The anatomic variation of the superior peroneal retinaculum and inferior peroneal retinaculum and its association to peroneal tendon disorders

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ความผันแปรทางกายวิภาคของ superior peroneal retinaculum และ inferior peroneal retinaculum ที่เกี่ยวเนื่องกับความผิดปกติของเส้นเอ็น peroneal

น.ส.พิมพ์พิมล แดงอินทวัฒน์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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Thesis Title	The anatomic variation of the superior peroneal retinaculum and inferior peroneal retinaculum and its association to peroneal tendon disorders
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พิมพ์พิมล แดงอินทวัฒน์ : ความผันแปรทางกายวิภาคของ superior peroneal retinaculum และ inferior peroneal retinaculum ที่เกี่ยวเนื่องกับความผิดปกติของเส้นเอ็น peroneal. (The anatomic variation of the superior peroneal retinaculum and inferior peroneal retinaculum and its association to peroneal tendon disorders) อ.ที่ปรึกษาหลัก : ศ. ดร. พญ.วิไล ชินธเนศ, อ.ที่ปรึกษาร่วม : ดร. นพ.จิรันดร์ อภินันทน์

การระบุตำแหน่งทางกายวิภาคที่แน่นอนของ superior peroneal retinaculum (SPR) และ inferior peroneal retinaculum (IPR) เพื่อใช้ในการทำหัตถการจะสามารถป้องกันการเกิดการเคลื่อนหลุดซ้ำของเส้นเอ็น peroneal ได้ การศึกษาครั้งนี้ทำการศึกษาลักษณะทางสันฐานวิทยา รวมถึงความผันแปรทางกายวิภาค การฉีกขาดของเส้นเอ็น peroneal และปัจจัยต่างๆ ที่เกี่ยวข้อง โดยทำการศึกษาในขาอาจารย์ใหญ่จำนวน 109 ข้าง พบว่าลักษณะทางสันฐานวิทยาของ SPR มีความผันแปรตามลักษณะทางกายวิภาคที่พบ โดยสามารถแบ่งได้เป็น 3 ลักษณะคือ type I (subtype Ia and Ib) (มี 2 bands), type II (มี 1 band) and type III (มี 1 band) ซึ่งสามารถพบได้ 57.80% (12.84%, 44.04%), 1.83%, และ 41.28% ตามลำดับ จุดกึ่งกลางของ SPR ที่จุดเกาะต้นเมื่อเทียบกับตาตุ่มนอก พบว่ามีระยะห่างในแนวแกนขวางและแกนตั้งที่ 7.26±3.15 and 10.45±4.52 มิลลิเมตรตามลำดับ ลักษณะทางสัณฐานวิทยาของ IPR มีความสอดคล้องกับงานวิจัยที่ผ่านมา โดยสามารถวัดความยาว ความกว้างที่จุดเกาะต้น จุดกึ่งกลาง และจุดเกาะปลาย รวมถึงความหนาของ IPR ได้ดังนี้ 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) และ 0.48 ± 0.16 (0.20-0.87) มิลลิเมตร ตามลำดับ จากการศึกษา superior peroneal tunnel พบ low level-lying ของกล้ามเนื้อ peroneus brevis (PB) ถึงร้อยละ 78.89 ส่วน inferior peroneal tunnel นั้นแบ่งได้เป็น 2 ช่อง สำหรับเส้นเอ็น PB และ PL นอกจากนี้ยังมีการพบกล้ามเนื้อ accessory peroneal อันประกอบไปด้วยกล้ามเนื้อ peroneus quatus (11.9%), peroneus digiti quinti (30.3%) และ unusual accessory peroneal muscles (1.83%) พบการฉีกขาดของเส้นเอ็น PB 12.84% ซึ่งสอดคล้องกันอย่างมีนัยสำคัญทางสถิติกับ type Ib ข้อมูลทางสันฐานวิทยาในการศึกษาครั้งนี้น่าจะมีประโยชน์ในการใช้ทำหัตถการเย็บซ่อม SPR และ IPR

สาขาวิชา วิทยาศาสตร์การแพทย์ ลายมือชื่อนิสิต .....
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KEYWORD: Superior peroneal retinaculum Inferior peroneal retinaculum Morphometric data Peroneal tendon tear Recostruction

Pimpimol Dangintawat : The anatomic variation of the superior peroneal retinaculum and inferior peroneal retinaculum and its association to peroneal tendon disorders. Advisor: Prof. Vilai Chentanez, M.D., Ph.D. Co-advisor: Jirun Apinun, M.D., Ph.D

The precise information for SPR and IPR reattachment is essential for the prevention of recurrent symptom of peroneal tendon dislocation/subluxation. Therefore, this study was conducted to investigate the characteristics, the attachments and morphometric parameters of the SPR, IPR and the prevalence, origin and insertion of the accessory peroneal muscles, peroneal tendon tear, and related structures. The association between the peroneal tendon tear and those structures were evaluated. One hundred and nine embalmed cadaveric legs were dissected in prone position. The SPR was variable in its length, width, angle, thickness, and insertion patterns. Based on the characteristics and insertion pattern, it could be divided into 3 types: type I (double band with subtype Ia and Ib), type II (single band) and type III (single band) with the prevalence of 57.80% (12.84%, 44.04%), 1.83%, and 41.28%, respectively. The average coordinate (X and Y-axis) of the midpoint origin measured from the tip of fibular in all types was 7.26±3.15 and 10.45±4.52 mm. The mean of length, width at the origin, width at the middle part, width at the insertion, and thickness of the IPR 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) mm, respectively. The angle of the IPR to the horizontal axis was 38.51 ± 7.07 (11.67-54.00) degrees. The low level-lying of peroneus brevis muscle in the superior peroneal tunnel was found in 78.89% cases. The inferior peroneal tunnel was divided into the upper and lower tunnels. The normal contents were the tendons of peroneus brevis (PB) and peroneus longus (PL) in the upper and lower tunnels, respectively. The accessory peroneal muscles were found in 48 cases with the prevalence of peroneus quatus (PQ), peroneus digiti quinti (PDQ) and unusual accessory peroneal muscles as 11.9%, 30.3%, and 1.83%, respectively. The prevalence of (PB) tendon tear was found in 12.84% (14 cases) and was associated with SPR type Ib with statistically significance. Precise information of the characteristic, morphometric data and coordinate of the attachment sites were essential for surgical procedure and reconstruction of SPR and IPR.

Field of Study: Medical Sciences Student's Signature .....

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Pimpimol Dangintawat

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Chapter I

Backgrounds and rationales

Backgrounds and rationales

Although the injury to lateral compartment of the leg at ankle level usually involves lateral ligamentous complex, the injury to peroneal tendon can occur as well. There are various types of peroneal tendon disorders including peroneus brevis tendons tear, peroneus longus tendon tear[1, 2] , and peroneal tendon subluxation/dislocation[3]. The peroneal tendon disorders occurred frequently in athletes[3, 4]. This pathology will decrease the ability in walking, running and sport performances. In addition, the peroneal tendon disorders can cause the lateral ankle instability[5, 6].

The pathomechanics of peroneal tendon tear related to the immediately eccentric contraction in dorsiflexion position while the foot was attached to the ground. This mechanism of injury is similarly to the lateral ankle sprain[7, 8]. Therefore, only 60% of the patients with peroneal tendon disorders can be diagnosed at the first time of evaluation[9, 10]. Moreover, the peroneal tendon subluxation/dislocation were often misdiagnosed as the lateral ankle sprain[3]. Therefore, the best choice of diagnosis peroneal tendon subluxation/dislocation is magnetic resonance imaging (MRI) by observing at the retromalleolar groove[7].

There are several factors related to the peroneal tendon disorders especially the anatomic variation and supernumerary contents in the superior peroneal tunnel[11-13]. The supernumerary contents are generally asymptomatic. However, several previous studies found that there was a correlation between the incidence of peroneal tendon tear and low level-lying of peroneus brevis muscle[9, 13, 14]. In contrast, Mirmiran (2015) founded that there was no significant association between the low level-lying of peroneus brevis muscle and peroneal tendon dislocation[15]. Therefore, the association between the incidence of peroneal tendon tear and anatomical variations are still controversy[4, 9, 15].

Although the superior peroneal retinaculum (SPR) is the primary stabilizer of the peroneal tunnel to fit in their alignment at the superior peroneal tunnel, this retinaculum can cause the peroneal tendon subluxation/ dislocation as well. It was claimed to be the laxity or tear of SPR[10]. Moreover, the anatomic description of SPR were extremely variable in width, thickness and their pattern of insertion[7]. Maffulli (2006) stated that the SPR was thinner in the peroneal tendon dislocation than normal[5].

The treatments for peroneal tendon disorders consisted of conservative and surgical treatments. The conservative treatments for peroneal tendon tear composed of medications, reduce activities, shoe modifications, custom-made insoles, lateral heel wedges and immobilization. Anyway, previous studies reported that conservative treatments might not prevent the recurrent episode of dislocation/subluxation of peroneal tendon[5, 7, 16]. Therefore, the surgical treatment was required after unsuccessful conservative treatments[8, 17, 18]. Nowadays, several surgical techniques for peroneal tendon subluxation/dislocation had been described including rerouting of the tendon beneath calcaneofibular ligament, reconstruction or soft tissue repairing[6] and soft tissue repairing with fibular groove deepening[3]. Anyway, the superior procedure had not been described. The surgical techniques for repairing the peroneal tendon tear were tendon transfer, tuberization and resection[4, 6, 19]. All surgical procedures for the peroneal tendon tear and subluxation/dislocation repair had to incise the superior SPR 2-3 millimeters posterior to fibula even though the SPR was intact. After repairing the pathology, the SPR was reattached by suturing. Most of the previous literatures of the surgical procedures described the area of SPR construction at the lateral wall of the calcaneus, but the specific area has not been documented. Moreover, Maffulli (2006) suggested that the successful treatment of peroneal tendon dislocation and prevention recurrent symptom was the reattachment of SPR to its anatomical position[5].

As aforementioned, the anatomical knowledge of this region especially the anatomy of SPR and IPR was essential for the successful diagnosis, treatment and prevention of the recurrent symptom. Therefore, this current study will focus on the morphology of the SPR, IPR and others structures in the superior peroneal tunnel. The

association between the incidence of peroneal tendon tear and their variations of the fibular contour and the supernumerary structure for improving the successful outcome in surgical procedures in this area will be evaluated.

Research questions

Primary research questions

1. What are the morphology of the SPR and IPR in Thai cadavers?
2. What are the contour of retromalleolar groove, peroneal tubercle and retrotrochlear eminence in Thai cadavers?
3. Are there any extraordinary contents in the superior peroneal tunnel in Thai cadavers?

Secondary research question

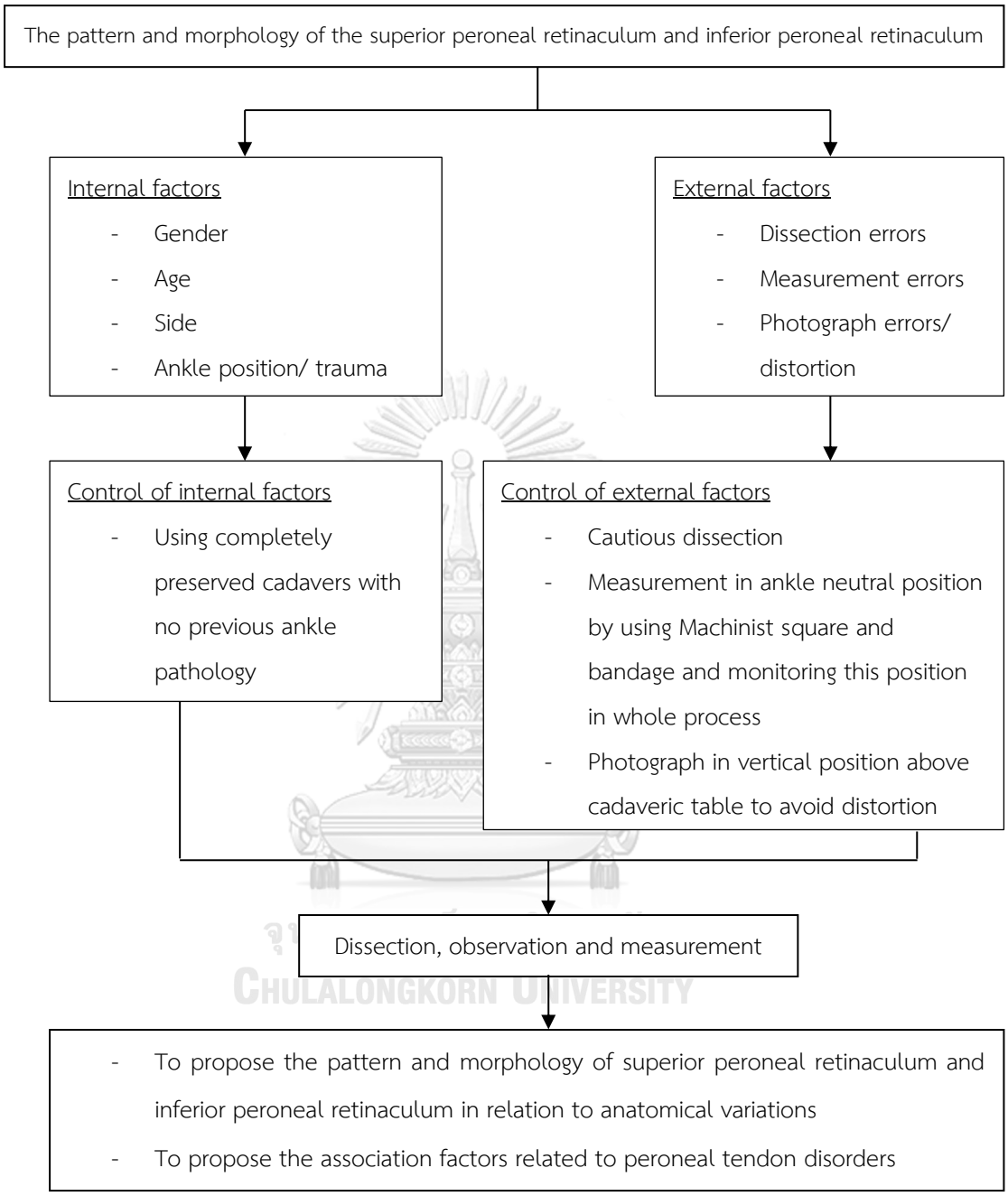
1. What are the associations between longitudinal tear of peroneus brevis and
    a) the length, width, thickness of the SPR?
    b) contour of retromalleolar groove?
    c) low level lying of peroneus brevis muscle?
    d) present of supernumerary muscles?

Objectives

1. To investigate the morphology including attachment, length, width, angle and thickness of SPR and IPR
2. To define the pattern of the SPR and IPR
3. To study the morphology of the retromalleolar groove contour, peroneal tubercle and retrotrochlear eminence
4. To investigate the presence of the supernumerary muscles including peroneus quartus (PQ), peroneus digiti minimi quinti (PDQ) and other accessory muscles
5. To investigate the present of the low level lying of the peroneus brevis muscle in the superior peroneal tunnel
6. To identify and classify the presence of the peroneus brevis tendon tear into grade that described by Sobel et al.
7. To study the association between the present of the peroneus brevis tendon tear and anatomical variations within the superior peroneal tunnel

a) the length, width and thickness of the SPR
b) the contour of retromalleolar groove, peroneal tubercle and retrotrochlear eminence
c) the low level lying of peroneus brevis muscle in superior peroneal tunnel
d) the presence of supernumerary muscles including PQ, PDQ and other accessory muscles

Conceptual framework



Keywords

superior peroneal retinaculum, inferior peroneal retinaculum, peroneal tendon tear

Research design

Descriptive study

Expected benefits and applications

This current study will explain more anatomical knowledge in detail of the superior peroneal retinaculum and inferior peroneal retinaculum related to the surgical implications. The knowledge of the anatomy of the superior and inferior peroneal retinaculum may have the potential to improve the surgical outcomes and decrease the recurrent episode of the peroneal tendon dislocation.

Chapter II

Review of the related literatures

The anatomy of the peroneus brevis and peroneus longus muscles

The muscles of lateral compartment of leg consist of peroneus longus (PL) and peroneus brevis (PB). PL originated from the head and superior 2/3 of lateral surface of fibula and coursed along its shaft and posterior to lateral malleolus while the PB originated from the inferior 2/3 of the lateral surface of fibula. At the ankle level, PB coursed anterior to PL and posterior to lateral malleolus in the same common sheath. The lateral malleolus acted as a pulley to change the alignment of PB and PL tendons. Then, these tendons were separated in their own tunnel at the peroneal tubercle. At this level, PB coursed anterior to peroneal tubercle and inserted at the dorsal surface of tuberosity on the lateral side of the base of 5th metatarsals. PL position was inferior to peroneal tubercle and beneath cuboid. It crossed the plantar surface of the foot to insert at the inferior aspect of the base of medial cuneiform and inferolateral aspect of 1st metatarsal[4, 7, 18, 20, 21] (Fig. 2.1).

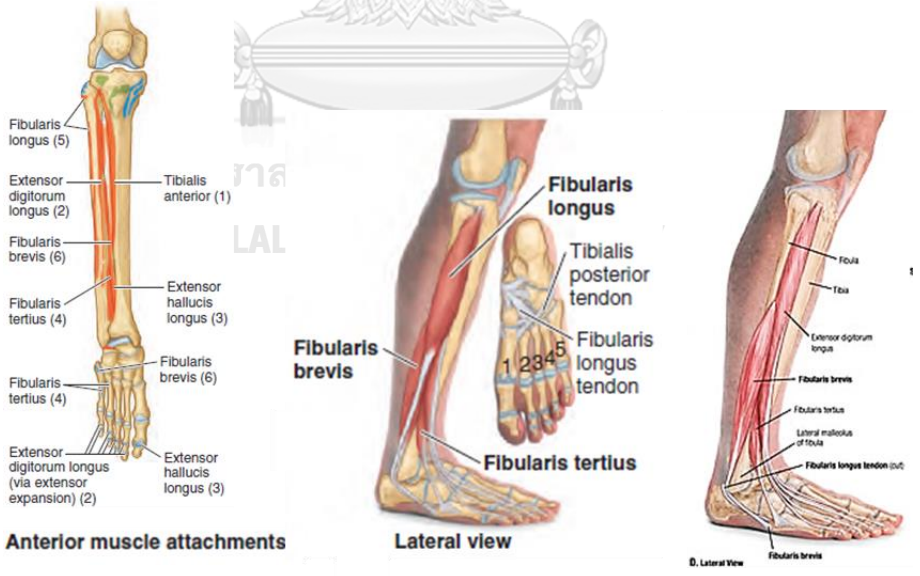


Figure 2. 1. The anatomy of the peroneus longus and peroneus brevis muscle (Modified from Moore (2014))[20]

The muscles of the lateral compartment were innervated by superficial peroneal nerve, a branch from common peroneal nerve. The lateral compartment of the leg received arterial supply from the anterior tibial artery to its superior part and the fibular artery to its distal part as described in table 2.1[21].

Table 2. 1 Attachment, action, innervation and blood supply of the peroneus longus and peroneus brevis muscles [20-22]

Muscle	**Proximal attachment**	**Distal attachment**	**Action**	**Innervation**	**Blood supply**
Peroneus longus	Head and superior 2/3 of the lateral surface of fibula	inferior aspect of the base of medial cuneiform and inferolateral aspect of 1st metatarsal	Foot eversion and weakly plantarflexion	Superficial peroneal nerve (**L5, S1**, S2)	Peforating branches of anterior tibial artery and fibular artery
Peroneus brevis	Inferior 2/3 of inferior surface of lateral surface of fibula	the dorsal surface of tuberosity on the lateral side of the base of 5th metatarsals	Foot eversion and weakly plantarflexion	Superficial peroneal nerve (**L5, S1**, S2)	Peforating branches of anterior tibial artery and fibular artery

The peroneal muscles acted as a prime mover of foot evertor and pronator. They also assisted gastrosoleus muscle in plantarflexion of the ankle. The PL assisted the gastrosoleus muscle more than PB. In addition, both PB and PL served as a dynamic stabilizer of lateral ankle by balancing the foot during standing and walking[7, 18, 20, 21, 23].

The accessory peroneal muscles

Although, the muscle of lateral compartment of the leg consisted of PB and PL in general, several previous studies reported the present of the supernumerary muscles in this compartment as well. Previous meta-analysis study of Yammine (2015) showed that the prevalence of the accessory peroneal muscle was found in 16% in human population[24]. However, the prevalence of these accessory muscles from several previous studies were varied.

Previous studies had described the accessory peroneal muscles in different names according to their insertion pattern such as peroneus accessories, peroneus digiti minimi and peroneus digiti quinti[18, 25]. Sobel et al. (1990) categorized the peroneus accessories and peroneus digiti minimi into peroneus quartus by their origin[25]. Therefore, the supernumerary or accessory muscles of the peroneus muscle generally referred to the peroneus quartus muscle (PQ) and the peroneus digiti quinti muscle (PDQ). The present of the peroneal accessory muscles around this compartment was generally asymptomatic.

Peroneus quartus (PQ) muscle

Peroneus quartus muscle was the most common accessory muscle that presented in the lateral compartment of the leg. The prevalence of PQ varied from 5% - 22% [12, 26-28]. The previous meta-analysis stated that the prevalence of PQ was higher in Indian population when compared to others and PQ was predominant in male [24].

This muscle arose from peroneus brevis or distal shaft of fibula and inserted as a single tendon at various points such as retrotrochlear eminence of calcaneus, peroneal tubercle of calcaneus, dorsal surface of 5th metatarsal or merged with PB and PL tendon at peroneal tubercle (table 2.2). Moreover, Bilgili et al. (2014) reported that PQ had 2 separated tendons and inserted at different points. In this case, the PQ tendon was bifurcated and coursed around PB tendon, then, inserted at retrotrochlear eminence and cuboid bone[26] (Fig. 2.2).

The PQ had been reported to be co-existed with the hypertrophy of the peroneal tubercle or retrotrochlear eminence [18, 25]. However, the hypertrophy of the

peroneal tubercle and retrotrochlear eminence were also presented in asymptomatic ankle without presented of PQ[27, 29].

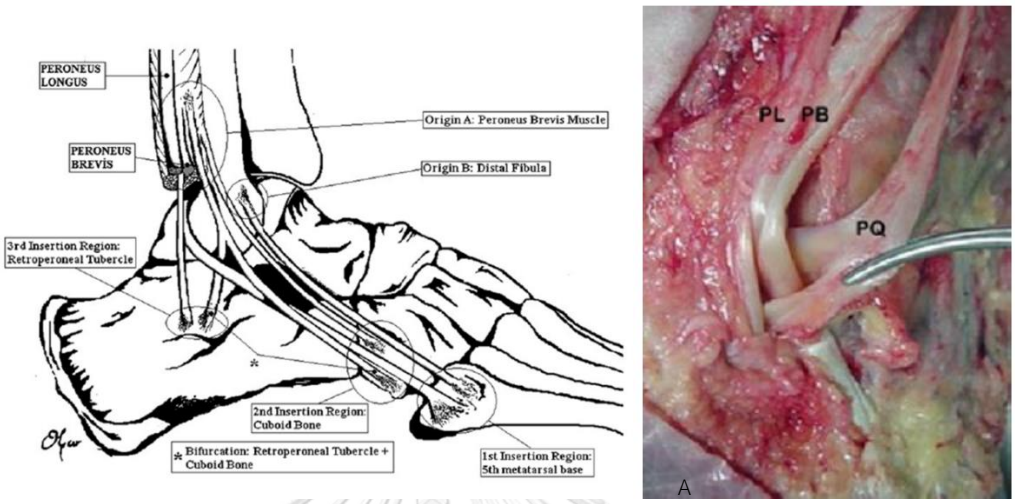


Figure 2. 2 The origin and insertion of peroneus quartus muscle A) the peroneus quartus muscle and its insertion at lateral wall of calcaneus B) the bifid peroneus quartus tendon coursed around the peroneus brevis tendon and inserted at calcaneus and cuboid, PL: peroneus longus, PB: peroneus brevis, PQ: peroneus quartus (Bilgili (2014))[26]

Table 2. 2 Previous studies of the origin, insertion, nationality and prevalence of peroneus quartus muscle

Authors	Origin	Insertion	Nationality	Number of specimens	Prevalence (% (case))
Sobel et al. (1990) [25]	- Peroneus brevis	- Peroneal tubercle - Peroneus longus distal to retromalleolar groove - Peroneus brevis just distal to retromalleolar groove - Lateral retinaculum - 2 separated tendons; base of 5th metatarsal and head of 5th metatarsal		124	21.7% (27)
	- Peroneus longus	- Peroneal tubercle - Inserted to peroneus longus itself at the retromalleolar groove - Peroneus brevis			
Zammit and Singh (2003)[27]	- Peroneus brevis - Posterolateral aspect of fibula	Retrotrochlear eminence of calcaneus	British	102	6.6% (6)
Uğurlu et al. (2010) [30]	The muscle belly of the peroneus brevis	Posterior part of calcaneus	Turkish	22	9% (2)
Ulna et al. (2010)[31]	-	-	Turkish	115	5%
Athavale et al. (2010) [28]	- Lower part of the lateral surface of the fibula, inferior to the origin of the PB. - Undersurface of PB. - Adjoining part of posterior intermuscular septum.	- Retrotrochlear eminence - Peroneal tubercle - Merged with PB and PL tendon at the peroneal tubercle	Indian	92	(20)

Authors	Origin	Insertion	Nationality	Number of specimens	Prevalence (% (case))
Prakash et al. (2011) [32]	- The middle part of the fibula - The muscle belly of the peroneus brevis	- Posterior side of the lateral muscle - Peroneal tubercle of calcaneus	Indian	70	4.3% [33]
Bilgili et al. (2014) [26]	- Peroneus brevis - Distal of fibula	- Retrotrochlear eminence - Cuboid - 5th metatarsal - 2 different tendons bifurcated around PB and insertion at retrotrichlear eminence and cuboid	Turkish	115	5.2% (6)
Hur et al. (2015) [34]	The deep or posterolateral portion of muscle belly of peroneus brevis (15%)	- Tendon of the peroneus brevis (3.8%) - Lateral surface of calcaneus (2.5%) - Inferior peroneal retinaculum (2.5%) - Dorsal surface of the base of 5th metatarsal bone (1.3%)	Korean	80	16.3% (13)

Peroneus digiti quinti muscle (PDQ)

The peroneus digiti quinti or peroneus digiti minimi quinti muscle (PDQ) was the accessory muscle that commonly found in Caucasian[24]. The prevalence of this muscle was varied and was found bilaterally more than PQ[24]. PDQ arose from the peroneus brevis tendon and gave a slender single tendon inserted at the 5th metatarsal in different part or 5th toe[24, 35] (Fig. 2.3). Jadhav et al. (2013) reported the prevalence of PDQ as 51% in Indian cadavers and 3% of those cases had dual insertion at 4th and 5th matarsals. Moreover, Demir (2015) described the insertion pattern of PDQ as 2 different types; single tendon attached on the 5th metatarsal bone and two separated tendons attached on different sites of 5th metatarsal bone[35] (table 2.3).

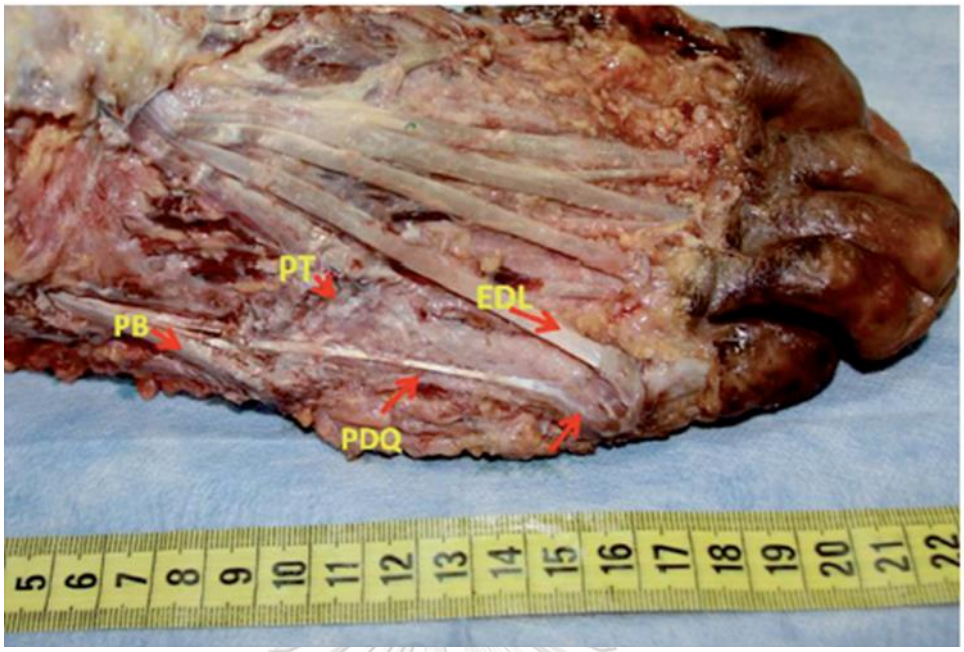


Figure 2. 3 The peroneus digiti quinti muscle (PDQ); PB: peroneus brevis tendon, PT: peroneus tertius tendon, EDL: extensor digitorum longus tendon (Demir et al. (2015))[35]

Table 2. 3 Previous studies of the origin, insertion, nationality and prevalence of peroneus digiti quinti muscle

Authors	Origin	Insertion	Nationality	Number of specimens	Prevalence (%(n))
Jadhav et al. (2013)[36]	Peroneus brevis tendon slip	- Dorsal digital expansion of 5th toe - Extensor tendon - Base of proximal phalanx of 5th toe - Head of 5th metatarsal - 2 seperated tendon attach on shaft of 4th metatarsal and head of 5th metatarsal	Indian	100	51(51)
Demir et al. (2015)[35]	Peroneus brevis tendon	- Dorsolateral at base of 5th metatarsal - Dorsolateral at ridge of 5th metatarsal - Dorsolateral of 5th toe (proximal and middle phalanges) - Lateral to extensor digitorum longus and extend to 5th toe - 2 separate tendons attached to dorsolateral of 4th metatarsal and dorsomedial of 5th metatarsal	Turkish	25	32(8)

Other accessory muscles

Tubb et al. (2014) had reported an accessory muscle called, peroneotalocalcaneus muscle (Fig.2.4A). This muscle originated from the anterior intermuscular septum and peroneus longus muscle and inserted on the superior surface of the talus and calcaneus[37].

Fabrizio (2015) had reported an anomalous fibularis (peroneal) muscle (Fig. 2.4B). This muscle arose from the muscle belly of PL muscle in the proximal half and gave a long slender tendon, coursed posterior to lateral malleolus and inserted on the superficial aspect of inferior peroneal retinaculum[38].

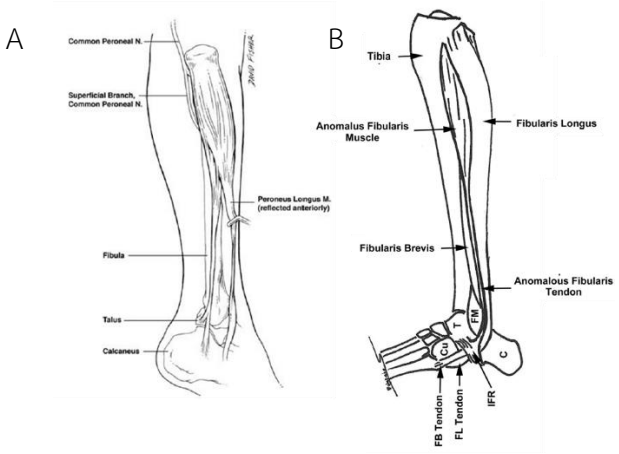


Figure 2. 4 The other accessory muscles that originated from peroneus longus muscle; A: peroneotalocalcaneus muscle, B: anomalous fibularis (peroneal) muscle (modified from Tubb ei al. (2014) and Fabrizio (2015))[37, 38]

The anatomy of superior peroneal tunnel and its retinaculum

Superior peroneal tunnel

The space that both peroneal tendons located at the posterior aspect of the lateral malleolus was called superior peroneal tunnel[39]. The boundaries of superior peroneal tunnel were composed of the superior peroneal retinaculam (SPR) as the roof and retromalleolar groove of lateral malleolus as the floor. The floor of superior peroneal tunnel could be divided into 2 parts from lateral to medial; the osseous and non-osseous parts. The osseous part of the tunnel was retromalleolar groove of fibula while the non-osseous parts (medial part) was formed by lower part of posterior intermuscular septum of the leg[12] (Fig. 2.5).

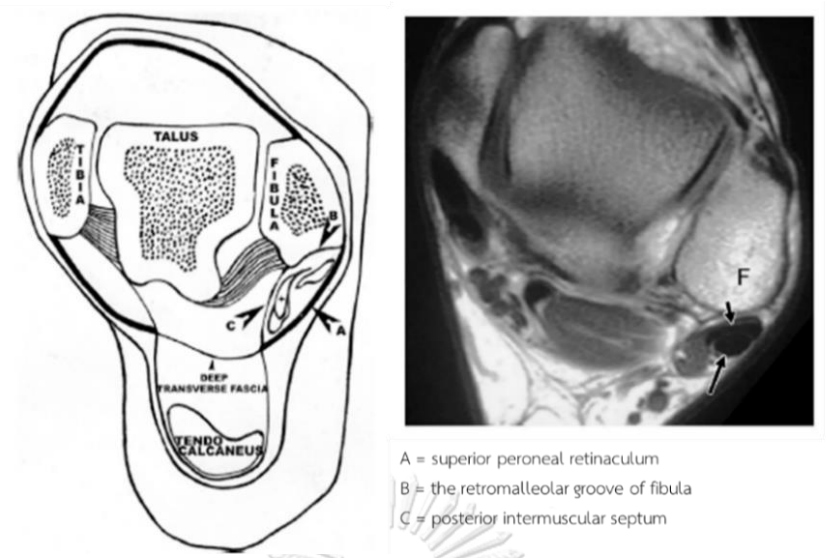


Figure 2. 5 The cross sectional structure and T-1 MR imaging of the superior peroneal tunnel (modified from Wang (2005) and Athavale (2011))[12, 18]

The normal content of superior peroneal tunnel consisted of the PB and PL tendons. The course of peroneal tendons changed from proximal to distal. At the proximal part, the PB tendon lied medial to the PL tendon and some part of PB tendon overlapped on the PL tendon. At this level, the osseous part of superior peroneal tunnel contained only PL tendon. In the distal part, the PL tendon lied more superficial to PB tendon. The space of this tunnel was narrower in the distal part especially its osseous part [12, 18].

Several previous studies reported the additional structures in superior peroneal tunnel such as the muscle belly of the peroneus brevis, the accessory peroneal nerve, and supernumerary muscles (peroneus quartus muscle) [7, 12, 13, 18]. The additional structures in superior peroneal tunnel could decrease the space of the superior peroneal tunnel. Although the contours of retromalleolar groove of fibula was primarily concave surface, convex and flat contour were also present as well. Therefore, the contour of retromalleolar groove was one of the possible factors that could decrease the superior peroneal tunnel space [7, 12].

The present of the additional structures and the variation of retromalleolar groove contour were not only the related factors to decrease the superior peroneal tendon space but also cause the peroneal tendon disorders as well.

The anatomy of the superior peroneal retinaculum

The superior fibular retinaculum or superior peroneal retinaculum (SPR) was a fibrous band located superior to peroneus longus and peroneus brevis tendon as the roof of the superior peroneal tunnel[12, 18, 39]. The standard textbook of anatomy, Moore et al. (2014) described that "the SPR is the retinaculum spans between the distal tip of fibula and the calcaneus" while Standring et al. (2014) described that the SPR also attached to the deep transverse fascia of the leg[20, 21].

Previous study of the anatomy of SPR by Davis (1994) described the morphology of SPR into 5 types based on their attachments and insertion patterns[40]. The detail of each type was shown in table 2.4 and figure 2.6.

Table 2. 4 The type of superior peroneal retinaculum[40]

Type	Definition
Type I	The SPR originated from lateral malleolus and divided into 2 bands then insert at the lateral border of calcaneal tendon and lateral wall of calcaneus
Type II	The SPR originated from lateral malleolus and divided into 2 bands then insert at the lateral wall of the calcaneus
Type III	The SPR originated from lateral malleolus and insert at the lateral border of calcaneal tendon
Type IV	The SPR originated from lateral malleolus and insert at the lateral wall of calcaneus
Type V	The SPR originated from lateral malleolus and most of fibers insert loosely at fibrous tissue (pretendinous fascia) of the lateral border of calcaneal tendon and had small fiber insert at lateral wall of calcaneus

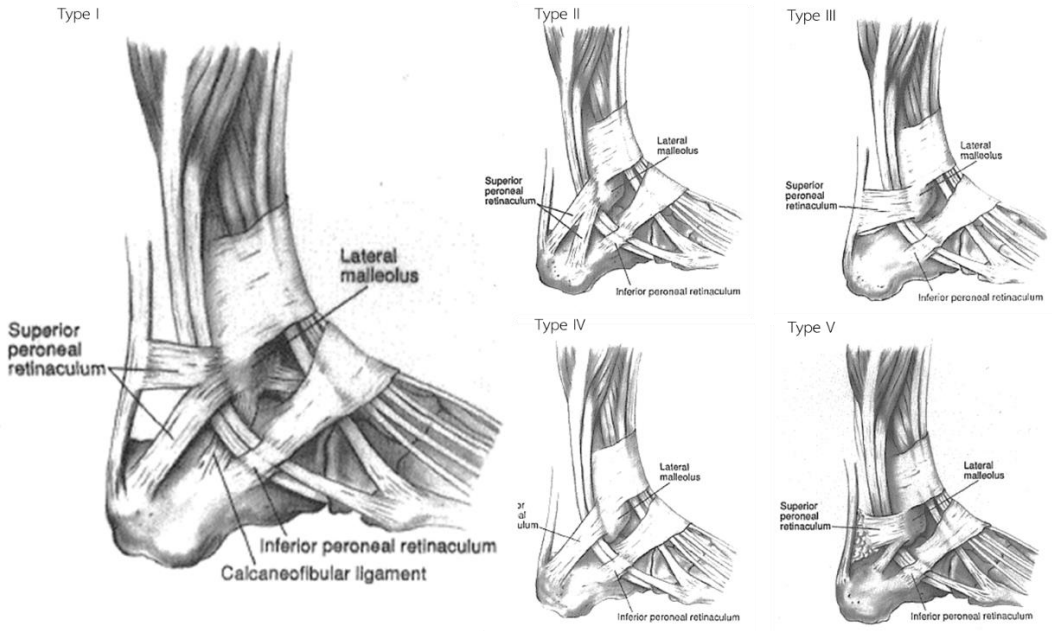


Figure 2. 6 The types of superior peroneal retinaculum based on their attachment and insertion pattern (Davis (1994))[40]

Several previous studies revealed that SPR coursed parallel to the calcaneofibular ligaments of the ankle joint[30, 40]. Therefore, the SPR played a vital role as a stabilizer to maintain the peroneus longus and peroneus brevis tendon to fit in their positions at the ankle level and assisted the lateral ligaments of ankle joint to maintain its stability[5, 7, 30]. The laxity or deficit of the SPR could be a possible cause of the peroneal tendon subluxation/dislocation. The instability of SPR can lead to the recurrent symptom of the subluxation/dislocation[21]. In addition, the present of the peroneus brevis muscle belly and the supernumerary muscle, PQ, could over stretch the SPR at the superior peroneal tunnel. This situation was the indirect cause of peroneal tendon subluxation[7].

The anatomy of the inferior peroneal tunnel and its retinaculum

The inferior peroneal tunnel was covered by the inferior peroneal retinaculum (IPR) which was the continuity of inferior extensor retinaculum. IPR could divided into 2 layers; the superficial layer coursed posteriorly and inferiorly then inserted at the lateral surface of os calsi just above the posterolateral tubercle of calcaneus[21]. The

deep layer of IPR attached to the peroneal tubercle, therefore, the inferior peroneal tunnel were separated into upper and lower tunnels for the PB and PL tendons respectively[22, 39]. After the peroneal tendons exited this tunnel, they would insert to their insertion sites(Fig. 2.7).

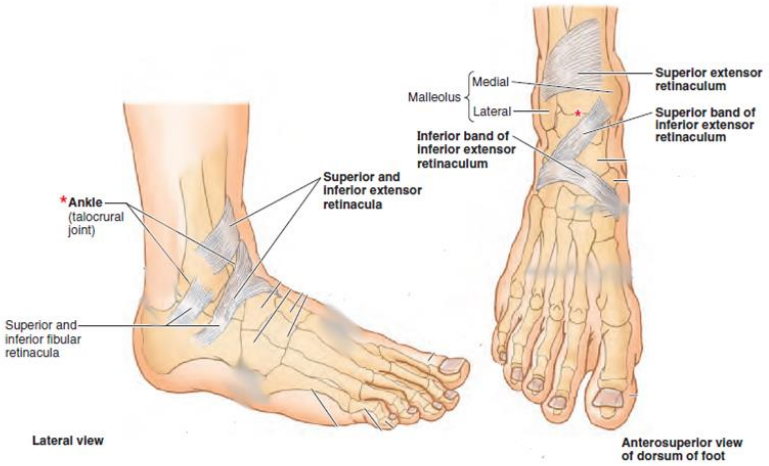


Figure 2. 7 The anatomy of superior and inferior peroneal retinaculum showed the continuity of inferior peroneal retinaculum from inferior extensor retinaculum to insert at the posterolateral tubercle of calcaneus (Moore (2014))[20]

The peroneal tendon disorders

The peroneal tendon disorders consisted of peroneal tendon tenosynovitis, peroneal tendon tear or disruption [4, 6, 9, 14], and peroneal tendon subluxation and dislocation[4, 5, 7]. The mechanism of the injury could occur by the eccentric contraction of peroneus muscles during ankle dorsiflexion position. This pathomechanisms was similarly to the inversion mechanism of lateral ankle sprain. Moreover, most of the patients always complained about the posterior lateral malleolar pain, with popping or snapping sound during movement or feeling instability at the lateral ankle similarly to the lateral ligamentous complex sprain[7, 10]. Therefore, peroneal tendon disorders might be misdiagnosed as the lateral ankle sprain[5, 7, 8]. Only 60% of cases could be diagnosed as the peroneal tendon disorders at the first time evaluation[10]. The misdiagnosed or untreated the peroneal tendons subluxation would predisposed to the recurrence of peroneal tendon dislocation[5].

As mention before, the additional structures could decrease the space of superior peroneal tunnel. Therefore, the presence of the peroneus brevis muscle belly and peroneus quartus muscle could over stretch the SPR at the superior peroneal tunnel. In this condition, the laxity or deficit of the SPR would be occurred. These might be a possible cause of SPR tear, and lead to the peroneal tendon subluxation/dislocation. The instability of SPR can lead the recurrent symptom of the subluxation/dislocation[24]. Moreover, Roth (2009) stated that the peroneal tendon subluxation could also cause the peroneus brevis tendon tear[7].

The peoneal tendon tears

The peroneal tendons tear or attrition was reported as the acute mechanical injury or repetitive injury such as traumatic injury, mechanical irritation or attrition within retromalleolar groove, subluxation of SPR, incompetent of SPR and ankle instability[4, 9, 27]. Bassett and Speer (1993) stated that the degree of ankle plantarflexion (15 – 25 degrees) had association to impinge the peroneus brevis tendon to distal tip of fibula[33]. In this angle, the PB tendon was risk for injury. The mechanical injury was not the only factor caused the peroneal tendon tear or attrition, the presence of additional structures, the peroneus brevis muscle belly, in superior peroneal tunnel could cause the peroneal tendon tear as well. Anyway, previous study of Unlu et al. (2010) revealed that the low-level lying or distal extension of peroneus brevis muscle belly did not show the relationship to the peroneus brevis tendon tear. In contrast, the proximal extension had a potential relation to the peroneus brevis tendon tears [14, 31].

Zammit et al. (2003) stated that there were several anatomic factors associated with peroneal tendon tear such as the prominence of retrotrochlear eminence and the thinning or laxity of the SPR[27]. Moreover, the presence of the peroneus quartus muscle might have a potential to create the attrition or tear of peroneal tendon at the retromalleolar groove[1, 25, 31].

Sobel et al. (1990) classified peroneal tendon tear or attrition into 4 grades depended on their severe of pathology as described in table 2.5 (Fig. 2.8).

Table 2. 5 The Sobel' classification of peroneal tendon tear[1]

grade	Description
I	The thinned or flattened of peroneus brevis tendon
II	Partial-thickness split, the length of tear less than 1 cm
III	Full-thickness split, the length of tear around 1 – 2 cm
IV	Full-thickness split, the length of tear longer than 2 cm

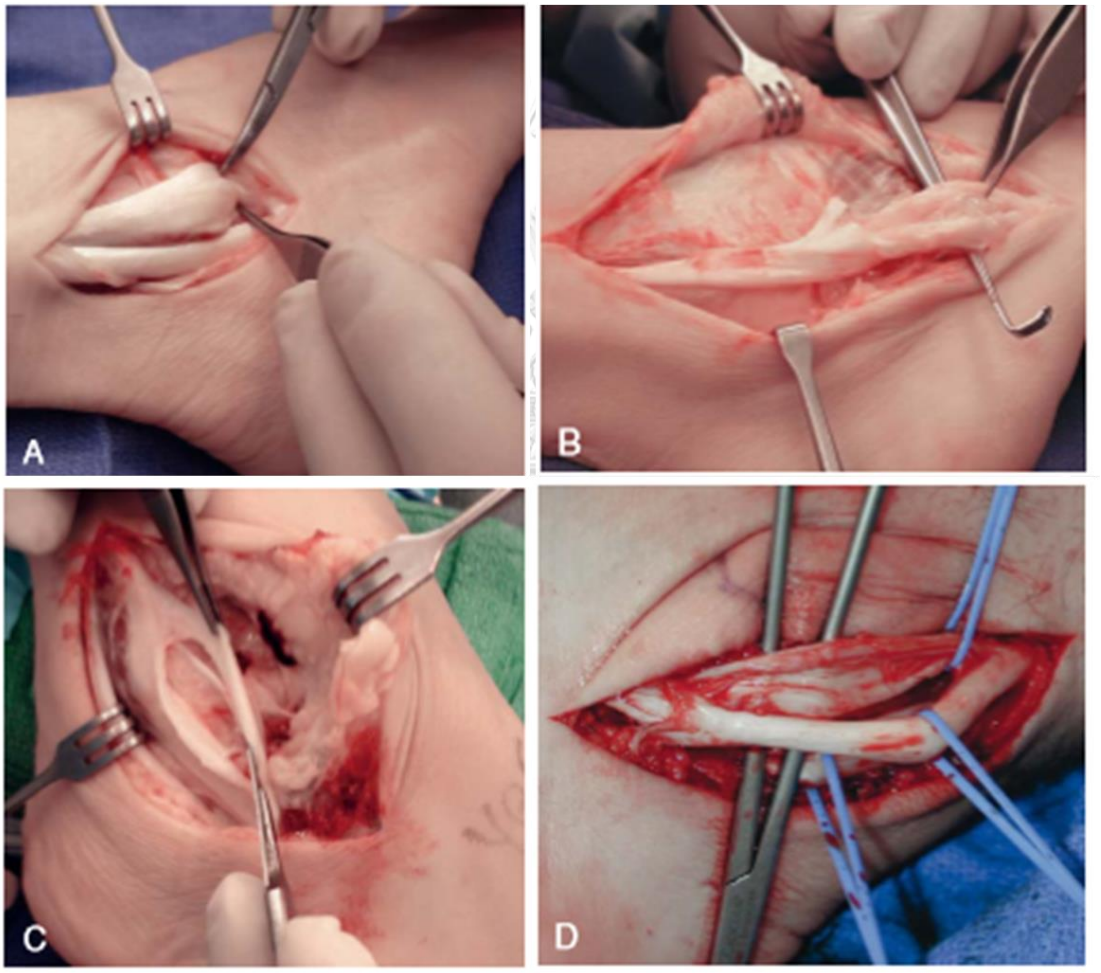


Figure 2. 8 The peroneus brevis tendon tear in patients. A; grade I tear with thinning of peroneus brevis tendon, B; grade II tear with partial tear of peroneus brevis tendon, C; grade III tear with full-thickness of tear length 1 – 2 cm, D; grade IV tear with full-thickness of tear length more than 2 cm (Coughin (2014))[4]

The peroneal tendon subluxation/dislocation

The peroneal tendon subluxation/ dislocation were the condition that the peroneal tendons were misalignment[10] (Fig. 2.9). Peroneal tendon subluxation/ dislocation could be occurred by several conditions including insufficient or tear of the SPR, shallow of retromalleolar groove, misdiagnosed of peroneal tendon disorders and unsuccessful conservative treatments of peroneal tendon disorders[4, 5, 7].

The mechanism of injury of the SPR was occurred when the ankle was in dorsiflexion position while the peroneal tendon were eccentrically contraction [5, 7]. However, the degree of plantarflexion was also one of the factors that related to this injury. During full inversion, the SPR is protected when the ankle plantarflexion more than 25° [33]. The degree of subluxation of the peroneal tendons were related to the levels of injury to SPR and could be classified into 4 grades as described in table 2.6 [7].

Table 2. 6 Superior peroneal retinaculum disorders classification [17, 41, 42]

Grade	Description
I	The peroneus longus tendon was anteriorly subluxed on the fibrocartilagenous ridge, the superior peroneal retinaculum (SPR) was still attached to the periosteum on the posterior aspect of the fibula but separated from the fibrous lip and lateral malleolus
II	The distal portion of the dense fibrous lip on the posterior edge of the lateral malleolus was elevated with the retinaculum, the stability of peroneal tendons decreased
III	A thin fragment of the bone was avulsed with the retinaculum from its anterior attachment
IV	The SPR was completely elevated from its posterior attachment and the SPR was usually found lying deep to the peroneal tendons

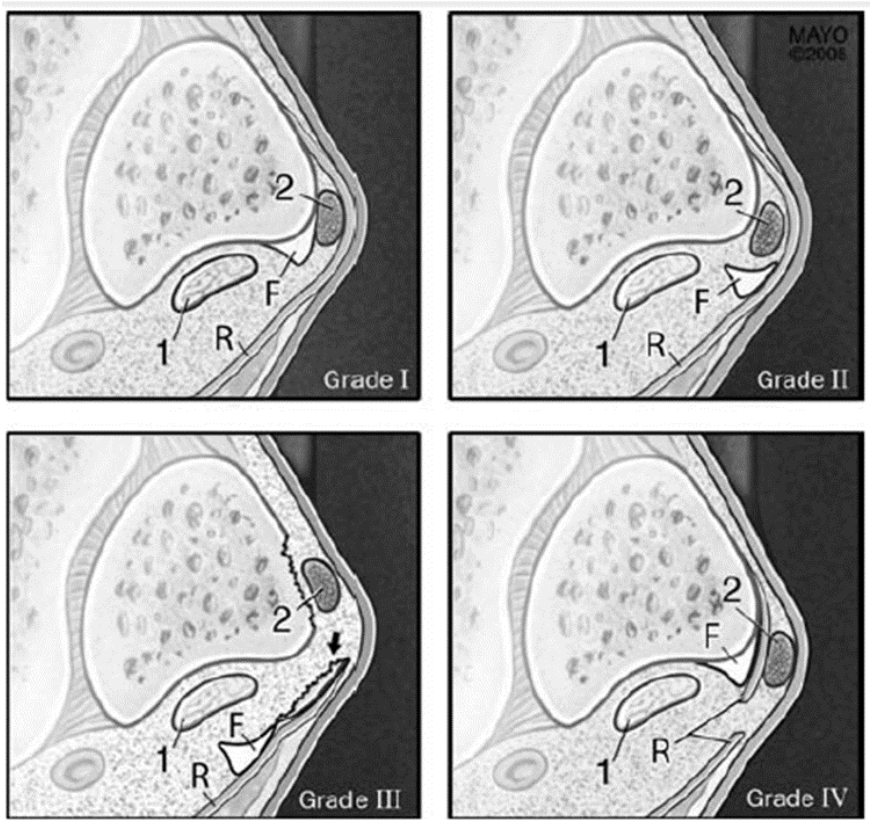


Figure 2. 9 The cross sectional diagram at the retromalleolar groove of peroneal tendon subluxation; grade I: the tendon stripped anteriorly to the lateral malleolus while SPR still attached to the periosteum, grade II: the fibrous lip of SPR elevated from lateral malleolus, grade III: avulsion of the SPR and small fragment of lateral malleolus, grade IV: completed avulsion of the SPR from insertion and peroneal tendons lied superficial to its, 1; peroneus brevis tendon, 2; peroneus longus tendon, F; fibrocartilagenous ridge, R; SPR (Roth (2010)) [(7)]

Treatments for peroneal tendon disorders

The treatment of peroneal tendon disorders consisted of conservative and surgical treatments. The conservative treatments composed of medications, reduce activities, shoe modifications, custom-made insoles, lateral heel wedges and immobilization. However, there was only 50% success from these treatments[(7, 10)]. Moreover, the conservative treatments had no potential to prevent the recurrent symptom of the peroneal tendon dislocation[(16)].

After unsuccessful conservative treatments, the surgical treatment would be required. There were several procedures of surgical treatments for peroneal tendons tears. The choosing surgical technique was depended on the patient condition. However, the superior technique had not been documented [5, 10].

The surgical treatments of peroneal tendon tear

The surgical technique for peroneal tendon tear consisted of resection and tubulization technique[4]. The patient would be placed in prone position and general anesthesia will be applied. The surgical incision was created posterior to the lateral malleolus to avoid the sural nerve injury. Then, the SPR was identified and incised at least 2-3 millimeters even it was intact. The morphology of the tear would be classified to single or multiple tear. Then, the surgical techniques would be applied depending on its pathology. Whether, the multiple tears or flayed edge were presented, the resection technique would be applied to cut these tears (Fig. 2.10 B and C). While, tubulization for peroneus brevis tendon aimed to strengthen the tendon by stitching teared tendon together (Fig. 2.10 D and E). This technique would be used in both the flatten tendon or thick single tear[19]. The low-level lying of peroneus brevis muscle or present of the PQ would be excised [4, 9, 10, 22]. The groove deepening technique would be applied in the patients with shallow retromalleolar groove.

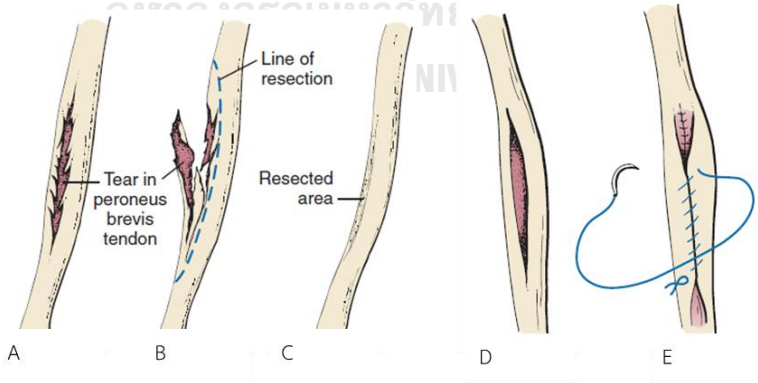


Figure 2. 10 The surgical techniques for peroneus brevis tendon tear; A: the peroneus brevis tendon tear, B: the resection area of the flayed tendon, C: the tendon after resection, D: the flatten or single thickness teared tendon, E: the tubularizing techniques for repairing tendon (Coughlin et al. (2014))[4]

The surgical treatments of peroneal tendons subluxation and dislocation

Nowadays, several surgical techniques for peroneal tendon subluxation/dislocation had been described including the rerouting tendon beneath calcaneofibular ligament, reconstruction or soft tissue repairing and soft tissue repairing with fibular groove deepening. Anyway, the superior procedure had not been described[5]. The surgical treatments were more successful in acute dislocation more than in chronic or recurrent cases[7]. All of the surgical procedures for the peroneal tendon subluxation/dislocation repair had to incise the SPR 2-3 millimeters posterior to fibula even the SPR was intact. After repairing the pathology, the SPR was reattached by suturing.

The surgical techniques for peroneal tendon subluxation/ dislocation [4, 7, 10]

1. Reattachment of the superior peroneal retinaculum

   The anatomical reattachment of SPR aimed to reattach the SPR which was the primary stabilizer of peroneal tendon in its anatomical position. The patient was placed in prone position under the general anesthesia. Then, 5 – 7 centimeter was incised posterior to the lateral malleolus around 1 centimeter to avoid sural nerve injury (5 centimeter proximal and 2 centimeter distal to distal tip of fibula). The SPR was identified and the surgeon created the hole at the lateral malleolus, then, reattached the SPR through the holes[4, 10]. Anyway, this technique was suitable for acute cases more than chronic cases (Fig. 2.11).

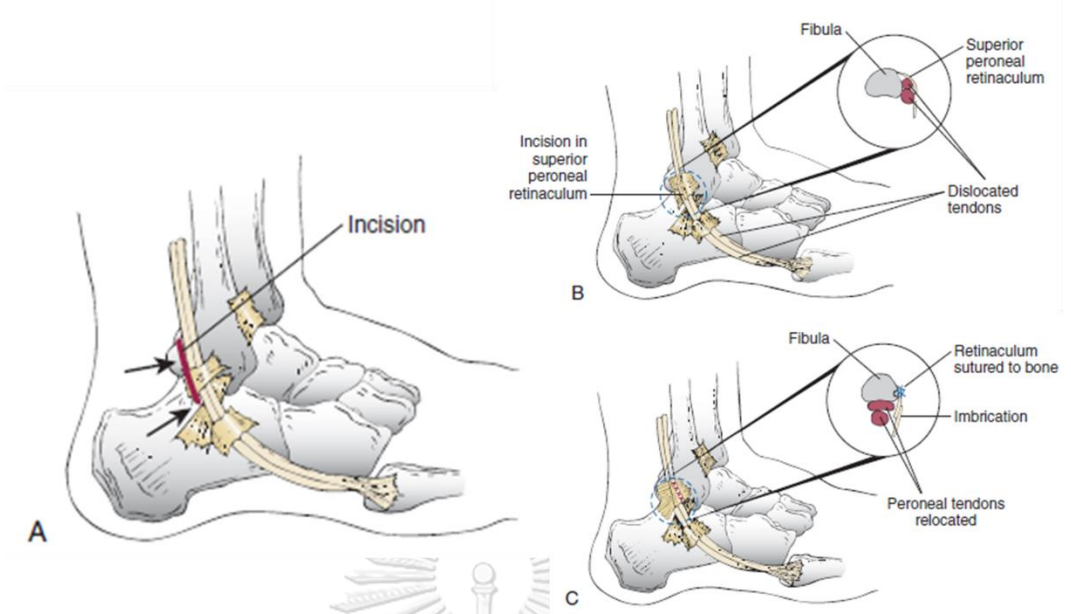


Figure 2. 11 The reattachment of the superior peroneal retinaculum technique; A: the incision applied posterior to lateral malleolus, B: the SPR incised at least 2-3 mm and relocated peroneal tendon beneath retromalleolar groove, C: reattach the SPR through the hole. (Coughlin et al. (2014))[4]

2. Reconstruction or soft tissue repairing (soft-tissue transfers)

The soft-tissue transfers was described by Jones et al. (1932). This technique was used the slip of calcaneal tendon to stabilize and to fix the peroneal tendons in their position (Fig. 2.12). Anyway, the using of calcaneal tendon slip could cause the weakness of gastrosoleus muscles. Therefore several modified techniques for reducing the complication were described such as the use of other tendons (peroneus brevis, plantaris or PQ) [4, 10].

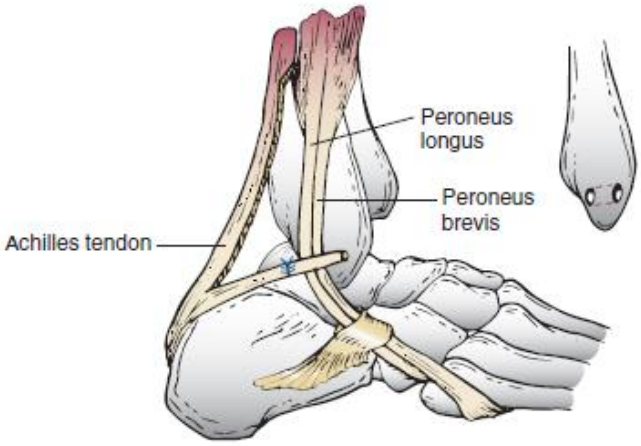


Figure 2. 12 The soft-tissue transfer technique that described by Jones et al. (Coughlin et al. (2014))

3. Bone block procedure

The bone block procedure was the surgical procedure that used the fragment of the bone as a donor. The fragment of calcaneus which the attachment of calcaneofibular ligament would be used. The peroneal tendons would be relocated beneath retromalleolar groove and fix these fragments with internal fixator (Fig. 2.13).

Anyway, the complications including infection, ankle joint stiffness, graft fracture, non-union, chronic pain, recurrent subluxation and tendon irritation from the internal fixator were reported[4, 10].

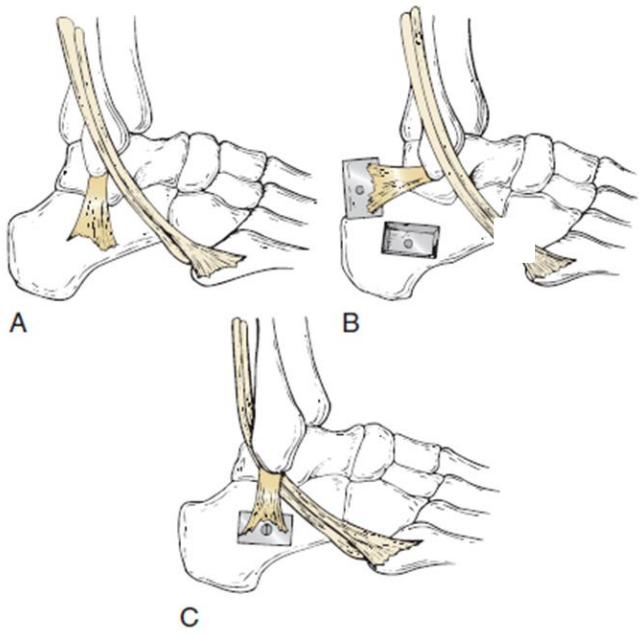


Figure 2. 13 The bone block procedure with using fragment of calcaneus which the attachment of calcaneofibular ligament; A: the anteriorly tendon dislocation, B: the bone block mobilized from calcaneus, C: the bone block was fixed by internal fixator after tendon was relocated (Coughlin et al. (2014))[4]

4. Tendon-rerouting techniques

The course of SPR was paralleled to calcaneofibular ligament, therefore, this ligament was a candidate as a graft donor for rerouting peroneal tendon in their position. The tendon rerouting technique was to relocate the peroneal tendons beneath the retromalleolar groove by using the calcaneofibular ligament. There were 2 types of rerouting techniques including using of the strip of the calcaneofibular ligament (Fig. 2.14 A and B) and the cutting of the peroneal tendons (Fig. 2.14 C and D).

A strip of calcaneofibular ligament was cut at its origin (the attachment at the distal fibula) then, the peroneal tendon was relocated. The calcaneofibular ligament was reattached to the distal fibula by internal fixator. The lateral ankle instability and internal fixator irritation were the complication of this technique.

Moreover, peroneus muscle weakness was the result of cutting the peroneal tendon and relocated beneath the calcaneofibular ligament[4].

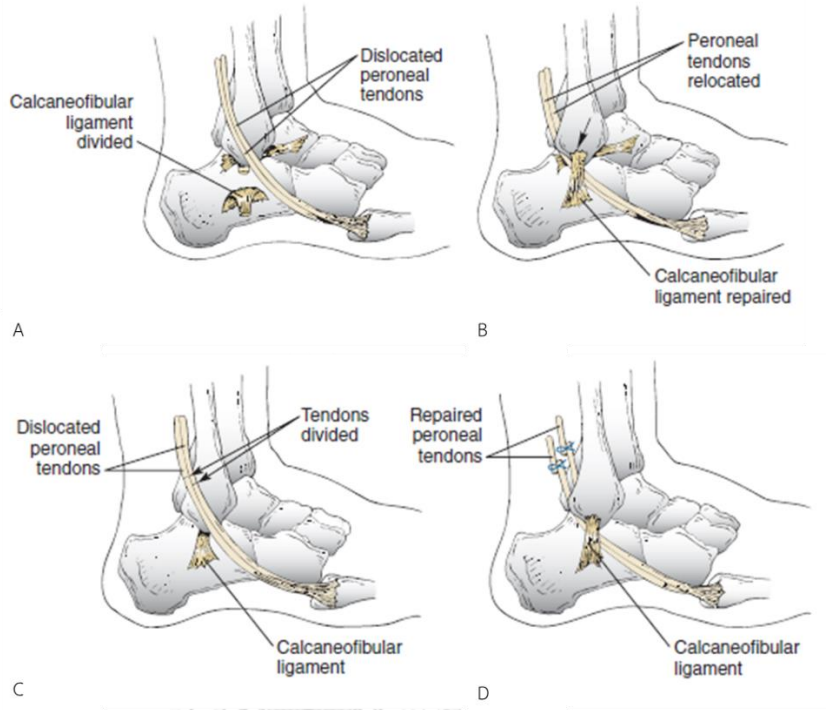


Figure 2. 14 The rerouting technique beneath calcaneofibular ligament; A & B: the strip of calcaneofibular ligament was cut and reattached by using internal fixator, C & D: the peroneal tendons were cut and reattached after relocated beneath the calcaneofibular ligament (Coughlin et al. (2014))[4]

5. Groove deepening procedure

The aimed of the fibular groove deepening was to improve the stability of the peroneal tendons[4, 43]. This technique would be applied to the patient with convex or flat contour of retromalleolar groove. After removing the cancellous bone, the peroneal tendons was relocated and the SPR was reattached (Fig. 2.15). Kollias and Ferkel (1997) reported the complication after using this technique including suture abscesses and chronic pain but the recurrent symptoms were not presented[43]. Other complications also reported such as redislocation, sural nerve injury, decrease range of motion in ankle joint and friction of the tendon after the repair[4].

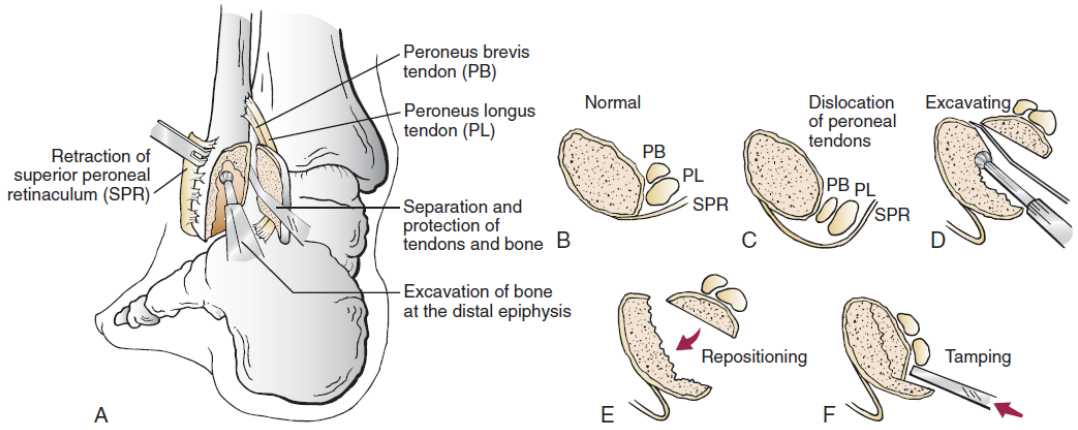


Figure 2. 15 The groove deepening technique (Coughlin et al. (2014))[4]

As aforementioned, the successful outcome of the surgical procedure will not only depend on the surgical technique, but also the anatomical knowledges. The knowledge of the pattern of the SPR will be useful in the reattachment of the SPR in anatomical position to avoid the redislocation of the peroneal tendons. To improve the stability of the peroneal tendons, groove deepening technique will be applied in the patient with flat or convex contour of the retromalleolar groove. According to the present of the supernumerary muscle in the superior peroneal tunnel, this muscle will be excised for increasing the space of superior peroneal tunnel. Therefore, the knowledge of the anatomical structures and variations in this region will be beneficial for the diagnosis, management, and improvement of the surgical outcomes.

Chapter III

Materials and Methods

Target population and sample population

This current study used the embalmed cadavers in the department of anatomy, faculty of medicine, Chulalongkorn University, Thailand

Inclusion criteria

- The cadavers were completely preserved in all processes without any trauma of the lower extremities

Exclusion criteria

- The cadavers who had deformity of foot except hallux valgus and flat foot

Sample size determination

From the pilot study of 20 legs, the standard deviation of the horizontal distance from the inferior tip of lateral malleolus to the lateral border of calcaneal tendon was 5.24 millimeter. This current study used the sample size equation from the descriptive study [44] and confidence interval set as 95%

$$n = {z^2}_{(1-\frac{\propto}{2})}\sigma^2 \Big/ d^2$$

When ${z^2}_{(1-\frac{\propto}{2})} = 1.96$ (two tail)

σ^2 = variance = $(SD)^2$ = 5.24

d = acceptable error = 1 mm

Therefore $$n = \frac{(1.96^2)(5.24^2)}{(1^2)}$$

n = 105.48

The calculated sample size was at least 105.48 legs. Therefore, 109 cadaveric legs were included in this current study.

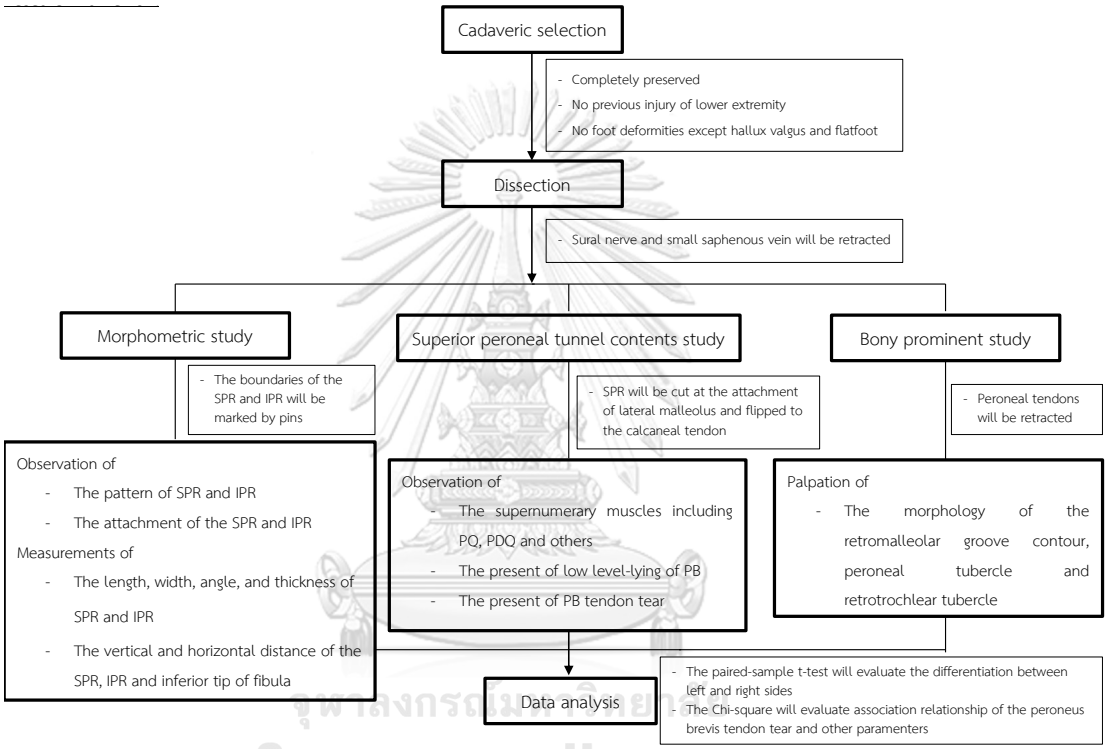
Materials and Methods

Tools

1. Dissection instruments i.e. blade, forceps, scissors, probe and clamps/wirer
2. Machinist square and bandages (for adjust the ankle to neutral position)
3. Digital vernier caliper (GuangLu ® 0-100 mm)

4. Goniometer
5. Pins
6. Scale
7. Digital camera

Research framework



Methods

Dissections

1. All cadavers were dissected in prone position. The incision was placed around 15 centimeters proximal to lateral malleolus from anterior compartment of the leg to medial border of calcaneal tendon. The incision continued distally until the shaft of metatarsal bones (Fig. 3.1A and B).

Figure 3. 1 The cadaveric leg before dissection (A) and the cadaveric leg after removing the skin from the anterior compartment of the leg to medial border of calcaneal tendon (B)

2. After removing the skin, sural nerve and small saphenous vein were distracted anteriorly (Fig. 3.2).

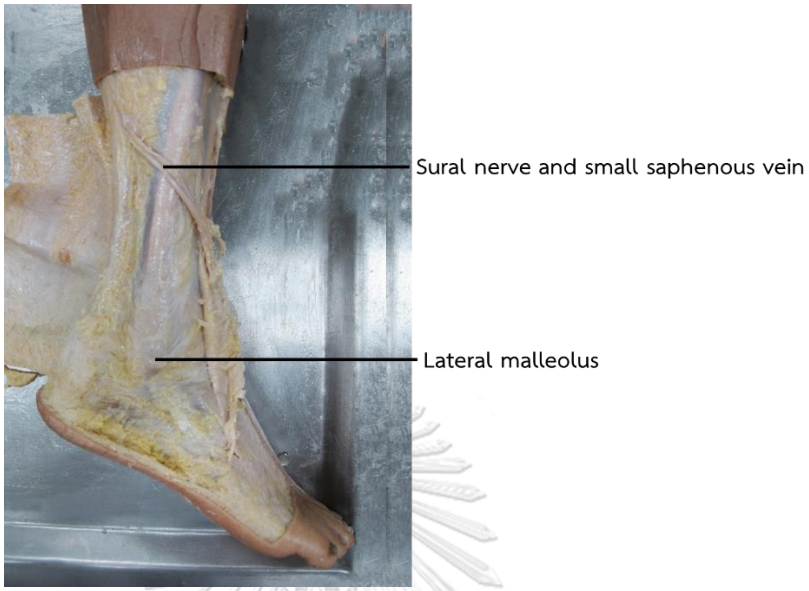


Figure 3. 2 The distraction of the sural nerve and small saphenous vein

3. The superior peroneal retinaculum (SPR) and inferior peroneal retinaculum (IPR) were identified.
4. The foot was adjusted in neutral position by releasing the calcaneal tendon with Z-plasty lengthening technique. Then, the foot was placed in machinist square and fixed with bandages to correct ankle position (Fig. 3.3).

Figure 3. 3 The foot was adjusted in neutral position by machinist square and bandages

5. The inferior tip of lateral malleolus was marked by pin (purple dot), boundaries of the SPR, IPR and lateral border of calcaneal tendon were marked by pins (Fig. 3.4).

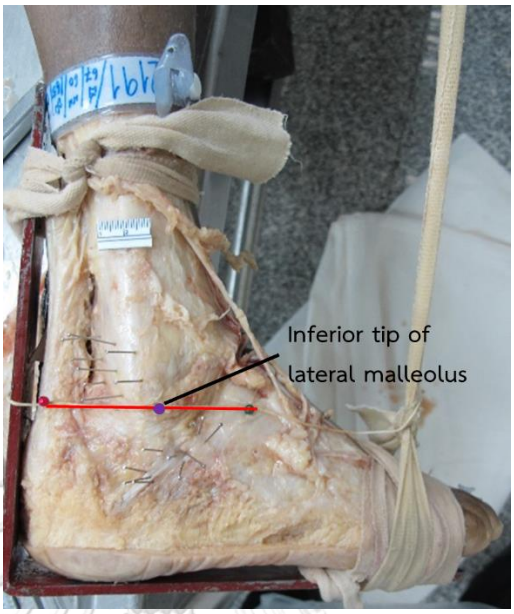


Figure 3. 4 The boundaries of the SPR, IPR and lateral border of calcaneal tendon were marked by pins

Observations

1. The **type of SPR** was identified as described by Davis (1994)[40]. The **attachments of SPR** were described.
2. The **attachments of the IPR** were described. The presence of the **prominence of the peroneal tubercle and retrotrochlear eminence** were identified and confirmed by palpation.
3. The SPR was cut at the attachment at the lateral malleolus and flipped to the lateral border of the calcaneal tendon, then, the content and extraordinary structures of the superior peroneal tunnel were observed.
4. The **presence of the accessory muscle** i.e. PQ, PDQ and other accessory muscle were identified. The origin and insertion of those muscles were described.
5. The **low level lying of peroneus brevis muscle** in the superior peroneal tunnel was identified.

6. The **presence of peroneus longus and peroneus brevis tendon tear** were identified and classified into grade I-IV as described by Sobel et al.[1, 40]
7. The **contour of retromalleolar groove** was described as convex, flat, concave, irregular and others contour.

Measurements

The measurements were taken by digital Vernier caliper (GuangLu ® 0-100 mm). The parameters were measured from 1. to 14. and repeated 3 times as an day interval.

1. Horizontal distance from the lateral border of calcaneal tendon to inferior tip of fibula (A) was measured. (Fig. 3.5)
2. Horizontal distance (B) and vertical distance (C) from most prominent part of the peroneal tubercle to the inferior tip of fibula were measured. (Fig. 3.5)

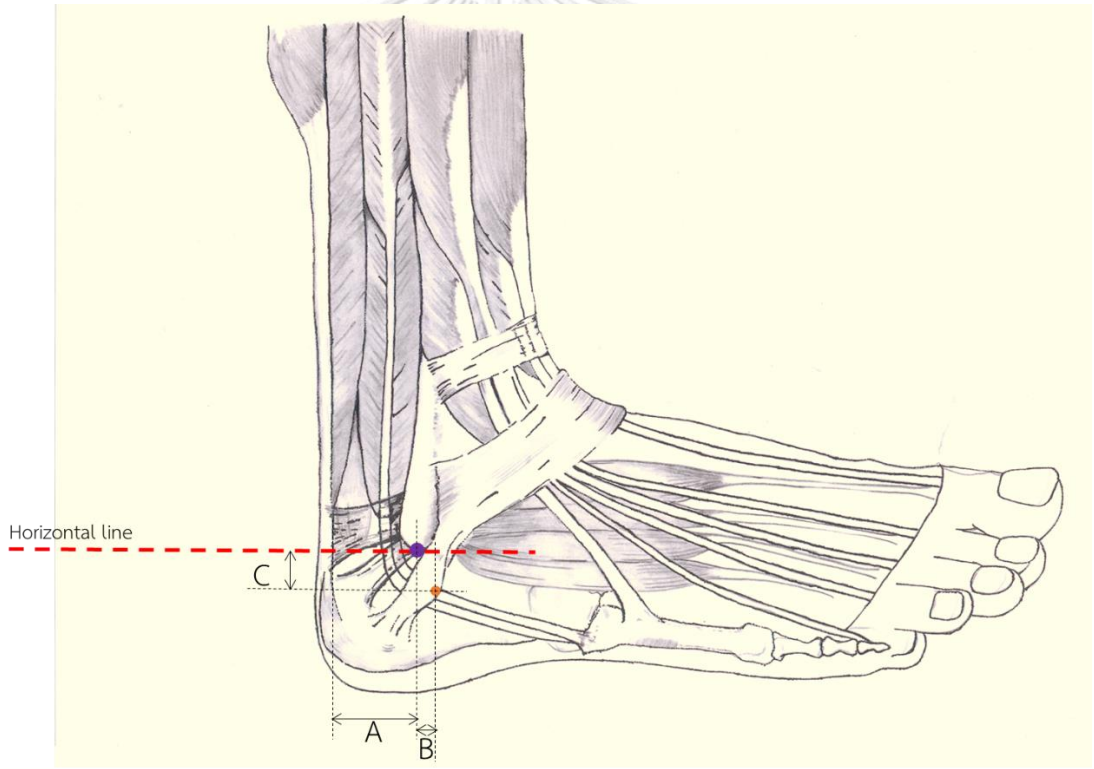


Figure 3. 5 The horizontal distance from lateral border of calcaneal tendon (A), the horizontal distance from peroneal tubercle (B) and vertical distance from peroneal tubercle (C) to the inferior tip of lateral malleolus were measured by digital Vernier caliper.

SPR

3. The width of the SPR at the lateral malleolus (origin) (D) and width of the SPR at posterior intermuscular septum (insertion) (E) were measured. Then, the pins were marked at the mid-point of both attachments of the SPR as shown in figure 3.6.
4. The length of the SPR was determined by the distance between the mid-point of both borders (origin and insertion) (F). If there is a distal band of SPR, the width of both attachments (G and H) and the distance between mid-points (I) was measured (Fig. 3.6).

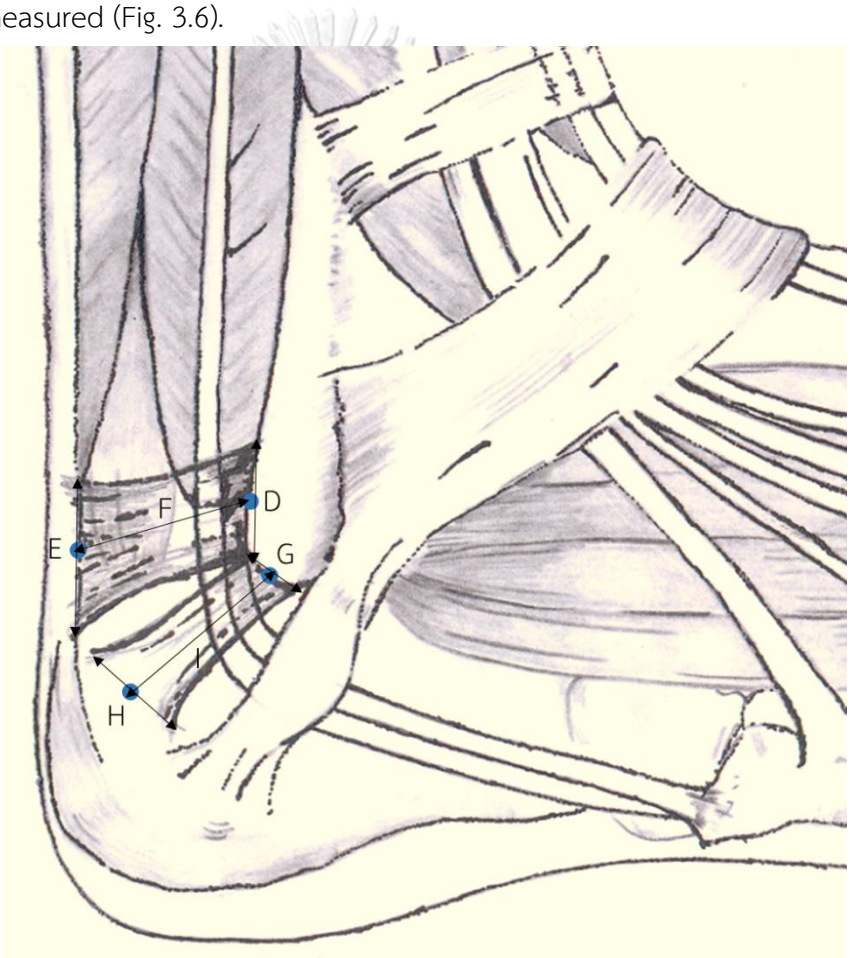


Figure 3. 6 The width at the origin (D) and insertion (E) of the SPR were measured, then, the distance between mid-point of origin and insertion was measured (F). If the distal band present, the width at the origin (G) and insertion (H) and the distance between mid-point of origin and insertion (I) was measured

5. The width at the middle part of SPR was measured from the mid-point of the upper and lower borders of the SPR (J) (Fig. 3.7). If there is a distal band of SPR, the width at the middle part of SPR was measured (K).

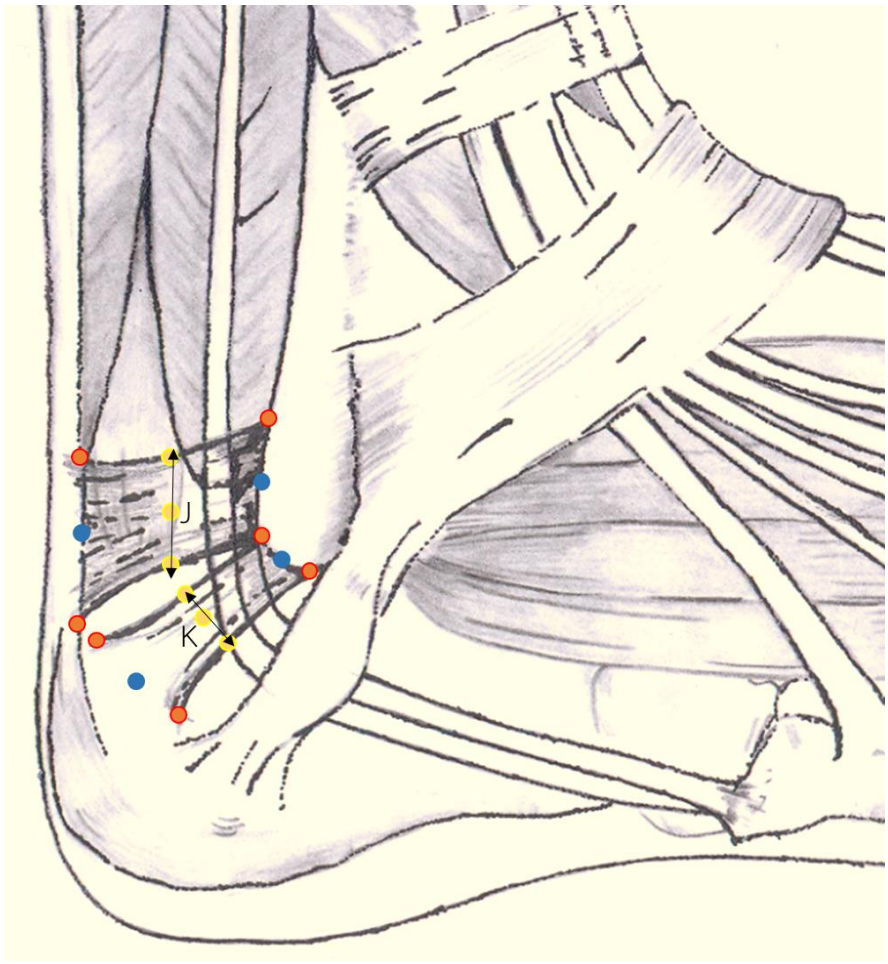


Figure 3. 7 The width at the middle part of the SPR (J) was measured. If the distal band present, the width at middle part of distal band (K) was determined as well.

6. The Vertical (L) and horizontal (M) distances from the mid-point of the attachment of the SPR at lateral malleolus (origin) to inferior tip of distal fibula were measured as shown in figure 3.8A and B.
7. Vertical (N) and horizontal (O) distances from the mid-point of the attachment of the SPR at the posterior intermuscular septum (insertion) to inferior tip of the fibula were measured (Fig. 3.8 A and B).

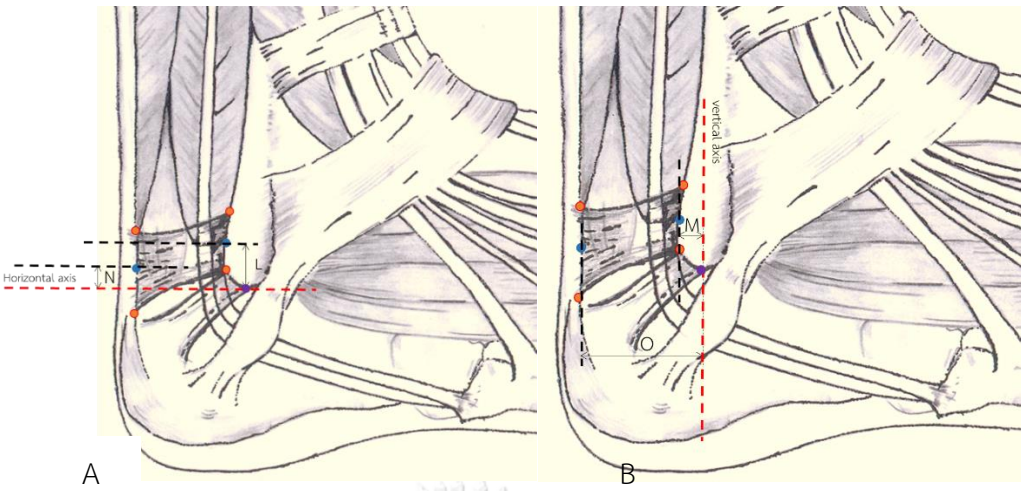


Figure 3. 8 The vertical and horizontal distance from the mid-point of the attachment of the proximal bands of the SPR; L: the vertical distance from the mid-point of the origin to inferior tip of the fibula, N: the vertical distance from the mid-point of the insertion to inferior tip of the fibula, M: the horizontal distance from the mid-point of the origin to inferior tip of the fibula, O: the horizontal distance of the mid-point of the insertion to the inferior tip of the fibula

8. The angle of the attachment of the SPR and the horizontal axis was measured by standard goniometer (Fig. 3.9).

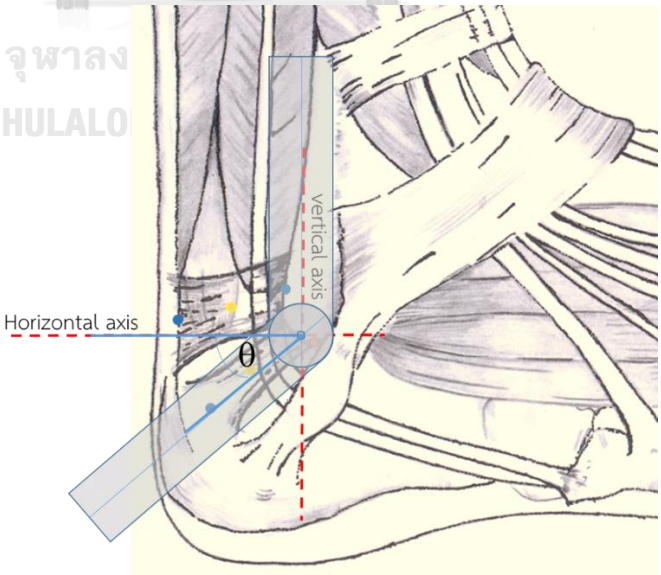


Figure 3. 9 The measurement of the angle of the attachments of SPR and the horizontal axis.

9. The thickness of the SPR at the mid-point of its length was measured both proximal and distal bands.

IPR

10. The width of the IPR which extends from the inferior extensor retinaculum (upper attachment) (P) and width of the IPR at the retrotrochlear eminence or other lateral wall of the calcaneus (lower attachment) (Q) were measured. Then, the pins were marked at the mid-point of both attachments of the IPR as shown in figure 3.10.
11. The length of the IPR was determined by the distance between the mid-point of both borders (upper and lower attachments) (R) (Fig. 3.10).
12. The width at the middle part of the IPR (S) was measured from the mid-point of the upper and lower borders of the IPR.

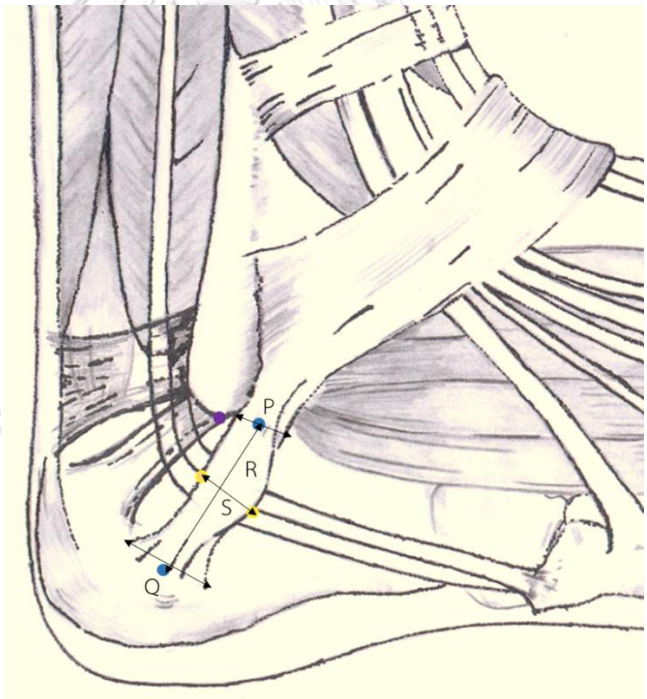


Figure 3. 10 The width at the upper attachment (P) and lower attachment (Q) of the IPR were measured, then, the distance between mid-point of upper and lower attachments of IPR (R) were measured. The width at middle part of the IPR (S) was measured between mid-point of upper and lower border of the IPR

13. The thickness of the IPR at the mid-point of its length was measured.
14. The angle of the attachments of the IPR and the horizontal axis was measured by standard goniometer (Fig. 3.11).

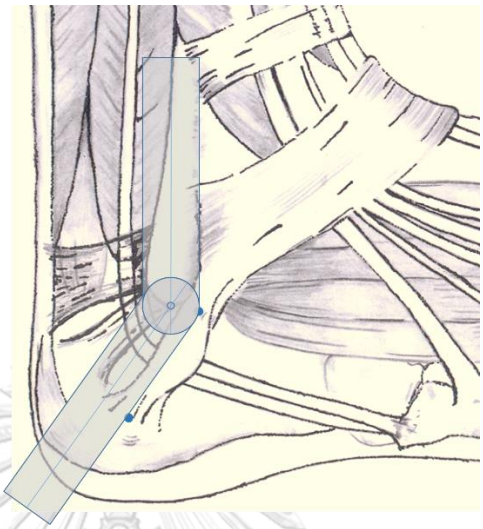


Figure 3. 11 The measurement of the angle of the attachments of SPR and the horizontal axis.

Data collections

All data will note in the CRF

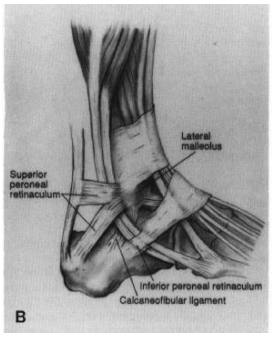
Case Record Form

Faculty of Medicine, Chulalongkorn University

Table NO. ..... Sex: ☐ Male ☐ Female Cadaveric Code: ..... Age: ..... Years Side: ☐ Left ☐ Right

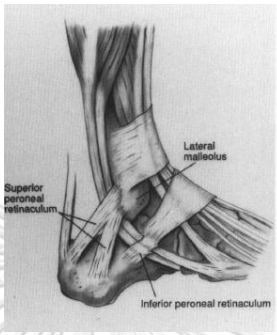
Superior peroneal retinaculum (SPR)

☐ Type I



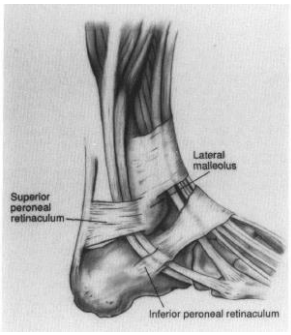
SPR had 2 band; proximal band inserted at lateral border of calcaneal tendon while distal band inserted at lateral wall of calcaneus

☐ Type II



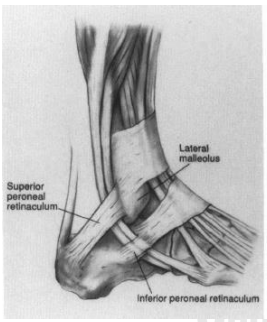
SPR had 2 bands inserted at lateral wall of calcaneus

☐ Type III



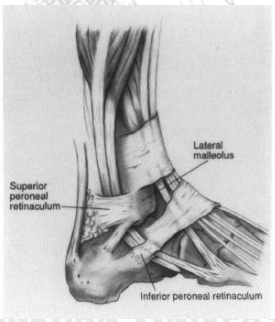
SPR had single wider band inserted at lateral border of calcaneal tendon

☐ Type IV



SPR had single band inserted at lateral wall of calcaneus

☐ Type V



SPR had 2 band; proximal band inserted loosely at pretendinous fascia of calcaneal tendon while distal band inserted at lateral wall of calcaneus

☐ Other

Origin:

.....

Insertion:

.....

Parameters	☐ Lt. (mm) ☐ Rt. (mm)			
	1st	2nd	3rd	Average
Horizontal distance from tip of fibula to calcaneal tendon (A)				
Horizontal distance from tip of fibula to peroneal tubercle (B)				
Vertical distance from tip of fibula to peroneal tubercle (C)				

Superior peroneal tunnel content

☐ peroneus brevis tendon ☐ peroneus longus tendon ☐ accessory peroneal nerve ☐ other ....

Superior peroneal retinaculum (SPR)

Parameters		☐ Lt. (mm) ☐ Rt. (mm)				
		Relation to fibular tip	1st	2nd	3rd	Average
Length from mid-point of origin to insertion	proximal band (F)					
	distal band (if present) (I)					
Length of upper border from origin to insertion	proximal band					
	distal band (if present)					
Length of lower border from origin to insertion	proximal band					
	distal band (if present)					
Width at the origin of SPR	proximal band (D)					
	distal band (if present) (G)					
Width at the insertion of SPR	proximal band (E)					
	distal band (if present) (H)					
Width at the middle part of SPR	proximal band (J)					
	distal band (if present) (K)					
Thickness at the middle part of SPR	proximal band					
	distal band (if present)					
Vertical distance from tip of fibula to mid-point of origin of SPR	proximal band (L)	☐ Above ☐ Below				
	distal band (if present)	☐ Above ☐ Below				
Horizontal distance from tip of fibula to mid-point of origin of SPR	proximal band M)	☐ Above ☐ Below				
	distal band (if present)	☐ Above ☐ Below				
Vertical distance from tip of fibula to mid-point of insertion of SPR	proximal band (N)	☐ Above ☐ Below				
	distal band (if present)	☐ Above ☐ Below				
Horizontal distance from tip of fibula to mid-point of insertion of SPR	proximal band (O)	☐ Above ☐ Below				
	distal band (if present)	☐ Above ☐ Below				

Parameters		☐ Lt. (mm) ☐ Rt. (mm)				
		Relation to fibular tip	1st	2nd	3rd	Average
Angle between SPR and horizontal axis (axis = tip of fibula)	proximal band	☐ Above ☐ Below				
	distal band (if present)	☐ ↑ ☐ ↓				
Peroneus brevis muscle fiber at superior peroneal retinaculum			☐ present	☐ absent		
	Note:					

Inferior peroneal retinaculum (IPR)

Parameters	☐ Lt. (mm) ☐ Rt. (mm)			
	1st	2nd	3rd	Average
Origin:				
Insertion:				
Length from origin to insertion (R)				
Width at origin of IPR (P)				
Width at insertion of IPR (Q)				
Width at middle part of IPR (S)				
Thickness at middle part of IPR				
Angle between fibula and IPR ☐ ↑ ☐ ↓				
Note:				

Contour of retromalleolar groove, peroneal tubercle and retrotrochlear eminence

Observation	☐ Lt. (mm) ☐ Rt. (mm)
Contour of retromalleolar groove	☐ concave ☐ flat ☐ convex ☐ irregular ☐ other.....
Peroneal tubercle	☐ prominent ☐ flat ☐ other.....
Retrotrochlear eminence	☐ prominent ☐ flat ☐ other.....

Peroneal tendon pathology (if present)

Parameters	☐ Lt. (mm) ☐ Rt. (mm)			
	1st	2nd	3rd	Average
Peroneus brevis				
Low level lying of peroneus brevis in superior peroneal tunnel	☐ present		☐ absent	
PB tendon tear (Sobel et al.) (if present) ☐ Grade I ☐ Grade II ☐ Grade III ☐ Grade IV				
Length of PB tear				
Peroneus longus				
Low level lying of peroneus longus in superior peroneal tunnel	☐ present		☐ absent	
PL tendon tear (Sobel et al.) (if present) ☐ Grade I ☐ Grade II ☐ Grade III ☐ Grade IV				
Length of PL tear				
Note:				

Accessory Peroneal muscle

Observation	☐ Lt. (mm) ☐ Rt. (mm)
Peroneus quartus muscle (PQ) (if present)	
Origin	
Insertion	
Peroneus digiti quinti muscle (if present)	
Origin	
Insertion	
Other accessory peroneal muscle (if present)	
Origin	
Insertion	

Data analysis

The statistical analysis in each parameter was performed by SPSS software version 22.0. Mean and standard deviation for each parameter were obtained. To determine the distribution of the sample population, Shaptro-Wilk test of normality was used. Comparisons of the parameters between genders and sides were done using unpaired t-test in parameter with normally distributed data and Mann-Whitney U test in parameter with non-normally distributed data. The statistical significance in this study will use α = 0.05 (p-value < 0.05).

The statistical analysis for evaluating the association relationship of the peroneus brevis tendon tear, the present of peroneus quartus muscle and the contour of the retromalleolar groove will be the Chi-square (for parametric test) or Kolmogorov – Smirnov sign test (for nonparametric test). The intraclass correlation coefficient (ICC) was used to determine the intra-tester reliability.

Ethical consideration

This study has been approved by the human research ethics committee and the director of King Chulalongkorn Memorial hospital (IRB NO.110/61).

Chapter IV

Results

The formaldehyde-embalmed cadaveric legs from 55 males and 54 females provided by Department of Anatomy, Faculty of Medicine, Chulalongkorn University were used. All cadavers had no gross evidence of lower extremity injuries and foot deformity. The average age of the cadavers was 77.44 ± 12.91 (34 - 94) years (age rage 34-94). The demographic data was shown in table 4.1.

Table 4. 1 The demographic data of the cadavers

Parameters	Mean ± SD (range)			*p*
	Male	Female	Total	
Age	78.91 ± 10.14 (50 - 93)	75.88 ± 15.25 (34 - 94)	77.44 ± 12.91 (34 - 94)	0.227
Horizontal distance from calcaneal tendon to inferior tip of fibula	42.31 ± 5.18 (31.95 – 53.45)	39.99 ± 4.04 (28.42 – 47.96)	41.16 ± 4.86 (28.42 – 53.45)	0.012
Horizontal distance from tip of fibula to peroneal tubercle	8.12 ± 4.29 (1.50 – 18.57)	6.16 ± 3.68 (0.00 – 19.09)	7.15 ± 4.10 (0.00 – 19.09)	0.012
Vertical distance from tip of fibula to peroneal tubercle	15.11 ± 3.78 (3.45 – 25.78)	13.94 ± 2.95 (7.68 – 19.60)	14.53 ± 3.43 (3.45 – 25.78)	0.076

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

The anatomy of the superior peroneal retinaculum and its tunnel

Characteristic, origin and the attachment of the SPR

The SPR had a common origin which extended from the fibrocartilagenous ridge of the posterolateral surface of the lateral malleolus but its insertion was varied. The SPR might be a single band or split into proximal and distal bands to insert on the posterior intermuscular septum and lateral wall of calcaneus. The direction of proximal band might be slightly upward or parallel to the horizontal axis. In this study, the SPR could be classified into 3 types according to their insertion patterns (**Fig. 4.1-4.3**). Type I consisted of double bands while type II and type III had single band. Detail of the characteristic of each type was described in table 4.2. However, type I could be divided into to 2 subtypes: type Ia (**Fig. 4.1A-4.1B**) and type Ib (**Fig. 4.1C-4.1D**) based on the site of splitting into proximal and distal bands. The splitting site of type Ia was closed to its origin while that of type Ib was split at its middle part. The prevalence of each type was shown in Table 4.3. The most common was type Ib and the least common was type II.

Table 4. 2 The types of SPR

Type		Definition
Type I	Type Ia	The SPR originated from fibrocartilagenous ridge of the posterolateral surface of lateral malleolus and split near its origin into 2 bands: the proximal band coursed slightly upward and the distal bands coursed slightly downward to insert on the posterior intermuscular septum and lateral wall of calcaneus respectively
	Type Ib	The SPR originated from fibrocartilagenous ridge of the posterolateral surface of lateral malleolus and divided at its middle part into 2 bands: the proximal coursed slightly upward or parallel to the horizontal plane and the distal bands coursed slightly downward to insert on the posterior intermuscular septum and lateral wall of calcaneus respectively
Type II	The SPR originated fibrocartilagenous ridge of the posterolateral surface of lateral malleolus and coursed slightly downward to insert on the lateral wall of the calcaneus	
Type III	The SPR originated fibrocartilagenous ridge of the posterolateral surface of lateral malleolus and coursed slightly upward or parallel to the horizontal plane to insert on the posterior intermuscular septum	

Table 4. 3 The prevalence of the SPR

Type	n (%)				
	Total	Left		Right	
		Male	Female	Male	Female
Type Ia	14 (12.84)	1 (0.92)	6 (5.50)	3 (2.75)	4 (3.67)
Type Ib	48 (44.04)	13 (11.93)	12 (11.01)	8 (7.34)	15 (13.76)
Type II	2 (1.83)	-	2 (1.83)	-	-
Type III	45 (41.28)	14 (12.84)	7 (6.42)	16 (14.68)	8 (7.34)

In addition, the symmetrical pattern was found in 29 (52.73%) cadavers. The prevalences were 15 (27.27%), 13 (23.64%) and 1 (1.82%) cadavers in type III, type Ib and type Ia, respectively. In cases of asymmetrical pattern, the characteristic features were type Ib with type III, type Ia with type Ib, type Ia with type III, type Ia with type II

and type Ia with type II with a prevalence 12 (21.82%), 9 (16.36%), 2 (3.64%), 1 (1.82%) and 1 (1.82%) cadavers, respectively. One cadaver with only one leg of type III was not included for considering the symmetrical pattern.

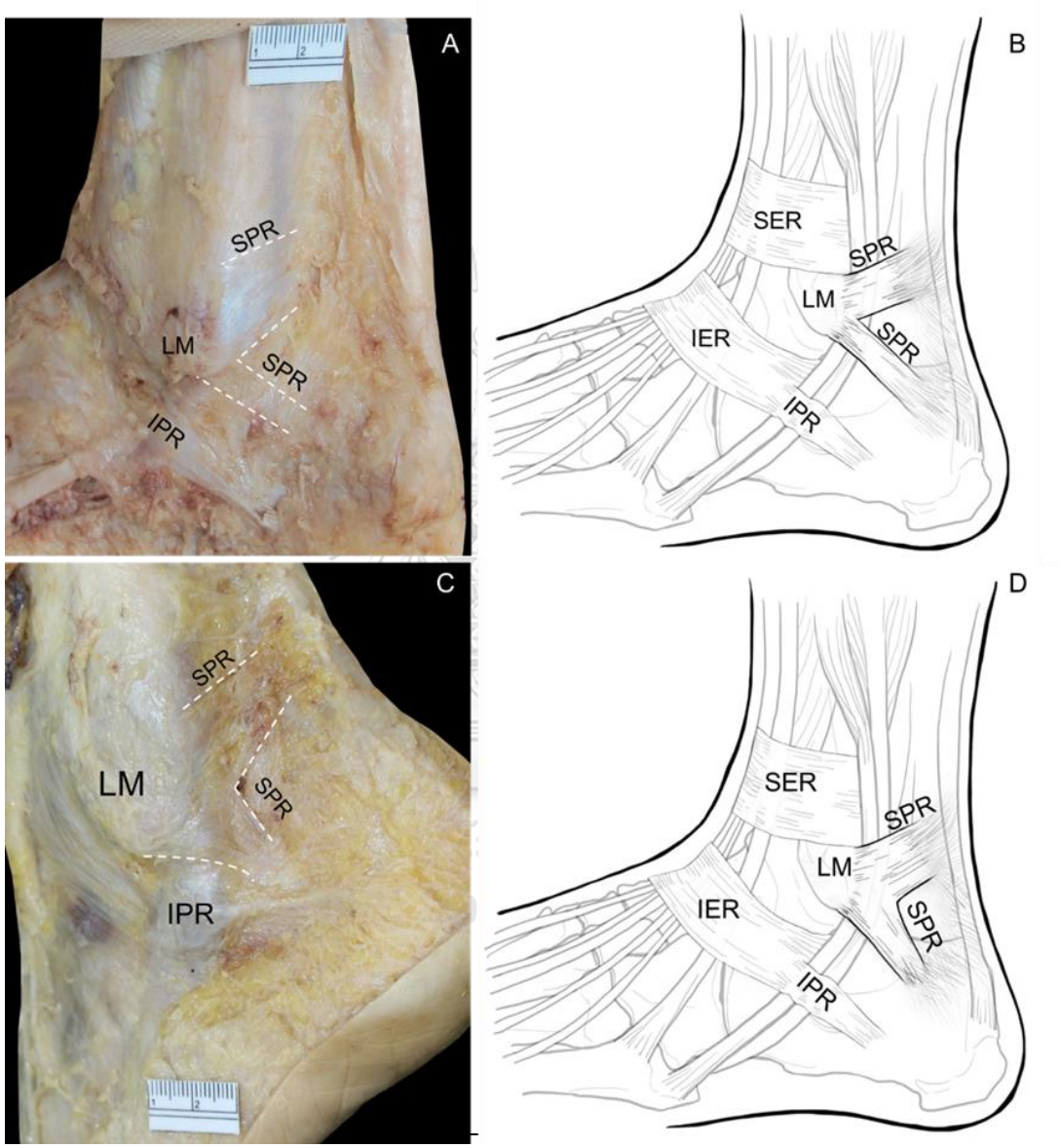


Figure 4. 1 Type Ia (A and B) and Ib(C and D) of SPR had 2 bands inserted on the posterior intermuscular septum and lateral wall of calcaneus.: SPR, superior peroneal retinaculum; IPR, inferior peroneal retinaculum; LM, lateral malleolus; SER, superior extensor retinaculum; IER, inferior extensor retinaculum.

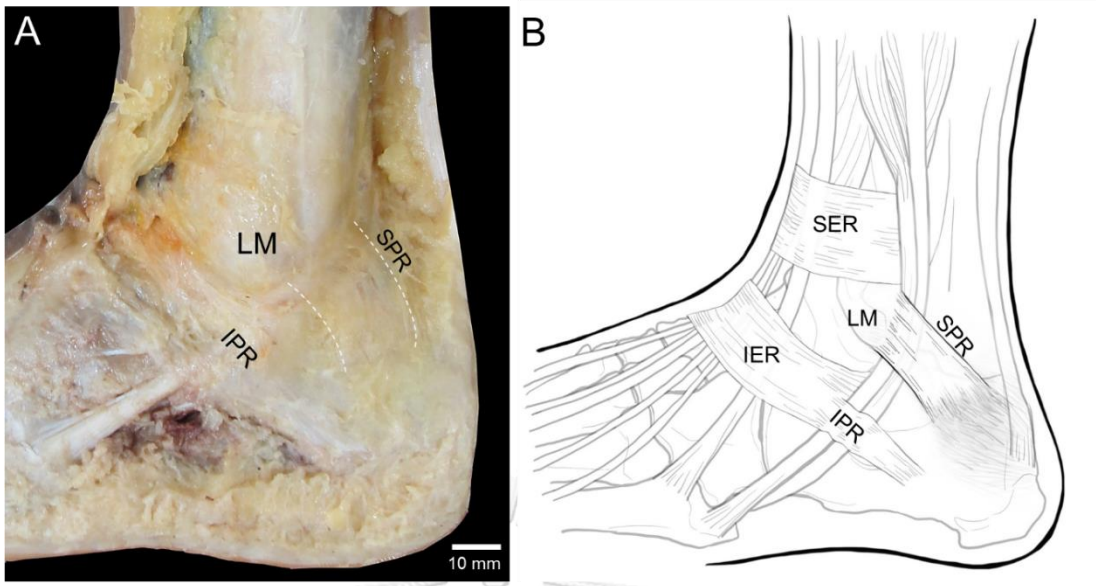


Figure 4. 2 Type II of SPR (A and B) had single band inserted on lateral wall of the calcaneus.: SPR, superior peroneal retinaculum; IPR, inferior peroneal retinaculum; LM, lateral malleolus; SER, superior extensor retinaculum; IER, inferior extensor retinaculum.

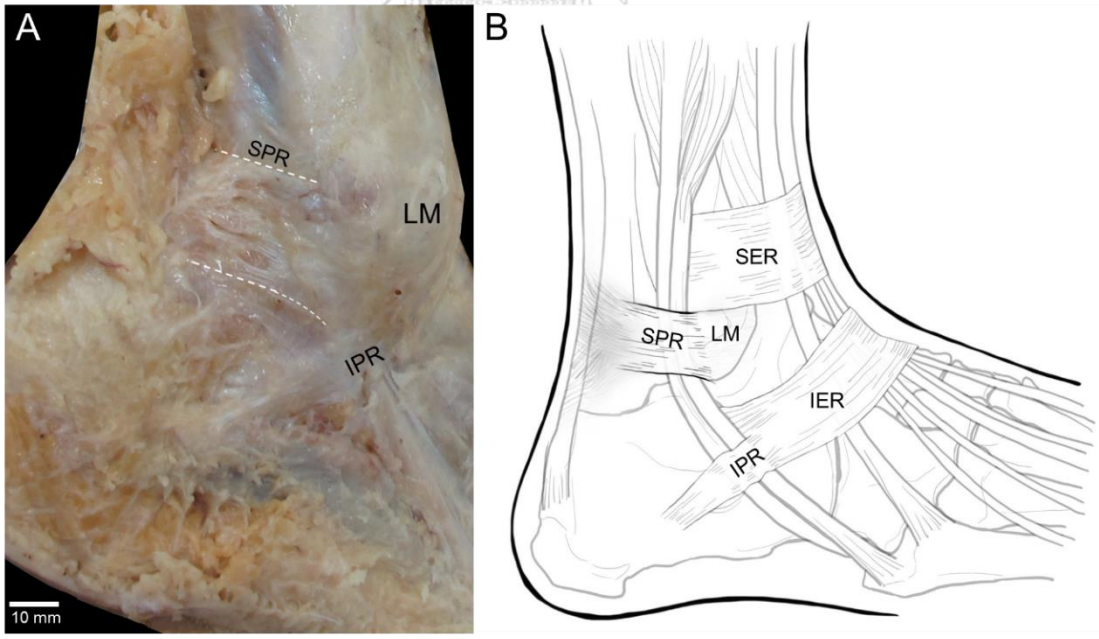


Figure 4. 3 Type III of SPR (A and B) inserted on posterior intermuscular septum.: SPR, superior peroneal retinaculum; IPR, inferior peroneal retinaculum; LM, lateral malleolus; SER, superior extensor retinaculum; IER, inferior extensor retinaculum.

The length of the SPR

The results of the length of the SPR revealed that the mean length of all SPR which inserted on the posterior intermuscular septum and lateral wall of calcaneus were 22.05±3.99 and 28.41±5.49 mm., respectively. The distal band of type Ib was the longest, while type III was the shortest. Comparisons of SPR length between genders and sides revealed only the length of SPR which inserted on the posterior intermuscular septum in type Ib had statistically significance between genders (p=0.018).

Comparisons of the length of SPR in each type revealed no statistically significant difference except, the length of the SPR bands which inserted on the posterior intermuscular septum between types of the SPR revealed that only the type Ib and type III had the statistically significant difference (p=0.015). Detail morphometric data was tabulated in Table 4.4.

Table 4. 4 The length of the SPR

SPR	Mean ± SD (range)						
	Total	Left			Right		
		Male	Female	Total	Male	Female	Total
Type Ia							
- Proximal band	22.86±5.06 (16.51-32.83)	32.83	20.60±2.64 (16.51-23.90)	22.34±5.21 (16.51-32.83)	26.69±6.33 (19.86-32.35)	20.91±3.10 (16.70-24.11)	23.39±5.26 (16.70-32.35)
- Distal band	23.73±4.82 (16.27-32.72)	23.29	22.43±6.07 (16.27-32.72)	22.55±5.56 (16.27-32.72)	23.46±6.39 (17.16-29.94)	26.00±1.27 (24.64-27.72)	24.91±4.03 (17.16-29.94)
Type Ib							
- Proximal band	22.80±3.18 (16.24-31.15)	24.16±4.16 (18.45-31.15)	21.76±1.96 (18.97-25.22)	23.01±3.45 (18.45-31.15)	23.78±2.30 (20.34-27.76)	21.92±3.09 (16.24-26.29)	22.57±2.93 (16.24-27.76)
- Distal band	29.77±4.92 (22.38-40.71)	30.05±5.49 (23.44-40.71)	27.42±3.40 (22.38-32.72)	28.79±4.71 (22.38-40.71)	32.49±4.60 (25.57-39.44)	29.95±5.17 (22.50-38.71)	30.83±5.03 (22.50-39.44)
Type II	26.39±3.54 (23.89-28.89)	-	26.39±3.54 (23.89-28.89)	26.39±3.54 (23.89-28.89)	-	-	-
Type III	20.82 ± 4.15 (13.13–36.64)	20.63 ± 3.51 (15.68-26.60)	19.63 ± 2.09 (16.47-21.56)	20.30 ± 3.09 (15.68-26.60)	21.59 ± 3.60 (14.68-27.61)	20.69 ± 7.15 (13.13-36.64)	21.27 ± 4.92 (13.13-36.64)

The width of the SPR

The width of the SPR was obtained from origin, middle part and the insertion. Most of SPR had a common origin at the lateral malleolus with an average of 18.37±4.13 (8.05-28.98) mm. The results of the width revealed that the widest part of the SPR at its origin was found in the proximal band of the type Ib with an average of 19.73±3.40 (13.17-28.98) mm. as described in table 4.4. This follow in numerical order by type Ia, type III and type II with an average of 17.58±3.36 (10.33-21.74), 17.31±4.65 (8.05-26.22) and 14.53±5.54 (10.62-18.45) mm., respectively.

The results of the width at the middle part revealed that the type Ib of the proximal band of the SPR was the widest part with an average 17.23±3.35 (11.38-24.50) mm. (**Table 4.5**). In contrast, the widest part of the width of insertion was found in the type III with a mean length of 14.55±3.42 (5.64-21.12) mm. The average width at insertion both inserted on the posterior intermuscular septum and lateral wall of calcaneus were 14.34±3.80 and 10.32±3.42 mm., respectively. In addition, the average of width at insertion of SPR inserted on the lateral calcaneus was lesser than those inserted on the lateral intermuscular septum. The data of the width were normally distributed and comparisons of the width of SPR between genders and sides in each type revealed only the proximal and distal band of width at insertion of type Ia had statistically significant difference ($p = 0.018$ and 0.040, respectively). Moreover, the width at origin of type Ib was statistically significant wider than type III ($p = 0.004$).

Table 4. 5 The width of the SPR

SPR	Mean ± SD (range)														
	Width at origin					Width at middle part					Width at insertion				
	Left		Right		Total	Left		Right		Total	Left		Right		Total
	M	F	M	F		M	F	M	F		M	F	M	F	
Type Ia															
- Proximal	20.73	15.88 ±3.93 (10.33 - 21.11)	18.61 ±2.75 (16.55 - 21.74)	18.57 ±2.59 (14.98 - 21.07)	17.58 ±3.36 (10.33 - 21.74)	18.02	13.35 ±3.51 (9.07- 18.19)	20.04 ±0.95 (19.42 - 21.13)	17.44 ±4.96 (10.61 - 22.51)	16.29 ±4.29 (9.07- 22.51)	7.82	11.45 ±3.93 (6.31- 17.42)	15.89 ±1.95 (13.66 - 17.28)	16.53 ±4.61 (11.38 - 21.70)	13.59 ±4.47 (6.31- 21.70)
- Distal	-	-	-	-	-	10.40	11.09 ±4.25 (5.20- 15.34)	14.75 ±4.48 (11.44 - 19.85)	12.39 ±1.40 (10.46 - 13.72)	12.20 ±3.58 (5.20- 19.85)	7.59	9.18± 3.38 (4.59- 14.17)	12.12 ±1.93 (10.80 - 14.33)	12.33 ±2.49 (8.76- 14.49)	10.48 ±3.00 (4.59- 14.49)
Type Ib															
- Proximal	19.71 ±3.47 (13.53 - 27.71)	18.04 ±2.74 (13.17 - 22.28)	21.96 ±4.71 (15.37 - 28.98)	19.90 ±2.47 (12.45 - 24.26)	19.73 ±3.40 (13.17 - 28.98)	18.53 ±3.84 (12.25 - 24.50)	15.63 ±1.97 (12.95 - 18.64)	17.81 ±3.40 (11.38 - 22.39)	17.08 ±3.52 (12.45 - 24.26)	17.23 ±3.35 (11.38 - 24.50)	15.56 ±4.54 (10.17 - 24.07)	13.38 ±2.30 (8.23- 16.43)	15.42 ±5.00 (7.96- 24.38)	14.07 ±3.55 (9.53- 22.90)	14.52 ±3.85 (7.96- 24.38)
- Distal	-	-	-	-	-	12.21 ±1.76 (9.17- 14.80)	12.34 ±3.69 (8.43- 20.43)	13.02 ±1.33 (11.16 - 15.38)	12.31 ±2.19 (8.43- 16.39)	12.28 ±2.86 (8.43- 20.43)	10.15 ±2.91 (5.65- 15.04)	10.30 ±5.50 (6.37- 26.94)	10.72 ±2.06 (6.14- 12.88)	10.00 ±2.93 (7.28- 18.46)	10.22 ±4.25 (5.65- 26.94)
Type II															
	-	14.53 ±5.54 (10.62 - 18.45)	-	-	14.53 ±5.54 (10.62 - 18.45)	-	13.10 ±4.14 (10.17 - 16.02)	-	-	13.10 ±4.14 (10.17 - 16.02)	-	10.83 ±7.00 (5.88- 15.78)	-	-	10.83 ±7.00 (5.88- 15.78)
Type III															
	16.33 ±4.60 (8.05- 22.88)	18.26 ±3.85 (14.10 - 25.34)	18.97 ±5.07 (11.49 - 26.22)	15.07 ±3.85 (10.81 - 20.08)	17.31 ±4.65 (8.05- 26.22)	15.28 ±3.71 (8.84- 13.98)	17.55 ±1.68 (15.27 - 20.35)	16.00 ±4.66 (7.84- 22.37)	13.81 ±5.20 (8.49- 23.36)	15.63 ±4.18 (7.84- 23.98)	14.25 ±2.99 (10.54 - 21.12)	16.05 ±1.85 (13.72 - 18.21)	15.39 ±3.23 (8.55- 21.02)	12.16 ±4.58 (5.64- 17.85)	14.55 ±3.42 (5.64- 21.12)

The angle of the SPR

The results of the angle of the SPR revealed that all of them were acute angle from the horizontal axis, except those aligned parallel to the horizontal axis. The prevalence of parallel alignment of SPR was found in 1 and 4 cases of type Ib, and type III, respectively. The average upward angle of all type was10.02±5.80 degrees. All distal bands coursed downward to their insertion on the lateral border of calcaneus. The mean downward angle of all type was 40.75±18.98 degrees. Detail of the angle of SPR in each type was described in table 4.6. This parameter was normally distributed.

Comparisons of the angle of SPR between genders and sides revealed no statistically significant difference. However, the angle of proximal band of type Ib was statistically lesser than type II (p=0.037).

Table 4. 6 The angle of the SPR

SPR	Mean ± SD (range)						
	Total	Left			Right		
		Male	Female	Total	Male	Female	Total
Type Ia							
- Proximal band	12.21±6.69 (3.33-26.00)	15.33	13.72±9.08 (4.67-26.00)	13.95±8.31 (4.67-26.00)	9.56±5.75 (3.33-14.67)	11.17±4.24 (5.67-14.67)	10.48±4.55 (3.33-14.67)
- Distal band	29.76±17.83 (2.33-59.33)	38.67	33.89±20.14 (6.67-59.33)	34.57±18.47 (6.67-59.33)	16.33±8.72 (6.33-22.33)	31.41±20.15 (2.33-48.33)	24.95±17.13 (2.33-48.33)
Type Ib							
- Proximal band	9.27±4.92 (0.00-19.33)	8.14±5.02 (0.00-13.33)	11.83±5.83 (2.00-19.00)	10.32±5.78 (0.00-19.00)	7.33±2.54 (3.67-10.00)	8.56±4.04 (3.67-19.33)	8.13±3.58 (3.67-19.33)
- Distal band	44.02±18.23 (3.67-83.33)	40.78±13.65 (14.67-67.00)	46.67±16.96 (10.67-73.33)	43.72±15.36 (10.67-73.33)	49.04±18.09 (30.00-69.67)	41.82±22.84 (3.67-83.33)	44.33±21.18 (3.67-83.33)
Type II	18.69±4.68 (15.38-22.00)	-	18.69±4.68 (15.38-22.00)	18.69±4.68 (15.38-22.00)	-	-	-
Type III	9.76±6.11 (0.00-23.00)	10.52±5.23 (2.33-18.33)	9.76±6.14 (0.00-16.00)	10.27±5.40 (0.00-18.33)	10.31±5.95 (0.00-20.00)	7.33±8.23 0.00-23.00)	9.32±6.76 (0.00-23.00)

The thickness of the SPR

The thickness of the SPR was measured at its middle part. The average thickness of all type both SPR which inserted on posterior intermuscular septum and lateral wall of calcaneus were 0.47±0.20 and 0.38±0.19 mm., respectively. The thickest SPR was found in the single band of type III while the thinnest of the SPR was found in the distal band of type Ib. This parameter was not normally distributed. Comparisons of the thickness of SPR between genders and sides showed no statistically significant difference (**Table 4.7**).

Table 4. 7 The thickness of the SPR

SPR	Mean ± SD (range)						
	Total	Left			Right		
		Male	Female	Total	Male	Female	Total
Type Ia							
- Proximal band	0.45±0.21 (0.15-0.75)	0.56	0.51±0.24 (0.19-0.75)	0.52±0.22 (0.19-0.75)	0.55±0.13 (0.42-0.68)	0.24±0.88 (0.15-0.34)	0.37±0.19 (0.15-0.68)
- Distal band	0.47±0.20 (0.24-0.82)	0.38	0.57±0.23 (0.27-0.82)	0.54±0.23 (0.27-0.82)	0.58±0.05 (0.54-0.64)	0.31±0.09 (0.24-0.44)	0.49±0.20 (0.24-0.82)
Type Ib							
- Proximal band	0.46±0.20 (0.17-0.98)	0.43±0.20 (0.17-0.86)	0.46±0.19 (0.19-0.80)	0.46±0.18 (0.17-0.86)	0.57±0.33 (0.22-0.98)	0.39±0.15 (0.20-0.63)	0.46±0.22 (0.20-0.98)
- Distal band	0.33±0.17 (0.08-0.78)	0.33±0.17 (0.13-0.63)	0.26±0.14 (0.08-0.57)	0.29±0.15 (0.08-0.63)	0.33±0.20 (0.17-0.63)	0.39±0.20 (0.11-0.78)	0.37±0.19 (0.11-0.78)
Type II	0.73±0.25 (0.55-0.91)	-	0.73±0.25 (0.55-0.91)	0.73±0.25 (0.55-0.91)	-	-	-
Type III	0.47 ± 0.20 (0.14-0.93)	0.52 ± 0.20 (0.28-0.87)	0.44 ± 0.28 (0.14-0.93)	0.49 ± 0.22 (0.14-0.93)	0.46 ± 0.18 (0.22-0.76)	0.45 ± 0.17 (0.27-0.73)	0.46 ± 0.17 (0.22-0.76)

The distance from midpoint of origin and insertion of the SPR and inferior tip of fibula

In order to locate the precise attachment of the SPR, the horizontal and vertical distances from the midpoint of the common origin and the insertion of the SPR to the inferior tip of fibula were obtained. The midpoint of the origin was always above the fibular tip but the midpoint of insertion was varied with the type. Since the proximal band of Type I and the single band of type III inserted on the posterior intermuscular septum, therefore, the midpoint of insertion would be always above the fibular tip. In contrast that of the distal band of type Ia, Ib and II which inserted on the lateral wall of calcaneus would be always below the fibular tip. The longest horizontal and vertical distances from midpoint of the origin were found in type Ia. The longest horizontal and vertical distance from midpoint of insertion was found in type Ia (**Table 4.8**). The X-coordinate represented the horizontal distance from the tip of fibula and the Y-coordinate represented the vertical distance from tip of fibula. The average coordinate (X, Y) of origin in all types was 7.26±3.15 (0.87-15.15) and 10.45±4.52 (1.69-26.23) mm. The coordinates (X, Y) of the insertion could be divided into 2 categories belonging to the insertion site. The average coordinates of SPR which inserted on the posterior intermuscular septum was 24.06±4.94 and 13.35±5.18, and those inserted on the lateral wall of calcaneus was 21.45±7.88 and 13.59±6.73 mm (**Table. 4.8 and Fig. 4.4**). The data were normally distributed and comparisons of the horizontal and vertical distances from mid-point of origin and insertion to inferior tip of fibula between genders and sides showed that only the vertical distance of type Ib at its origin and the vertical distance of type II Iat its insertion was significantly different between sides ($p = 0.003$ and 0.014, respectively).

Table 4. 8 The horizontal and vertical distances from midpoint of SPR origin and insertion to the fibular tip

Type		Mean ± SD (range) mm.							
		Origin				Insertion			
		X axis	*p*	Y axis	*p*	X axis	*p*	Y axis	*p*
Type Ia									
Proximal band	Lt.	8.63±3.43 (5.41-13.69)	0.849	12.32±5.36 (4.55-18.82)	0.058	26.09±5.50 (20.18-32.64)	0.879	14.31±2.87 (10.75-19.45)	0.152
	Rt.	9.02±4.00 (2.62-15.15)		20.04±8.13 (2.47-26.23)		25.62±5.87 (15.02-32.52)		19.19±7.94 (4.12-25.76)	
	Total	8.82±3.59 (2.62-15.15)		16.18±7.73 (2.47-26.23)		25.85±5.47 (15.02-32.64)		16.75±6.27 (4.12-25.76)	
Distal band	Lt.	NA	NA	NA	NA	22.94±8.00 (14.90-35.14)	0.909	14.48±4.64 (7.20-22.38)	0.166
	Rt.	NA		NA		23.42±7.64 (11.58-35.13)		10.11±6.32 (1.53-20.03)	
	Total	NA		NA		23.18±7.52 (11.58-35.14)		12.30±5.79 (1.53-22.38)	
Type Ib									
Proximal band	Lt.	6.46±3.16 (1.76-11.75)	0.749	8.27±2.56 (3.85-14.33)	0.003	23.27±5.80 (10.46-35.67)	0.568	12.54±4.39 (4.24-21.44)	0.125
	Rt.	6.74±2.56 (2.36-11.64)		10.70±2.77 (4.21-15.98)		24.10±3.96 (16.57-32.37)		14.68±5.07 (5.32-22.64)	
	Total	6.59±2.86 (1.76-11.75)		9.43±2.91 (3.85-15.98)		23.67±4.97 (10.46-35.67)		13.56±4.80(4.24-22.64)	
Distal band	Lt.	NA	NA	NA	NA	20.94±8.39 (8.54-36.79)	0.439	14.19±6.94 (0.00-27.69)	0.824
	Rt.	NA		NA		20.95±7.70 (11.17-38.66)		13.73±7.19 (0.00-31.79)	
	Total	NA		NA		20.94±7.98 (8.54-38.66)		13.97±6.99 (0.00-31.79)	
Type II									
Single band	Lt.	7.31±1.48 (6.27-8.36)	NA	9.13±5.13 (5.51-12.76)	NA	26.22±7.53 (20.90-31.55)	NA	4.48±2.48 (2.73-6.24)	NA
Type III									
Single band	Lt.	7.75±3.09 (2.73-14.65)	0.587	9.78±3.57 (1.69-17.33)	0.988	21.90±3.83 (13.85-29.14)	0.014	12.27±5.37 (1.06-20.34)	0.790
	Rt.	7.22±3.39 (0.87-13.74)		9.79±3.02 (4.62-17.28)		25.51±4.81 (17.43-36.49)		12.64±4.00 (3.12-18.37)	
	Total	7.47±3.22 (0.87-14.65)		9.79±3.25 (1.69-17.33)		23.82±4.70 (13.85-36.49)		12.47±4.64 (1.06-20.34)	

Type	Mean ± SD (range) mm.							
	Origin				Insertion			
	X axis	*p*	Y axis	*p*	X axis	*p*	Y axis	*p*
All cases of SPR based on insertion site								
Posterior intermuscular septum	7.26±3.15 (0.87-15.15)		10.45±4.52 (1.69-26.23)		24.06±4.94 (10.46-36.49)		13.35±5.18 (1.06-25.76)	
Lateral wall of calcaneus	NA		NA		21.45±7.87 (8.54-38.66)		13.59±6.73 (0.00-31.79)	

X axis - the horizontal distance, Y axis - the vertical distance

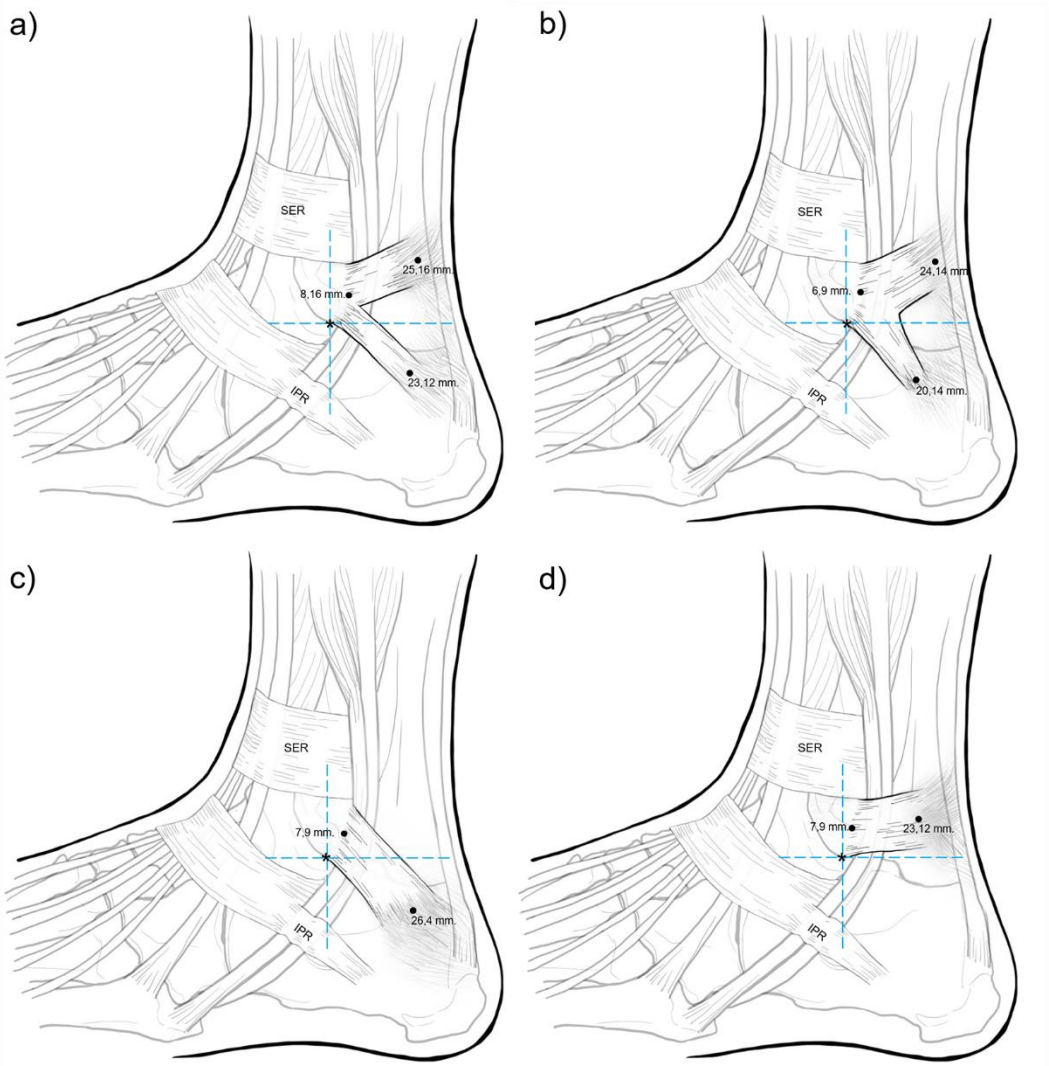


Figure 4. 4 The coordinate of mid-point of SPR origin and insertion measured from the tip of fibula (*) in each type (X, Y axis). (a) Type Ia, (b) Type Ib, (c) Type II and (d) Type III: SPR, superior peroneal retinaculum, IPR, inferior peroneal retinaculum, SER, superior extensor retinaculum.

The anatomy of the inferior peroneal retinaculum and its tunnel

Characteristic, origin and the attachment of the IPR

The inferior peroneal retinaculum (IPR) 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 cases (31.19%). Most of them were thick and had clear border separated from the surrounding fascia (**Fig. 4.5A & B**).

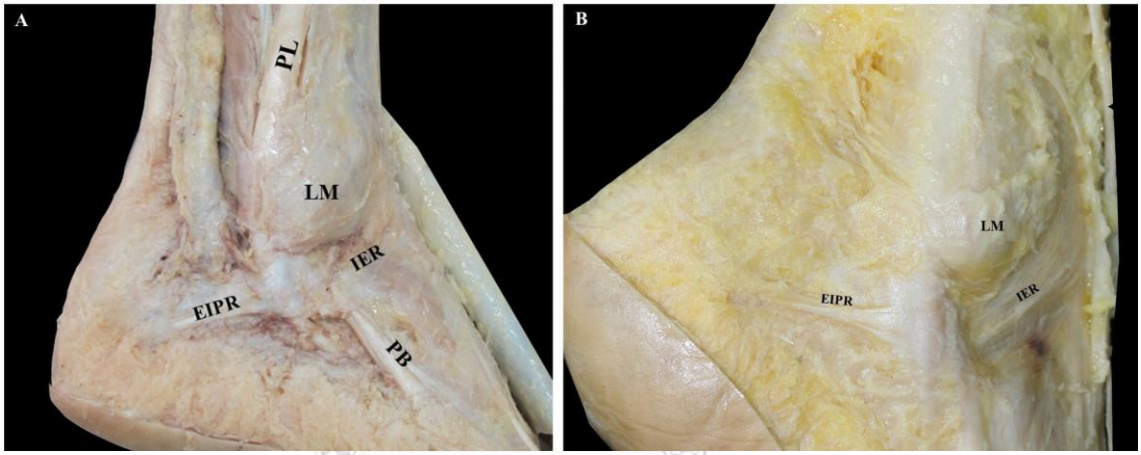


*Figure 4. 5 The extension band of the IPR (**A and B**); PB - peroneus brevis tendon; PL - peroneus longus tendon; EIPR – extension band of inferior peroneal*

Width of the IPR

The results of the width of the IPR revealed that the width at the middle part was the widest with the mean length of 14.50 ± 2.37 (6.68 - 21.34) mm. The width at the origin and the width at the insertion 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 width at the origin and the width at the middle part in male were wider than female but width at the insertion was wider in female. These parameters were normally distributed. Comparisons between sides and genders revealed only the width at the origin of was significantly different between sides ($p = 0.047$) (**Table. 4.9**).

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. 4.9**).

Table 4. 9 The morphometric data of the inferior peroneal retinaculum

Parameters	Mean ± SD (range)								
	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

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 with normal data distribution (**Table. 4.9**). 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.

Thickness of the IPR

From the observation, the IPR of the upper tunnel was very thin when compared to the IPR of the lower tunnel. Therefore, only the thickness of the 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 of male specimen was thicker than female specimen but there were no statistically significant differences between genders and sides (**Table. 4.9**).

The accessory peroneal muscle

Accessory peroneal muscles were found in 47 from 109 cases (44.04%). Co-existence of PQ and unusual accessory peroneal muscle was present in one male case. The number of PQ, PDQ and unusual peroneal muscles was found in 13 (11.93%), 33 (30.28%) and 2 (1.83%) cases, respectively.

The most frequent accessory peroneal muscle was PDQ **(Figure 4.6)**. PDQ was found bilaterally in 12 (36.36%) cases (6 males and 6 females). All of them originated from the PB tendon but their insertions were varied as shown in Table 4.10. On the dorsum of the foot, almost of the PDQ were tendinous structure except one which consisted of muscle fibers **(Figure 4.6B)**. Most of the PQ originated from the PB muscle belly and less frequently originated from the PB tendon. The PQ inserted on various sites including retrotrochlear eminence, peroneal tubercle, cuboid and dorsolateral surface of base of 5^{th} metatarsal as described in Table 4.10 and Figure 4.7. The PQ was also found bilaterally in 2 (15.83%) cases (1 male and 1 female).

Figure 4. 6 Peroneus digitiquinti (PDQ) tendon (A) and muscle (B) on the dorsal surface of foot PB, peroneus brevis tendon; PL, peroneus longus tendon; EDL, extensor digitorum longus tendon

Table 4. 10 The prevalence of the accessory peroneal muscle, origin and insertion

Muscle	n			Origin	Insertion
	Male (n = 55)	Female (n = 54)	Total (n = 109)		
Peroneus Quartus	8 (7.34%)	5 (4.59%)	13 (11.93%)	- Peroneus brevis muscle belly (9) - Peroneus brevis tendon (3) - Peroneus longus tendon (1)	- Retrotrochlear eminence of calcaneus (9) - Base of 5th metatarsal (1) - Cuboid (1) - Peroneal tubercle (2)
Peroneus digiti quinti	17 (15.60%)	16 (14.68%)	33 (30.28%)	- Peroneus brevis tendon (33) - Single tendon (32) - Muscle fiber (1)	- Base of 5th proximal phalanx (26) - Base of 5th middle phalanx (1) - PDQ tendon merge with extensor digitorum longus and inserted at base of 5th distal phalanx (4) - Shaft of 5th metatarsal (2)
Unusual accessory peroneal	1 (0.92%)	1 (0.92%)	2 (1.83%)	Peroneus longus muscle (1)	- Peroneal tubercle between the inferior peroneal retinaculum septum (1)
				Peroneus longus tendon and peroneus brevis muscle (1)	- The tendon bifurcated, one inserted at the talus and peroneal tubercle, the other at the retrotrochlear eminence (1)

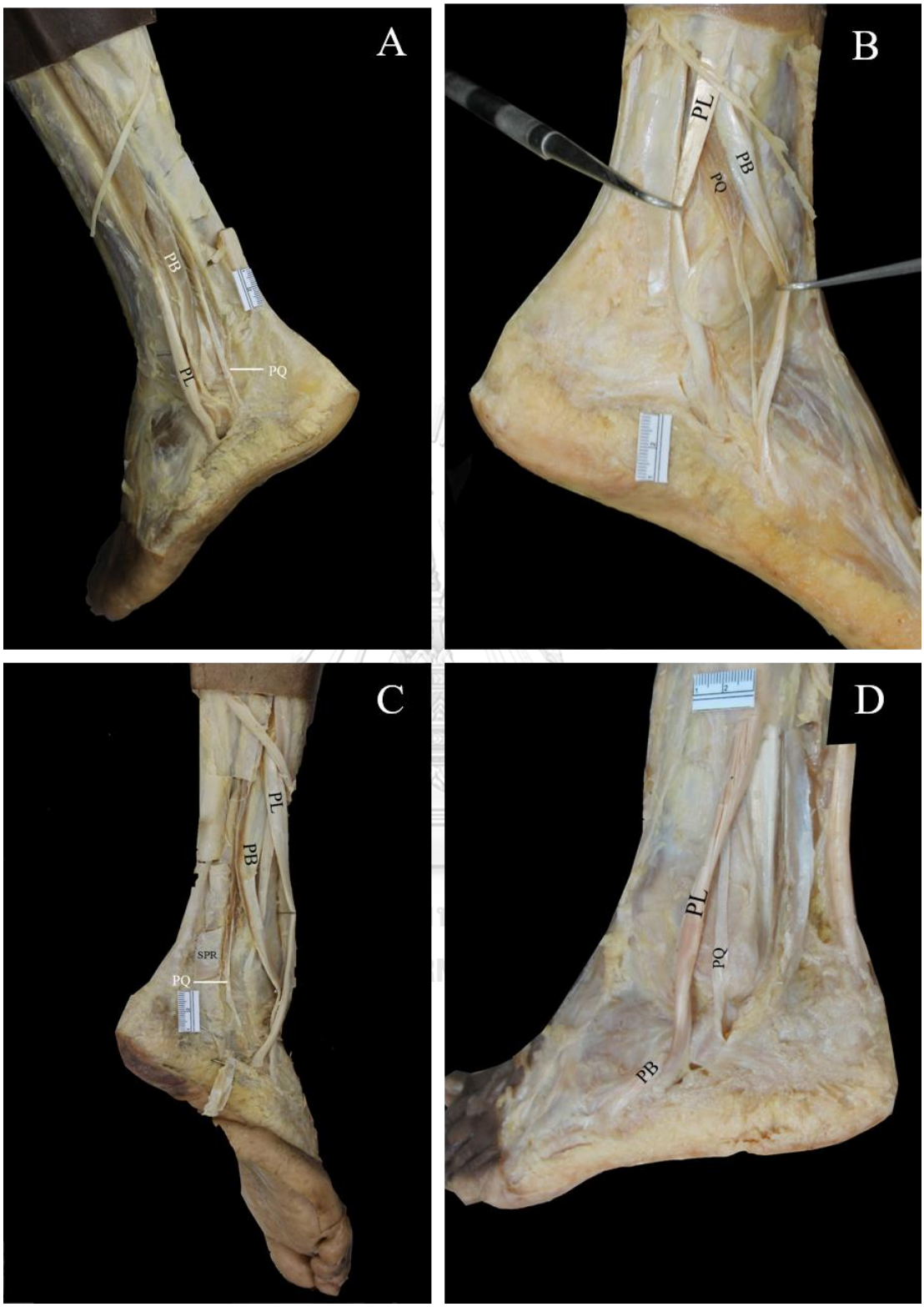


Figure 4. 7 Location of Peroneus quartus (PQ) insertion; A) retrotrochlear eminence, B) 5th metatarsal C) cuboid, D) peroneal tubercle; PB, peroneus brevis tendon; PL, peroneus longus tendon; SPR, superior peroneal retinaculum

The unusual accessory peroneal muscles were observed in 2 specimens (1 male, 1 female). In one case, the unusual accessory peroneus muscle originated from the PL muscle and inserted on the peroneal tubercle **(Figure 4.8)**. The other unusual accessory peroneal muscle had 2 heads of origin, one from the PL tendon and the other from the lower part of the PB muscle at the distal end of fibula. Both parts united and coursed over the PL tendon at the lateral malleolus before splitting into two tendons. Then, the tendon inserted on the retrotrochlear eminence, the other part inserted on the talus and peroneal tubercle **(Figure 4.9)**. In addition, as aforementioned, there was the co-existed PQ which inserted at retrotrochlear eminence in this case.

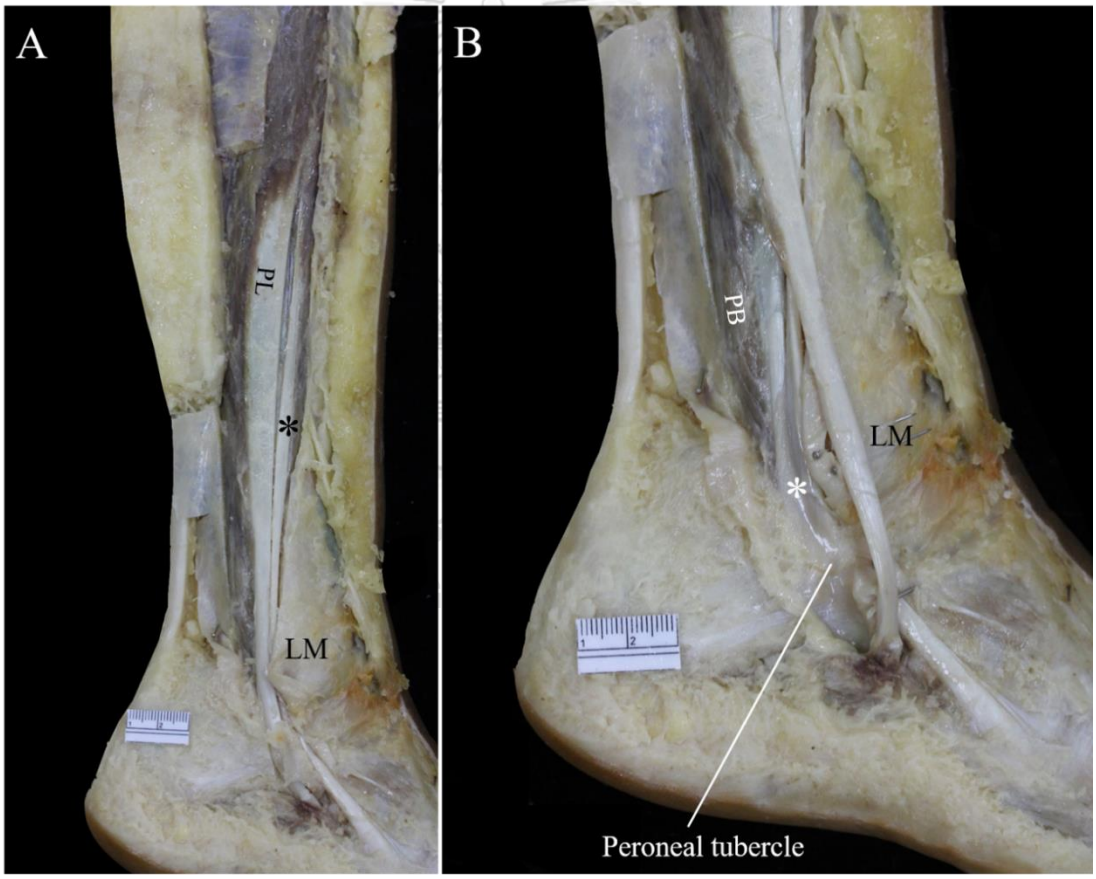


Figure 4. 8 The unusual accessory peroneal muscle (*) A) arose from peroneus longus muscle (PL) B) inserted at peroneal tubercle; LM: lateral malleolus, PB: peroneus brevis muscle

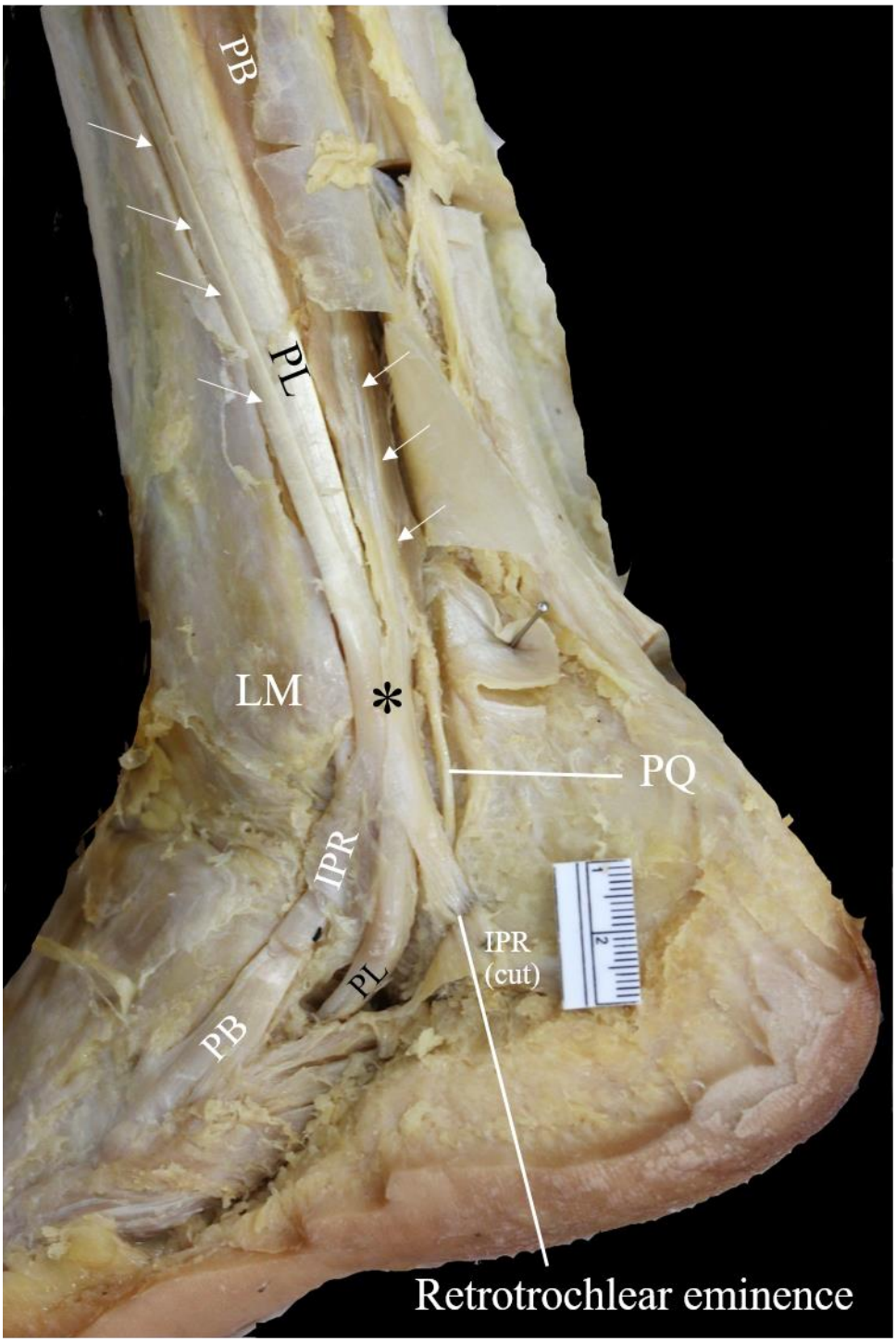


Figure 4. 9 The unusual accessory peroneal muscle (*) which co-existed with peroneus quartus muscle (PQ); the origin of unusual accessory peroneal muscle (↓) from PL and PB; PL, peroneus longus tendon; PB, peroneus brevis tendon; LM, lateral malleolus; IPR, inferior peroneal retinaculum

Superior peroneal tunnel and its content

After cutting the SPR at its origin, the content of the superior peroneal tunnel was exposed. The superior peroneal tunnel (SP tunnel) located posterior to lateral malleolus. This tunnel was covered by the SPR. The floor of the SP tunnel was the retromalleolar groove and posterior intermuscular septum of the leg. The contents of the SP tunnel generally composed of the PB and PL tendons (Fig. 4.10). The PL tendon lied superficial to the PB tendon, however, the muscle fiber of PB was found in the superior peroneal tunnel as well. The presence of the PB muscle fiber in the SP tunnel was called the low level-lying of peroneus brevis muscle. The low level-lying of peroneus brevis muscle was found in 86 (78.89%) cases.

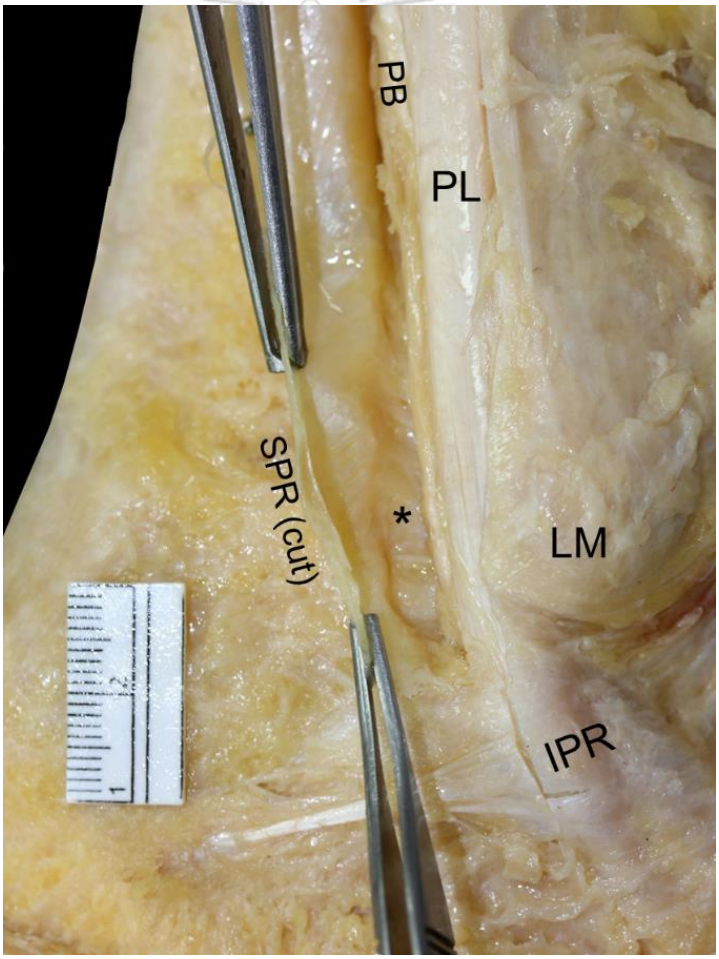


*Figure 4. 10 The SPR was cut at its origin to expose contents of the superior peroneal tunnel that composed of peroneus brevis and peroneus longus tendon; PL – peroneus longus tendon; PB – peroneus brevis tendon; LM – lateral malleolus; SPR – superior peroneal retinaculum; * - floor of the superior peroneal tunnel*

Moreover, the evidence of PB tendon tear was found in 14 from 109 cases (12.84%) **(Figure 4.11A – 4.11C)**. The location of the PB tear was found superior to lateral malleolus. This tear extended proximal to the entrance of inferior peroneal tunnel in most cases. Most of them were found in SPR type Ib (10 cases) (**Table 4.12**). Moreover, one male cadaver with symmetrical SPR type Ib had bilateral PB tendon tears. The prevalence of the PB tendon tear in type Ib was significantly higher than the others (p = 0.001).

The PB tendon tear could categorize to single **(Fig. 4.11A & B)** and multiple tear **(Fig. 4.11C)**. In addition, there were 2 cases of PB tendon tear extended from the retromalleolar groove to the inferior peroneal tunnel (IP tunnel). In that cases, the PB tendon tear was found in the upper tunnel of the IP tunnel. However, there was no PL tendon tear in any cases. There was no statistically significant association between PB tendon tear to the low level-lying of the PB muscle belly as showed in table 4.12.

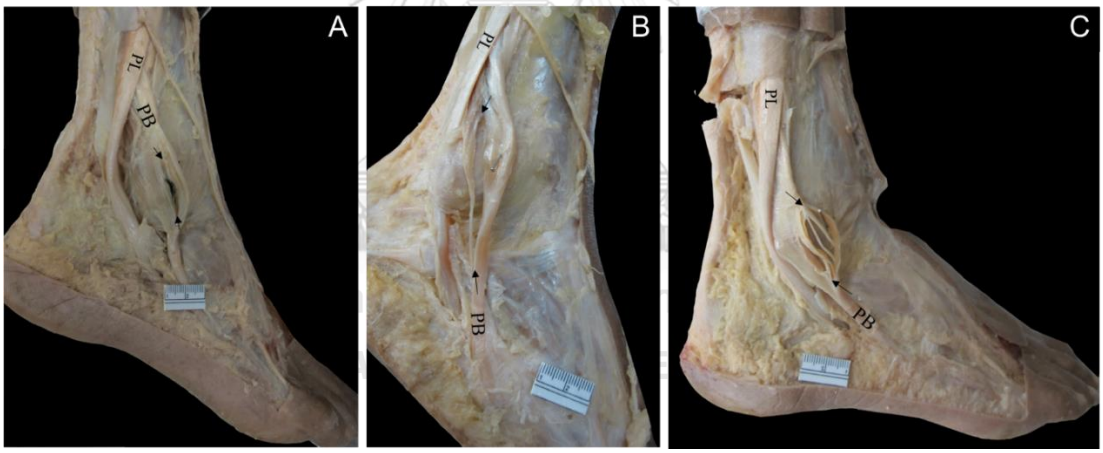


Figure 4. 11 The grade IV of peroneus brevis tendon tear (arrow); A. single tear of PB tendon; B and C. multiple tear of PB tendon; PL: peroneus longus tendon, PB: peroneus brevis tendon

Table 4. 11The prevalence of the PB tendon tear

SPR	n (%) Peroneus brevis tendon tear		*p*-value
	Presence	Absent	
Type Ia	1 (7.14)	13 (92.86)	$p = 0.001$
Type Ib	10 (20.83)	38 (79.17)	
Type III	3 (6.67)	42 (93.33)	

Table 4. 12 The association between the peroneus brevis tendon tear with the presence of low level-lying of the peroneus brevis muscle

		Peroneus brevis tendon tear		Total	Chi-square
		Present	Absent		
the low level-lying of peroneus brevis	Present	13	73	86	p = 0.170
	Absent	1	22	23	

The additional contents of the superior peroneal tunnel

In this study, the additional contents in the superior peroneal tunnel were PQ and the unusual accessory peroneal muscle. In this study, the accessory peroneal muscle was found in 47 from 109 cases (44.04%). Most of the PQ (13 cases) travelled in the SP tunnel as the additional content (**Fig. 4.7**). Moreover, other 2 cases the unusual accessory peroneal muscles were coursed in the SP tunnel before inserted in their insertion site (**Fig. 4.8 – 4.9**). The characteristic, origin and insertion of this muscle were described in the accessory peroneal muscles.

The inferior peroneal tunnel and its contents

The space under the IPR was called the IP tunnel. This tunnel could be divided into 2 tunnels by the attachment of the IPR to the peroneal tubercle as the upper and lower tunnels. The contents of the IP tunnel generally composed of PB tendon in upper tunnel and PL tendon in lower tunnel (**Fig. 4.12A**).

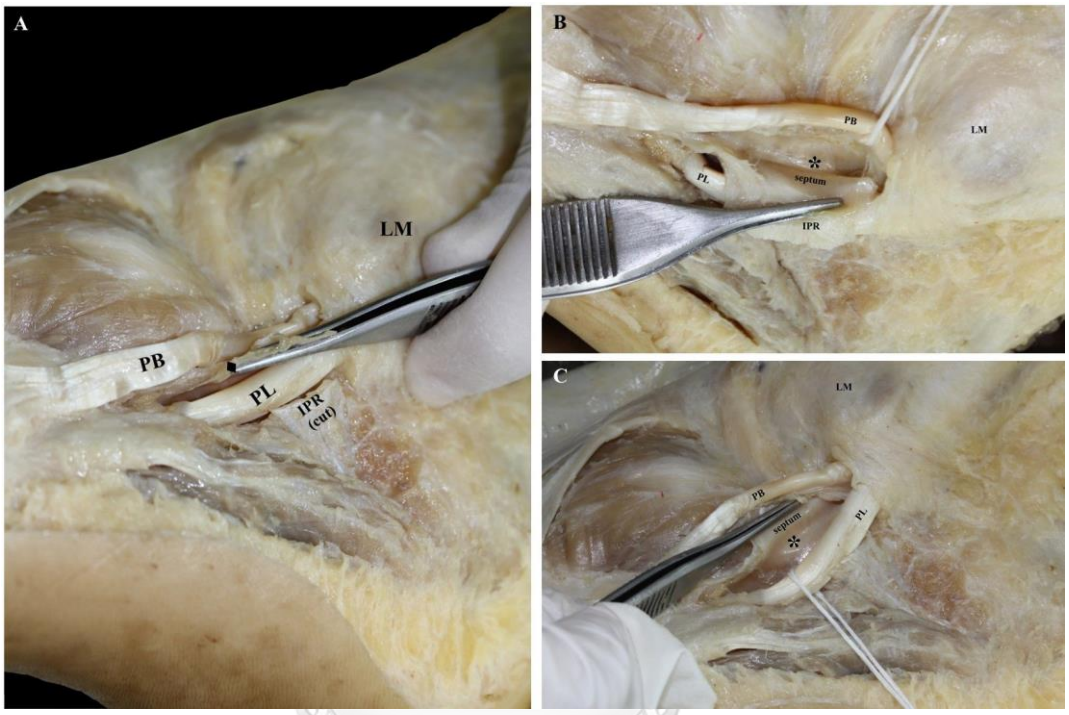


Figure 4. 12 Interior of the IP tunnel after cutting IPR origin and insertion; ***A.*** *PB in the upper tunnel and PL in the lower tunnel;* ***B.*** *The septum and peroneal tubercle (*) in the floor of the upper tunnel;* ***C.*** *The septum and peroneal tubercle (*) in the floor of the lower tunnel; ◆ - cutting edges of IPR; * - the attachment of the septum to the peroneal tubercle; PB - peroneus brevis tendon; PL - peroneus longus tendon; LM - lateral malleolus*

However, the interior of the upper tunnel revealed the additional contents including 2 cases of the peroneus digiti quinti muscle (PDQ) (**Fig. 4.13A**) and another 2 cases of peroneus quartus muscle (PQ) (**Fig. 4.13B - D**). In this study, the total number of PDQ was found in 33 (30.28%) of cases. Most of the PDQ split from PB tendons after it exited out of the upper tunnel. Only 2 cases of them split from the PB tendon in the IP tunnel. 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 the PQ in this study was found in 13 (11.93%) of cases. Most of the PQ inserted on the retrotrochlear eminence. Only two cases of PQ (one female and one male) were found in the upper tunnel and inserted on the peroneal tubercle. In the female specimen, the PQ originated from PB muscle. Its tendon coursed through the upper tunnel and inserted on the peroneal tubercle (**Fig. 4.13B**). In the male specimen, the slender tendon of the PQ split from the anterolateral part of the PL tendon (**Fig. 4.13C**) and passed along the posterior border of the lateral malleolus to insert on the IPR. In addition, a part of this tendon traveled into the upper tunnel and attached to the peroneal tubercle (**Fig. 4.13D**).

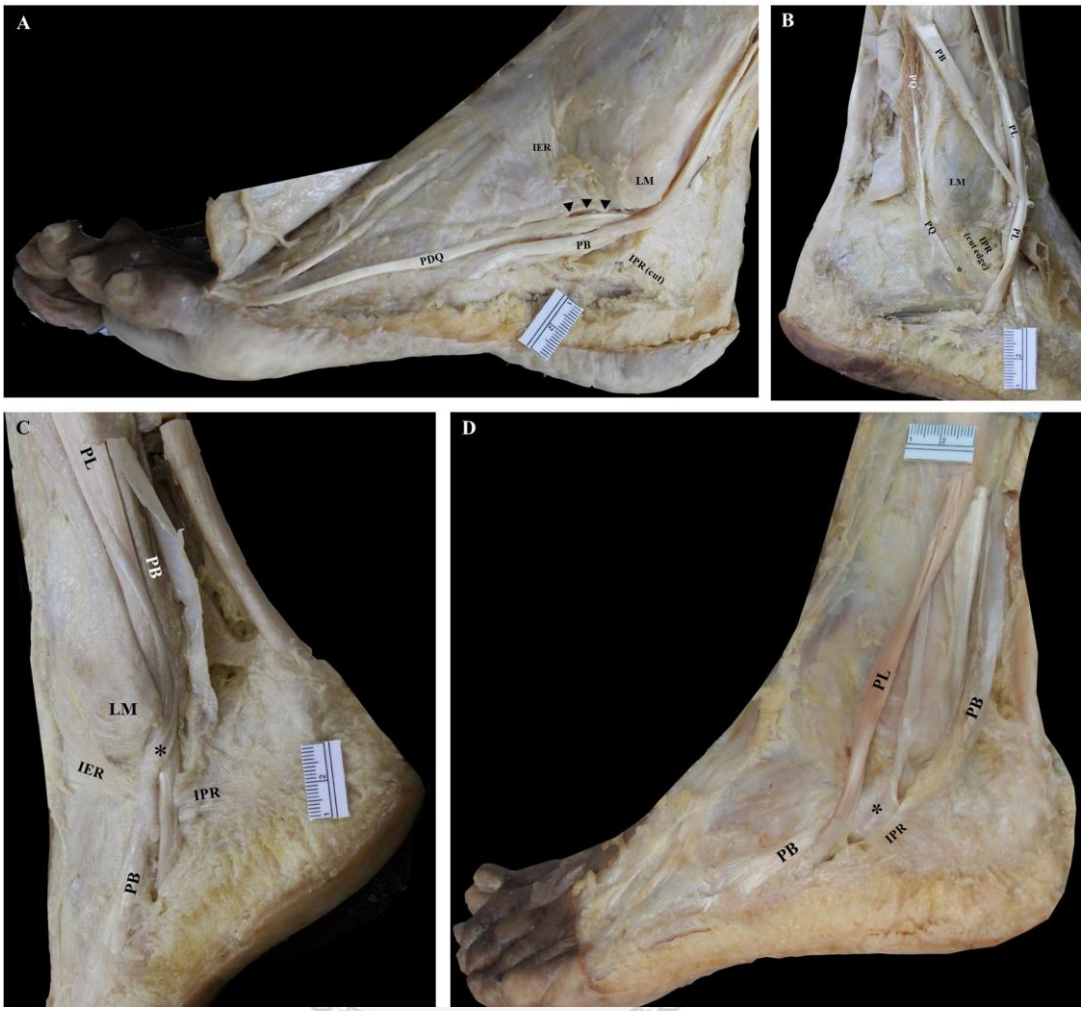


Figure 4. 13 Additional content in the upper tunnel of inferior peroneal tunnel; ***A.****P DQ;* ***B.*** *The PB and PL were elevated to show the PQ originated from PB;* ***C.*** *Origin of PQ from PL;* ***D.*** *The PL was elevated from the lower tunnel to show the attachment of PQ tendon on the peroneal tubercle (✱);* ▼ *- cutting edge of the IPR; PB - peroneus brevis tendon; PL – peroneus longus tendon; PDQ - peroneus digiti quinti muscle; PQ – peroneus quartus muscle; IER - inferior extensor retinaculum; IPR - inferior peroneal retinaculum; LM, lateral malleolus*

The additional content was also found in the lower tunnel as well. The unusual accessory peroneal muscle originated from the PL muscle and coursed along the anterior border of the PL tendon (**Fig. 4.14A**). At the lateral malleolus, it passed deep to the PL tendon and lodged in the lower tunnel to insert on the peroneal tubercle (Fig. 4.14B). The peroneal tubercle lied between the PB and PL tendon in all cases.

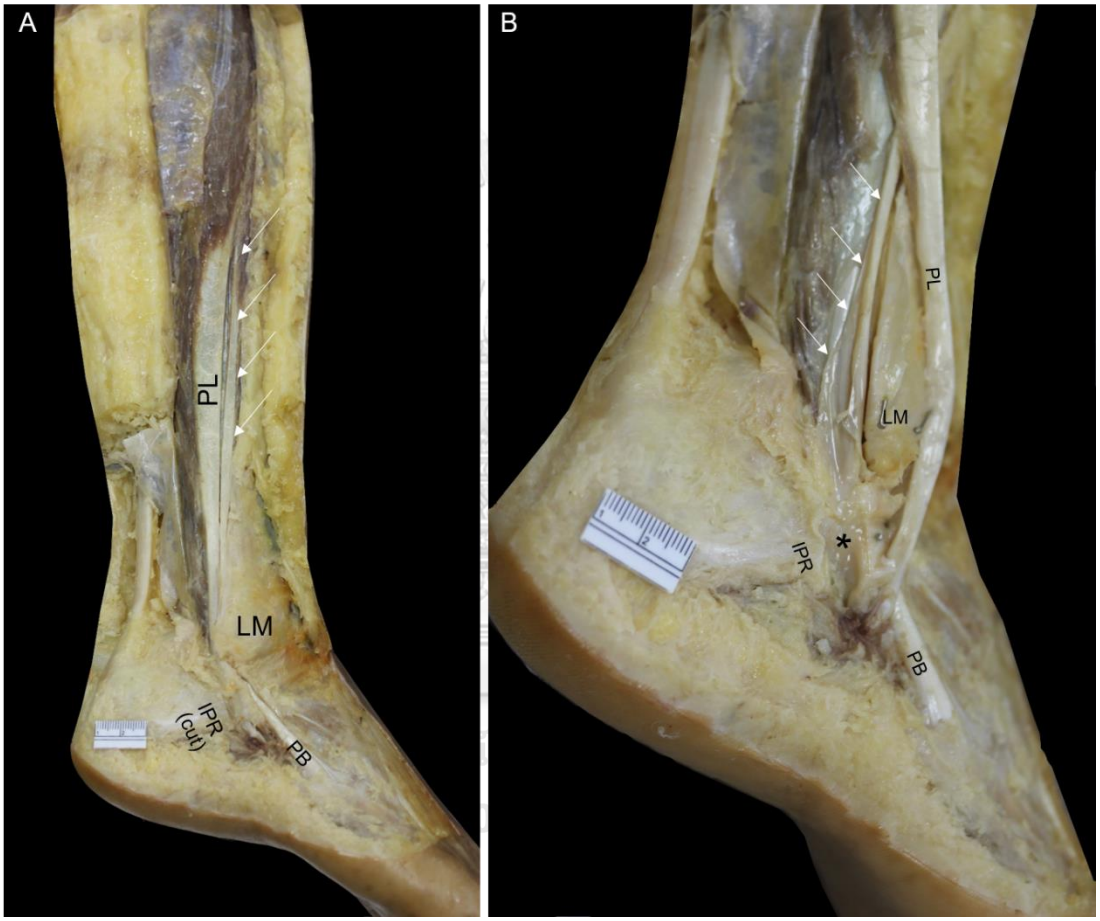


Figure 4. 14 Additional content in the lower IP tunnel; ***A.*** *The unusual accessory peroneal muscle (arrow) originated from PL and coursed anterior to PL tendon;* ***B.*** *The tendon of unusual accessory peroneal tendon traveled deep to PL tendon and entered the lower tunnel to insert on peroneal tubercle; PL - peroneus longus tendon; PB – peroneus brevis tendon;* ✱ *- peroneal tubercle; IPR - inferior peroneal retinaculum; LM – lateral malleolus; IER - inferior extensor retinaculum*

The morphology of the retromalleolar groove contour, retrotrochlear eminence and peroneal tubercle

The retromalleolar groove located posterior to the lateral malleolus. This structure was the part of the floor of the superior peroneal tunnel. The retromalleolar groove contour could classify to concave, flat, convex and irregular contour. The prevalence of concave, flat, convex and irregular contour were found in 93 (85.32%), 10 (9.17%), 3 (2.75%) and 3 (2.75%) cases, respectively (**Table 4.13**).

The retrotrochlear eminence was the bony prominence of the lateral wall of the calcaneus which located posterior to the peroneal tubercle in all cases. This bony prominence was the insertion site of the PQ muscle and unusual accessory peroneal muscle. The prominence of the retrotrochlear eminence was found in 87 (79.82%) cases.

The peroneal tubercle was the bony prominence that located between the PB and PL tendons in all cases. This bony prominence was the septum of the inferior peroneal tunnel. The prominence of the peroneal tubercle was found in 51 (46.79%) cases.

All of the bony prominence including retromalleolar groove contour, the retrotrochlear eminence and the peroneal tubercle were asymptomatic.

The data analysis revealed that there was no statistically significant association of the presence of the accessory peroneal muscles (both PQ and PDQ) to neither the prominence of the peroneal tubercle nor the prominence of the retrotrochlear tubercle **(Table 4.14 and 4.15)**. Moreover, there was no statistically significant association of the PB tendon tear to neither the prominence of peroneal tubercle nor the prominence of retrotrochlear tubercle as well **(Table 4.16)**. In addition, there was no statistically significant association of the PB tendon tear to the contour of the retromalleolar groove (**Table. 4.16**).

There was no coexistence of PQ and PB tendon tear in any case. The PB tendon tear was found to co-exist with the presence of PDQ in 6 (42.86%) cases. However, there was no statistically significant association of the PB tendon tear to neither the present of the PQ nor the PDQ **(Table 4.17)**.

Table 4. 13 The association between the peroneus brevis tendon tear with the retromalleolar groove contour

		Peroneus brevis tendon tear		Total	Chi-square
		Present	Absent		
the retromalleolar groove contour	Concave	13	80	93	p = 0.786
	Flat	1	9	10	
	Convex	0	3	3	
	Irregular	0	3	3	

Table 4. 14 The association between the peroneus quartus (PQ) with prominence of peroneal tubercle and retrotrochlear eminence

		Peroneus quartus (PQ)		Total	Chi-square
		Present	Absent		
Prominence of retrotrochlear eminence	Present	12	75	87	p = 0.232
	Absent	1	21	22	
Prominence of peroneal tubercle	Present	7	44	51	p = 0.578
	Absent	6	52	58	

Table 4. 15 The association between the peroneus digiti quinti (PDQ) with prominence of peroneal tubercle and retrotrochlear eminence

		Peroneus digitiquinti (PDQ)		Total	Chi-square
		Present	Absent		
Prominence of retrotrochlear eminence	Present	27	60	87	p = 0.732
	Absent	6	16	22	
Prominence of peroneal tubercle	Present	17	34	51	p = 0.515
	Absent	16	42	58	

Table 4. 16 The association between the peroneus brevis tendon tear with prominence of peroneal tubercle and retrotrochlear eminence

		Peroneus brevis tendon tear		Total	Chi-square
		Present	Absent		
Prominence of retrotrochlear eminence	Present	13	74	87	p = 0.193
	Absent	1	21	22	
Prominence of peroneal tubercle	Present	7	44	51	p = 0.796
	Absent	7	51	58	

Table 4. 17 The association between the peroneus brevis tendon tear with the presence of the peroneus quartus and peroneus digiti quinti

		Peroneus brevis tendon tear		Total	Chi-square
		Present	Absent		
Presence of the peroneus quartus	Present	0	13	13	p = 0.140
	Absent	14	82	96	
Presence of the peroneus digiti quinti	Present	6	27	33	p = 0.272
	Absent	8	68	76	

Chapter V

Discussion

The anatomy of superior peroneal retinaculum and related structures

The morphology of the SPR has been described in the standard text book and previous reports [12, 20, 21, 40]. The origin of SPR observed in this study was from the fibrocartilagenous ridge of the lateral malleolus with an extension to the distal tip of the fibula which was in accordance with the previous studies [12, 20, 21, 40]. The SPR had at least one insertion site either on the posterior intermuscular septum or lateral wall of the calcaneus. The insertion on the posterior intermuscular septum was in accordance with that described previously [21]. Moreover, the MRI study also revealed that the horizontal band of the SPR attached to the superficial and deep aponeuroses of the posterior compartment of the lower portion of the leg [45]. The insertion on the lateral wall of the calcaneus was similar to the results of Davis et al., 1994, but the insertion of the SPR on the lateral border of the calcaneal tendon in that report was not found in this study. The SPR has been previously divided into 5 types base on its insertion pattern [40]. Different characteristic and insertion pattern was described in this study. Here, the SPR was classified into 3 types based on its characteristic and insertion pattern. Type Ia and Ib were quite similar to type I of Davis's classification but the prevalence of type I in this study was higher (58% vs 47%). The difference between these two subtypes was the site of splitting into proximal and distal bands noted in this study has not been described elsewhere. The course and attachment of type II and type III in this study was in the same direction as type II of Davis's classification. However, the prevalence of type II in this study was lesser (2% vs 13%) but the prevalence of type III was higher (41% vs 13%). The symmetry in type was also reported here. Type III and type Ib were more common.

The average length of SPR inserted on the posterior intermuscular septum was approximately 23 mm. However, the length of type III was shorter than the others. The length of distal band was quite equal in both type Ia and Ib. To the best of our knowledge, this is the first anatomical study of the length of SPR. The average width

of origin in accordance with previous report [40]. The thickness of SPR reported in this study was lesser than previous study in MRI [46]. This might be resulted from the difference in the method and the site of measurement.

The SPR had an essential role to be the primary stabilizer of the peroneal tendons and resisted the subluxation/dislocation [4, 7]. The insufficiency of the SPR could cause the attrition of the peroneal tendons and lead to tear. The peroneal tendon tear or attrition was reported as a consequence of acute mechanical or repetitive injury such as trauma, mechanical irritation or attrition within retromalleolar groove, subluxation of SPR, incompetent of SPR and ankle instability [4, 9, 27]. There were several anatomic factors associated with peroneal tendon tear including the presence of the accessory peroneal muscles, the prominence of retrotrochlear eminence and the thinning or laxity of the SPR [4, 9, 24, 27].

In this study, the PB tendon tear was found in 14 cases and associated with SPR type Ib statistically significance. The morphometric data showed that the site of splitting of this type was in its middle part which was thinner than the rest. This would cause a decreasing in the strength of this retinaculum and resulted in SPR insufficiency.

The angle between the proximal and distal bands in this type was wider than the others. In addition, the width of the SPR type Ib was wider than the others. These characteristics might decrease the flexibility of this type by fixing this retinaculum at its origin more than others. These features might lead to increase the risk of peroneal tendon attrition within retromalleolar groove. Furthermore, bilateral PB tendon tear was found in one case of symmetrical SPR type Ib. Taken together; the presence of type Ib might have a potential to increase the risk of PB tendon tear. Moreover, only 13 from 87 cases with prominent retrotrochlear eminence were coexisted with PB tendon tear. Therefore, no statistically significance association was reported. Previous studies had reported that the presence of the PQ might have a potential to create the attrition or tear of peroneal tendon at the retromalleolar groove [1, 25, 31]. However, all of the PB tendon tear cases in this study were not coexisted with the presence of PQ. Moreover, the presence of PDQ in this study was not significant associated with PB tendon tear.

Previous studies claimed that the reattachment of the SPR to its anatomical position could prevent the recurrent symptom of the subluxation/ dislocation even the groove deepening techniques was not performed [3]. Therefore, the knowledge of the width and coordinate of the midpoint of origin measured from the fibular tip will provide the precise area for the SPR reattachment on the lateral malleolus. Furthermore, the angle of the SPR and the coordinate of horizontal and vertical distance from midpoint of SPR insertion from the fibular tip reported here can be used to design the direction and also the precise area for SPR reattachment on the lateral wall of calcaneus. This data is also useful for the SPR reconstruction in case of calcaneus fracture with a complication of SPR injury, especially in Sander A type [47, 48]. Moreover, the reconstruction of the SPR by using the autologous graft including gracilis tendon, tensor fascia latae and plantaris tendon had been reported [49-51]. The morphometric data of SPR including its length, width and thickness provided in this study will be beneficial for the design and harvesting of the graft.

The accessory peroneal muscles

The space under the SPR was called SP tunnel. The boundaries of this tunnel consisted of SPR as its roof, posterior intermuscular septum and retromallolar groove as its floor. The boundaries of SP tunnel was in accordance with previous literatures [12, 18, 39, 45]. The contents of the SP tunnel generally composed of PB and PL tendons however, the low level-lying of the PB muscle was found. The prevalence of the low level-lying of the PB muscle was found in 80% of cases. This prevalence was higher than previous literature [15]. The additional content was reported in the SP tunnel including PQ was found in this study in accordance with previous literatures [25-27] . Interestingly, the unusual accessory peroneal muscle, additional contents has not been reported were found in this study.

The prevalence of the accessory peroneal muscles in this study was 44.04 %. These muscles were PDQ, PQ and unusual accessory peroneal muscles. The prevalence of PQ in this study was 11.93% and predominantly found in male which was in accordance with the previous studies (5 – 22 %) [12, 24, 26-28]. The PQ muscle arose only from PB muscle belly and its tendon but not from the distal shaft of fibula or

posterior intermuscular septum as previously described [24, 26, 28]. The PQ had a single tendon and inserted on various sites including retrotrochlear eminence, peroneal tubercle, base of 5th metatarsal and cuboid. However, Bilgili et al. (2014) reported a case of PQ with 2 separated tendons and inserted at different points. In that case, the PQ tendon was bifurcated and coursed above and beneath the PB tendon to insert at the retrotrochlear eminence and cuboid bone [26]. The PQ had been reported to be co-existed with the hypertrophy of the peroneal tubercle or retrotrochlear eminence [18, 25]. In this study, only 7 from 51 cases with prominent peroneal tubercle and 12 from 87 cases with prominent retrotrochlear eminence were found to have this co-existence. Therefore, the association between the prominence of the retrotrochlear eminence or peroneal tubercle with the presence of PQ was not statistical significance. Moreover, the hypertrophy of the peroneal tubercle and prominent retrotrochlear eminence were also present in asymptomatic ankle without the presence of PQ in accordance with previous studies [27, 29].

Tubb et al. (2014) reported an unusual accessory muscle called peroneotalocalcaneus muscle. This muscle originated from the anterior intermuscular septum and PL muscle and inserted on the superior surface of the talus and calcaneus [37]. Moreover, Fabrizio (2015) reported an anomalous fibularis (peroneal) muscle. This muscle arose from the muscle belly of PL muscle in the proximal half and gave a long slender tendon, coursed posterior to lateral malleolus and inserted on the superficial aspect of inferior peroneal retinaculum [38]. In this study, the unusual accessory peroneal muscles were found in 2 cases (1.83%), male and female each. One of them arose from the PL and inserted at the peroneal tubercle between the inferior peroneal retinaculum septum. The other arose from the PL tendon and PB muscle and had two tendons with different insertions. One tendon inserted on the talus and peroneal tubercle while the other inserted on the retrotrochlear eminence. The co-existence of the PQ and unusual accessory peroneal muscle had been reported.

The prevalence of PDQ was 33% which was similar to the previous studies (30-50%) [35, 36]. This muscle was commonly found bilaterally and predominantly in male [24]. In contrast, the prevalence of bilateral PDQ in Indian population was only 5% [36]. The PDQ muscle was reported to separate from PB tendon as a slender tendon [35, 36].

Interestingly, this study found one PDQ with muscle fibers. Most of the PDQ inserted on the different parts of the 5th toe including shaft of metatarsal and bases of proximal, middle and distal phalanges. Moreover, the PDQ tendon merged with that of the extensor digitorum longus and inserted at the base of distal phalanx in 3 cases. Demir et al. (2015) described the insertion pattern of PDQ as 2 different types; single tendon attached to the 5th metatarsal bone and two separated tendons attached to different parts of the 5th metatarsal bone[35]. Moreover, dual insertion of PDQ on the 4th and 5th metatarsals were reported in 3% of PDQ cases [36]. In this study, all PDQ had a single tendon.

The anatomy of inferior peroneal retinaculum and related structures

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 [21, 39]. 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 with the IPR. The prevalence of the extension band was found in 31.19% of cases. This extension band may play a role in stabilization of PL tendon in the lower tunnel. In this study, we found two 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 stabilized the PL tendon in this tunnel.

IP tunnel was divided into 2 tunnels: the upper and lower tunnels. Generally, the content of these tunnels were PB and PL tendons, respectively [39]. 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 [24, 35, 36] or in the upper tunnel[52]. 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 [24, 25, 27, 34]. 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 [28, 34]. 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. The mechanism of injury was dorsiflexion with internal rotation of the foot and iatrogenic injury after surgical repair of fractured os peroneum[53, 54]. 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 IP tunnel 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 width at IPR origin in the left side of male and female specimens was significantly different. This finding would support the previous studies which revealed that the incidence of the PB tendon tear was more common than the PL tendon tear [1, 4]. In this study, we reported two cases of PB tendon tear in the upper tunnel but none of PL tears in the lower tunnel.

Chapter VI

Conclusion

The characteristic and morphometric data of the SPR were described. SPR could be divided by the insertion pattern into type Ia, type Ib, type II and type III. SPR had at least one insertion band on the posterior intermuscular septum or lateral wall of calcaneus. The average coordinates (X, Y) of origin in all types were 7.26±3.15 (0.87-15.15) and 10.45±4.52 (1.69-26.23) mm. The average coordinates of SPR which inserted on the posterior intermuscular septum were 24.06±4.94 and 13.35±5.18, and those inserted on the lateral wall of calcaneus were 21.45±7.88 and 13.59±6.73 mm. The morphometric data provide in this study may have beneficial for SPR surgical procedures in both reattachment and reconstruction. The type Ib had a trend to be associated with PB tendon tear.

The prevalence of PQ, PDQ and unusual accessory peroneal muscle in this study was in agreement with the previous reports. Co-existence of PQ and one unusual accessory peroneal muscle was revealed in one male specimen. There was no association between the PQ or PDQ and the prominence of retrotrochlear eminence or peroneal tubercle. Moreover, the PB tendon tear was not significant associated with the presence of accessory peroneal muscle, the prominence of retrotrochlear eminence and peroneal tubercle.

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 IP tunnel and the extension band was found in 31%. The additional contents were found in both IP tunnels: PDQ and PQ in the upper IP tunnel and the unusual accessory peroneal muscle in the lower tunnel. All these data are beneficial for surgical treatment of IPR injury.

The limitation of this study was the use of the formalin fixed cadaver which might cause the unusual position of the foot and ankle. Although the adjustment of

the foot and ankle to the neutral position by Achilles tendon releasing and a supporting frame was performed, the embalmed cadaveric legs might yield different results from fresh or soft-embalmed cadaveric legs.

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Appendix

1. The comparison each parameter between sides

1.1 The length of SPR

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia Proximal band	Lt.	7	22.34±5.21	16.51-32.83	0.200	0.222	0.716	-
	Rt.	7	23.39±5.26	16.70-32.35	0.200	0.796		
	Total	14	22.86±5.06	16.51-32.83	0.191	0.101	-	-
Distal band	Lt.	7	22.55±5.56	16.27-32.72	0.200	0.635	0.381	-
	Rt.	7	24.91±4.03	17.16-29.94	0.200	0.466		
	Total	14	23.73±4.82	16.27-32.72	0.200	0.903	-	-
Type Ib Proximal band	Lt.	25	23.01±3.45	18.45-31.15	0.061	0.039	-	0.633
	Rt.	23	22.57±2.93	16.24-27.76	0.200	0.879		
	Total	48	22.80±3.18	16.24-31.15	0.200	0.545	-	-
Distal band	Lt.	25	28.79±4.71	22.38-40.71	0.003	0.020	-	0.073
	Rt.	23	30.83±5.03	22.50-39.44	0.200	0.277		
	Total	48	29.77±4.92	22.38-40.71	0.012	0.015	-	-
Type II Single band	Lt.	2	26.39±3.54	23.89-28.89	NA	NA	-	-
Type III Single band	Lt.	21	20.30 ± 3.09	15.68-26.60	0.200	0.540	0.438	-
	Rt.	24	21.27 ± 4.92	13.13-36.64	0.200	0.062		
	Total	45	20.82 ± 4.15	13.13–36.64	0.200	0.011	-	-

1.2 The width of SPR origin

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia								
Proximal band	Lt.	7	16.57±4.03	10.33-21.11	0.200	0.550	0.278	-
	Rt.	7	19.59±2.42	14.98-21.74	0.200	0.930		
	Total	14	17.58±3.36	10.33-21.74	0.200	0.322	-	-
Distal band	Lt.	7	NA	NA	NA	NA	-	-
	Rt.	7	NA	NA	NA	NA		
	Total	14	NA	NA	NA	NA	-	-
Type Ib								
Proximal band	Lt.	25	18.91±3.19	13.17-27.71	0.200	0.530	0.081	-
	Rt.	23	20.23±3.45	15.37-28.98	0.200	0.211		
	Total	48	19.73±3.40	13.17-28.98	0.170	0.114	-	-
Distal band	Lt.	25	NA	NA	NA	NA	-	-
	Rt.	23	NA	NA	NA	NA		
	Total	48	NA	NA	NA	NA	-	-
Type II Single band	Lt.	2	14.53±5.54	10.62-18.45	NA	NA	-	-
Type III								
Single band	Lt.	21	16.98±4.37	8.05-25.34	0.200	0.999	0.656	-
	Rt.	24	17.61±4.97	10.81-26.22	0.200	0.100		
	Total	45	17.31±4.65	8.05-26.22	0.200	0.389	-	-

1.3 The width of SPR middle part

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia Proximal band	Lt.	7	14.02±3.66	9.07-18.19	0.200	0.401	-	0.013
	Rt.	7	18.55±3.81	10.61-22.51	0.029	0.065		
	Total	14	16.29±4.29	9.07-22.51	0.046	0.0185	-	-
Distal band	Lt.	7	10.99±3.89	5.20-15.34	0.200	0.419	-	0.338
	Rt.	7	13.40±3.04	10.46-19.85	0.034	0.034		
	Total	14	12.20±3.58	5.20-19.85	0.200	0.401	-	-
Type Ib Proximal band	Lt.	25	17.02±3.36	12.25-24.50	0.200	0.163	0.844	-
	Rt.	23	17.09±3.30	11.38-24.26	0.200	0.890		
	Total	48	17.23±3.35	11.38-24.50	0.200	0.204	-	-
Distal band	Lt.	25	12.28±2.86	8.43-20.43	0.200	0.105	0.686	-
	Rt.	23	12.58±1.90	8.43-16.39	0.200	0.997		
	Total	48	12.28±2.86	8.43-20.43	0.200	0.133	-	-
Type II Single band	Lt.	2	13.10±4.14	10.17-16.02	NA	NA	-	-
Type III Single band	Lt.	21	16.04±3.31	8.84-23.98	0.200	0.919	0.546	-
	Rt.	24	15.27±4.85	7.84-23.36	0.200	0.207		
	Total	45	15.63±4.18	7.84-23.98	0.200	0.541	-	-

1.4 The width of SPR insertion

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia								
Proximal band	Lt.	7	10.93±3.84	6.31-17.42	0.200	0.812	0.018	-
	Rt.	7	16.25±3.47	11.38-21.70	0.200	0.979		
	Total	14	13.59±4.47	6.31-21.70	0.200	0.953	-	-
Distal band	Lt.	7	8.96±3.15	4.59-14.17	0.200	0.916	0.040	-
	Rt.	7	12.24±2.08	8.76-14.49	0.200	0.588		
	Total	14	10.60±3.08	4.59-14.49	0.200	0.532	-	-
Type Ib								
Proximal band	Lt.	25	14.51±3.74	8.23-24.07	0.099	0.036	0.926	-
	Rt.	23	14.53±4.05	7.96-24.38	0.106	0.252		
	Total	48	14.52±3.85	7.96-24.38	0.014	0.008		
Distal band	Lt.	25	10.22±4.25	5.65-29.94	0.009	0.000	-	0.556
	Rt.	23	10.25±2.63	6.14-18.46	0.200	0.045		
	Total	48	10.23±3.53	5.65-26.94	0.014	0.000	-	-
Type II								
Single band	Lt.	2	10.83±7.00	5.88-15.78	NA	NA	NA	NA
Type III								
Single band	Lt.	21	14.86±2.76	10.54-21.12	0.200	0.877	0.573	-
	Rt.	24	14.26±3.97	5.64-21.02	0.200	0.335		
	Total	45	14.55±3.42	5.64-21.12	0.200	0.516	-	-

1.5 The thickness of SPR

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia								
Proximal band	Lt.	7	0.52±0.22	0.19-0.75	0.072	0.086	0.217	-
	Rt.	7	0.37±0.19	0.15-0.68	0.200	0.789		
	Total	14	0.45±0.21	0.15-0.75	0.184	0.139	-	-
Distal band	Lt.	7	0.54±0.23	0.27-0.82	0.200	0.363	0.291	-
	Rt.	7	0.43±0.16	0.24-0.64	0.200	0.387		
	Total	14	0.49±0.20	0.24-0.82	0.200	0.236	-	-
Type Ib								
Proximal band	Lt.	25	0.46±0.18	0.17-0.86	0.200	0.324	0.954	-
	Rt.	23	0.46±0.22	0.20-0.98	0.200	0.050		
	Total	48	0.46±0.20	0.17-0.98	0.200	0.023	-	-
Distal band	Lt.	25	0.29±0.15	0.08-0.63	0.055	0.150	0.180	-
	Rt.	23	0.37±0.19	0.11-0.78	0.200	0.435		
	Total	48	0.33±0.17	0.08-0.78	0.056	0.036	-	-
Type II Single band	Lt.	2	0.73±0.25	0.55-0.91	NA	NA	-	-
Type III								
Single band	Lt.	21	0.49 ± 0.22	0.14-0.93	0.200	0.504	-	0.707
	Rt.	24	0.46 ± 0.17	0.22-0.76	0.018	0.032		
	Total	45	0.47 ± 0.20	0.14-0.93	0.042	0.079	-	-

1.6 The angle of SPR

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia								
Proximal band	Lt.	7	13.95±8.31	4.67-26.00	0.200	0.448	0.351	-
	Rt.	7	10.48±4.55	3.33-14.67	0.200	0.185		
	Total	14	12.21±6.69	3.33-26.00	0.200	0.230	-	-
Distal band	Lt.	7	34.57±18.47	6.67-59.33	0.200	0.881	0.332	-
	Rt.	7	24.95±17.13	2.33-48.33	0.200	0.746		
	Total	14	29.76±17.83	2.33-59.33	0.200	0.547	-	-
Type Ib								
Proximal band	Lt.	25	10.32±5.78	0.00-19.00	0.120	0.176	0.125	-
	Rt.	23	8.13±3.58	3.67-19.33	0.200	0.016		
	Total	48	9.27±4.92	0.00-19.33	0.200	0.580	-	-
Distal band	Lt.	25	43.72±15.36	10.67-73.33	0.114	0.295	0.910	-
	Rt.	23	44.33±21.18	3.67-83.33	0.200	0.450		
	Total	48	44.02±18.23	3.67-83.33	0.180	0.392	-	-
Type II								
Single band	Lt.	2	18.69±4.68	15.38-22.00	-	-	-	-
Type III								
Single band	Lt.	21	10.27±5.40	0.00-18.33	0.200	0.349	0.609	-
	Rt.	24	9.32±6.76	0.00-23.00	0.200	0.391		
	Total	45	9.76±6.11	0.00-23.00	0.200	0.254	-	-

1.7 The horizontal distance from midpoint of SPR origin to the fibular tip

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia								
Proximal band	Lt.	7	8.63±3.43	5.41-13.69	0.200	0.148	0.849	-
	Rt.	7	9.02±4.00	2.62-15.15	0.200	0.980		
	Total	14	8.82±3.59	2.62-15.15	0.200	0.941	-	-
Distal band	Lt.	7	NA	NA	NA	NA	-	-
	Rt.	7	NA	NA	NA	NA		
	Total	14	NA	NA	NA	NA	-	-
Type Ib								
Proximal band	Lt.	25	6.46±3.16	1.76-11.75	0.008	0.048	-	0.749
	Rt.	23	6.74±2.56	2.36-11.64	0.084	0.387		
	Total	48	6.59±2.86	1.76-11.75	0.002	0.019	-	-
Distal band	Lt.	25	NA	NA	NA	NA	-	-
	Rt.	23	NA	NA	NA	NA		
	Total	48	NA	NA	NA	NA	-	-
Type II								
Single band	Lt.	2	7.31±1.48	6.27-8.36	NA	NA	NA	NA
Type III								
Single band	Lt.	21	7.75±3.09	2.73-14.65	0.200	0.367	0.849	-
	Rt.	24	7.22±3.39	0.87-13.74	0.200	0.394		
	Total	45	7.47±3.22	0.87-14.65	0.200	0.398	-	-

1.8 The vertical distance from midpoint of SPR origin to the fibular tip

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia								
Proximal band	Lt.	7	12.32±5.36	4.55-18.82	0.200	0.551	-	0.058
	Rt.	7	20.04±8.13	2.47-26.23	0.010	0.004		
	Total	14	16.18±7.73	2.47-26.23	0.200	0.240	-	-
Distal band	Lt.	7	NA	NA	NA	NA	-	-
	Rt.	7	NA	NA	NA	NA		
	Total	14	NA	NA	NA	NA	-	-
Type Ib								
Proximal band	Lt.	25	8.27±2.56	3.85-14.33	0.200	0.576	0.003	-
	Rt.	23	10.70±2.77	4.21-15.98	0.200	0.939		
	Total	48	9.43±2.91	3.85-15.98	0.200	0.681	-	-
Distal band	Lt.	25	NA	NA	NA	NA	-	-
	Rt.	23	NA	NA	NA	NA		
	Total	48	NA	NA	NA	NA	-	-
Type II								
Single band	Lt.	2	9.13±5.13	5.51-12.76	NA	NA	NA	NA
Type III								
Single band	Lt.	21	9.78±3.57	1.69-17.33	0.200	0.663	0.988	-
	Rt.	24	9.79±3.02	4.62-17.28	0.200	0.682		
	Total	45	9.79±3.25	1.69-17.33	0.200	0.446	-	-

1.9 The horizontal distance from midpoint of SPR insertion to the fibular tip

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia								
Proximal band	Lt.	7	26.09±5.50	20.18-32.64	0.200	0.119	0.879	-
	Rt.	7	25.62±5.87	15.02-32.52	0.200	0.543		
	Total	14	25.85±5.47	15.02-32.64	0.200	0.315		
Distal band	Lt.	7	22.94±8.00	14.90-35.14	0.200	0.322	0.909	-
	Rt.	7	23.42±7.64	11.58-35.13	0.200	0.946		
	Total	14	23.18±7.52	11.58-35.14	0.200	0.636		
Type Ib								
Proximal band	Lt.	25	23.27±5.80	10.46-35.67	0.200	0.514	0.568	-
	Rt.	23	24.10±3.96	16.57-32.37	0.200	0.553		
	Total	48	23.67±4.97	10.46-35.67	0.200	0.428		
Distal band	Lt.	25	20.94±8.39	8.54-36.79	0.177	0.137	-	0.439
	Rt.	23	20.95±7.70	11.17-38.66	0.200	0.037		
	Total	48	20.94±7.98	8.54-38.66	0.037	0.011		
Type II								
Single band	Lt.	2	26.22±7.53	20.90-31.55	NA	NA	NA	NA
Type III								
Single band	Lt.	21	21.90±3.83	13.85-29.14	0.200	0.616	-	0.879
	Rt.	24	25.51±4.81	17.43-36.49	0.049	0.236		
	Total	45	23.82±4.70	13.85-36.49	0.010	0.240		

1.10 The vertical distance from midpoint of SPR insertion to fibular tip

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia								
Proximal band	Lt.	7	14.31±2.87	10.75-19.45	0.200	0.684	0.152	-
	Rt.	7	19.19±7.94	4.12-25.76	0.193	0.095		
	Total	14	16.75±6.27	4.12-25.76	0.200	0.423		
Distal band	Lt.	7	14.48±4.64	7.20-22.38	0.200	0.752	0.166	-
	Rt.	7	10.11±6.32	1.53-20.03	0.200	0.540		
	Total	14	12.30±5.79	1.53-22.38	0.200	0.704		
Type Ib								
Proximal band	Lt.	25	12.54±4.39	4.24-21.44	0.200	0.693	0.125	-
	Rt.	23	14.68±5.07	5.32-22.64	0.200	0.597		
	Total	48	13.56±4.80	4.24-22.64	0.200	0.379		
Distal band	Lt.	25	14.19±6.94	0.00-27.69	0.200	0.685	0.824	-
	Rt.	23	13.73±7.19	0.00-31.79	0.200	0.824		
	Total	48	13.97±6.99	0.00-31.79	0.200	0.946		
Type II								
Single band	Lt.	2	4.48±2.48	2.73-6.24	NA	NA	NA	NA
Type III								
Single band	Lt.	21	12.27±5.37	1.06-20.34	0.110	0.133	0.790	-
	Rt.	24	12.64±4.00	3.12-18.37	0.200	0.126		
	Total	45	12.47±4.64	1.06-20.34	0.200	0.081		

1.11 The length of IPR

	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Length	Lt.	54	23.54 ± 3.41	18.20-33.68	0.074	0.006	0.725	-
	Rt.	55	23.29 ± 3.70	17.05-33.08	0.200	0.439		
	Total	109	23.42 ± 3.54	17.05-33.68	0.200	0.030	-	-

1.12 The width of IPR origin (Wo)

	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Wo	Lt.	54	13.41 ± 2.86	8.22 - 20.92	0.200	0.171	0.635	-
	Rt.	55	13.17 ± 2.25	5.83 - 18.74	0.200	0.115		
	Total	109	13.29 ± 2.56	5.83- 20.92	0.076	0.115	-	-

1.13 The width of IPR middle part (Wm)

	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov - Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Wm	Lt.	54	14.68 ± 2.31	9.35-21.34	0.029	0.156	0.434	-
	Rt.	55	14.32 ± 2.44	6.86-19.63	0.200	0.711		
	Total	109	14.50 ± 2.37	6.68-21.34	0.200	0.267	-	-

1.14 The width of IPR insertion (Wi)

	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov - Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Wi	Lt.	54	10.38 ± 2.74	5.17-19.17	0.200	0.299	0.278	-
	Rt.	55	9.82 ± 2.53	4.59-14.94	0.200	0.789		
	Total	109	10.10 ± 2.63	4.59-19.17	0.155	0.712	-	-

1.15 The thickness of IPR

	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov - Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Thickness	Lt.	54	0.47 ± 0.16	0.20-0.82	0.200	0.184	0.747	-
	Rt.	55	0.49 ± 0.15	0.21-0.87	0.200	0.586		
	Total	109	0.48 ± 0.16	0.20-0.87	0.200	0.097	-	-

1.16 The angle of IPR to horizontal axis

	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov - Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Angle	Lt.	54	38.99 ± 7.28	23.33-54.00	0.200	0.488	-	0.565
	Rt.	55	38.05 ± 6.89	11.67-48.67	0.049	0.003		
	Total	109	38.51 ± 7.07	11.67-54.00	0.024	0.020	-	-

2. Comparison each parameter between genders

2.1 The length of SPR

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov- Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia Proximal band	M	4	28.22±6.01	19.86-32.83	-	0.266	0.084	-
	F	10	20.72±2.66	16.51-24.11	0.200	0.368		
Distal band	M	4	23.42±5.22	17.16-29.94	-	0.680	0.890	-
	F	10	23.86±4.94	16.27-32.72	0.200	0.800		
Type Ib Proximal band	M	21	24.02±3.50	18.45-31.15	0.200	0.563	0.018	-
	F	27	21.85±2.60	16.24-26.29	0.200	0.766		
Distal band	M	21	30.98±5.19	23.44-40.71	0.200	0.094	0.134	-
	F	27	28.83±4.57	22.38-38.71	0.200	0.093		
Type II Single band	F	2	26.39±3.54	23.89-28.89	-	-	-	-
Type III Single band	M	30	21.13±3.53	14.68-27.61	0.200	0.384	-	0.123
	F	15	20.20±5.27	13.13-36.64	0.003	0.002		

2.2 The width of SPR origin

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov - Smirnov	Shapiro- Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia Proximal band	M	4	19.14±2.48	16.55-21.74	-	0.460	-	0.304
	F	10	16.96±3.57	10.33-21.11	0.200	0.487		
Distal band	M	4	NA	NA	-	-	-	-
	F	10	NA	NA	-	-		
Type Ib Proximal band	M	21	20.57±4.03	13.53-28.98	0.200	0.588	0.132	-
	F	27	19.07±2.71	13.17-25.87	0.200	0.815		
Distal band	M	21	NA	NA	-	-	-	-
	F	27	NA	NA	-	-		
Type II Single band	F	2	26.39±3.54	23.89-28.89	-	-	-	-
Type III Single band	M	30	17.69±4.95	8.05-26.22	0.200	0.511	0.450	-
	F	15	16.56±4.06	10.81-25.34	0.200	0.752		

2.3 The width of SPR middle part

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia Proximal band	M	4	19.53±1.27	18.02-21.13	-	0.800	-	0.076
	F	10	14.99±4.42	9.07-22.51	0.200	0.463		
Distal band	M	4	13.66±4.26	10.40-19.85	-	0.190	-	0.945
	F	10	11.61±3.34	5.20-15.34	0.029	0.079		
Type Ib Proximal band	M	21	18.16±3.66	11.38-24.50	0.200	0.801	0.062	-
	F	27	16.22±2.78	12.45-24.26	0.200	0.084		
Distal band	M	21	12.57±1.59	9.17-15.38	0.200	0.914	0.751	-
	F	27	12.33±2.90	8.43-20.43	0.200	0.145		
Type II Single band	F	2	26.39±3.54	23.89-28.89	-	-	-	-
Type III Single band	M	30	15.94±3.99	7.90-23.98	0.200	0.938	0.934	-
	F	15	15.55±4.30	8.49-23.36	0.156	0.525		

2.4 The width of SPR insertion

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia Proximal band	M	4	13.87±4.34	7.82-17.28	-	0.302	-	0.945
	F	10	13.48±4.75	6.31-21.70	0.200	0.951		
Distal band	M	4	10.99±2.76	7.59-14.33	-	0.841	-	0.733
	F	10	10.44±3.33	4.59-14.49	0.200	0.551		
Type Ib Proximal band	M	21	15.98±4.78	7.96-24.38	0.033	0.325	-	0.224
	F	27	13.85±3.09	8.23-22.90	0.200	0.300		
Distal band	M	21	10.25±2.51	5.65-12.88	0.013	0.005	-	0.137
	F	27	10.23±4.42	6.37-26.94	0.000	0.000		
Type II Single band	F	2	26.39±3.54	23.89-28.89	-	-	-	-
Type III Single band	M	30	14.84±3.11	8.55-21.12	0.200	0.935	0.437	-
	F	15	13.98±4.00	5.64-18.21	0.082	0.027		

2.5 The thickness of SPR

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia Proximal band	M	4	0.55±0.11	0.42-0.68	-	0.780	-	0.374
	F	10	0.40±0.23	0.15-0.75	0.200	0.068		
Distal band	M	4	0.53±0.11	0.38-0.64	-	0.595	-	0.539
	F	10	0.47±0.23	0.24-0.82	0.146	0.077		
Type Ib Proximal band	M	21	0.49±0.26	0.17-0.98	0.003	0.042	-	0.655
	F	27	0.42±0.17	0.19-0.80	0.200	0.310		
Distal band	M	21	0.33±0.17	0.13-0.63	0.133	0.129	-	0.972
	F	27	0.33±0.18	0.08-0.78	0.039	0.153		
Type II Single band	F	2	26.39±3.54	23.89-28.89	-	-	-	-
Type III Single band	M	30	0.49±0.19	0.22-0.87	0.010	0.043	-	0.457
	F	15	0.45±0.22	0.14-0.93	0.200	0.602		

2.6 The angle of SPR

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov - Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia Proximal band	M	4	11.00±5.51	3.33-15.33	-	0.303	-	0.945
	F	10	12.70±7.32	4.67-26.00	0.200	0.172		
Distal band	M	4	21.95±13.24	6.33-38.67	-	0.822	-	0.240
	F	10	32.90±19.04	2.33-59.33	0.200	0.584		
Type Ib Proximal band	M	21	7.56±4.39	0.00-13.33	0.200	0.536	0.241	-
	F	27	9.29±4.93	2.00-19.33	0.200	0.555		
Distal band	M	21	46.64±15.43	25.67-69.67	0.159	0.113	0.894	-
	F	27	47.63±20.96	3.67-83.33	0.200	0.982		
Type II Single band	F	2	26.39±3.54	23.89-28.89	-	-	-	-
Type III Single band	M	30	10.77±5.26	2.33-20.00	0.200	0.278	0.320	-
	F	15	8.47±7.18	0.00-23.00	0.200	0.201		

2.7 The horizontal distance from midpoint of SPR origin to the fibular tip

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov - Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia Proximal band	M	4	9.16±1.54	7.89-11.11	-	0.323	-	0.733
	F	10	8.69±4.21	2.62-15.15	0.188	0.450		
Distal band	M	4	NA	NA	-	-	-	-
	F	10	NA	NA	-	-		
Type Ib Proximal band	M	21	6.74±2.80	3.10-11.75	0.015	0.083	-	0.787
	F	27	6.49±2.96	1.76-11.64	0.164	0.097		
Distal band	M	21	NA	NA	-	-	-	-
	F	27	NA	NA	-	-		
Type II Single band	F	2	26.39±3.54	23.89-28.89	-	-	-	-
Type III Single band	M	30	7.98±3.10	0.87-14.65	0.127	0.219	0.151	-
	F	15	6.50±3.34	1.10-12.68	0.200	0.626		

2.8 The vertical distance from midpoint of SPR origin to the fibular tip

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov - Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia Proximal band	M	4	19.85±6.54	11.48-26.23	-	0.740	-	0.304
	F	10	14.71±7.98	2.47-23.83	0.200	0.236		
Distal band	M	4	NA	NA	-	-	-	-
	F	10	NA	NA	-	-		
Type Ib Proximal band	M	21	8.92±3.10	4.21-14.33	0.097	0.081	0.280	-
	F	27	9.84±2.73	3.85-15.98	0.200	0.878		
Distal band	M	21	NA	NA	-	-	-	-
	F	27	NA	NA	-	-		
Type II Single band	F	2	26.39±3.54	23.89-28.89	-	-	-	-
Type III Single band	M	30	9.79±3.44	1.69-17.28	0.200	0.970	-	0.824
	F	15	9.77±2.98	6.48-17.33	0.200	0.043		

2.9 The horizontal distance from midpoint of SPR insertion to the fibular tip

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov - Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia Proximal band	M	4	29.19±4.58	22.79-32.52	-	0.196	-	0.240
	F	10	24.52±5.41	15.02-32.64	0.200	0.873		
Distal band	M	4	24.37±4.14	19.24-27.92	-	0.368	-	0.635
	F	10	22.70±8.66	11.58-35.14	0.200	0.254		
Type Ib Proximal band	M	21	24.80±6.15	10.46-35.67	0.200	0.673	0.166	-
	F	27	22.79±3.69	14.95-32.37	0.189	0.446		
Distal band	M	21	21.48±7.40	8.54-36.79	0.200	0.658	0.686	-
	F	27	20.53±8.52	11.17-38.66	0.116	0.004		
Type II Single band	F	2	26.39±3.54	23.89-28.89	-	-	-	-
Type III Single band	M	30	24.23±4.38	15.97-35.65	0.114	0.554	0.223	-
	F	15	22.61±5.11	13.85-36.49	0.085	0.106		

2.10 The vertical distance from midpoint of SPR insertion to fibular tip

Type	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov - Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Type Ia Proximal band	M	4	19.85±6.98	11.80-25.76	-	0.228	-	0.240
	F	10	15.51±5.87	4.12-24.42	0.200	0.715		
Distal band	M	4	11.21±8.56	1.53-22.38	-	0.704	-	0.454
	F	10	12.73±4.82	2.81-20.03	0.050	0.363		
Type Ib Proximal band	M	21	12.34±5.70	4.24-22.64	0.145	0.142	0.119	-
	F	27	14.52±3.80	8.97-22.58	0.200	0.475		
Distal band	M	21	15.76±7.54	3.98-31.79	0.200	0.607	0.117	-
	F	27	12.57±6.32	0.00-22.12	0.200	0.211		
Type II Single band	F	2	26.39±3.54	23.89-28.89	-	-	-	-
Type III Single band	M	30	12.14±5.01	1.06-20.34	0.200	0.212	0.816	-
	F	15	12.70±3.81	3.50-18.84	0.200	0.558		

2.11 The length of IPR

	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Length	M	54	23.19±3.61	17.57-33.68	0.200	0.035	0.518	-
	F	55	23.63±3.49	17.05-33.08	0.200	0.500		

2.12 The width of IPR origin (Wo)

	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Wo	M	54	12.70±2.70	5.83-20.68	0.200	0.050	0.017	-
	F	55	13.87±2.30	9.47-20.92	0.200	0.358		

2.13 The width of IPR middle part (Wm)

	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Wm	M	54	14.04 ± 2.21	9.35-18.53	0.200	0.615	0.694	-
	F	55	14.58 ± 2.53	6.86-21.34	0.971	0.198		

2.14 The width of IPR insertion (Wi)

	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Wi	M	54	10.68 ± 2.66	5.17-19.17	0.200	0.342	0.022	-
	F	55	9.52 ± 2.50	4.59-14.54	0.200	0.385		

2.15 The thickness of IPR

	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Thickness	M	54	0.46 ± 0.16	0.20-0.87	0.054	0.041	-	0.121
	F	55	0.49 ± 0.15	0.21-0.82	0.979	0.471		

2.16 The angle of IPR to horizontal axis

	side	n	Mean±SD	Range	Normality testing		Statistic testing	
					Kolmokorov-Smirnov	Shapiro-Wilk (Sig.)	Unpaired t-test	Mann-Whitney U test
Angle	M	54	36.99 ± 7.25	11.67-36.66	0.018	0.005	-	0.063
	F	55	38.22 ± 6.61	26.00-54.00	0.049	0.657		

3. The comparison of SPR in each type

3.1 The length of SPR

	Type	Statistic testing					
		One-way ANOVA test	Post HOC test (LSD)	Kruskal-Wallis H	Mann-Whitney U test	Unpaired t-test	Mann-Whitney U test
The comparison between Single band which inserted on posterior intermuscular	Type Ia and type Ib	0.035	0.955	-	-	-	-
	Type Ia and type III		0.088		-	-	-
	Type Ib and type III		0.016		-	-	-
The comparison between distal band	Type Ia and Ib	-	-	-	-	0.000	-

3.2 The width of SPR origin

			Type	Statistic testing					
				One-way ANOVA test	Post HOC test (LSD)	Kruskal-Wallis H	Mann-Whitney U test	Unpaired t-test	Mann-Whitney U test
The comparison between Single band which inserted on posterior intermuscular			Type Ia and type Ib	-	-	0.289	0.788	-	-
			Type Ia and type III				0.510	-	-
			Type Ib and type III				0.112	-	-
The comparison between distal band			Type Ia and Ib	-	-	-	-	-	-

3.3 The width of SPR middle part

			Type	Statistic testing					
				One-way ANOVA test	Post HOC test (LSD)	Kruskal-Wallis H	Mann-Whitney U test	Unpaired t-test	Mann-Whitney U test
The comparison between Single band which inserted on posterior intermuscular			Type Ia and type Ib	-	-	0.289	0.788	-	-
			Type Ia and type III				0.510	-	-
			Type Ib and type III				0.112	-	-
The comparison between distal band			Type Ia and Ib	-	-	-	-	0.783	-

3.4 The width of SPR insertion

			Type	Statistic testing					
				One-way ANOVA test	Post HOC test (LSD)	Kruskal-Wallis H	Mann-Whitney U test	Unpaired t-test	Mann-Whitney U test
The comparison between Single band which inserted on posterior intermuscular			Type Ia and type Ib	0.685	0.418	-	-	-	-
			Type Ia and type III		0.411		-	-	-
			Type Ib and type III		0.977		-	-	-
The comparison between distal band			Type Ia and Ib	-	-	-	-	-	0.304

3.5 The thickness of SPR

			Type	Statistic testing					
				One-way ANOVA test	Post HOC test (LSD)	Kruskal-Wallis H	Mann-Whitney U test	Unpaired t-test	Mann-Whitney U test
The comparison between Single band which inserted on posterior intermuscular			Type Ia and type Ib	0.872	0.813	-	-	-	-
			Type Ia and type III		0.631		-	-	-
			Type Ib and type III		0.717		-	-	-
The comparison between distal band			Type Ia and Ib	-	-	-	-	0.011	-

3.6 The angle of SPR

			Type	Statistic testing					
				One-way ANOVA test	Post HOC test (LSD)	Kruskal-Wallis H	Mann-Whitney U test	Unpaired t-test	Mann-Whitney U test
The comparison between Single band which inserted on posterior intermuscular			Type Ia and type Ib	0.236	0.091	-	-	-	-
			Type Ia and type III		0.162		-	-	-
			Type Ib and type III		0.678		-	-	-
The comparison between distal band			Type Ia and Ib	-	-	-	-	0.016	-

3.7 The horizontal distance from midpoint of SPR origin to the fibular tip

			Type	Statistic testing					
				One-way ANOVA test	Post HOC test (LSD)	Kruskal-Wallis H	Mann-Whitney U test	Unpaired t-test	Mann-Whitney U test
The comparison between Single band which inserted on posterior intermuscular			Type Ia and type Ib	-	-	0.101	0.034	-	-
			Type Ia and type III		-		0.234	-	-
			Type Ib and type III		-		0.249	-	-
The comparison between distal band			Type Ia and Ib	-	-	-	-	-	-

3.8 The vertical distance from midpoint of SPR origin to the fibular tip

			Type	Statistic testing					
				One-way ANOVA test	Post HOC test (LSD)	Kruskal-Wallis H	Mann-Whitney U test	Unpaired t-test	Mann-Whitney U test
The comparison between Single band which inserted on posterior intermuscular			Type Ia and type Ib	0.000	0.000	-	-	-	-
			Type Ia and type III		0.000		-	-	-
			Type Ib and type III		0.673		-	-	-
The comparison between distal band			Type Ia and Ib	-	-	-	-	-	-

3.9 The horizontal distance from midpoint of SPR insertion to the fibular tip

			Type	Statistic testing					
				One-way ANOVA test	Post HOC test (LSD)	Kruskal-Wallis H	Mann-Whitney U test	Unpaired t-test	Mann-Whitney U test
The comparison between Single band which inserted on posterior intermuscular			Type Ia and type Ib	0.328	0.147	-	-	-	-
			Type Ia and type III		0.181		-	-	-
			Type Ib and type III		0.881		-	-	-
The comparison between distal band			Type Ia and Ib	-	-	-	-	0.354	-

3.10 The vertical distance from midpoint of SPR insertion to fibular tip

		Statistic testing					
	Type	One-way ANOVA test	Post HOC test (LSD)	Kruskal-Wallis H	Mann-Whitney U test	Unpaired t-test	Mann-Whitney U test
The comparison between Single band which inserted on posterior intermuscular	Type Ia and type Ib	0.021	0.036	-	-	-	-
	Type Ia and type III		0.006		-	-	-
	Type Ib and type III		0.288		-	-	-
The comparison between distal band	Type Ia and Ib	-	-	-	-	0.417	-

4. The comparison between the presence of PB tendon tear and morphometric data of SPR based on insertion site

	SPR	mean±SD Peroneus brevis tendon tear		*p*-value
		Presence	Absent	
Inserted on posterior intermuscular septum	Length	22.33±2.57	22.01±4.17	0.780
	Width at origin	18.52±4.63	18.34±4.07	0.885
	Width at middle part	17.01±4.16	16.27±3.86	0.512
	Width at insertion	14.86±4.61	14.27±3.68	0.588
	Thickness	0.47±0.26	0.47±0.19	0.571
	Angle	11.43±5.12	9.82±5.89	0.335
Inserted on lateral wall of calcaneus	Length	28.06±4.60	28.48±5.70	0.820
	Width at middle part	12.50±1.58	12.35±2.89	0.878
	Width at insertion	9.78±3.49	10.44±3.42	0.450
	Thickness	0.40±0.26	0.37±0.18	0.946
	Angle	46.94±14.48	39.39±19.70	0.235

5. The comparison between the SPR type in the PB tendon tear and morphometric data of SPR based on insertion site

SPR			mean±SD			p-value
			Type Ia	Type Ib	Type III	
Inserted on posterior intermuscular septum		Length	23.90	22.88±2.27	19.97±2.93	0.191
		Width at origin	18.56	20.09±4.05	13.27±3.47	0.070
		Width at middle part	13.22	18.02±4.21	14.91±3.68	0.363
		Width at insertion	10.90	15.67±5.21	13.47±1.44	0.554
		Thickness	0.60	0.44±0.28	0.52±0.30	0.795
		Angle	23.67	10.87±3.45	9.22±5.75	0.024
Inserted on lateral wall of calcaneus		Length	19.52	28.91±3.82	-	-
		Width at middle part	12.25	12.53±1.68	-	-
		Width at insertion	10.40	9.71±3.67	-	-
		Thickness	0.81	0.34±0.21	-	-
		Angle	44.67	47.17±15.24	-	-

6. The comparison between the SPR type in the PB tendon tear and morphometric data of SPR

SPR		mean±SD			p-value
		Type Ia	Type Ib	Type III	
Inserted on posterior intermuscular septum	Length	23.90	22.88±2.27	19.97±2.93	0.191
	Width at origin	18.56	20.09±4.05	13.27±3.47	0.070
	Width at middle part	13.22	18.02±4.21	14.91±3.68	0.363
	Width at insertion	10.90	15.67±5.21	13.47±1.44	0.554
	Thickness	0.60	0.44±0.28	0.52±0.30	0.795
	Angle	23.67	10.87±3.45	9.22±5.75	0.024
Inserted on lateral wall of calcaneus	Length	19.52	28.91±3.82	-	-
	Width at middle part	12.25	12.53±1.68	-	-
	Width at insertion	10.40	9.71±3.67	-	-
	Thickness	0.81	0.34±0.21	-	-
	Angle	44.67	47.17±15.24	-	-

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