Innervation Patterns of the Lumbrical Muscles of the Foot in Human Fetuses

Betül Asena Kara, MSc*
Deniz Uzmansel, MD, PhD*
Orhan Beger, MSc*

Background: We sought to describe the innervation patterns of the foot lumbrical muscles and their morphological properties in human fetuses and to define the communicating branches between the medial (MPN) and lateral (LPN) plantar nerves, which play a part in the innervation of those muscles.

Methods: Thirty formalin-fixed fetuses (13 male and 17 female) with a mean ± SD gestational age of 25.5 ± 3.8 weeks (range, 18–36 weeks) from the inventory of the Mersin University Faculty of Medicine Anatomy Department were bilaterally dissected. Innervation patterns of the lumbrical muscles and the communicating branches between the MPN and the LPN were detected and photographed.

Results: No variations were seen in lumbrical muscle numbers. In the 60 feet, the first lumbrical muscle started directly from the flexor digitorum longus tendon in 48 and from the flexor hallucis longus slips in addition to the flexor digitorum longus tendon in 12. Fifty-five feet had the classic innervation pattern of the lumbrical muscles, and five had variations. No communicating branches were seen in 48 feet, whereas 12 had connections.

Conclusions: This study classified innervation patterns of the foot lumbrical muscles and defined two new innervation types. During surgeries on the foot and ankle in neonatal and early childhood terms, awareness of the communicating branches between the MPN and the LPN and innervation of the intrinsic muscles of the foot, such as the lumbrical muscles, might aid in preventing possible complications. (J Am Podiatr Med Assoc 110(3): 1-5, 2020)

The lumbrical muscles on the sole of the foot begin from the flexor digitorum longus tendons and attach to the dorsal digital expansions of the proximal phalanges of the lesser toes.[1] The first lumbrical muscle is innervated by the medial plantar nerve (MPN), and the other three lumbrical muscles are innervated by the deep branch of the lateral plantar nerve (LPN).[1,2] The lumbrical muscles provide extension of the interphalangeal joints and flexion of the metatarsophalangeal joint.[1,3] In addition to their motor functions, the lumbrical muscles also play a role in sensory functions because of the many muscle spindles within.[1,3] By proprioceptive bridging between the flexor structures on the plantar surface and the extensor structures on the dorsal surface, the lumbrical muscles control the joint movements during walking and stance according to foot motion.[1,3] Electromyography studies showed that the lumbrical muscles significantly support the medial longitudinal arch in addition to other intrinsic muscles on the sole of foot.[4] Despite all that, studies on the lumbrical muscles of the foot are very limited. No previous anatomical or morphological studies were found in the literature on growth dynamics of the lumbrical muscles in fetuses.

In this study, the main objective was to describe the structural properties of the lumbrical muscles in fetuses and their innervation patterns. Another focal point was to define the communicating branches between the MPN and the LPN.

Materials and Methods

Thirty formalin-fixed fetuses (13 male and 17 female) with a mean ± SD gestational age of 25.5

*Department of Anatomy, Mersin University Faculty of Medicine, Mersin, Turkey.

Corresponding author: Orhan Beger, MSc, Department of Anatomy, Mersin University Faculty of Medicine, Ciftlikkoy Campus, 33343, Mersin, Turkey. (E-mail: obeger@gmail.com)

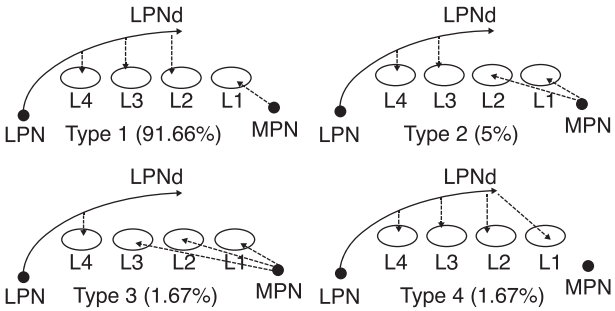

Figure 1. Innervation patterns of the lumbrical muscles (L1–L4) and their incidence rates. LPN, lateral plantar nerve; LPNd, deep branch of the lateral plantar nerve; MPN, medial plantar nerve.

± 3.8 weeks (range, 18–36 weeks) without any deformities in the foot region in the inventory of Mersin University Faculty of Medicine Anatomy Department (Mersin, Turkey) were bilaterally dissected. The study was approved by the ethics board of the Faculty of Medicine, Mersin University. The MPN and the LPN were exposed after lifting the anatomical structures one by one on the sole under microscope guidance (Carl Zeiss f-170; Carl Zeiss Microscopy, Jena, Germany). By following the nerve pathways from proximal to distal, the communicating branches between the MPN and the LPN, in addition to the innervation patterns of the lumbrical muscles, were investigated. Moreover, the presence and attachment sites of the lumbrical muscles were noted. All of the samples were photographed. The data obtained from the study were statistically reviewed. Normality controls were performed with the Shapiro-Wilk test. The paired samples t test was used in side (right/left) comparisons, and the independent-samples t test was used in sex comparisons. Statistical significance was set as $P < .05$.

Results

No significant differences were found when sides or sexes were compared ($P > .05$). All of the feet had four lumbrical muscles.

The innervation patterns of the lumbrical muscles were divided into four types (Fig. 1): type 1—the first lumbrical muscle is innervated by the MPN and the others are innervated by the deep branch of the LPN (classic pattern), 91.66% (55 feet) (Fig. 2); type 2—the first and second lumbrical muscles are innervated by the MPN and the others are innervated by the deep branch of the LPN, 5% (three feet) (Fig. 3A); type 3—the first three lumbrical muscles are innervated by the MPN and the fourth is innervated by the deep branch of the LPN, 1.67% (one foot) (Fig. 3B); and type 4—all of the lumbrical muscles are innervated by the deep branch of the LPN, 1.67% (one foot) (Fig. 3C).

The connections between the MPN and the LPN are divided into four types according to the classification of Govsa et al[5] (Fig. 4) as follows: type 1—no connection, 80% (48 feet) (Fig. 5A); type 2—branch from the LPN to the MPN, 15% (nine feet) (Fig. 5B); type 3—reserve communicating branches, 3.33% (two feet) (Fig. 5C); and type 4—branch from the MPN to the LPN, 1.67% (one foot) (Fig. 5D).

In the 60 feet, the first lumbrical muscle started directly from the flexor digitorum longus tendon in 48 and from the flexor hallucis longus slip plus the flexor digitorum longus tendon in 12 (Fig. 6). All of the lumbrical muscles were attached to the dorsal digital expansions of the proximal phalanges of the lesser toes.

Discussion

In this study, data related to the anatomical structure of the foot lumbrical muscles in human

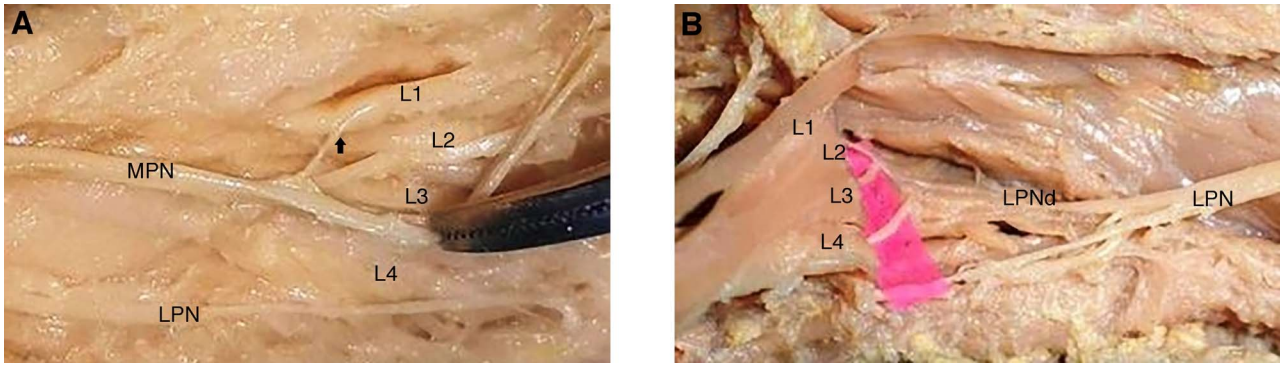

Figure 2. A, Innervation of the first lumbrical muscle (L1) (arrow) by the medial plantar nerve (MPN). B, Innervation of L2 through L4 by the deep branch of the lateral plantar nerve (LPNd). LPN, lateral plantar nerve.

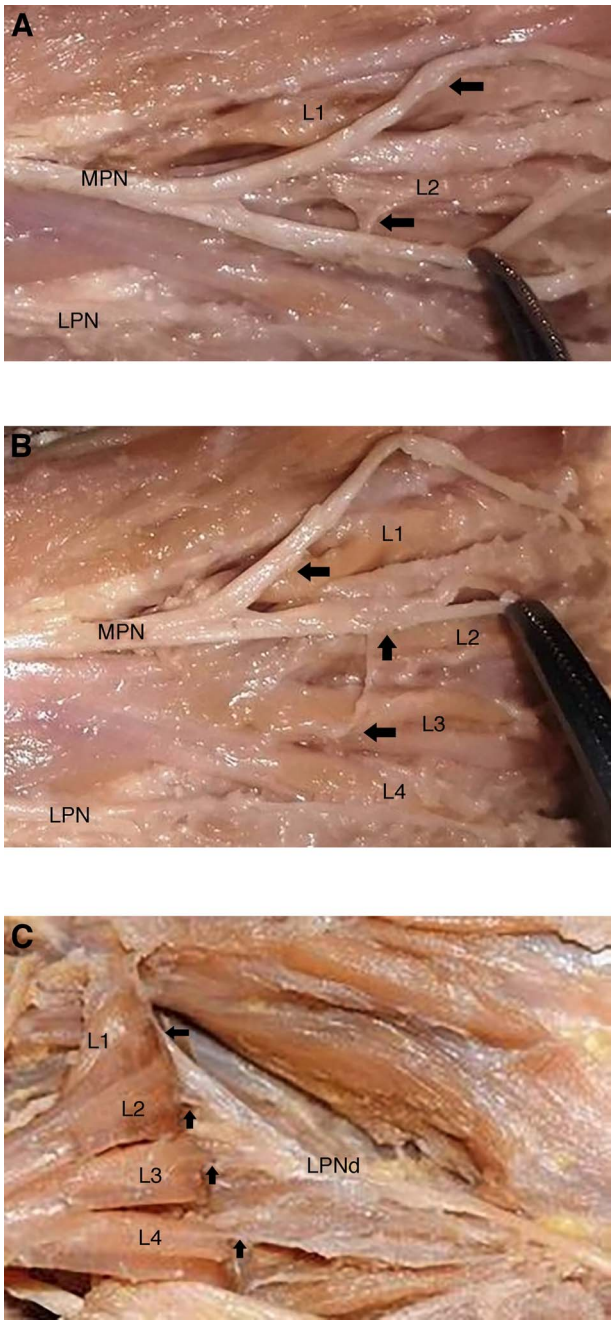

Figure 3. A, Innervation of the first and second lumbrical muscles (L1–L2) (arrows) by the medial plantar nerve (MPN). B, Innervation of L1 through L3 (arrows) by the MPN. C, Innervation of L1 through L4 (arrows) by the deep branch of the lateral plantar nerve (LPNd). LPN, lateral plantar nerve.

fetuses were obtained by considering the presence, attachment sites, and innervations of these muscles. Although in previous studies[6-8] the rate of missing one or more lumbrical muscles was reported to be

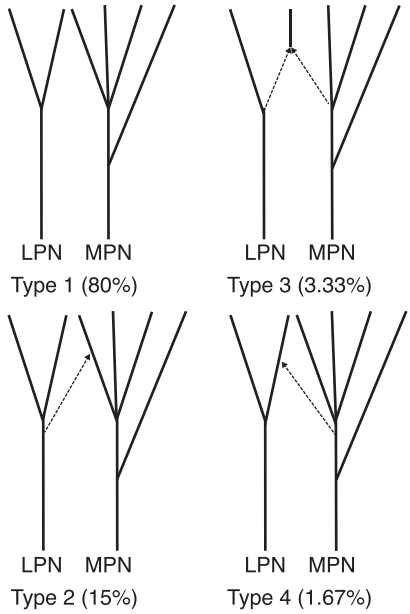

Figure 4. The communicating branches between the medial plantar nerve (MPN) and the lateral plantar nerve (LPN) and their incidence rates.

8% to 45%, the present samples all had four lumbrical muscles. There is no consensus regarding the origins of the lumbrical muscles in the literature.[3,8] There are a few cases reported that the lumbrical muscles originated from the tibialis posterior, flexor hallucis longus, flexor digitorum brevis, or flexor hallucis longus slips.[3,8] In these case series, it was observed that the first lumbrical muscle originated from the flexor hallucis longus slips in 12 feet (20%).

Studies on innervation patterns of the lumbrical muscles in the foot are quite limited. Brooks[2] reported the classic pattern in nine feet (type 1) and a variative pattern in one foot (type 2). The study by Akita et al[9] on innervation patterns of intrinsic sole muscles reported the classic pattern (type 1) in all 38 feet. However, in just one foot they reported a communicating branch between the MPN and the deep branch of the LPN, which innervates the first lumbrical muscle.[9] In the present study, the innervation patterns of the lumbrical muscles were classified, and two new types were found. In one foot, we detected innervation by the MPN in the first three lumbrical muscles and by the deep branch of the LPN in the fourth lumbrical muscle (type 3). In another foot, all of the lumbrical muscles were innervated by the deep branch of the LPN (type 4). To our knowledge, this is the first study in which the innervation patterns of the lumbrical muscles are classified in human fetuses. Being aware of different

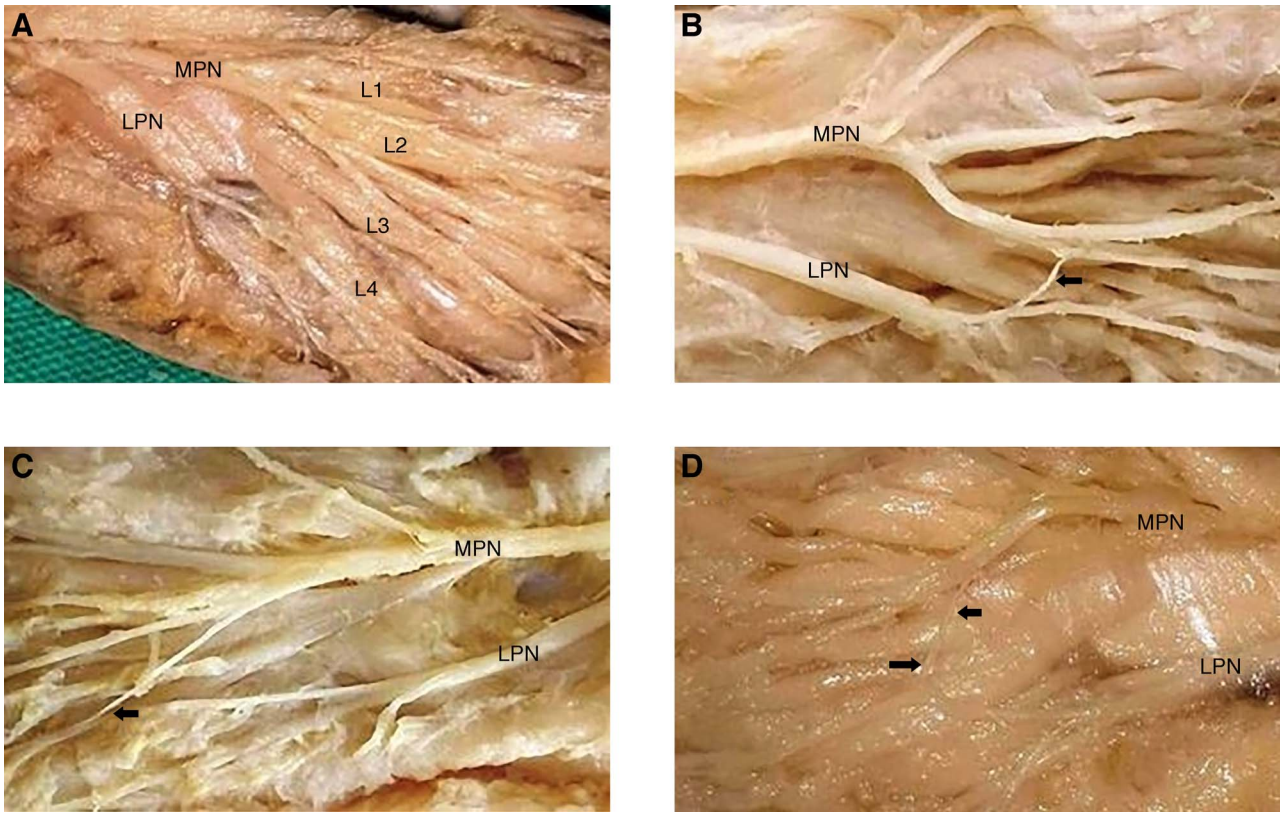

Figure 5. Connection types between the medial plantar nerve (MPN) and the lateral plantar nerve (LPN). A, Type 1. B, Type 2. C, Type 3. D, Type 4. L1–L4, first through fourth lumbrical muscles.

innervation patterns of the lumbrical muscles is important to prevent iatrogenic injury during early childhood surgeries.

The incidence rate of the communicating branches between the MPN and the LPN varied greatly in previous studies.[5,9-12] Govsa et al[5] reported a communicating branch between the MPN and the LPN in 14 of 50 feet (28%), Akita et al[9] in two of 38 (5.2%), Levitsky et al[10] in 19 of 71 (26.8%), Arakawa et al[11] in 19 of 22 (86.4%), and Jones and Klenerman[12] in all 20 feet included in their study. Communicating branches between the MPN and the LPN were found in 12 of 60 feet (20%) in the present study. Govsa et al[5] defined four types according to the structural properties of connections between the MPN and the LPN. Type 1 (no connection) was seen in 36 feet (72%), type 2 (originated from the LPN) in ten (20%), type 3 (reserve communicating branches) in two (4%), and type 4 (originated from the MPN) in two (4%).[5] The present results about the communicating branches between the MPN and the LPN were similar to the study results of Govsa et al.[5]

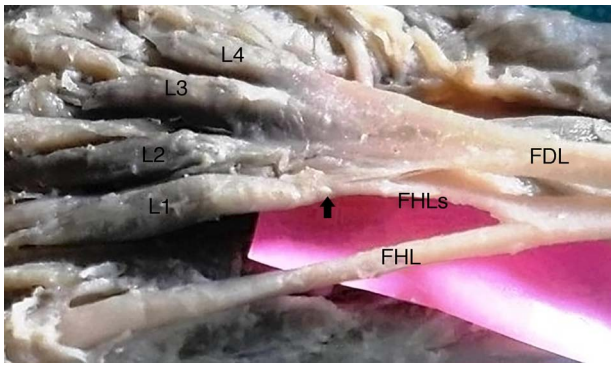

Figure 6. Attachment of the first lumbrical muscle (L1) (arrow) to the flexor hallucis longus slips (FHLs). FDL, flexor digitorum longus; FHL, flexor hallucis longus.

Conclusions

Innervation patterns of the lumbrical muscles were classified, and two new types were found. In addition, the presence rate of communicating branches between the MPN and the LPN was found to be 20% in human fetuses. The data related to the communicating branches and the presence, attach-

ment sites, and innervations of the lumbrical muscles with the increased gestational age of fetuses ranging from 18 to 36 weeks can be beneficial in understanding the growth dynamics during the fetal period. Moreover, we think that these results can also be used in neonatal congenital surgeries of the foot and ankle by helping avoid interventional complications and, therefore, providing better results in biomechanical studies and, finally, in rehabilitation programs.

Financial Disclosure: This study was supported by Mersin University (grant 2016-2-TP2-1903).
Conflict of Interest: None reported.

References

1. Standring S, Borley NR, Collins P, et al: "Ankle and Foot," in *Gray's Anatomy: The Anatomical Basis of Clinical Practice*, Vol 1, edited by S Standring, p 1453, Churchill Livingstone, London, 2008.
2. Brooks HS: Variations in the nerve supply of the lumbrical muscles in the hand and foot, with some observations on the innervation of the perforating flexors. J Anat Physiol **21:** 575, 1887.
3. Hur MS, Kim JH, Gil YC, et al: New insights into the origin of the lumbrical muscles of the foot: tendinous slip of the flexor hallucis longus muscle. Surg Radiol Anat **37:** 1161, 2015.
4. Fiolkowski P, Brunt D, Bishop M, et al: Intrinsic pedal musculature support of the medial longitudinal arch: an electromyography study. J Foot Ankle Surg **42:** 327, 2003.
5. Govsa F, Bilge O, Ozer MA: Anatomical study of the communicating branches between the medial and lateral plantar nerves. Surg Radiol Anat **27:** 377, 2005.
6. Chaney DM, Lee MS, Khan MA, et al: Study of ten anatomical variants of the foot and ankle. JAPMA **86:** 532, 1996.
7. Kura H, Luo ZP, Kitaoka HB, et al: Quantitative analysis of the intrinsic muscles of the foot. Anat Rec **249:** 143, 1997.
8. Kafka RM, Aveytua IL, Fiacco RC, et al: "Intrinsic Muscles of the Foot," in *Bergman's Comprehensive Encyclopedia of Human Anatomic Variation*, Vol 1, edited by RS Tubbs, p 445, Wiley-Blackwell, Hoboken, NJ, 2016.
9. Akita K, Sakamoto H, Sato T: Lateromedial and dorsoplantar borders among supplying areas of the nerves innervating the intrinsic muscles of the foot. Anat Rec **255:** 465, 1999.
10. Levitsky KA, Alman BA, Jevsevar DS, et al: Digital nerves of the foot: anatomic variations and implications regarding the pathogenesis of interdigital neuroma. Foot Ankle **14:** 208, 1993.
11. Arakawa T, Sekiya S, Terashima T, et al: Pseudoganglion on the connecting branch between the deep branch of the lateral plantar nerve and medial plantar nerve. Clin Anat **24:** 646, 2011.
12. Jones JR, Klenerman L: A study of the communicating branch between the medial and lateral plantar nerves. Foot Ankle **4:** 313, 1984.