VIA MEDICA

CASE REPORT

Folia Morphol.
Vol. 82, No. 2, pp. 429–433
DOI: 10.5603/FM.a2022.0018

ISSN 0015–5659
eISSN 1644–3284
journals.viamedica.pl

Case report of the double-headed extensor hallucis longus

K. Ruzik[1], K. Westrych[1], R.S. Tubbs[2–5], Ł. Olewnik[1], P. Łabętowicz[6], N. Zielinska[1]

[1]*Department of Anatomical Dissection and Donation, Medical University of Lodz, Poland*
[2]*Department of Neurosurgery, Tulane University School of Medicine, New Orleans, LA, United States*
[3]*Department of Neurosurgery and Ochsner Neuroscience Institute, Ochsner Health System, New Orleans, LA, United States*
[4]*Department of Anatomical Sciences, St. George's University, Grenada, West Indies*
[5]*Department of Surgery, Tulane University School of Medicine, New Orleans, LA, United States*
[6]*Department of Normal and Clinical Anatomy, Medical University of Lodz, Poland*

[Received: 28 October 2021; Accepted: 30 November 2021; Early publication date: 17 February 2022]

Background: *We present a case report of double-headed extensor hallucis longus (EHL) with potential clinical significance.*

Materials and methods: *Cadaveric dissection of the right lower limb of a 70-year-old at death female was performed for research and teaching purposes at the Department of Anatomical Dissection and Donation, Medical University of Lodz. The limb was dissected using standard techniques according to a strictly specified protocol. Each head and tendon of the muscle was photographed and subjected to further measurements.*

Results: *During dissection, an unusual type of EHL muscle was observed. It consisted of two muscle bellies, a main tendon and an accessory tendon. Both muscle bellies were located on anterior surface of the fibula and the interosseous membrane. The main tendon insertion was located on the dorsal aspect of the base of the distal phalanx of the big toe, while the accessory tendon insertion was located medially.*

Conclusions: *The EHL muscle is highly morphologically variable at both the point of origin and the insertion. Knowledge of its variations is connected to several pathologies such as foot drop, tendonitis, tendon rupture, and anterior compartment syndrome.* (Folia Morphol 2023; 82, 2: 429–433)

Key words: extensor hallucis longus, additional muscle belly, anatomical variations, hallux valgus, embryology

INTRODUCTION

The extensor hallucis longus (EHL), in addition to the tibialis anterior and extensor digitorum longus, is part of the anterior compartment of the lower limb [24, 35]. Its origin is located on the anterior surface of the fibula and on the interosseous membrane lateral to the origin of the tibialis anterior and medial to the origin of the extensor digitorum longus. The EHL is situated in the middle of these muscles and is largely covered by them [17].

The thin muscle belly becomes the tendon situated behind the superior and inferior extensor retinaculum and is then inserted into the dorsal aspect of the base of the distal phalanx of the big toe [38]. The

Address for correspondence: K. Ruzik, MD, Department of Anatomical Dissection and Donation, Medical University of Lodz, ul. Żeligowskiego 7/9, 90–752 Łódź, Poland, e-mail: kacper.ruzik@umed.lodz.pl

EHL is innervated by branches originating from the deep fibular nerve and is supplied by branches of the anterior tibial artery [2, 34].

The role of the EHL is to extend the great toe. It is also responsible for dorsiflexion of the foot, adjunct foot eversion and inversion. There are EHL classifications for fetuses and adults, and more recently an exact classification was proposed by Zielinska et al. [1, 7, 17, 22, 26, 27, 38], distinguishing three types of EHL with subtypes. Anatomical variations of the EHL can predispose to hallux valgus deformity, tendonitis and acute compartment syndrome [11, 16, 33].

The present report describes a case of a two-headed EHL. Knowledge of the morphological variability of this muscle is significant for orthopaedic surgeons, physiotherapists and anatomists [17, 27].

CASE REPORT

During a routine dissection performed for research and teaching purposes at the Department of Anatomical Dissection and Donation, Medical University of Lodz, a supernumerary head of the EHL was found (Fig. 1). The dissection was performed using traditional anatomical methods according to a previously described protocol [17, 24, 27]. The subject of the dissection was a 70-year-old at death female cadaver.

The right lower limb was positioned in the supine position on the dissection table. First, all the skin, subcutaneous tissue and superficial fascia were removed up to the crural region and from the area of the foot. Secondly, the crural fascia was then carefully removed. Then the muscle bellies and tendons were cleaned from the medial to lateral side. After that, the muscles of the anterior crural compartment were separated from each other. Finally, the tendons were dissected to identify potential additional tendon bands.

Each head of the muscle and each tendon was photographed and measured using an electronic calliper with an accuracy of up to 0.1 mm (Mitutoyo Corporation, Kawasaki-shi, Kanagawa, Japan), each measurement being performed twice by two researchers.

The dominant muscle belly originated from the anterior surface of the fibula and from the interosseous membrane 208.45 mm above a line drawn between the malleoli. The width and thickness of the muscle were 19.67 mm × 3.55 mm at the origin. The length of the muscle belly was 167.88 mm. The width and thickness of the muscle were 4.27 mm × 1.91 mm upon passing the muscle belly.

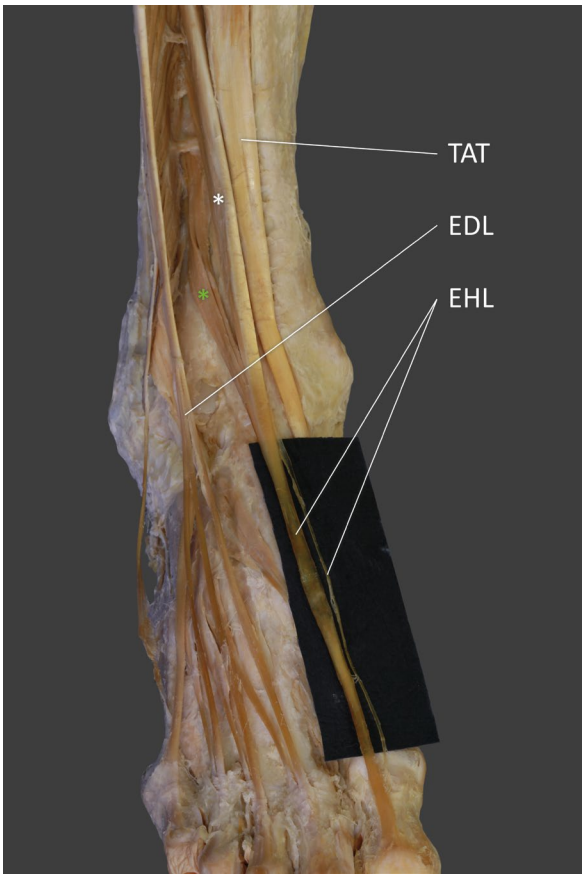

Figure 1. Supernumerary head of the extensor hallucis longus (EHL); EDL — extensor digitorum longus; TAT — tibialis anterior tendon; white star — main mussle belly; green star — additional muscle belly.

The lesser muscle belly appeared from beneath the anterior surface of the fibula and from the interosseous membrane 83.44 mm above a line drawn between the malleoli. The width and thickness of the muscle were 12.55 mm × 2.30 mm at the origin. The length of the muscle belly was 87.02 mm. The width and thickness of the muscle were 3.32 mm × 1.03 mm upon passing the muscle belly.

The type of insertion corresponds to subtype 2B proposed by Zielinska et al. [38]. The main tendon length was 184.60 mm. The width and thickness of the tendon were 5.63 mm × 0.95 mm at the insertion, which was located on the dorsal aspect of the base of the distal phalanx of the big toe. The additional tendon length was 119.59 mm. The width and thickness of the tendon were 2.33 mm × 0.42 mm at the insertion, which was located on the dorsal aspect of the proximal phalanx of the hallux, medial to the insertion of the EHL main tendon.

No extension point (i.e. the point where the tendon begins to expand into its insertional footprint) was observed at any of the described tendons.

Declarations and ethical approval

The cadavers were the property of the Department of Anatomical Dissection and Donation, Medical University of Lodz,

This article describes no studies involving human participants or animals performed by any of the authors.

DISCUSSION

Accessory muscle bellies in the upper and lower limbs have been widely reported. Such anatomical variations are common among large muscles such as the quadriceps femoris, coracobrachialis, biceps brachii, subscapularis and also vestigial muscles such as the plantaris [15, 29, 32, 36, 37]. An accessory muscle head can be related to potential compression of nerves or vessels but can be useful during reconstruction surgery [25, 36]. Whether additional muscle bellies are rare anatomical variations or are more often observed thanks to more carefully performed studies and better embalming of human cadavers is an open question. For example, Olewnik et al. [28] found an additional head of the quadriceps femoris muscle in 68 out of 106 lower limbs and opened the discussion: is it quadriceps or multiceps femoris?

Evolutionary aspect

The EHL, despite the quadratus plantae and plantaris muscles, appeared first in Mammalia [8, 18]. In all hominoids, it originates from the medial aspect of the fibula shaft, and in *Hylobates* and *Pan* there is an additional origin from the lateral condyle of the tibia [6]. In all taxa, insertion is onto the dorsum of the distal phalanx of the hallux. However, Ferrero et al. [12] reported an additional insertion onto the dorsum of the proximal phalanx in a gorilla limb. Origins from the interosseous membrane of the leg have also been demonstrated in the gorilla. Interestingly, Ferrero et al. [12] only reported this type of proximal attachment in a single orangutan limb. It was not described among apes.

Embryological aspect

To understand the complexity of the variations of the EHL insertion, it is necessary to consider its embryological basis. In a 5-week embryo, the limbs start to form when the mesoderm migrates into the limb bud and anterior and posterior condensations start to generate the musculoskeletal system of the lower limb [3, 4]. The posterior condensation develops into the extensor musculature of the lower limb. The EHL splits from the deep portion of this extension mass, although its tendon remains fused with the extensor digitorum longus, with which it is often fused in later life [13, 20, 21].

Retinoic acid, sonic hedgehog (SHH), HOX genes (Hoxd-9, Hoxd-10, Hoxd-11, Hoxd-12, Hoxd-13), the apical ectodermal ridge, and the zone of polarizing activity are described as factors responsible for forming the lower limb musculature. Aberrant gene expressions can cause malformations of the limbs [5].

Morphological variability

Anatomy textbooks describe the insertion of the EHL into the dorsum of the base of the distal phalanx of the big toe. However, several studies have described variations of this insertion [1, 7, 17, 22, 26, 27].

Al-Saggaf [1] described three types of possible distal attachment. Type I (most common) was characterised as a single tendinous insertion on the dorsal aspect of the base of the distal phalanx of the big toe. In subsequent years, new classifications based on adult cadavers, fetuses and ultrasonography were proposed [1, 7, 9, 17, 22, 26, 27]. The most recent classification proposed by Zielinska et al. [38] summarizes the previously mentioned studies. They proposed three types of EHL insertion.

The proximal attachment of the EHL is less varied than the insertion. Egea et al. [10] described a case report of a double origin of the EHL. In contrast to our study they reported a medial and lateral origin of this muscle; we present upper and lower muscle bellies with separate innervations.

Clinical significance

The EHL tendon has been used in a variety of tendon transfer and tenodesis surgeries to correct iatrogenic hallux varus deformity, equinovarus foot deformity, clawed hallux associated with a cavus foot, and dynamic hyperextension of the hallux though it is usually used to prevent pedal imbalance after transmetatarsal amputation [16, 31].

Importantly, rupture or significant injury to the EHL tendon can result in a dropped hallux, loss of dorsiflexion, resulting in an unpaired gait [11]. This

can be treated surgically by transferring the first slip of the extensor digitorum longus and extensor hallucis brevis to the injured EHL. Rupture of this tendon is a result of laceration [11].

The EHL is also implicated in tendonitis, when the tendon becomes overstressed causing inflammation and pain [23]. Excessive calf muscle tightness, overextension during exercise, and falling of the foot arch are listed as the most common factors [23]. The condition can be treated with stretching, non-steroidal anti-inflammatory drugs, and walking boots in more severe cases [19].

The anterior compartment of the leg is also the most common site for acute compartment syndrome, which can result from trauma, blunt force injury, or reperfusion after acute interruption of flow to muscles in the crural compartment. Swelling after these insults can lead to muscle ischemia because the muscles in these compartments are highly bound by the tough crural fascia, making it difficult for them to expand in response to injury. When the muscles expand, they can compress the artery, resulting in ischemic injury. Nerves can also be compressed causing loss of neuromuscular function. Importantly, definitive management of acute compartment syndrome is a subcutaneous fasciotomy [33]. There is also chronic compartment syndrome resulting from excessive exercise, causing pain and swelling. The pressure is increased by increases in blood flow and muscle mass from excessive exercise. As a result, arteries can be compressed [33]. It is feasible that an additional muscle belly will aggravate the symptoms of both acute and chronic compartment syndrome and be another anatomical structure that can compress nerves or vessels.

The hallux valgus deformity is a common forefoot pathology. It is characterised by lateral deviation of the great toe (hallux) and medial deviation of the first metatarsal and has several possible causes, the most common being wrongly matched footwear [38]. Other factors include muscle imbalance, genetic predisposition, ligamentous laxity and long-standing work in an upright posture [30]. However, the involvement of the EHL in hallux valgus pathogenesis is unclear. Natsis et al. [22] found that hallux valgus coincided with an accessory tendon of the EHL in 65.4% of the feet examined. If additional tendons predispose to hallux valgus deformity, it seems likely that a second muscle belly also affects the development of this pathology. However, biomechanical research is needed to confirm this prediction.

CONCLUSIONS

The EHL muscle is highly morphologically variable at both the points of origin and insertion. Knowledge of its variations is related to several pathologies such as foot drop, tendonitis, tendon rupture, and anterior compartment syndrome.

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 [14].

The authors wish to express their gratitude to all those who donated their bodies to medical science.

Conflict of interest: None declared

REFERENCES

1. Al-Saggaf S. Variations in the insertion of the extensor hallucis longus muscle. Folia Morphol. 2003; 62(2): 147–155, indexed in Pubmed: 12866676.
2. Aragonés P, Rodríguez-Niedenführ M, Quinones S, et al. Popliteal artery: Anatomical study and review of the literature. Ann Anat. 2021; 234: 151654, doi: 10.1016/j.aanat.2020.151654, indexed in Pubmed: 33278577.
3. Bardeen C. Studies of the development of the human skeleton. (A). The development of the lumbab, sacbal and coccygeal vertebwe. (B). The cubves and the pbopobtionate regional lengths of the spinal column during the first thbee months of embbyonic developnent. (C). The development of the skeleton of the posterior limb. Am J Anat. 1905; 4(3): 265–302, doi: 10.1002/aja.1000040302.
4. Bardeen C. Development and variation of the nerves and the musculature of the inferior extremity and of the neighboring regions of the trunk in man. Am J Anat. 1906; 6(1): 259–390, doi: 10.1002/aja.1000060108.
5. Barham G, Clarke NMP. Genetic regulation of embryological limb development with relation to congenital limb deformity in humans. J Child Orthop. 2008; 2(1): 1–9, doi: 10.1007/s11832-008-0076-2, indexed in Pubmed: 19308596.
6. Beddard F. VII. Contributions to the anatomy of the anthropoid apes. Trans Zool Soc Lndon. 1893; 13(5): 177–218, doi: 10.1111/j.1096-3642.1893.tb00049.x.
7. Bibbo C, Arangio G, Patel DV. The accessory extensor tendon of the first metatarsophalangeal joint. Foot Ankle Int. 2004; 25(6): 387–390, doi: 10.1177/107110070402500604, indexed in Pubmed: 15215022.
8. Boyer E. The musculature of the inferior extremity of the orang-utan Simia satyrus. Am J Anat. 1935; 56(2): 193–256, doi: 10.1002/aja.1000560203.
9. Denk CC, Oznur A, Sürücü HS. Double tendons at the distal attachment of the extensor hallucis longus muscle. Surg

Radiol Anat. 2002; 24(1): 50–52, doi: 10.1007/s00276-002-0016-7, indexed in Pubmed: 12197010.
10. Egea JM, Cabeza L, Ortiz R, et al. Double origin of the extensor hallucis longus muscle: a case report. Surg Radiol Anat. 2019; 41(12): 1421–1423, doi: 10.1007/s00276-019-02309-5, indexed in Pubmed: 31482300.
11. Fadel GE, Alipour F. Rupture of the extensor hallucis longus tendon caused by talar neck osteophyte. Foot Ankle Surg. 2008; 14(2): 100–102, doi: 10.1016/j.fas.2007.11.004, indexed in Pubmed: 19083623.
12. Ferrero EM, Pastor F, Fernandez F, Barbosa M, Diogo R, Wood B. Comparative anatomy of the lower limb muscles of hominoids: attachments, relative weights, innervation and functional morphology. In: Everett F, Hughes and Medison E. Hill (ed.) PRIMATES: Classification, Evolution and Behavior. Nova publishers 2012.
13. Gros J, Tabin CJ. Vertebrate limb bud formation is initiated by localized epithelial-to-mesenchymal transition. Science. 2014; 343(6176): 1253–1256, doi: 10.1126/science.1248228, indexed in Pubmed: 24626928.
14. Iwanaga J, Singh V, Takeda S, et al. Acknowledging the use of human cadaveric tissues in research papers: Recommendations from anatomical journal editors. Clin Anat. 2021; 34(1): 2–4, doi: 10.1002/ca.23671, indexed in Pubmed: 32808702.
15. Je SS, Park B, Kim J, et al. Five-headed biceps brachii muscle with a rare origin from the tendon of pectoralis major muscle. Anat Sci Int. 2016; 91(1): 110–113, doi: 10.1007/s12565-015-0288-8, indexed in Pubmed: 26012790.
16. Johnson KA, Spiegl PV. Extensor hallucis longus transfer for hallux varus deformity. J Bone Joint Surg Am. 1984; 66(5): 681–686, indexed in Pubmed: 6725316.
17. Karauda P, Shane Tubbs R, Polguj M, et al. Morphological variability of the extensor hallucis longus in human fetuses. Ann Anat. 2021; 234: 151627, doi: 10.1016/j.aanat.2020.151627, indexed in Pubmed: 33171222.
18. Lewis OJ. The phylogeny of the cruropedal extensor musculature, with special reference to the primates. J Anat. 1966; 100(PT 4): 865–880.
19. Lezak B, Summers S. Anatomy, Bony Pelvis and Lower Limb, Extensor Hallucis Longus Muscle. StatPearls Publishing, Treasure Island (FL) 2021.
20. Lezak B, Wehrle CJ, Summers S. Anatomy, Bony Pelvis and Lower Limb, Posterior Tibial Artery. StatPearls Publishing, Treasure Island (FL) 2020.
21. Mróz I, Kielczewski S, Pawlicki D, et al. Blood vessels of the shin — anterior tibial artery - anatomy and embryology — own studies and review of the literature. Folia Med Cracov. 2016; 56(1): 33–47, indexed in Pubmed: 27513837.
22. Natsis K, Konstantinidis GA, Symeonidis PD, et al. The accessory tendon of extensor hallucis longus muscle and its correlation to hallux valgus deformity: a cadaveric study. Surg Radiol Anat. 2017; 39(12): 1343–1347, doi: 10.1007/s00276-017-1881-4, indexed in Pubmed: 28601923.
23. Ng JM, Rosenberg ZS, Bencardino JT, et al. US and MR imaging of the extensor compartment of the ankle. Radiographics. 2013; 33(7): 2047–2064, doi: 10.1148/rg.337125182, indexed in Pubmed: 24224598.
24. Olewnik Ł. Fibularis tertius: anatomical study and review of the literature. Clin Anat. 2019; 32(8): 1082–1093, doi: 10.1002/ca.23449, indexed in Pubmed: 31408221.
25. Olewnik Ł, Paulsen F, Tubbs RS, et al. Potential compression of the musculocutaneous, median and ulnar nerves by a very rare variant of the coracobrachialis longus muscle. Folia Morphol. 2021; 80(3): 707–713, doi: 10.5603/FM.a2020.0085, indexed in Pubmed: 32844391.
26. Olewnik Ł, Podgórski M, Polguj M, et al. Is ultrasound effective in determining variation of the insertion of the extensor hallucis longus tendon? Clin Anat. 2020; 33(8): 1235–1239, doi: 10.1002/ca.23572, indexed in Pubmed: 32017249.
27. Olewnik Ł, Podgórski M, Polguj M, et al. A cadaveric study of the morphology of the extensor hallucis longus: a proposal for a new classification. BMC Musculoskelet Disord. 2019; 20(1): 310, doi: 10.1186/s12891-019-2688-8, indexed in Pubmed: 31266496.
28. Olewnik Ł, Tubbs RS, Ruzik K, et al. Quadriceps or multiceps femoris? Cadaveric study. Clin Anat. 2021; 34(1): 71–81, doi: 10.1002/ca.23646, indexed in Pubmed: 32644202.
29. Olewnik Ł, Zielinska N, Karauda P, et al. A three-headed plantaris muscle: evidence that the plantaris is not a vestigial muscle? Surg Radiol Anat. 2020; 42(10): 1189–1193, doi: 10.1007/s00276-020-02478-8, indexed in Pubmed: 32382814.
30. Perera AM, Mason L, Stephens MM. The pathogenesis of hallux valgus. J Bone Joint Surg Am. 2011; 93(17): 1650–1661, doi: 10.2106/JBJS.H.01630, indexed in Pubmed: 21915581.
31. Roukis TS. Flexor hallucis longus and extensor digitorum longus tendon transfers for balancing the foot following transmetatarsal amputation. J Foot Ankle Surg. 2009; 48(3): 398–401, doi: 10.1053/j.jfas.2008.12.013, indexed in Pubmed: 19423046.
32. Ruzik K, Waśniewska A, Olewnik Ł, et al. Unusual case report of seven-headed quadriceps femoris muscle. Surg Radiol Anat. 2020; 42(10): 1225–1229, doi: 10.1007/s00276-020-02472-0, indexed in Pubmed: 32318799.
33. Via AG, Oliva F, Spoliti M, et al. Acute compartment syndrome. Muscles Ligaments Tendons J. 2015; 5(1): 18–22, indexed in Pubmed: 25878982.
34. Vittoria N, Giuseppe M, Ivano D, et al. The innervation of extensor hallucis longus muscle: an anatomical study for selective neurotomy. Acta Neurochir (Wien). 2009; 151(10): 1275–1279, doi: 10.1007/s00701-009-0504-1, indexed in Pubmed: 19730770.
35. Zdilla MJ, Paulet JE, Lear JJ, et al. A review of extensor hallucis longus variants featuring a novel extensor primi internodii hallucis muscle merging with extensor hallucis brevis. J Foot Ankle Surg. 2018; 57(6): 1218–1220, doi: 10.1053/j.jfas.2018.03.031, indexed in Pubmed: 30146339.
36. Zielinska N, Olewnik Ł. Six-headed coracobrachialis muscle. Folia Morphol. 2022; 81(3): 809–813, doi: 10.5603/FM.a2021.0082, indexed in Pubmed: 34608984.
37. Zielinska N, Olewnik Ł, Karauda P, et al. A very rare case of an accessory subscapularis muscle and its potential clinical significance. Surg Radiol Anat. 2021; 43(1): 19–25, doi: 10.1007/s00276-020-02531-6, indexed in Pubmed: 32656573.
38. Zielinska N, Tubbs RS, Ruzik K, et al. Classifications of the extensor hallucis longus tendon variations: Updated and comprehensive narrative review. Ann Anat. 2021; 238: 151762, doi: 10.1016/j.aanat.2021.151762, indexed in Pubmed: 33992748.