Journal of Morphological Sciences
J Morphol Sci
Brazilian Society of Anatomy

Original Article
J Morphol Sci 2023;40:417-424

Clinically Oriented Morphological Study of the Peroneal Muscles in Human Cadavers

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Disclose and conflicts of interest: none to be declared by all authors

ABSTRACT

Introduction: the objective of this anatomical investigation was to record the morphology of peroneus longus (PL), brevis (PB) and tertius (PT) muscles in human cadaveric specimens.

Material and Methods: this study utilized 40 cadaveric formalin fixed lower limb specimens. The leg region was meticulously dissected to expose the muscle belly and their tendons to study the morphology. They were traced till their insertion in the foot. The morphometric data were recorded by using the digital Vernier caliper.

Results: PL tendon was inserting to the first metatarsal and medial cuneiform bones in 32 specimens (80%), to the shaft of first metatarsal in 3 cases (7.5%) and in 5 specimens, tendon got inserted into the second metatarsal (12.5%). Thirty PB specimens (75%) had tubular morphology at the insertion and 10 specimens (25%) showed a fan or triangular shaped flattened insertion into the fifth metatarsal. The PT was observed in all of our specimens (100%). It presented a single tendon at the site of insertion in 28 specimens (70%), presented a flattered broad insertion (band like) in 7 specimens (17.5%). This morphology shared a slip to the PB and in 5 specimens (12.5%), the muscle got inserted into the fourth metatarsal and gave fibrous expansion to the extensor digitorum longus.

Conclusion: we believe that the morphological data of the peroneal muscles presented in this study are beneficial to the plastic and reconstructive surgeries, ankle and foot surgeries during the muscle flap and correction procedures of the lower extremity.

Keywords: Muscles; Musculotendinous junction; Sesamoid bones; Metatarsal bones.

Introduction

The peroneal muscles are prone for inconsistency in their morphology and are often associated with the additional bands, tendons and muscles[1,2]. Morphological variations of peroneal muscles can be interpreted based on their embryological and evolutionary basis[3,4]. The insertion of peroneal muscles can be variable as they are still in the process of human evolution of bipedal morphology[5]. The course of peroneus longus (PL) is multifarious and this muscle can be involved in the pathological changes of the lower leg, ankle and foot[6]. It is necessary to a radiologist to know the compound anatomy of PL muscle and its tendon to offer the best diagnosis[6]. The prior knowledge of the morphology and morphometry of the peroneal muscles could help in avoiding the subsequent persistence of postoperative pain and improper foot movements. The anatomical details of PL are enlightening to the plastic and reconstructive surgeons. Since the length of PL tendon is inconstant and inflexible, this favors it to be a graft for the surgical procedures[7]. The PL tendon autografts are utilized in the reconstruction of deltoid, medial patellofemoral and anterior cruciate ligaments[8-10]. Lateral and superficial positioning of the PL muscle facilitates the easy harvesting of the muscle, which can be utilized for the reconstruction of other defective tissue and grafting. Superior peroneal retinaculum can be reconstructed by using the peroneus brevis (PB) muscle. This procedure is commonly performed in skiers[11]. PB is also utilized in the surgical repair of the tendo-calcaneus[12]. The peroneus tertius (PT) is exclusively found in human and absent in hominid apes[13]. PT is redirected as the 5th tendon of the extensor digitorum longus (EDL) muscle and it can be transplanted to replace the paralyzed tibialis anterior muscle[14].

The variability in the insertion of PT may add to the pathophysiology of Jone's fracture[15]. PT flaps can be considered in correcting the sloppiness of the ankle and also in the transplantation surgeries of the foot[16]. The surgical reconstruction of the soft tissues at the lower extremity are difficult due to the scarcity of superficial fascia and the absence of muscles over the structures like bone, tendon, nerve and vessel. Hence,

DOI: 10.51929/jms.40.417.2023
ISSN 2177-0298

myocutaneous flaps are raised in these concerned surgeries. During the tendon transfer or muscle transposition procedures, the degree of postoperative normal function depends on the morphology of the muscle, which is utilized as a graft. This requires some prior knowledge about the dimensions and morphology of the muscle and its tendon. In this context, the objective of this anatomical study was to record the morphometry and morphology of the PL, PB and PT muscles and their tendons in embalmed adult human cadavers.

Material and Methods

This study was executed by utilizing 40 human cadaveric formalin fixed lower limb specimens. The present study did not segregate the specimens into right and left side or male and female. The specimens which exhibited the pathological changes were not considered in the present study. The leg region was methodically dissected to look for the morphology of peroneal tendons and they were traced till their insertion at the foot. The pattern of their insertions, muscle length and tendon length were carefully noted. The width and thickness of the muscles were measured at the origin, midpoint and musculo-tendinous junction. The PL muscle was measured at four parts, from 2cm below the head of fibula to musculo-tendinous junction (AB in Fig. 1), length from musculo-tendinous junction until the lateral malleolus (BC in Fig. 1), from 2 cm above the lateral malleolus to the peroneal tubercle (CD in Fig. 1) and from the peroneal tubercle until the site of insertion (DE in Fig. 1). The PB (Fig. 2A) was measured at its belly from 4cm below the fibular head to the musculotendinous junction (FG in Fig. 2B), from the musculo-tendinous junction to the superior peroneal retinaculum (GH in Fig. 2B), from the retinaculum to the peroneal trochlea (HI in Fig. 2B) and from the peroneal trochlea till the site of insertion (IJ in Fig. 2B). The belly of PT was measured from its origin to the musculotendinous junction (KL in Fig. 2B) and the dimension from its musculo-tendinous junction till its insertion (LM in Fig. 2B) was also measured. Various dimensions of all the three muscles were determined by applying the digital Vernier caliper (Mitutoyo Corporation, Kawasaki, Japan). The present study was approved by the ethics committee of our institution and is performed in accordance with the ethical standards laid down by the “Declaration of Helsinki”.

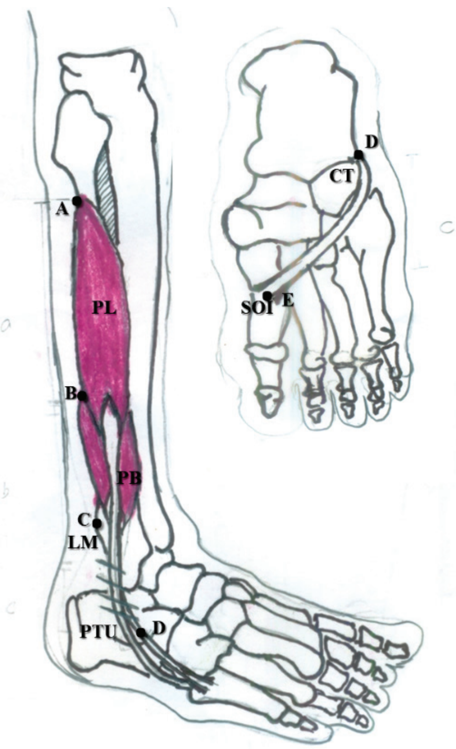

Figure 1. Schematic diagram showing the dimensions of PL muscle measured at various points in this study (PL-peroneus longus; PB-peroneus brevis; LM-lateral malleolus; PTU-peroneal tubercle; CT-cuboid tunnel; SOI-site of insertion; AB-measurement from 2cm below the head of fibula to musculo-tendinous junction; BC-length from musculo-tendinous junction to the lateral malleolus; CD-dimension from 2 cm above the lateral malleolus to the peroneal tubercle; DE-from the peroneal tubercle until the site of insertion).

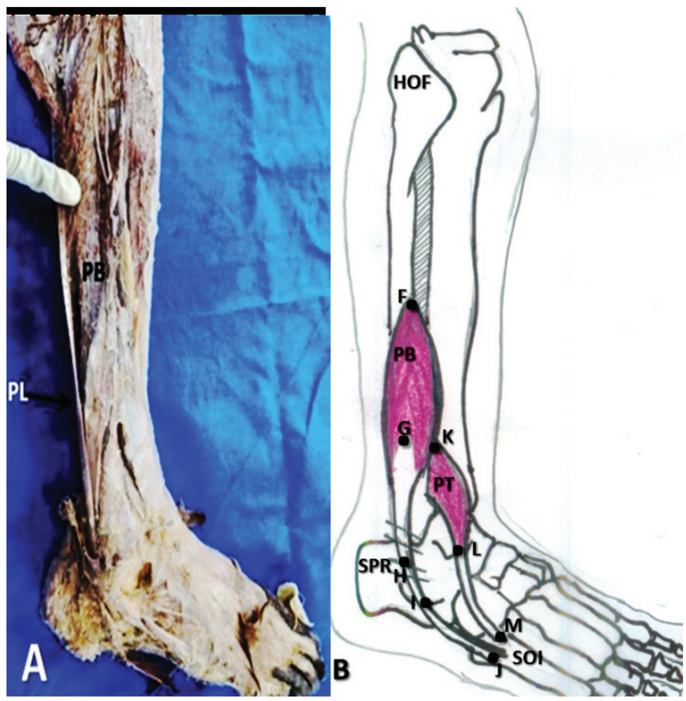

Figure 2A. Cadaveric lower limb showing the peroneus longus (PL), its course into retro-malleolar groove and descending down across the foot and peroneus brevis (PB) muscles; 2B. Schematic diagram showing the dimensions of PB and peroneus tertius (PT) muscles measured at various points in this study (SPR-superior peroneal retinaculum; SOI-site of insertion; FG-length of belly of PB from 4 cms below the fibular head to the musculotendinous junction; GH-measurement from the musculo-tendinous junction to the SPR; HI-from the SPR to the peroneal trochlea; IJ-from the peroneal trochlea till the SOI; KL-length of belly of PT from its origin till the musculotendinous junction; LM-dimension from its musculo-tendinous junction till its SOI).

Results

Peroneus longus (PL, Figs. 2A and 3)

Among the 40 specimens, 38 (95%) had convex shape and 2 (5%) had flat presentation at the retromalleolar groove (Fig. 3). The sesamoid bone was present in PL at the cuboidal tunnel in 37 (92.5%) specimens. The insertion of PL was at the first metatarsal bone base (Fig. 3) and medial cuneiform bone in 32 specimens (80%), to the shaft of first metatarsal in 3 cases (7.5%)

and in 5 specimens, tendon got inserted into the second metatarsal (12.5%). The 3 specimens (7.5%) showed that the lower attachment of the PL was additionally attaching into the neck of the first metatarsal. The tendon was plastered to the cuboid tunnel at its tubercle through a slip in 4 specimens (10%). The mean PL muscle length measured from 2 cm below the head of fibula to its musculo tendinous junction was 195 ± 48.22 mm, from the musculo tendinous junction to 2cm above the lateral malleolus was 130.07 ± 70.8 mm. The length from the lateral malleolus to the peroneal trochlea was 42.18 ± 24.48 mm and from peroneal trochlea to the site of insertion was 80.1 ± 25.6 mm. The mean thickness and width of PL at its origin, midpoint and at musculotendinous junction are represented in Table 1.

Peroneus brevis (PB, Fig. 2A)

The PB tendon was found below the PL tendon at the retromalleolar groove (Fig. 2A) in all the specimens. The flat morphology of tendon was observed in retromalleolar groove in 32 specimens (80%) and convex shaped tendon was observed in 8 specimens (20%). Thirty specimens (75%) had tubular morphology at the insertion and 10 specimens (25%) showed a fan or triangular shaped flattened insertion into the fifth metatarsal.

The PB muscle length was 172.02±36.6 mm, the length from musculo-tendinous junction to the superior peroneal retinaculum was 49.09±11.32 mm, from the superior peroneal retinaculum to the peroneal trochlea was 56±12.67 mm and from the peroneal trochlea to the insertion was 55.3±15.8 mm

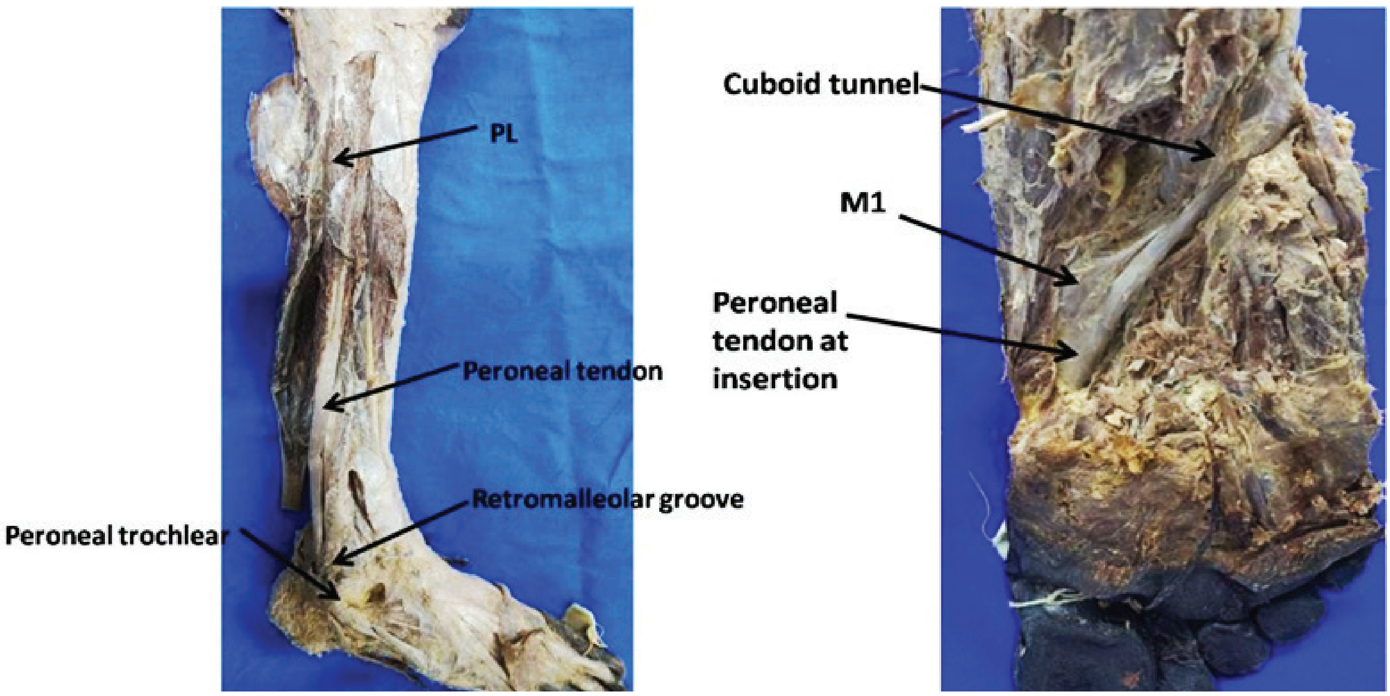

Figure 3. Cadaveric lower limb showing the origin of peroneus longus (PL), its course into the retromalleolar groove and descending down across the foot in the cuboidal tunnel and inserting with a slip to the first metatarsal bone (M1).

Table 1. Width and thickness of the peroneal muscles at different locations (n=40).

	Peroneus Longus	Peroneus brevis	Peroneus Tertius
At origin			
Width	20.52±3.86	19.55±4.56	2.7±0.66
Thickness	7.67±3.21	2.7±2.14	0.75±0.29
Midpoint			
Width	21.15±4.18	18.75±4.05	0.78±0.27
Thickness	8.36±3.31	2.7±0.78	0.66±0.21
Musculotendinous Junction			
Width	18.67±3.96	8.2±2.99	0.78±0.27
Thickness	5.95±3.12	2.9±0.79	0.54±0.2

Measurements are in mm, mean±SD.

respectively. The mean width and thickness of PB at its origin, midpoint and at musculotendinous junction are represented in Table 1.

Peroneus tertius (PT, Fig. 4)

The PT was looking like the 5th tendon of the EDL, as this was thinnest. It was originating from the distal 2/3rd of fibula in 20 cases (50%), 10 specimens (25%) showed origin from the lower 1/3rd of fibula and remaining 10 specimens (25%) showed the origin from EDL. The PT presented a single tendon (Fig. 4A) at the site of insertion in 28 specimens (70%), presented a flattered broad insertion (band like) in 7 specimens (17.5%). This morphology shared a slip to the PB (Fig. 4B) and in 5 specimens (12.5%), it was observed that the muscle got inserted into the fourth metatarsal and gave fibrous expansion to the EDL (Fig. 4C).

The muscle belly length of PT was 10.8±1.94 mm and the mean tendon length measured from the musculotendinous intersection to the insertion site at the base of fifth metatarsal was 69.3±29.58 mm respectively. The mean width and thickness of PT at its origin, midpoint and at musculotendinous junction are represented in Table 1.

The present study did not observe, third muscle in the lateral leg compartment (0%).

Discussion

During the sixth week of intraembryonic life, rudimentary portions of the peroneal muscles gets detached from the muscles of front of leg[17]. The PB originates more proximal in the fetuses than its adult position and eventually separates from the PL tendon[17]. It was reported that, it is not uncommon to find the third muscle in the peroneal compartment and which is reported to have a prevalence of upto 95% in cadaveric samples[18]. 'Peroneus quartus' is the term, which is oftenly used to describe one or several accessory muscles in the peroneal leg compartment[19]. Presence of additional peroneal muscles could lead to crowding at the retromalleolar groove, which eventually leads to stretching of the superior peroneal retinaculum. This can make the ankle unstable[20]. Presence of accessory muscle may affect the PB, at the retinaculum by compressing the tendon leading to the peroneal pathology[21]. Witvrouw *et al.*[22] opined that, it will create bias during the evaluation of the range of motion at the foot and ankle. Our specimens did not reveal any additional muscle at the lateral compartment of leg. However, few interesting variations were observed, which may have impact on the eversion, plantar flexion, ankle stability and maintenance of arches of foot. The stability of peroneal tendons can be affected by the morphology of retromalleolar groove due to

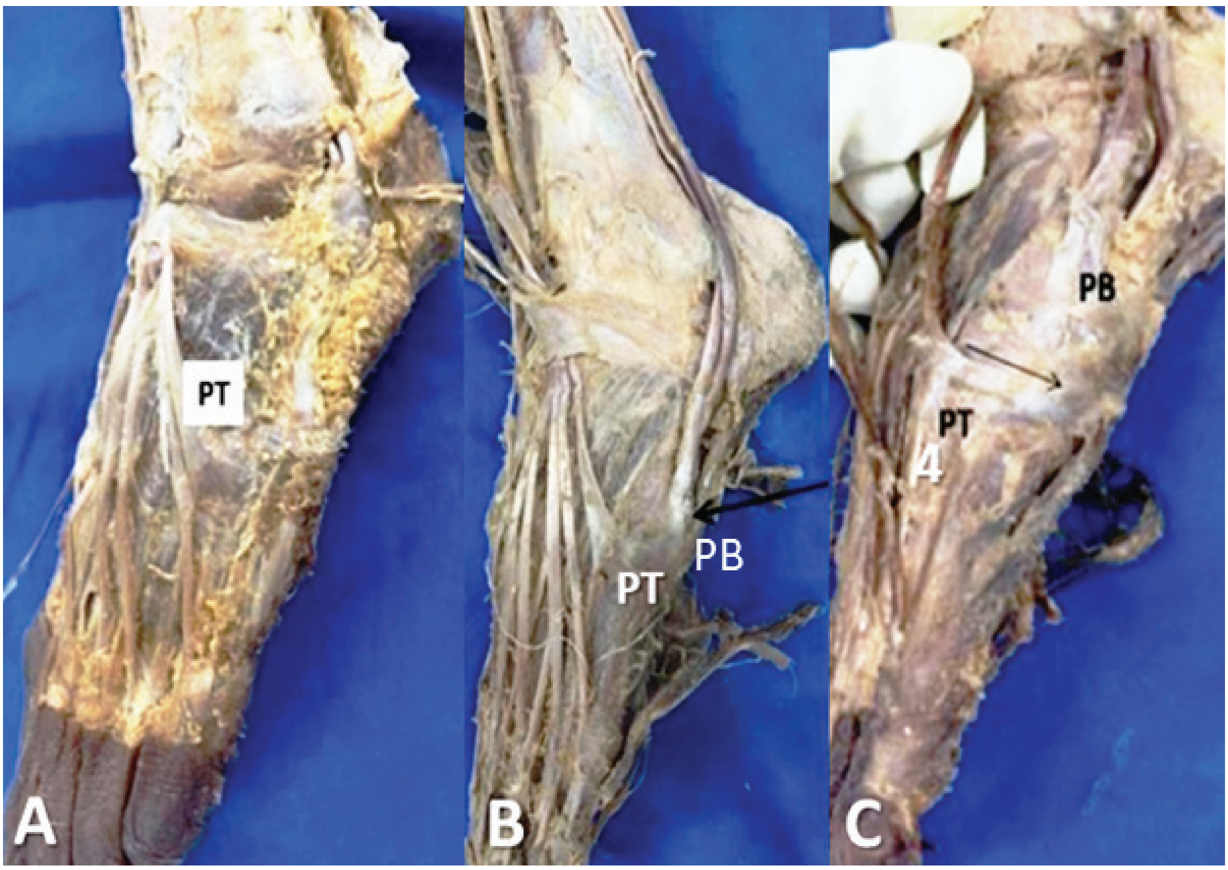

Figure 4A. Insertion of the peroneus tertius (PT); 4B. band like insertion (flattered shape) of PT into the peroneus brevis (PB); 4C. flattered tendon of PT attached to the fourth metatarsal (arrow) and fourth tendon of extensor digitorum longus (4).

the changes in its shape, which result in instability and tearing[23,24]. But there were no significant changes found in our study, as we could observe only the flat and concave shaped tendon. PL may give additional slips to the nearby structures like the first dorsal interosseous muscle and medial cuneiform bone[25,26]. In 12.5% of our specimens, the PL tendon got inserted into the second metatarsal bone and in 7.5% cases, the distal attachment of the PL was having giving an extra slip to the neck along with the base of the first metatarsal bone. There was adherence of PL slip to the cuboid tunnel at its tubercle in 10% cases. It is believed that, the type of variations observed in the present study can cause difficulty in making a clinical diagnosis at the first local examination of the patient[27]. In this anatomical investigation, sesamoid bone was present in PL at the cuboidal tunnel in 92.5% specimens. According to the previous report, the sesamoid bone named 'os peroneum' is present in each and every individual (100%), however ossified only in 20% of the cases[28]. The presence of os peroneum in the cuboidal tunnel can lead to the painful syndrome, particularly at the lateral aspect of the posterior region of foot[29].

Injury to the PL tendon is a common feature in young sports person and wearing kind of peroneal tendon tears are commonly associated. Apart from tendon tears, the peroneal compartment is also involved in increase in the pressure, which can cause acute pain, paresthesia and weakness of the muscle action. On a serious note, these compartment syndromes should be dealt with at most care, which can require medical and surgical intervention. It was reported that, size of the PL dictates the type of foot and movements of the back of foot at the coronal plane and since the flat foot is observed in a patient with larger PL, this determines the tendon loading during the gait[30]. Our study recorded the detailed dimensions of the PL, at different locations, which are clinically oriented. Since the PL tendon is used a graft in the reconstruction of anterior cruciate ligament, these morphometric data will be enlightening to the operating surgeon. In the ACL reconstruction, the graft size of less than 8 cm had higher postoperative complications. The best graft can have a minimum of 2 cm at femoral tunnel, 4 cm inside the joint, and 2 cm at the tibial tunnel[31]. The present study offers the length of PL tendon at various locations, the data of them are enlightening to the surgeon, while harvesting the PL tendon autograft. The length of PL tendon is much more than the required 80 mm size of the autograft for the ACL reconstruction. Predictive equation can be obtained by using the width of the PL and this can help in the effective planning of the arthroscopic ACL reconstruction[32]. The present study provides the width and thickness of the PL at various locations, the data can be utilized during the harvesting of the graft.

The PB can be utilized to shelter the deficiencies in the lower third of the leg. Mathes *et al.*[33] described the PB turnover flap, which had a richer blood supply and sufficient tissue size. Yang *et al.*[34] confirmed that, since PB has a greater vasculature, the reverse flap can give the best results in comparison to other grafts. PB has a high vascular supply with the sufficient muscle volume, which makes it more suitable for the surgical repair and reconstruction. The PB is a low-laying muscle, which has no significant variation at its insertion, but gives some slips to the nearby structures and it gets inserted to the fifth metatarsal bone by forming a flattered structure. Morphology of the PB tendon varies from tubular to the flattered morphology to the base of 5th metatarsal at its insertion. This facilitates the stabilization of the eversion of the foot. In the present study, 75% of PB had tubular morphology at the insertion and 25% showed a fan or triangular shaped flattened insertion into the fifth metatarsal. The flat morphology of tendon was observed in retromalleolar groove in 80% specimens and convex shaped tendon was observed in 20%. The present study observed that, PB had an average of 27mm thickness and 87mm width at its midpoint. In the present study, the PB muscle length was 172.02±36.6 mm, the length from the musculo-tendinous junction to the superior peroneal retinaculum was 49.09±11.32 mm, from the superior peroneal retinaculum to the peroneal trochlea was 56±12.67 mm and from the peroneal trochlea to the insertion was 55.3±15.8 mm respectively. Thus it was observed that the contractile component of the muscle was of more length, than its tendon. The PB muscle belly length of our study is lesser than the data reported by Wickiewicz *et al.*[35], which was 230 mm. The reason may be because of the ancestral variations and this present study is from cadaveric samples. Wickiewicz *et al.*[35] recorded the length in the maximum stretched state of the limb. The morphometric data of the PB is clinically important as the thickening of PB tendon is an important criterion in the diagnosis of PB tendinitis[36]. There are few radiological reports available about the morphometry of the PB, however the same are scarce in the cadaveric samples. In this context, the present study offers various dimensions like width, length and thickness of the PB muscle and its tendon separately at different locations. This data can be considered as the morphological database for the sample population of our region.

The PT muscle largely contributes in stabilizing the arches of foot during the walking. However, this is considered to be an insignificant function and PT can be used by the surgeons as a replacement for the defective muscles at the lower leg. The PT, which mostly represented as a lateral slip of the EDL[37]. Kimura and Takahashi[38] reported an absence frequency of PT, which was 4.8%. However, Johnson[39] observed this muscle in only 5% of their cases and they reported that, in such cases it is replaced by an accessory muscle at the peroneal compartment. These accessory fibular muscle would share the same origin and insertion site of the PT as per Yammine[40]. However, the present study observed PT in all the specimens (100%) and we could not observe the absence of PT in our cadaveric study (0%). The frequency of prevalence of PT among various population subgroups globally, is represented in Table 2. Ramirez *et al.*[41] reported that, PT is observed in all of their specimens from Bolivian population (100%), which can be compared to the frequency of our study. The frequency of prevalence of PT was variable among various population subgroups (Table 2) as the ancestral variations seemed to exist. Hansen Jr *et al.*[42] reported that, some of the origin and insertion site variations of PT, such as the tendon slip which inserts into the 4th metatarsal would also get inserted into the 5th metatarsal, with a broad fan shaped slip. This morphology was seen in the present investigation as well (Figs. 4B and 4C). Sometimes, the tendon may also get inserted into the proximal part of the fifth metatarsal bone and also into the fascia covering the 4th intermetatarsal space[43]. This type of morphology would increase the formation of bridge over the lateral mid foot, which in turn increases the eversion action and also play essential role in the walking[43,44]. Such additional slips on the site of insertion initiates the torsion and stress fracture[15]. As the PT muscle function is associated with the EDL and tibialis anterior, reconstruction of the defective soft tissue can be done with this muscle easily[45]. There will be no functional postoperative weakness, because this muscle works as a group along with the other muscles. Our study also provided the morphological details of the PT at various locations. PT's mean length of the tendon measured from the musculotendinous junction to the insertion at the base of fifth metatarsal was 69.3±29.58 mm, which is slightly higher than the previously reported data of 64 mm by Bhatt *et al.*[46]. However, Marin *et al.*[47] reported the PT tendon length as 81.3 mm. The present study recorded the tendon width of PT as 7.8±2.7 mm, which is higher than the finding of Verma and Seema[48], who got the reading as 5 mm. According to de Gusmão *et al.*[49], the mean width of the PT was 4.5 mm. The present study observed a higher dimension, because this was taken at the musculotendinous junction. The dimensions of PT is important because of its clinical implications. Osteomyelitis of the lower limb can be treated by the local flap muscle of PT[50] and by altering the site of insertion of PT, the claw foot deformity can be treated[50,51].

The present study has few limitations like the smaller sample size, the findings will be more accurate with a larger sample size. We did not take the gender and side of the specimen into consideration. The right and left side comparison, male versus female analysis will be more interesting.

Table 2. Frequency of prevalence of PT among various population.

Authors	Population	Frequency
Adachi[52]	Japanese	95.5%
Nakano[53]	Chinese	89.3%
Werneck[54]	Caucasian	95.6%
Sokolowska-Pituchowa *et al.*[55]	Polish	78.6%
Bertelli and Khoury[56]	French	91%
Stevens *et al.*[57]	British	95%
Marin *et al.*[47]	Brazilian	93.8%
Witvrouw *et al.*[22]	Belgian	81.5%
Ramirez *et al.*[41]	Chile	49.11%
Ramirez *et al.*[41]	Bolivian	100%
Ashaolu *et al.*[58]	Nigerian	63%
Ercikti *et al.*[59]	Turkish	95.4%
Salem *et al.*[60]	Bahraini	42%
Salem *et al.*[60]	Tunisian	67.7%
Salem *et al.*[60]	Egyptian	52.8%
Salem *et al.*[60]	Kuwaiti	41.2%
Salem *et al.*[60]	Saudi	38.5%
Sirasanagandla and Al Balushi[61]	Omani	59.9%
Present study (2023)	Indian	100%

Conclusion

The present study has provided details about the morphological variants of the peroneal muscles and the data about their dimensions in our sample population. The morphological details of the present study are important to both the clinicians and anatomists. We believe that, these detailed data will enlighten the operating surgeons performing the procedures like tendon transfer, tendinoplasty and resection surgeries of the ankle and foot.

Acknowledgments

The authors of this manuscript sincerely thank the body donors, whose cadavers are utilized in this manuscript for the scientific research.

References

1. Olewnik Ł, Gonera B, Kurtys K, Podgórski M, Polguj M, Topol M. A proposal for a new classification of the fibular (lateral) collateral ligament based on morphological variations. Ann Anat. 2019;222:1-11.

2. Olewnik Ł, Podgórski M, Ruzik K, Polguj M, Topol M. New classification of the distal attachment of the fibularis brevis - Anatomical variations and potential clinical implications. Foot Ankle Surg. 2020;26:308-13.

3. Diogo R, Molnar J. Comparative anatomy, evolution, and homologies of tetrapod hindlimb muscles, comparison with forelimb muscles, and deconstruction of the forelimb-hindlimb serial homology hypothesis. Anat Rec (Hoboken). 2014;297:1047-75.
4. Olewnik Ł, Zielinska N, Ruzik K, *et al*. Morphological variability of the fibularis longus tendon in human fetuses. Ann Anat. 2022;239:151838.
5. Bhargava KN, Sanyal KP, Bhargava SN. Lateral musculature of the leg as seen in hundred Indian Cadavers. Ind J Med Sci. 1961;15:181-5.
6. Hallinan JTPD, Wang W, Pathria MN, Smitaman E, Huang BK. The peroneus longus muscle and tendon: a review of its anatomy and pathology. Skeletal Radiol. 2019;48:1329-44.
7. Karykowska A, Domagała ZA, Gworys B. Musculus peroneus longus in foetal period. Folia Morphol (Warsz). 2022;81:124-33.
8. Ellis SJ, Williams BR, Wagshul AD, Pavlov H, Deland JT. Deltoid ligament reconstruction with peroneus longus autograft in flatfoot deformity. Foot Ankle Int. 2010;31:781-9.
9. Grunfeld R, Oh I, Flemister S, Ketz J. Reconstruction of the deltoid-spring ligament. Techniques in Foot and Ankle Surgery. 2016;15:39-46.
10. Rhatomy S, Asikin AIZ, Wardani AE, Rukmoyo T, Lumban-Gaol I, Budhiparama NC. Peroneus longus autograft can be recommended as a superior graft to hamstring tendon in single-bundle ACL reconstruction. Knee Surg Sports Traumatol Arthrosc. 2019;27:3552-9.
11. Stein RE. Reconstruction of the superior peroneal retinaculum using a portion of the peroneus brevis tendon. A case report. J Bone Joint Surg Am. 1987;69:298-9.
12. Maffulli N, Spiezia F, Longo UG, Denaro V. Less-invasive reconstruction of chronic achilles tendon ruptures using a peroneus brevis tendon transfer. Am J Sports Med. 2010;38:2304-12.
13. Bergman RA, Thompson SA, Afifi AK, Saadeh FA. Compendium of Human Anatomic Variations, Text, Atlas and World Literature. Urban and Schwarzenburg, Baltimore and Munich, 1988, pp. 141.
14. Hollinshead WH. Anatomy for Surgeons, Vol. 3, 2nd Edn, Back and Limbs, Joanna Cotler Books, 1969, pp. 812-819.
15. Vertullo CJ, Glisson RR, Nunley JA. Torsional strains in the proximal fifth metatarsal: implications for Jones and stress fracture management. Foot Ankle Int. 2004;25:650-6.
16. Ozkan T, Tuncer S, Ozturk K, Aydin A, Ozkan S. Tibialis posterior tendon transfer for persistent foot drop after peroneal nerve repair. J Reconstr Micro Surg. 2009;25:157-64.
17. Bardeen CR. Development and variation of the musculature of the inferior extremity and the neighboring regions of the trunk in man. Am J Anat. 1906;6:259-390.
18. Sookur PA, Naraghi AM, Bleakney RR, Jalan R, Chan O, White LM. Accessory muscles: anatomy, symptoms, and radiologic evaluation. Radiographics. 2008;28:481-99.
19. Murlimanju BV, D'Souza PS, Prabhu LV, Saralaya VV, David SJ. Peroneus quartus, an accessory muscle in human: case report and its clinical importance. Clin Ter. 2012;163:307-9.
20. Oden RR. Tendon injuries about the ankle resulting from skiing. Clin Orthop Relat Res. 1987;216:63-9.
21. Zammit J, Singh D. The peroneus quartus muscle. Anatomy and clinical relevance. J Bone Joint Surg Br. 2003;85:1134-7.
22. Witvrouw E, Borre KV, Willems TM, Huysmans J, Broos E, De Clercq D. The significance of peroneus tertius muscle in ankle injuries: a prospective study. Am J Sports Med. 2006;34:1159-63.
23. Edwards ME. The relations of the peroneal tendons to the fibula, calcaneus, and cuboideum. Am J Anat. 1928;42:213-53.
24. Wang XT, Rosenberg ZS, Mechlin MB, Schweitzer ME. Normal variants and diseases of the peroneal tendons and superior peroneal retinaculum: MR imaging features. Radiographics. 2005;25:587-602.
25. Patil V, Frisch NC, Ebraheim NA. Anatomical variations in the insertion of the peroneus (fibularis) longus tendon. Foot Ankle Int. 2007;28:1179-82.
26. Shyamsundar S, Wazir A, Allen PE. Variations in the insertion of peroneus longus tendon-a cadaver study. Foot Ankle Surg. 2012;18:293-5.
27. Edama M, Takabayashi T, Hirabayashi R, *et al*. Anatomical variations in the insertion of the peroneus longus tendon. Surg Radiol Anat. 2020;42:1141-4.
28. Bianchi S, Bortolotto C, Draghi F. Os peroneum imaging: normal appearance and pathological findings. Insights Imaging. 2017;8:59-68.
29. Sobel M, Pavlov H, Geppert MJ, Thompson FM, DiCarlo EF, Davis WH. Painful os peroneum syndrome: a spectrum of conditions responsible for plantar lateral foot pain. Foot Ankle Int. 1994;15:112-24.
30. Murley GS, Tan JM, Edwards RM, De Luca J, Munteanu SE, Cook JL. Foot posture is associated with morphometry of the peroneus longus muscle, tibialis anterior tendon, and Achilles tendon. Scand J Med Sci Sports. 2014;24:535-41.
31. Challa S, Satyaprasad J. Hamstring graft size and anthropometry in south Indian population. J Clin Orthop Trauma. 2013;4:135-8.
32. Khan MJ, Asif N, Firoz D, Khan AQ, Sabir AB, Siddiqui YS. Prediction of peroneus longus graft diameter for anterior cruciate ligament reconstruction by inframalleolar harvest and from anthropometric data. Int J Burns Trauma. 2021;11:377-84.
33. Mathes SJ, Nahai F, Mathes SJ, Hahai F. (Eds.) Peroneus Brevis Flap. In: Reconstructive Surgery: Principles, Anatomy and Technique. Churchil Livingstone, New York, 1997, pp. 1437-1446.
34. Yang YL, Lin TM, Lee SS, Chang KP, Lai CS. The distally pedicled peroneus brevis muscle flap anatomic studies and clinical applications. J Foot Ankle Surg. 2005;44:259-64.
35. Wickiewicz TL, Roy RR, Powell PL, Edgerton VR. Muscle architecture of the human lower limb. Clin Orthop Relat Res. 1983;179:275-83.
36. Park J, Kim YH, Choi WJ, *et al*. The value of the peroneus brevis tendon cross-sectional area in early diagnosing of peroneus brevis tendinitis: The peroneus brevis tendon cross-sectional area. Medicine (Baltimore). 2022;101:e31276.
37. Kaneff A. Organogensis of the human extensor digitorum longus and the peroneus tertius evaluated from the viewpoint of evolutionary myology. Anat Anz. 1980;148:152-67.
38. Kimura K, Takahashi Y. The peroneus tertius muscle in the crab-eating monkey (Macaca fascicularis). Okajimas Folia Anat Jpn. 1985;62:173-85.
39. Johnson DC. Tendon Variations of the Peroneal Musculature in Man. Yale Medicine Thesis Digital Library. 2, 1973. https://elischolar.library.yale.edu/ymtdl/2
40. Yammine K. The accessory peroneal (fibular) muscles: peroneus quartus and peroneus digiti quinti. A systematic review and meta-analysis. Surg Radiol Anat. 2015;37:617-27.
41. Ramirez D, Gajardo C, Caballero P, Zavando D, Cantín M, Suazo GI. Clinical evaluation of fibularis tertius muscle prevalence. Int J Morphol. 2010;28:759-64.
42. Hansen Jr. ST. Functional Reconstruction of the Foot and Ankle. Lippincott Williams & Wilkins, Philadelphia, 2000.
43. Krammer EB, Lischka MF, Gruber H. Gross anatomy and evolutionary significance of the human peroneus III. Anat Embryol (Berl). 1979;155:291-302.
44. Jungers WL, Meldrum DJ, Stern JT. The functional and evolutionary significance of the human peroneus tertius muscle. J Hum Evol. 1993;25:377-86.
45. Yildiz S, Yalcin B. An unique variation of the peroneus tertius muscle. Surg Radiol Anat. 2012;34:661-3.
46. Bhatt CR, Modi MS, Mehta CD. Variation in fibularis teritius tendon and its clinical implications. Journal of Orthopaedics. 2010;7:e1.
47. Marin L, Barbosa FR, de Andrade O, *et al*. Anatomic study of the peroneus tertius muscle in humans. Arq Méd ABC. 2006;31:23-6.
48. Verma P, Seema. Analysis of fibularis tertius in terms of frequency, morphology, morphometry and clinical significance in North Indian cadavers. International Journal of Anatomy and Research. 2015;3:1646-50.
49. de Gusmão LCB, Brito Lima JS, Gaia Duarte FH, de Farias Souto AG, de Melo Veloso Couto B. Anatomical basis for the use of the fibularis tertius muscle in myocutaneous flaps. Revista Brasileira de Cirurgia Plástica. 2013;28:191-5.

50. Arnold PG, Yugueros P, Hanssen AD. Muscle flaps in osteomyelitis of the lower extremity: a 20-year account. Plast Reconstr Surg. 1999;104:107-10.
51. Brody PJ, Grumbine N. Peroneus tertius reconstruction for flexible clawtoes associated with cavus deformity: a preliminary report. J Foot Surg. 1984;23:357-61.
52. Adachi B. Beitrage zur anatomie der Japaner. XII. Die statistic der muskelvarietten Z Morphol Anthropol. 1909;12:261-312.
53. Nakano T. Beitrage zur anatomie der chinesen. Die statistic dermuskelvarietaten. Folia Anat Jpn. 1923;1:273-82.
54. Werneck HJL. Contribuição para o estudo de algunsaspectosmorfológicos do M. fibularistertiusembrancos, negros e mulatos, com pesquisa in vivo da presença de seutendão. Tese (Doutorado), Faculdade de Medicina da UFMG, Belo Horizonte, Brazil, 1957.
55. Sokolowska-Pituchowa J, Miśkiewicz CZ, Skawina A, Makoś K, Gorczyca J. The third peroneal muscle in human fetuses. Folia Morphologica. 1979;38:489-98.
56. Bertelli J, Khoury Z. The peroneus tertius island muscle flap. Surg Radiol Anat. 1991;13:243-4.
57. Stevens K, Platt A, Ellis H. A cadaveric study of the peroneus tertius muscle. Clin Anat. 1993;6(2):106-10.
58. Ashaolu JO, Olorunyomi OI, Opabunmi OA, Ukwenya VO, Thomas MA. Surface anatomy and prevalence of fibularis tertius muscle in a south-western Nigerian population. Forensic Med Anat Res. 2013;1:25-9.
59. Ercikti N, Apaydin N, Kocabiyik N, Yazar F. Insertional characteristics of the peroneus tertius tendon: revisiting the anatomy of an underestimated muscle. J Foot Ankle Surg. 2016;55:709-13.
60. Salem A, Kader GA, Almallah A, *et al*. Variations of peroneus tertius muscle in five Arab populations: a clinical study. Trans Res Anat. 2018;13:1-6.
Sirasanagandla SR, Al Balushi AW. Variations of peroneus tertius muscle in Omani population: a surface anatomical study. Ethiop J Health Sci. 2021;31:1061-8.

Received: March 8, 2023
Accepted:May 7, 2023

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