Variant insertion of the fibularis tertius muscle is an evidence of the progressive evolutionary adaptation for the bipedal gait

Rashmoni Jana, Tara Sankar Roy

Department of Anatomy, All India Institute of Medical Sciences, New Delhi, India

Abstract

Fibularis tertius (FT) is often considered as part of extensor digitorum longus (EDL) muscle. The muscle is absent in hominoid apes and with the acquisition of the bipedal gait; the muscle emerged as a recent addition in the human foot. From its various modes of insertions, it is evident that the muscles of the sole are in search of its distal attachment, which can best support the relatively weak human midfoot. We describe an unusual insertion of the muscle in support of this hypothesis.

Introduction

The arch of the human foot is intrinsically unstable and to make the bipedal gait more effective and efficient, certain evolutionary musculoskeletal adjustments are in progress that are reflected in many of the muscles and bones of the foot.[1] Phylogenetically, the human fibularis tertius (FT) muscle is relatively young structure and coincides with bipedal locomotion.[2-6] Its various modes of insertions suggested that it helps in the midfoot stability, which is also a recent development in the ontogeny.[3] In this case report, we describe a unique case of variant insertions of the FT muscle and a lateral plantar muscle and have discussed the possible biomechanical advantage of these insertion, in support of the aforesaid hypothesis.

Case Report

During routine cadaveric dissection a number of variant connections and insertions of the FT muscle were observed in the right foot of a 64-year-old female. The FT, after originating from lower part of fibula bifurcated into medial and lateral slips in the dorsum of the foot. The medial slip crossed the tarsometatarsal, metatarsophalangeal and interphalangeal joints to attach to the under surface of the dorsal digital expansion of the fifth toe and on the dorsum of the head of the fifth metatarsal bone (Figure 1). At the mid foot region, the lateral slip formed a thick (5 mm × 20 mm) oblique fibrotendinous band that crossed the lateral border of the foot and connected the FT with the flexor digiti minimi brevis (FDMB), a muscle residing in the third planter layer. Another notable variation was seen in the FDMB muscle, which originated from lateral process of the calcaneal tuberosity along with abductor digiti minimi and passed onto the lateral surface of the fifth metatarsal bone close to the tendinous insertion of the FT muscle of the dorsum of the foot (Figure 1, inset). The tendon of the FDMB received the lateral head of the FT insertion at the base of the fifth metatarsal bone. No abnormality was noted in the innervations pattern of the anomalous muscles. No scar was found in the skin of leg and foot. The anatomy of the left foot was unremarkable. Because these findings were detected during cadaveric dissection, we were unable to detail the case history.

Correspondence: Tara Sankar Roy, Department of Anatomy, All India Institute of Medical Sciences, Ansari Nagar, New Delhi - 110029, India.
Tel. +91.11.265.948.80 - Fax: +91.11.265.886.63.
E-mail: tarasankar@hotmail.com; tsroy@aiims.ac.in

Key words: foot anomaly, musculotendinous variation, fibularis tertius, anomalous leg muscle.

Acknowledgments: the authors would like to thank the contribution of the first MBBS students (2008-09) for their excellent dissection and preparation of the specimen.

Received for publication: 20 September 2011.
Accepted for publication: 14 October 2011.

This work is licensed under a Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).

©Copyright R. Jana et al., 2011
Licensee PAGEPress, Italy
Clinics and Practice 2011; 1:e81
doi:10.4081/cp.2011.e81

Discussion

Classically the anatomy textbooks describe that the FT muscle inserting into the dorsal surface of the base of the fifth metatarsal bone, extending into the nearby deep fascia.[7,8,9] Numerous studies list varying insertions of the FT muscle. Rourke *et al.*[6] enumerated the various modes of insertion of the FT, and in their own study it was observed that the tendon was inserted into the dorsal surface of the shaft of both the fourth and fifth metatarsals that extended onto the under surface of the bone. Bryce[10] described that the tendon ended partly or wholly upon the fourth metatarsal bone. The FT may be absent up to 18% of population and its absence neither affected the movement of the midtarsal joints nor increased the incidence of either ankle or 5th metatarsal bone injury.[9,11] Also duplication of the FT tendon has been reported to have a 1-2% incidence in human.[12-15] The FT has been described as a partially separated portion of extensor digitorum longus (EDL).[7,16] Even intertendinous connections have been observed between the FT and the EDL.[9] Wood-Jones[17] reported that probably the FT has migrated from the foot in an upward direction and became an extrinsic muscle of the leg. The more proximal attachment of the FT muscles to the tarsal bones suggests a more evolved structure.[4,18] We presume that due to specialized and efficient needs of the human foot during walking and running, the FT might have lost its insertion into the fifth digit; therefore, a strong fascial attachment has been developed on the dorsum of the lateral border of the foot. Joshi *et al.*[5] found that in 4% cases (n=110), the insertion extended beyond fifth metatarsal up to metatarsophalangeal joint of fifth toe, and in 1.5% cases, it extended up to the proximal phalanx of little toe. In the present study, the insertion of the muscle (FT) was on the dorsum of the fifth metatarsal near its head, and a there was an aponeurotic extension of this tendon that progressed towards the lateral surface of the proximal phalanx of the little toe. Rourke *et al.*[6] noted that the tendinous fibers fanned out and curved like a hockey stick to get inserted around the fifth metatarsal. A bi- or trifurcated trapezoidal insertion of the FT tendon into the fifth metatarsal was also observed.[9] The bifurcated tendon in the present case is another variant insertion of FT as mentioned by Rourke *et al.*[6] Although it is a weak muscle, but the contractions of the FT may be responsible for delayed healing of the fifth metatarsal shaft fracture.[19] Avulsion fracture or stress fracture of the fifth metatarsal bone is common but more distal insertion of the FT tendon has little influence on healing.[19] The FT has been used with great advantage in various reconstructive and corrective surgeries in the foot.[6]

The FDMB arises from the medial part of the plantar surface of the base of the fifth metatarsal bone, and from the sheath of fibularis longus. In this case study, it has taken origin from the lateral process of the calcaneal tuberosity. It has a distal tendon that inserts into the lateral side of the base of the proximal phalanx of the little toe; this tendon usually blends laterally with the abductor digiti minimi. Some of its deeper fibres extend to the lat-

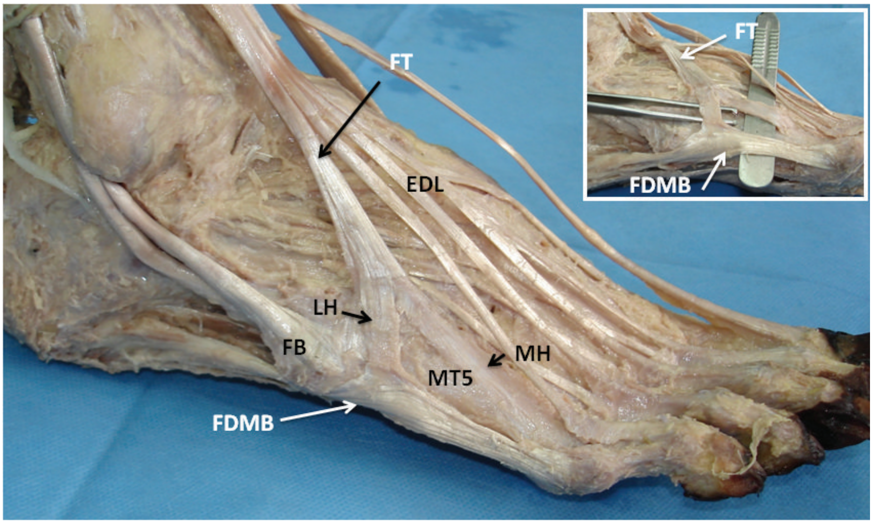

Figure 1. Photograph of the lateral aspect of the foot showing the structures of the dorsum and proximal portion of the fifth metatarsal bone (MT5). The medial slip (MH) of the bifurcated fibularis tertius tendon (FT) attached to the dorsal digital expansion of the 5th toe, and the lateral slip (LH) attached to flexor digiti mini brevis (FDMB). Fibularis brevis tendon (FB) attached to the base of the fifth metatarsal bone. EDL, Extensor digitorum longus. Inset: Surgical forceps and knife handle is placed under MS and FDMB close to the insertion of this tendon into the metatarsal bone. The entire course of the FDMB and the broad site of attachment of this structure to the base of the fifth metatarsal bone are seen.

eral part of the distal half of the fifth metatarsal bone, constituting what may be described as distinct muscle, opponens digiti minimi. These aberrant muscles are of special interest with their peculiar insertions. They were found in the different fascial compartments for the little toe as FT comes from dorsal surface and gets connected with a third plantar layer muscle FDMB. To our knowledge, there are no previous reports which have mentioned the existence of a well-developed dorsal and plantar muscle which inserted into both the fifth metatarsal and toe, until this case study.

During development, the hindlimb bud muscles originate from lumbar (L) and sacral (S) somites, whereas the connective tissue and tendon originate from somatopleuric mesoderm. The mechanism by which the muscles become anchored to the developing bones by the tendons is not clear. The myogenic cells from the differentiated somite mass invade the limb bud. The primitive myoblasts migrate through a non-random, structured network of extracellular fibrils. The extracellular fibrils direct the migration of the cells. Initially blocks of premuscle are formed that divide and subdivide rapidly. The final subdivisions get attached to developing bones (tarsal, metatarsal, and phalanges in the foot) to form individual muscles of the limb. The mechanisms that that lead to divisions of these muscle masses are not known. It can be speculated that the myogenic mass that forms the FT (L_5, S_1) and FDMB (S_2, S_3) are very close in the early embryo. The anchoring and separating mechanism of individual muscle mass in the extracellular fibrils got intermingled for these muscles that may be responsible for this kind of anomaly.[8,20]

Electromyographic studies show that FT along with extensor digitorum longus and tibialis anterior acts as a dorsiflexor of the foot. When it acts with fibulars longus and brevis, it acts as a strong evertor of the foot. During the stance phase of walking the FT helps in transmission of body weight along the lateral part of the foot and also maintain the lateral longitudinal arch. The lateral arch is adapted to transmit weight and thrust rather than to absorb such forces; as a result, the arch is always under compression. To be able to withstand these strong compression forces, muscles and ligaments that can handle such compression must support the arch of the foot. The FT muscle along with other extensor muscles of the foot becomes active during swing phase of walking helping the foot to clear off the ground. In cases where the FT is absent, the fibularis longus and brevis muscle is recruited during the swing phase of walking suggesting that the FT muscle, in hominoid lineage improved the human bipedalism.[11]

The lateral arch of foot is comparable to a segmental arched bridge with an overhead support from the FT muscle. The junction between the segments is potential weak points. The modifications of the FT insertion and the FDMB attachment noted in the present study and also by other researchers[5,6] stabilize the segments of the arch from the bottom or the sides.[21] An accessory or displaced attachment, communication between muscles or tendon may provide additional support to the arches of the foot. With evolution, the mid-foot became stable, and we presume that these accessory tendons may be remnant of some missing link muscles, which were present in subhuman primates.[22] The modifications of the muscle insertion acted like a truss between the segments of the arch (bowstring arch truss). Thus, it seems, the whole evolutionary process of the FT muscle is constantly evaluating the truss styles for the safety of the arches of the foot. To test this hypothesis, a detailed comparative study of the muscles, bones, and soft tissue of the hominoid apes, which have detailed similarities with modern humans, is required.

References

1. Harcourt-Smith WEH, Aiello LC. Fossils, feet and the evolution of human bipedal locomotion. J Anat 2004;204:403-6.
2. Sokolowska-Pituchowa J, Miaśkiewicz C, Skawina A, Makoś K. Morphology and some measurements of the peroneus tertius muscle in man. Folia Morphol (Warsz) 1974;33:91-103.
3. Jungers WL, Meldrum DJ, Stern JT. The functional and evolutionary significance of the human peroneus tertius muscle. J Hum Evol 1993;25:377-86.
4. Raheja S, Choudhry R, Singh P, et al. Morphological description of combined variation of distal attachments of fibulares in a foot. Surg Radiol Anat 2005;27:158-60.
5. Joshi SD, Joshi SS, Athavale SA. Morphology of peroneus tertius muscle. Clin Anat 2006;19:611-4.
6. Rourke K, Dafydd H, Parkin IG. Fibularis Tertius: Revisiting the Anatomy. Clin Anat 2007;20:946-9.
7. Romanes GJ. Cunningham's textbook of anatomy. 11th ed. London, Oxford: University Press; 1978. pp. 377-8.
8. Standring S, Gray H. Gray's anatomy: the anatomical basis of clinical practice, Chapter 84-8, 40th ed. London: Churchill Livingstone; 2008.
9. Stevens K, Platt A, Ellis H. A cadaveric study of the peroneus tertius muscle. Clin Anat 1993;6:106-10.
10. Bryce TH. Myology: Muscles of anterior region of leg and dorsum of foot. In: Schafer ES, Symington J, Bryce YH, editors. Quain's elements of anatomy. Vol 4. Part II, 11th ed. New York: Longmans, Green and Co; 1923. pp. 250.
11. Witvrouw E, Vanden Borre K, Willems TM, et al. The Significance of Peroneus Tertius Muscle in Ankle Injuries A Prospective Study. Am J Sports Med 2006;34:1159-63.
12. Macalister A. Additional observations on

muscular anomalies in human anatomy. Trans R Irish Acad 1872; 25: 125-30.
13. Werneck HJL. Contribuicao para o estudo de alguns aspectos morfologicos do M. Fibularis tertius em broncos, negros e mulatos, com pesquisa in vivo da presence seu tendao. Anals Fac Med Univ Minas Gerais 1957;17:417-520. [Article in Portuguese].
14. Stevens K, Platt A, Ellis H. A cadaveric study of the peroneous tertius muscle. Clin Anat 1993;6:106-10.
15. Lambert HW, Atsas S. An anterior fibulo-calcaneus muscle: An anomalous muscle discovered in the anterior compartment of the leg. Clin Anat 2010;23:911-4.
16. Williams PL, Bannister LH, Berry MM, et al. Gray's anatomy. 38th ed. London: Churchill Livingstone; 1995.
17. Wood Jones F. Structure and functions as seen in the foot. 2nd ed. London: Baillire, Tindall and Cox; 1949. pp. 158-9.
18. Hecker, P. Study on the peroneus on the tarsus. Anat Rec 1923;26:79-82.
19. Theodorou DJ, Theodorou SJ, Kakitsubata Y, et al. Fractures of Proximal Portion of Fifth Metatarsal Bone: Anatomic and Imaging Evidence of a Pathogenesis of Avulsion of the Plantar Aponeurosis and the Short Peroneal Muscle Tendon. Radiology 2003;226:857-65.
20. Larsen WJ. Human Embryology. 2nd ed. New York: Churchill Livingstone; 1997.
21. Kataria S, Roy TS. Unusual combination of musculotendinous variations in the plantar musculature. Clin Anat 2009;22:878-80.
22. Vereecke EE, D'Août K, Payne R, et al. Functional analysis of the foot and ankle myology of gibbons and bonobos. J Anat 2005; 206:453-76.