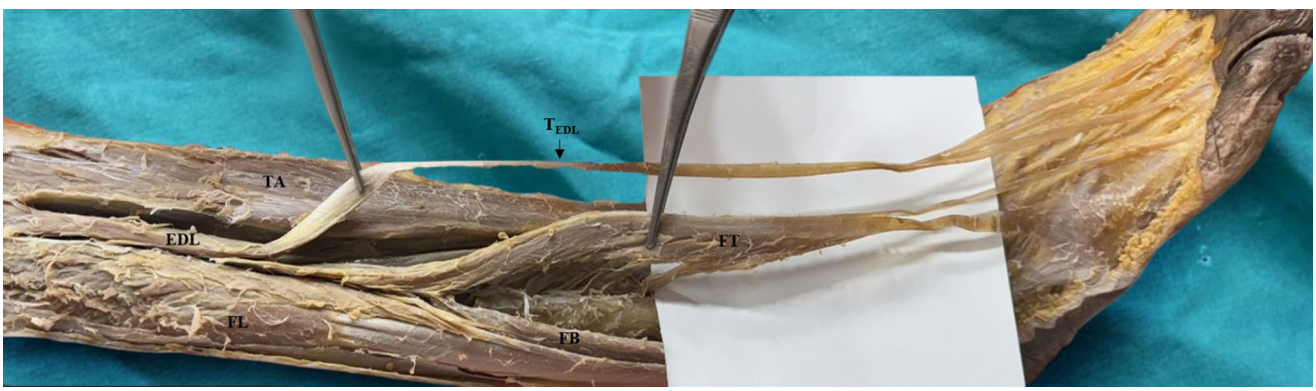

Fig. 1 Dissection of the right leg and dorsum of the foot showing smaller fleshy belly of EDL and hypertrophic FT (EDL: extensor digitorum longus, TA: tibialis anterior, FL: Fibularis longus, FB: Fibularis brevis, FT: Fibularis tertius)

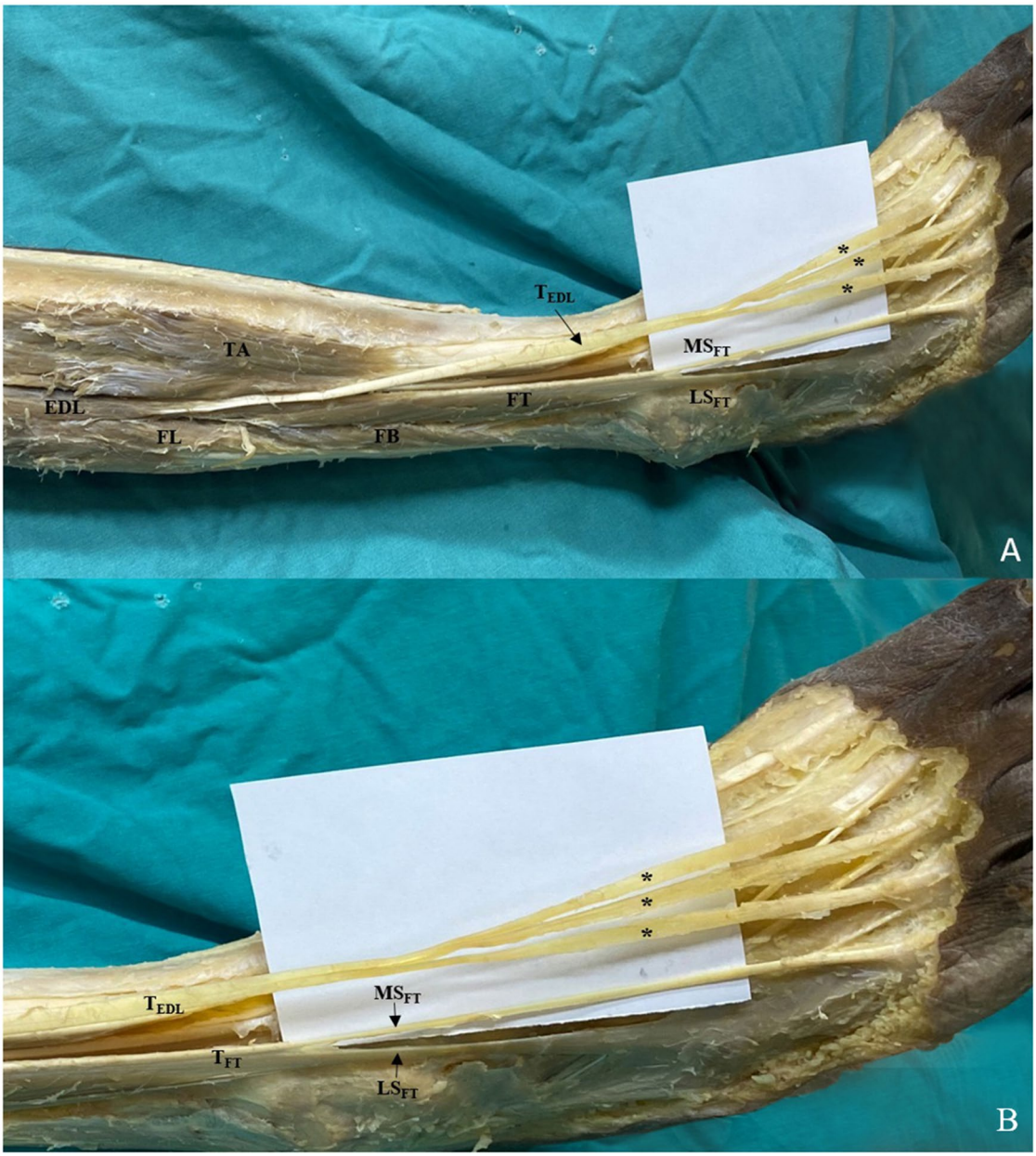

Fig. 2 **A**: A view of the variation of EDL and FT tendons. **B**: Closer view of the tendons (EDL: extensor digitorum longus, TA: tibialis anterior, FL: Fibularis longus, FB: Fibularis brevis, FT: Fibularis tertius, T_{EDL}: Tendon of extensor digitorum longus, T_{FT}: Tendon of fibularis tertius, MS_{FT}: Medial slip of fibularis tertius, LS_{FT}: Lateral slip of fibularis tertius, *Tendon slips of EDL)

distinct slips. The primary tendon divided into two slips, inserting onto the dorsal aspects of the second and third toes, while the accessory tendon also split into two slips, terminating at the dorsal surfaces of the fourth and fifth toes [3]. The difference between our study and that of Kamaşak et al. (2022) lies in the presence of the tendon extending to the fifth toe, while the similarity between both studies can be identified as the primary division of the EDL into two main tendons.

Kislalioglu et al. (2024) described an unusual attachment pattern of the EDL in an 87-year-old male cadaver, where the EDL exhibited a dual-bellied morphology with corresponding dual tendons. The tendon arising from the first belly bifurcated into two slips, inserting onto the distal phalanges of the second and third toes. Similarly, the tendon of the second belly divided into two slips, terminating at the distal phalanges of the fourth and fifth toes on the dorsal aspect of the foot [4]. One of the differences between this study and that of Kislalioglu et al. (2024) is that the EDL in

our study has a single muscle belly, whereas in Kislalioglu et al. (2024), the EDL consists of two bellies. Another distinction is the absence of a slip extending to the fifth toe in our study. The similarity between the two studies, however, is the presence of a common tendon for the slips directed toward the second and third toes.

Pasupulati et al. (2024) reported an atypical bilateral variation of the EDL in a 61-year-old female cadaver. The EDL was composed of two distinct muscle bellies, designated as the primary EDL and an accessory EDL (AEDL). In the left lower limb, the primary EDL tendon bifurcated into three slips, inserting onto the dorsal digital expansions of the second, third, and fourth toes, while the AEDL exclusively contributed a tendinous insertion to the fifth toe. Conversely, in the right lower limb, the EDL muscle belly gave rise to a single tendon, which subsequently divided into two slips inserting onto the second and third toes. The AEDL, however, produced two distinct tendinous slips that terminated at the dorsal digital expansions of the fourth and fifth toes [7]. One of the most striking differences between the variation observed in our study and that reported by Pasupulati et al. (2024) is that their study identified a bilateral variation, whereas our study documented a unilateral variation. Another distinguishing factor is that, in Pasupulati et al. (2024), the EDL in both extremities had a double muscle belly and also gave off a slip extending toward the fifth toe.

In a study of 100 cadavers examined by Jadhav Surekha et al. (2015), FT tendon duplication was identified in 2.82% of cases, where one tendon originated from the EDL and inserted into the fourth metatarsal bone, while the other attached to the dorsum of the fifth metatarsal bone. Moreover, in 1.14% of cases, the FT tendon exhibited an aponeurotic expansion at its insertion site, integrating with both the fourth and fifth metatarsal bones [1].

Several studies have reported that the FT tendon divides into two distinct slips, medial and lateral [1, 5]. In 22.98% of cases, the medial slip inserted onto the fourth metatarsal bone, while the lateral slip adhered to the fifth metatarsal bone [1]. Furthermore, in 2.29% of cases, the medial slip was found to attach to the fourth metatarsophalangeal joint, whereas the lateral slip inserted onto the dorsum of the head of the fifth metatarsal bone [1]. When the FT tendon variation in this study is compared with variations reported in the literature, the division of the FT tendon into medial and lateral slips can be identified as a common feature. The primary difference between the FT tendon variations in the literature and the variation observed in our study lies in the differences between the insertion points of the medial and lateral slips.

Yang et al. (2022) demonstrated that in the right lower extremity of a cadaveric specimen from an approximately 40-year-old Asian male, the EDL tendon bifurcated into three distinct tendinous slips, each directed toward the second, third, and fifth toes. Additionally, the FT tendon exhibited a bifurcated insertion pattern, with the primary tendon anchoring to the base of the fifth metatarsal bone, while the secondary tendon inserted into the base of the fourth metatarsal bone [10]. Unlike other studies in the literature, the study by Yang et al. (2022) is similar to ours in that it presents a variation involving both the EDL and FT tendons, rather than focusing solely on one or the other. However, it should be noted that there is a difference between the two studies in terms of the insertion points of both the EDL and FT tendons.

The extensor muscles of the leg are present in the human embryo during the early stages of development. The FT is regarded as a distinct portion of the EDL. Therefore, variations in the muscle bellies of these muscles might result either from evolutionary influences or from an unusual separation of the FT from the EDL.

When the FT exhibits an additional lateral insertion and is hypertrophic, as observed in the present case, it may contribute to increased evertor activity, potentially predisposing individuals to foot deformities and related pathological manifestations. This muscle is also a potential contributor to stress fractures at the base of the fifth metatarsal, with an increased likelihood of fractures when the muscle is hypertrophied. Furthermore, the FT can be widely and reliably utilized in local transpositional flaps for reconstructive procedures in the lower extremities.

The EDL plays an active or passive role in all phases of gait, and variations in its morphology can affect the precision of ankle and toe movements, as well as different gait phases. When the muscle presents a noticeably smaller fleshy belly, as observed in this case, its functional capacity may be compromised. The EDL has also been implicated in hyperextension contractures and deformities, particularly of the fifth toe. In such cases, it is crucial for surgeons to recognize that the tendon supplying the fifth toe originates from the FT rather than the EDL, ensuring accurate diagnosis and surgical intervention.

Conclusion

Given the EDL's critical role in the gait cycle, any reduction in its size or tendon count could potentially impact gait cycle. This presentation of an unusually small EDL supplying only the second, third, and fourth toes suggests a weakened toe extension, which may have led to an altered gait pattern compensated by other intrinsic foot muscles.

The FT muscle flap and tendon grafts are frequently utilized for correcting ankle joint laxity and foot drop, making a comprehensive understanding of FT morphology essential

for plastic surgeons. Variations in FT tendon insertion patterns have been associated with the differential diagnosis of chronic ankle pain and implicated in the occurrence of ankle injuries. There is no doubt that the FT represents a significant anatomical structure in terms of evolution, function, and morphology. It may play a crucial role in maintaining optimal muscular balance around the ankle joint, emphasizing the need for further investigation into its variations and clinical relevance in the future.

Surgeons should be cognizant of potential EDL and FT variations during surgery, as such anomalies may not always be apparent in imaging studies but can affect surgical outcomes.

Limitations

The limitation of this study no morphometric measurements were conducted for either muscle.

Acknowledgements The authors sincerely thank those who donated their bodies to science so that anatomical research could be performed. Results from such research can potentially increase mankind's overall knowledge that can then improve patient care. Therefore, these donors and their families deserve our highest gratitude.

Author contributions Kamaşak Arpaçay B: project development, data collection, data analysis and manuscript writing. Uğuz E: data collection and manuscript writing. Ulcay T: data analysis and manuscript editing. Aycan K: manuscript editing. All authors have read and approved the manuscript.

Funding No funding was received for conducting this study.

Data availability No datasets were generated or analysed during the current study.

Declarations

Ethical approval This study was conducted on cadaver, it is among the studies that do not require ethics committee approval. The cadaver belonged to the Department of Anatomy, Faculty of Medicine, Kırşehir Ahi Evran University. This study was reviewed and deemed exempt by our Kırşehir Ahi Evran University Faculty of Medicine Ethical Commitee.

Consent to participate Not applicable.

Consent to publish Not applicable.

Competing interests The authors declare no competing interests.

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