

## **Morphometric Analysis of Peroneus Tertius and Extensor Digitorum Longus**

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### **Abstract**

**Objective:** The objective of this study was to analyse morphometric characteristics of the Peroneus Tertius (PT) and Extensor Digitorum Longus (EDL) muscles with important correlations and associations that may describe their functional significance.

**Material and Methods:** The measurements PT and EDL muscles of cadavers were taken using a standard measuring tape. Minitab software Version 20.1 was used for statistical analysis methods of Spearman rho, Mood's Median test, Fishers Exact test, and Two-sample T-test.

**Results:** Of the 54 specimens of lower limbs, the mean length of origin of the PT from the fibula was  $13.80 \pm 5.52$  cm and 76% of the specimens with a separate origin of PT extended to its proximal half. The distal insertion of PT tendon was mostly as a single insertion into the base of the fifth metatarsal bone (55.55%). Spearman rho correlation value for the EDL muscle belly circumference with the number of intertendinous connections showed a mild negative correlation.

**Conclusions:** Knowledge of morphometric characteristics and the variations of these muscles aid in clinical applications and suggest

the use of radiological assessment of the muscle prior to surgical intervention.

### **Introduction**

Peroneus Tertius (PT) and Extensor Digitorum Longus (EDL) muscles in the anterior group of the lower limb are very closely related topographically. Some texts consider PT to be a part of EDL and even describe it as its 5th tendon [1], while some consider it to be a proximal migration of Extensor Digitorum Brevis [2].

The PT is considered of evolutionary significance as it is limited to humans and few apes closest in the evolutionary chain [3]. Electromyographic studies indicate that it works actively with the extensor digitorum longus during the swing phase of walking to induce dorsiflexion and eversion and to elevate the foot and toes from the ground, thus aiding bipedal motion [1, 4]. It also participates in strong eversion of the foot along with peroneus brevis and longus to prevent hyper inversion of the foot [5].

PT serves as a reference landmark for the anterolateral portal insertion during ankle arthroscopy [6]. The site of insertion of PT at the fifth metatarsal suggests that its actions can

impose torsional stresses on the areas of the bone in which Jones fractures and stress fractures occur [7], thus being important in its pathophysiology. The PT is further utilized in plastic surgery and orthopedic surgery for tendonoplasty, tendon transfer, or resection procedures on the foot [8]. Earlier studies have noted variations of PT [3, 9-11] and a recent study [9] has introduced a classification system for the sites of origin and insertion.

The wide diversity of the PT muscle requiring further in-depth evaluation inspired this study which analysed the PT muscle concerning variations of proximal and distal insertion, morphometry, and associations with the EDL muscle. This will expand the knowledge on the evolutionary significance of this muscle and be of value in its utilization during surgical procedures.

## Materials and Methods

Following routine dissections done on 27 cadavers by medical students at the Faculty of Medicine, University of Peradeniya, the anatomy of the PT and EDL muscles of the lower limb were defined clearly using blunt dissection. Measurements were taken using a standard measuring tape.

The length of the fibula was measured from the proximal end of the head of the fibula to the prominence of the lateral malleolus. The muscle belly morphology of PT and EDL muscles were identified. The presence and the number of inter-tendinous connections between PT and EDL were noted.

The sites of proximal and distal attachment were identified. The muscle lengths of PT (Fig 1; a) and EDL (Fig 2; f) and their muscle belly circumferences were measured. Four measurements of the PT tendon length were taken, from starting point distinct from the muscle fibers to the point of insertion (Fig 1; b), from the starting point distinct from the muscle fibers to the lateral malleolus (Fig 1; c), from the starting point within the muscle fibers to the lateral malleolus (Fig 1; d) and from the starting point within the muscle fibers to the point of insertion (Fig 1; e). The tendon length of EDL was measured from the starting point distinct from the muscle fibers to the lateral malleolus (Fig 2; g) and from the starting point within the muscle fibers to the lateral malleolus (Fig 2; h).

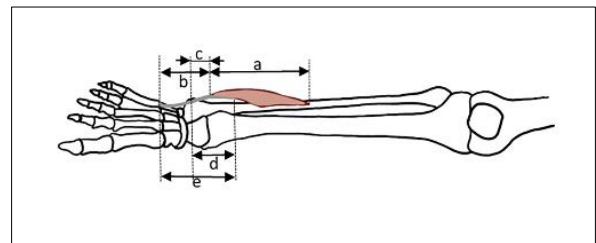


Figure 1: The measurements of peroneus tertius muscle length (a), tendon length from starting point distinct from the muscle fibers to the point of insertion (b), from the starting point distinct from the muscle fibers to the lateral malleolus (c), from the starting point within the muscle fibers to the lateral malleolus (d) and from the starting point within the muscle fibers to the point of insertion (e).

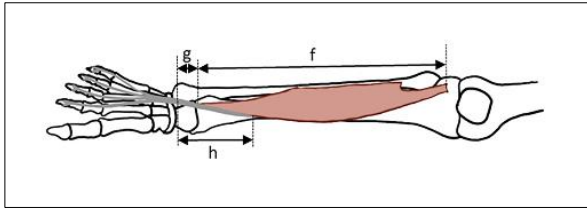


Figure 2: The measurements of extensor digitorum longus muscle length (f), tendon length from the starting point distinct from the muscle fibers to the lateral malleolus (g), and from the starting point within the muscle fibers to the lateral malleolus (h).

Minitab software Version 20.1 was used for statistical analysis methods of Spearman rho for correlations, while the Mood's Median test, Fishers Exact test, and Two-sample T-test were used to determine associations.

## Results

Of the specimens, 32 (59.26%) were male. Twenty six (48.15%) had a single continuous origin for PT and EDL, while in 25 (46.30%) they had separate origins. Intertendinous

connections between PT and EDL were identified in 16 specimens. The number of intertendinous connections ranged from one to seven, with nine of the specimens having 1 intertendinous connection between the two muscles.

Only one (4%) of the specimens which had a separate origin for PT had the classic site of origin from the distal third of the fibula, while five (20%) had an origin from the distal half and nineteen (76%) had an origin extending even proximal to the distal half.

The mean length of origin of the PT from the fibula was  $13.80 \pm 5.52$  cm ranging from 2.70 cm to 30.70 cm. Length of origin of PT from the fibula as a percentage of the length of the fibula was  $39.92 \pm 14.68\%$  ranging from 7.20% to 82.31%.

The distal attachment of the tendon of PT was mostly as a single insertion into the base of the fifth metatarsal bone (55.55%). The sites of insertion of the muscle observed are shown in Table 1 and Figs 3-4.

Table 1. The sites of insertion of peroneus tertius.

Site of Insertion	Olewnik et al., 2019 Classification type (9)	Count (Percentage)
Single insertion into the shaft of 5 <sup>th</sup> metatarsal	I	1(1.85%)
Single insertion into the base of the 5 <sup>th</sup> metatarsal	II	30(55.55%)
Wide insertion into the base of 4 <sup>th</sup> and 5 <sup>th</sup> metatarsal	III	3(5.55%)
Split insertion, one of which inserted into the base and other into shaft of 5 <sup>th</sup> metatarsal	IV	6(11.11%)

Split insertion, one to base of 5 <sup>th</sup> and the other to the 4 <sup>th</sup> metatarsal	V	8(14.81%)
A slip to Extensor digitorum longus (EDL <sup>2</sup> ) or peroneus brevis (PB <sup>3</sup> ) in addition to the attachment to the base of the 5 <sup>th</sup> metatarsal (Figs 3 & 4)	-	2(3.70%)
Wide insertion extending from the base to the shaft of the 5 <sup>th</sup> metatarsal	-	4(7.40%)
Damaged (Difficult to identify the proper anatomy)	-	3(5.55%)
Absent PT <sup>1</sup>	-	1(1.85%)

(1)PT: peroneus tertius; (2)EDL: extensor digitorum longus; (3)PB; peroneus brevis

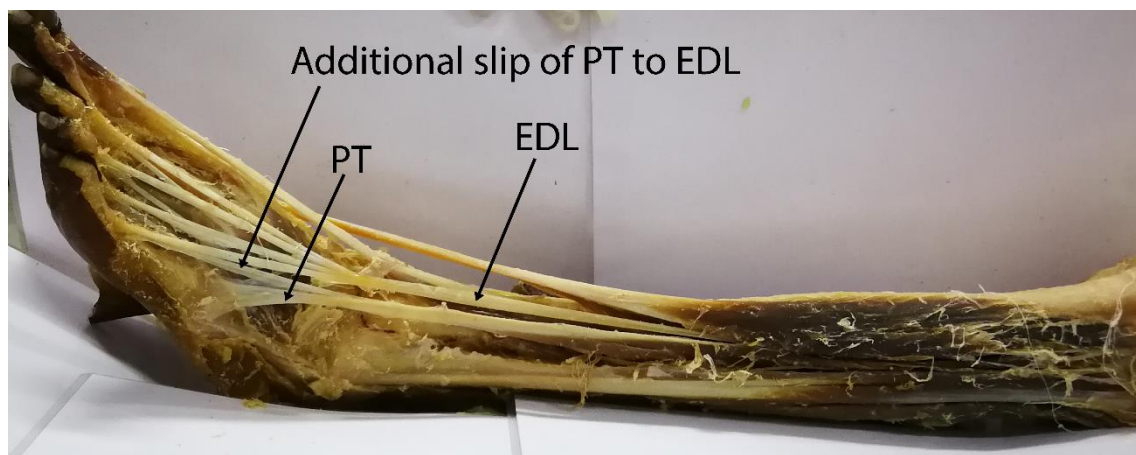


Figure 3: A slip from peroneus tertius tendon communicating with the 4<sup>th</sup> tendon of extensor digitorum longus in addition to the attachment to the base of the 5<sup>th</sup> metatarsal.

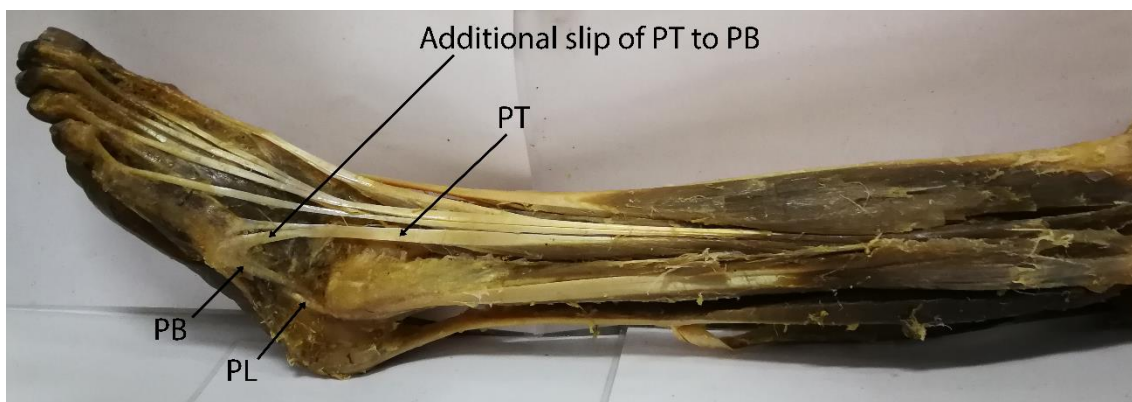


Figure 4: A slip from peroneus tertius tendon communicating with the tendon of peroneus brevis in addition to the attachment to the base of the 5<sup>th</sup> metatarsal.

The muscle belly circumference of PT measured  $3.52 \pm 0.72$  cm ranging from 2.0 cm to 4.9 cm while that of EDL was  $4.18 \pm 0.76$  cm ranging from 2.8 cm to 6.5 cm.

The length of the PT muscle was  $20.38 \pm 6.05$  cm ranging from 10.40 cm to 39.50 cm and that of the EDL muscle was  $28.83 \pm 6.50$  cm ranging from 13.40 cm to 40.00 cm. The length of the PT tendon without muscle fibers to its point of insertion was  $7.06 \pm 2.17$  cm. The lengths of the muscle tendons are summarized in Table 2.

Table 2. Tendon lengths of peroneus tertius (PT) and extensor digitorum longus (EDL). (SD: standard deviation, Min: minimum, Max: maximum)

Tendon		Mean (cm)	SD (cm)	Min (cm)	Max (cm)
PT tendon to insertion	Total extension	21.77	7.67	6.00	35.70
	Section without muscle fibers	7.06	2.17	4.20	17.70
PT tendon to lateral malleolus	Total extension	12.30	6.07	4.50	26.00
	Section without muscle fibers	1.17	2.02	0.00	8.00
EDL tendon to lateral malleolus	Total extension	22.33	3.30	15.40	35.30
	Section without muscle fibers	6.39	6.51	0.00	21.50

PT: peroneus tertius; EDL: extensor digitorum longus

Spearman rho was calculated to find out the correlations between morphological characteristics of PT and EDL. The value for the EDL muscle belly circumference with whether the PT and EDL were of single or separate origin was 0.014 with a p-value of 0.921 which shows that the size of EDL was not dependent on this factor. Spearman rho for the muscle belly circumference of PT and EDL was 0.521 with a p-value of 0.008 which showed a positive moderate correlation and the Spearman rho for the EDL muscle belly circumference with the number of intertendinous connections (-0.227) had a p-value of 0.106, which showed a mild negative correlation.

The Mood's median test revealed no significant association of intertendinous connection presence with the gender of the cadaver ( $p=0.454$ ) while the fisher's exact test showed no significant association between the gender and the site of insertion of PT. A Two-Sample T-Test was used to find out the association between gender and the morphometric measurements of PT and EDL which showed no significant gender difference in any of the measurements except the EDL muscle belly circumference which was larger in males (shown in Table 3).



Table 3. Two-Sample T-Test p values for morphometric measurements and gender of the specimens.

Measurement	The P-value for association with gender
PT muscle belly circumference	0.459
EDL muscle belly circumference	<0.001
PT muscle length	0.242
EDL muscle length	0.087

## Discussion

PT is encountered in the majority of humans and is affiliated with bipedal gait [6]. In this study, PT was absent in the left leg of one male cadaver while it was present in the right leg of the same. Though always comprising the minority, absence of this muscle has been reported in a small number by many studies [2-3, 12] and noted to be on the left side by similar studies [13-14]. Although data on the dominant side of the person is not available, a question is raised whether this tendency has a functional significance. Contrary to this study, a meta-analysis [6] reveal a weak association between male sex and the presence of PT. Peroneus tertius syndrome is a rare cause of foot pain and is successfully treated with excision of this muscle without resulting in a significant functional deficiency [15]. The PT thus considered a non-essential muscle is widely used for tissue replacement surgeries. It should be taken into consideration that being present in the majority, may have an important role in maintaining the stability of the foot. Long-term follow-up studies of patients with absence or surgical removal of PT are required to assess its functional significance.

Contrary to the textbook description of the proximal attachment of PT from the distal third of the fibula, 96% of the specimens had a much extensive origin with 76% extending to more than half of its length. Similarly, Stevens et al., 1993 reports 87% of studied specimens have an origin extending proximal to the distal third of the fibula [3]. Contradictory findings of some studies show that PT originates mostly from the distal third of the fibula [11, 16].

In this study, 26 (48.15%) specimens had an origin continuous with that of EDL and the length of origin of PT averaged from  $39.92 \pm 14.68\%$  of the length of the fibula which can be comparable to the findings of Stevens et al. (1993) [3]. This feature could cause difficulties in separating the two muscles during surgical procedures. It was also noticed that the size of EDL was not dependent on whether the PT and EDL were of single or separate origin.

The length of the PT tendon without muscle fibres averaged at 7.06 cm which is akin to other similar research [17], though, that measured by Gusmao et al. (2013) was averaged at 1.2 cm [18]. Knowledge of such morphometric features of this muscle favours its use in reconstruction surgeries of the lower limb. The average length of the PT muscle

measured at 20.38 cm which is comparable to the mean length of 23 cm measured by Nayak (2017) [19].

Inter-tendinous connections were present in 30.77% (16) of the specimens ranging from 1 to 7 in number. In a similar study by Stevens et al. (1993) [3], they were present varying from 1 to 4 in number in 15.0% of the limbs. These connections could have an importance in the distribution of forces during gait and balance which are the main functions of the lower limb muscles. A higher number of intertendinous connections could have a supportive role to the EDL as its size decreases. The size of EDL had an inverse correlation with the number of intertendinous connections, though the relationship was not statistically significant.

Insertion of PT to the base of the 5th metatarsal has been implicated in the pathology of Jones fracture. In this study 48 out of the 54 specimens had a clear distal insertion to the base of the 5th metatarsal supportive of the above. The sites of the distal insertion of the specimens in this study included the first five types out of the six distinguished by Olewnik (2019) [9], while additional sites of insertion were identified as to be communicating with EDL (Fig 3) or peroneus brevis (PB) (Fig 4) in addition to the attachment to the base of the 5th metatarsal and as a wide insertion extending from the base to the shaft of 5th metatarsal. Thus, it could be suggested that the proposed classification be further improved. This study revealed that the size of PT and EDL show a moderately positive correlation which suggests a complementary action between the two muscles.

Knowledge of morphometric characteristics and variations of these muscles aid in clinical aspects such as using as a landmark for procedures, tendon and muscle replacement surgeries, and in the assessment of pathological conditions such as Jones fracture or PT syndrome. The presence of a wide range of variations suggests radiological assessment of the muscles before surgical intervention.

### Conflict of interest

None

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