VIA MEDICA
ORIGINAL ARTICLE
Vol. 78, No. 3, pp. 582–587
DOI: 10.5603/FM.a2018.0108

ISSN 0015–5659
journals.viamedica.pl

Morphometric study of inferior peroneal retinaculum and contents of inferior peroneal tunnel

P. Dangintawat[1], J. Apinun[2], T. Huanmanop[3], S. Agthong[3], V. Chentanez[3]

[1]*Medical Science Programme, Faculty of Medicine, King Chulalongkorn Memorial Hospital, Chulalongkorn University, Bangkok, Thailand*
[2]*Department of Orthopaedics, Faculty of Medicine, King Chulalongkorn Memorial Hospital, Chulalongkorn University, Bangkok, Thailand*
[3]*Department of Anatomy, Faculty of Medicine, King Chulalongkorn Memorial Hospital, Chulalongkorn University, Bangkok, Thailand*

[Received: 12 October 2018; Accepted: 7 November 2018]

Background: *The aims of this study are to investigate the inferior peroneal retinaculum (IPR) regarding morphometric parameters, and contents in the inferior peroneal tunnel (IPT).*
Materials and methods: *One hundred and nine embalmed cadaveric legs were dissected in prone position.*
Results: *The extension band of the IPR was found in 31.19% of cases. The mean of length, width at the origin, width at the middle part, width at the insertion, and thickness of the IPR [mm] were 23.42 ± 3.54 (17.05–33.68), 13.29 ± 2.56 (5.83–20.92), 14.50 ± 2.37 (6.68–21.34), 10.10 ± 2.63 (4.59–19.17) and 0.48 ± 0.16 (0.20–0.87), respectively. The angle of the IPR to the horizontal axis was 38.51 ± 7.07 (11.67–54.00) degrees. The IPT was divided into the upper and lower tunnels. The normal contents were the tendons of peroneus brevis and peroneus longus in the upper and lower tunnels, respectively. However, additional contents were found in the upper tunnel in 2 cases. One was the tendon of peroneus digiti quinti, and peroneus quartus in the other one. Moreover, an unusual accessory peroneal muscle coursed into the lower tunnel and inserted on the peroneal tubercle. Tears of the peroneus brevis tendon were observed in 2 cases.*
Conclusions: *These morphometric data might be beneficial in surgical repair for IPR injury.* (Folia Morphol 2019; 78, 3: 582–587)

Key words: inferior peroneal retinaculum, inferior peroneal tunnel, morphometry

INTRODUCTION

Inferior peroneal retinaculum (IPR) is the continuity of the inferior extensor retinaculum and could be divided into 2 layers: superficial and deep layers. The superficial layer courses posteriorly and inferiorly to insert at the lateral surface of os calcis just above the posterolateral tubercle of calcaneus [8, 10]. The deep layer of IPR is attached to the peroneal tubercle. The space beneath IPR is called inferior peroneal tunnel (IPT). The peroneal tubercle is located between the peroneus brevis (PB) and peroneus longus (PL) tendons in the IPT [8]. Therefore, IPT is separated into upper and lower tunnels for the PB and PL tendons, respectively [3, 8].

Distal peroneal subluxation following IPR injury has been reported [7, 11]. The mechanism of injury was dorsiflexion with internal rotation of the foot and

Address for correspondence: V. Chentanez, MD, PhD, Department of Anatomy, Faculty of Medicine, King Chulalongkorn Memorial Hospital, Chulalongkorn University, Bangkok 10330, Thailand, tel: 66-860701084, e-mail: fmedvct@gmail.com

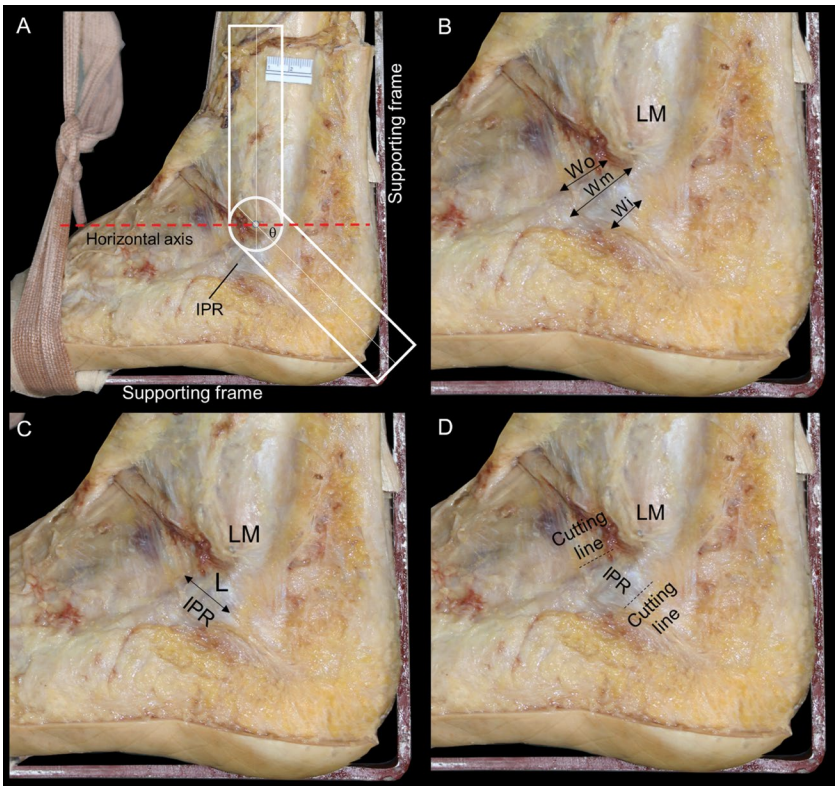

Figure 1. The foot was maintained in neutral position by an ankle supporting frame and measurement of all parameters; **A.** Angle of the inferior peroneal retinaculum (IPR) to the horizontal axis; **B.** The width at the origin, middle part and insertion; **C.** The length of the IPR; **D.** The cutting line; Wo — width at the origin; Wm — width at the middle part; Wi — width at the insertion; L — length of the IPR; LM — lateral malleolus; θ — angle of the IPR.

iatrogenic injury after surgical repair of fractured os peroneum. Those were treated by surgical repair of IPR.

To the best of our knowledge, the direct morphometric study of IPR is not available in the literature and standard anatomy textbooks. Therefore, the authors conducted this study to investigate the morphometric parameters of IPR, the contents of IPT and compared these parameters between genders and sides.

MATERIALS AND METHODS

Formaldehyde-embalmed cadaveric legs from 55 males and 54 females (age range 34–94) were provided by the Department of Anatomy, Faculty of Medicine, Chulalongkorn University. All cadavers had no gross evidence of lower extremity injuries and foot deformity. All the cadaveric legs were dissected and examined in prone position. The skin and subcutaneous tissue of the lateral leg and foot were removed. The boundaries and the attachment of the IPR were identified. The ankle was adjusted to neutral position by Achilles tendon released and using an ankle supporting frame (Fig. 1A). The standardised digital Vernier calliper (GuangLu® 0–100 mm; range 100 mm, resolution 0.01 mm) was used to measure each parameter. The width of IPR was measured in three parts: at the continuity from the inferior extensor retinaculum defined as the width at the origin (Wo), at the middle part (Wm) and at the attachment or insertion on the lateral wall of the calcaneus (Wi) (Fig. 1B).The length (L) of IPR was also measured (Fig. 1C). The angle of the alignment of IPR to the horizontal axis was evaluated by standard goniometer (BASELINE™ ce) (Fig. 1A). The axis of rotation was the inferior tip of fibula. The extension band of the IPR from its insertion on the lateral wall of the calcaneus was noted. In order to explore the contents of the IPT, the origin and insertion of the IPR were cut (Fig. 1D) and the thickness of the IPR over the lower tunnel was measured. Each parameter was measured 3 times and the average was calculated. To ensure consistency, the same digital Vernier calliper and standard goniometer were used. All measurements were done by the same investigator.

Statistical analysis

The statistical analysis was performed by using the IBM SPSS software version 22.0. Mean and standard deviation for each parameter were obtained. Results

Table 1. The morphometric data of the inferior peroneal retinaculum

	Total	Left			Right				
		Male	Female	P	Total	Male	Female	P	Total
Length from origin to insertion [mm]	23.42 ± 3.54 (17.05–33.68)	23.74 ± 2.75 (20.27–29.93)	23.33 ± 4.00 (18.20–33.68)	0.672	23.54 ± 3.41 (18.20–33.68)	23.54 ± 4.13 (17.05–33.08)	23.05 ± 3.26 (17.57–28.27)	0.630	23.29 ± 3.70 (17.05–33.08)
Width at origin [mm]	13.29 ± 2.56 (5.83–20.92)	14.18 ± 2.44 (9.47–20.92)	12.64 ± 3.08 (8.22–20.68)	0.047*	13.41 ± 2.86 (8.22–20.92)	13.57 ± 2.16 (10.15–17.85)	12.78 ± 2.31 (5.83–18.74)	0.197	13.17 ± 2.25 (5.83–18.74)
Width at middle part [mm]	14.50 ± 2.37 (6.68–21.34)	14.86 ± 2.44 (10.48–21.34)	14.49 ± 2.19 (9.35–18.53)	0.555	14.68 ± 2.31 (9.35–21.34)	14.32 ± 2.64 (6.86–19.63)	14.32 ± 2.27 (9.58–18.42)	0.993	14.32 ± 2.44 (6.86–19.63)
Width at insertion [mm]	10.10 ± 2.63 (4.59–19.17)	9.82 ± 2.37 (6.28–14.56)	10.93 ± 3.00 (5.17–19.17)	0.137	10.38 ± 2.74 (5.17–19.17)	9.22 ± 2.63 (4.59–13.99)	10.43 ± 2.31 (5.86–14.94)	0.097	9.82 ± 2.53 (4.59–14.94)
Thickness [mm]	0.48 ± 0.16 (0.20–0.87)	0.49 ± 0.16 (0.21–0.82)	0.46 ± 0.16 (0.20–0.82)	0.453	0.47 ± 0.16 (0.20–0.82)	0.50 ± 0.15 (0.21–0.76)	0.46 ± 0.16 (0.21–0.87)	0.322	0.49 ± 0.15 (0.21–0.87)
Angle [degrees]	38.51 ± 7.07 (11.67–54.00)	40.82 ± 7.11 (26.33–54.00)	37.16 ± 7.11 (23.33–48.33)	0.064	38.99 ± 7.28 (23.33–54.00)	39.23 ± 6.12 (26.00–48.67)	36.83 ± 7.52 (11.67–47.67)	0.199	38.05 ± 6.89 (11.67–48.67)

*Statistically significant; data are shown as mean ± standard deviation (range)

were separated into male, female, left and right groups. To determine the distribution of the sample population, Shapiro-Wilk test of normality was used. Comparisons of the parameters between genders and sides were done using unpaired t-test in normally distributed data and Mann–Whitney U test in non-normally distributed data. The intra-class correlation coefficient (ICC) was used to determine the intra-tester reliability.

Ethical consideration

This cadaveric study has been approved by the Institutional Review Board (IRB), Faculty of Medicine, Chulalongkorn University (IRB NO.110/61).

RESULTS

Characteristics, origin and attachment of IPR

Inferior peroneal retinaculum was the continuation of the inferior extensor retinaculum. This band coursed posteriorly and inferiorly to insert on the peroneal tubercle and lateral wall of the calcaneus, respectively. Moreover, the extension of the IPR from its insertion to the lateral process of the calcaneus was observed in 34 (31.19%) cases. Most of them were thick and had clear border separated from the surrounding fascia.

Width of the IPR

The results of the width of the IPR revealed that the Wm was the widest with the mean length of 14.50 ± 2.37 (6.68–21.34) mm. The Wo and the Wi had the mean length of 13.29 ± 2.56 (5.83–20.92) and 10.10 ± 2.63 (4.59–19.17) mm, respectively. Therefore, the shape of IPR was spindle-like. The Wo and Wm in male were wider than female but Wi was wider in female. These parameters were normally distributed. Comparisons between sides and genders revealed only Wo of was significantly different between sides ($p = 0.047$; Table 1).

Length of the IPR

The average length of the IPR was 23.42 ± 3.54 (17.05–33.68) mm. These parameters were normally distributed. Comparisons of the length of IPR between genders and sides revealed no statistically significant difference (Table 1).

Angle of the IPR

The results of the angle of IPR to the horizontal axis revealed that all of them were acute angle with an average of 38.51 ± 7.07 (11.67–54.00) degrees (Fig. 1C) with normal data distribution. The mean angle in male specimens was wider than that of the female specimens; however, this difference was not statistically significant. No statistically significant difference was demonstrated between side to side comparisons (Table 1).

Thickness of the IPR

From the observation, IPR of the upper tunnel was very thin when compared to IPR of the lower tunnel. Therefore, only the thickness of IPR over the lower tunnel was measured. The thickest IPR was found in the right side of male specimens with an average of 0.50 ± 0.15 (0.21–0.76) mm. These parameters were normally distributed. Although the mean thickness

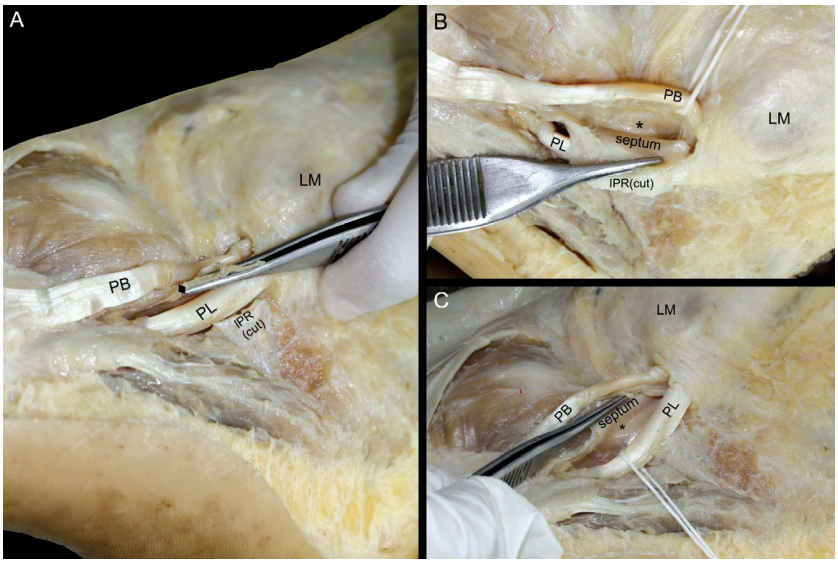

Figure 2. Contents of the inferior peroneal tunnel after cutting of inferior peroneal retinaculum (IPR) origin and insertion; **A.** Peroneus brevis tendon (PB) in the upper tunnel and peroneus longus tendon (PL) in the lower tunnel; **B.** The septum and peroneal tubercle (*) in the floor of the upper tunnel; **C.** The septum and peroneal tubercle (*) in the floor of the lower tunnel; ♦cutting edges of IPR; *the attachment of the septum to the peroneal tubercle; LM — lateral malleolus.

of male specimens was higher than that of female specimens, there were no statistically significant differences between genders and sides (Table 1).

The IPT and its contents

The contents of the IPT generally composed of PB tendon in upper tunnel and PL tendon in lower tunnel (Fig. 2A). However, There were additional contents in the upper tunnel including 2 cases of the peroneus digiti quinti muscle (PDQ) (Fig. 3A) and another 2 cases of peroneus quartus muscle (PQ) (Fig. 3B–D). In this study, the PDQ was found in 33 (30.28%) cases. Most PDQ split from PB tendons after it exited the upper tunnel. Only 2 cases of them split from PB tendon in the IPT. The other additional content found in the upper tunnel was PQ. This muscle was the accessory peroneal muscle located in the distal third of fibula. The prevalence of PQ in this study was 13 (11.93%) cases. Most PQ inserted on the retrotrochlear eminence. Only 2 cases of PQ (1 female and 1 male) were found in the upper tunnel. In the female specimen, PQ originated from PB muscle. Its tendon coursed through the upper tunnel and inserted on the peroneal tubercle (Fig. 3B). In the male specimens, the slender tendon of the PQ split from the anterolateral part of the PL tendon (Fig. 3C) and passed along the posterior border of the lateral malleolus to insert on IPR. In addition, a part of this tendon travelled into the upper tunnel and attached to the peroneal tubercle (Fig. 3D).

Moreover, there were 2 cases of PB tendon tears observed in the upper tunnel. The PB tear extended from the retromalleolar groove in both cases. The peroneal tubercle was located between PB and PL tendons in all cases.

The additional content was also found in the lower tunnel. The unusual accessory peroneal muscle originated from PL muscle and coursed along the anterior border of PL tendon (Fig. 4A). At the lateral malleolus, it passed deep to PL tendon and entered the lower tunnel to insert on the peroneal tubercle (Fig. 4B).

The intra-tester reliability on the data extraction indicated excellent reliability — ICC (3,1) = 0.970 – 0.999.

DISCUSSION

The characteristics and detailed morphology of IPR were explored in this study. IPR extends from the inferior extensor retinaculum, courses posteriorly and inferiorly to attach the peroneal tubercle and lateral wall of the calcaneus. The origin and insertion of IPR described in this study were in accordance with previous literatures [8, 10]. However, the extension band of the IPR from the insertion on the lateral wall to the lateral process of the calcaneus had not been reported. This band had a clear border separated from the surrounding fascia and coursed in the same direction

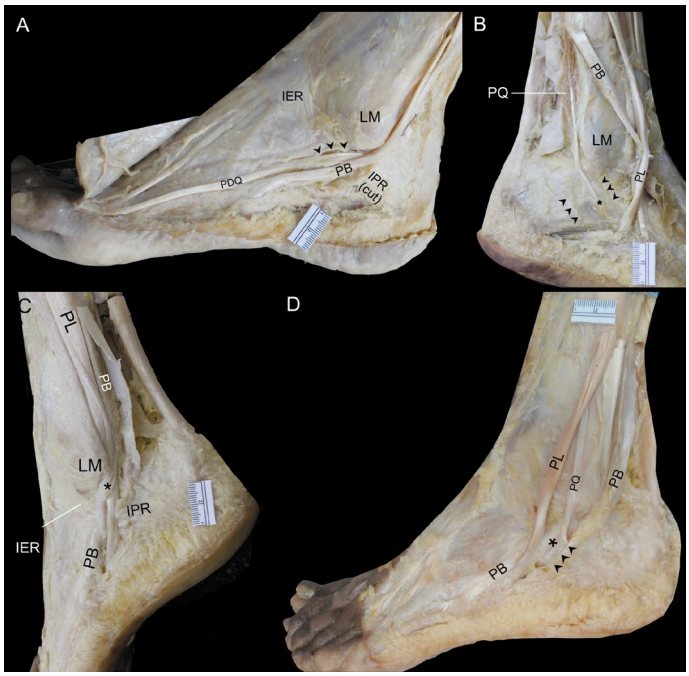

Figure 3. Additional contents in the upper inferior peroneal tunnel; **A.** Peroneus digiti quinti muscle (PDQ); **B.** The peroneus brevis tendon (PB) and peroneus longus tendon (PL) were elevated to show the peroneus quartus muscle (PQ) originated from PB; **C.** Origin of PQ from PL; **D.** The PL was elevated from the lower tunnel to show the attachment of PQ tendon on the peroneal tubercle (✱); ➘cutting edge of the inferior extensor retinaculum (IPR); LM — lateral malleolus; IER — inferior extensor retinaculum.

Figure 4. Additional content in the lower inferior peroneal tunnel; **A.** The unusual accessory peroneal muscle (arrow) originated from peroneus longus tendon (PL) and coursed anterior to PL tendon; **B.** The tendon of unusual accessory peroneal tendon travelled deep to PL tendon and entered the lower tunnel to insert on peroneal tubercle; PB — peroneus brevis tendon; IPR — inferior peroneal retinaculum; LM — lateral malleolus; ✱peroneal tubercle.

with the IPR. The prevalence of the extension band was found in 31.19% of cases. This extension band may play a role in stabilisation of PL tendon in the lower tunnel. In this study, we found 2 cases of PB tendon tear in the upper tunnel but none of PL tears in the lower tunnel.

The average length of IPR from its origin to the calcaneus was approximately 23 mm similarly in both genders. The middle portion of the IPR was the widest part. Therefore, it seemed to have a spindle-like shape. Since the IPR over the upper tunnel was very

thin, therefore, only the thickness of it over the lower tunnel was obtained with an average thickness of 0.48 mm. This might increase the strength of the lower tunnel and stabilised the PL tendon in this tunnel.

Inferior peroneal tunnel was divided into 2 tunnels: the upper and lower tunnels. Generally, the content of these tunnels were PB and PL tendons, respectively [8]. This literature revealed no other additional contents. However, the additional contents reported here was PDQ, PQ in the upper tunnel and unusual accessory peroneal muscle in the lower tunnel. The PDQ origin was reported to be from PB tendon after it exited out of the upper tunnel of IPR [4, 6, 12] or in the upper tunnel [2]. In this study, both PDQ arose from the PB tendon in the upper tunnel. PQ was previously reported to originate from the PB muscle or tendon, distal part of the fibula and PL [5, 9, 12, 13]. In this study, one PQ arose from PB and the other arose from PL. The insertions of PQ in both cases were on the peroneal tubercle, similar to previous studies [1, 5]. The unusual accessory peroneal muscle in the lower tunnel split from the PL tendon at the middle third of the fibula and inserted on the peroneal tubercle.

Injury of the IPR resulted in distal subluxation of the peroneal tendon was reported in the professional soccer players, which was treated by peroneal tubercle removal and relocation of the PL tendon together with suturing of the IPR [11]. The morphometric data found in this study can be beneficial in surgical repair of the injured IPR into its anatomical position to prevent residual instability or stenosis of the peroneal tendon. The additional contents in the IPT should be looked for during surgery and removed if overcrowding in the tunnel was found.

Most of the PB and PL tendons were intact. Only 2 cases of PB tear were found in the upper tunnel. Moreover, there was no evidence of PL tendon tear. Furthermore, all of the IPR in this study were intact and no gross evidence of the IPR tear. Comparisons between genders and sides revealed that only the Wo in the left side of male and female specimens was significantly different.

The limitation of this study includes the use of embalmed cadavers which might yield different results from fresh or soft-embalmed cadaveric legs.

CONCLUSIONS

The morphology and morphometric data of the IPR were described. The shape of the IPR was spindle-like with the wildest part in the middle. The angle of the IPR to the horizontal axis was approximately 38 degrees. IPR is thicker in the lower IPT and the extension band was found in 31%. The additional contents were found in both IPT: PDQ and PQ in the upper IPT and the unusual accessory peroneal muscle in the lower tunnel. All these data are beneficial for surgical treatment of IPR injury.

Acknowledgements

The authors appreciate the contributions of Dr. Somjet Tosamran and Amornrat Tothonglor in the dissection and data collection with special thanks to the technical staff members of the Department of Anatomy, Faculty of Medicine, Chulalongkorn University for their support in cadaveric care.

REFERENCES

1. Athavale SA, Gupta V, Kotgirwar S, et al. The peroneus quartus muscle: clinical correlation with evolutionary importance. Anat Sci Int. 2012; 87(2): 106–110, doi: 10.1007/s12565-011-0129-3, indexed in Pubmed: 22252433.
2. Chaney ME, Dao TV, Brechtel BS, et al. The fibularis digiti quinti tendon: A cadaveric study with anthropological and clinical considerations. Foot (Edinb). 2018; 34: 45–47, doi: 10.1016/j.foot.2017.11.012, indexed in Pubmed: 29278836.
3. Davda K, Malhotra K, O'Donnell P, et al. Peroneal tendon disorders. EFORT Open Rev. 2017; 2(6): 281–292, doi: 10.1302/2058-5241.2.160047.
4. Demir BT, Gümüşalan Y, Üzel M, et al. The variations of peroneus digiti quinti muscle and its contribution to the extension of the fifth toe. A cadaveric study. Saudi Med J. 2015; 36(11): 1285–1289, doi: 10.15537/smj.2015.11.12657, indexed in Pubmed: 26593160.
5. Hur MS, Won HS, Chung IH. A new morphological classification for the fibularis quartus muscle. Surg Radiol Anat. 2015; 37(1): 27–32, doi: 10.1007/s00276-014-1292-8, indexed in Pubmed: 24740146.
6. Jadhav SD, Gosavi SN, Zambare BR. Study of peroneus digiti minimi quinti in Indian population: a cadaveric study. Rev de Arg Anat Clin. 2013; 5: 67–72.
7. Sammarco VJ, Cuttica DJ, Sammarco GJ. Lasso stitch with peroneal retinaculoplasty for repair of fractured os peroneum: a report of two cases. Clin Orthop Relat Res. 2010; 468(4): 1012–1017, doi: 10.1007/s11999-009-0822-x, indexed in Pubmed: 19333665.
8. Sarrafian SK. Sarrafian's anatomy of the foot and ankle descriptive, topographic, functional. 3rd ed. Lippincott William&Wilkins, Wolters Kluwer, Philadelphia 2011: 131–132.
9. Sobel M, Levy ME, Bohne WH. Congenital variations of the peroneus quartus muscle: an anatomic study. Foot Ankle. 1990; 11(2): 81–89, indexed in Pubmed: 2265813.
10. Standring S. Section 9:pelvic girdle and lower limb. In: Tubbs RS, editor. Gray's Anatomy: the anatomical basis of clinical practice. 41 ed. Elsevier, London 2014: 1400–1417.
11. Staresinic M, Bakota B, Japjec M, et al. Isolated inferior peroneal retinculum tear in professional soccer players. Injury. 2013; 44 Suppl 3: S67–S70, doi: 10.1016/S0020-1383(13)70202-X, indexed in Pubmed: 24060023.
12. Yammine K. The accessory peroneal (fibular) muscles: peroneus quartus and peroneus digiti quinti. A systematic review and meta-analysis. Surg Radiol Anat. 2015; 37(6): 617–627, doi: 10.1007/s00276-015-1438-3, indexed in Pubmed: 25638531.
13. Zammit J, Singh D. The peroneus quartus muscle. Anatomy and clinical relevance. J Bone Joint Surg Br. 2003; 85(8): 1134–1137, indexed in Pubmed: 14653594.