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## **New aspect of morphometric study of the superior peroneal retinaculum: pertinent data for surgical repair and reconstruction**

Running head: Superior peroneal retinaculum

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### **Abstract**

**Background:** This study was conducted to investigate characteristics, attachments and morphometric parameters of the superior peroneal retinaculum (SPR).

**Materials and methods:** Morphology and morphometric details including width, length, thickness and angle of alignment of SPR in 109 embalmed cadaveric legs were investigated. The occurrence of peroneal tendon tear was also noted.

**Results:** Most of SPR originated from the fibrocartilaginous ridge of the lateral malleolus. The SPR might be a single band or split into proximal and distal bands inserted on the posterior intermuscular septum and lateral wall of calcaneus, respectively. Based on the characteristics and insertion patterns, the SPR 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 56.88% (12.84%, 44.04%), 1.83%, and 41.28%, respectively. The average coordinate (X, Y axis) of the midpoint of width at origin measured from the tip of fibula in all types was  $7.26\pm 3.15$  and  $10.45\pm 4.52$  mm. The average coordinate of the midpoint at insertion on the posterior intermuscular septum was  $24.06\pm 4.94$  and  $13.35\pm 5.18$ , and those inserted on the lateral wall of calcaneus was  $21.45\pm 7.88$  and  $13.59\pm 6.73$  mm. Prevalence of peroneus brevis (PB) tendon tear was 12.84% (14 cases) and was associated with SPR type Ib with statistical significance.

**Conclusions:** Precise information of the characteristics, morphometric data and coordinates of attachment sites of SPR are essential for surgical procedures and reconstruction.

**Key words:** morphometric data, peroneal tendon tear, reconstruction, superior peroneal retinaculum

## INTRODUCTION

The superior peroneal retinaculum (SPR) is the primary stabilizer of the peroneal tendons to fit in their alignment at distal fibular level [2, 6]. The space beneath the SPR is called the superior peroneal tunnel (SP tunnel)[2]. Contents of SP tunnel are peroneus brevis (PB) and peroneus longus (PL) tendons. Additional contents of the SP tunnel including peroneus quartus and unusual accessory peroneal muscle were reported [1, 24]. Insufficiency of SPR was claimed to be an associated factor related to peroneal tendon disorders [8, 17, 23]. This pathology caused disabilities in walking, running and sport performances. The anatomic descriptions of SPR are extremely variable in width, thickness and their patterns of insertion [6, 18]. Conservative treatments might not be able to prevent recurrent episodes of dislocation/subluxation of peroneal tendon [13, 18, 25]. Therefore, surgical treatment is required after unsuccessful conservative treatments [19, 22, 23]. Nowadays, several surgical procedures have been described [4, 10]. Maffulli et al [13] suggested that the key to successful treatment of peroneal tendon dislocation and prevention of recurrent symptom were the reattachment of SPR to its

anatomical position[13]. However, knowledge of the precise area for SPR reattachment is still lacking. Therefore, the authors conducted this study to investigate the characteristics, the attachments, the morphometric parameters of SPR including width, length, thickness and angle of alignment. The distance from the attachment to inferior tip of fibula in X and Y axis was measured in order to locate the precise area of attachment. The presence of peroneal tendon tear was also noted. Comparisons of these parameters between genders and sides were determined.

## **MATERIALS AND METHODS**

Formaldehyde-embalmed cadaveric legs with age range of 34 – 94 years (55 males and 54 females) from the Department of Anatomy, Faculty of Medicine, Chulalongkorn University were investigated. Lower extremities with injury and foot deformities were excluded. All cadaveric legs were dissected and evaluated in prone position. The skin and subcutaneous tissue were removed. Characteristics and attachments of the SPR were identified. The Achilles tendon was released and adjusted to neutral position by a supporting frame (Fig. 1A). The standardized digital Vernier caliper (GuangLu ® 0-100 mm; range 100 mm, resolution 0.01 mm) was used to measure each parameter. Width of SPR was measured both in origin at lateral malleolus (Wo) and at insertion (Wi) (Fig. 1B). Horizontal and vertical distances from mid-point of origin and insertion to the inferior tip of fibula were measured from X and Y axis (Fig. 1D, E). Length of the SPR band was also measured (Fig. 1C). The angle of the alignment of the SPR to the horizontal axis was evaluated by standard goniometer (BASELINE™<sup>ce</sup>) (Fig. 1A). The axis of rotation was the inferior tip of fibula. The origin of SPR was cut (Fig. 1F) and its thickness was measured at its middle part. The presence of the PB tendon tear was recorded. Each parameter was measured 3 times and the average was calculated. To ensure consistency, the same digital Vernier caliper and standard goniometer were used. All measurements were done by the same investigator.

### **Statistical analysis**

Statistical analysis was performed by using IBM SPSS software version 22.0. The intra-class correlation coefficient (ICC) was used to determine the intra-tester reliability. Mean and standard deviation for each parameter were obtained. Shapiro-

Wilk test of normality was used to determine the distribution of sample population. Unpaired *t*-test in normally distributed data and Mann-Whitney U test in non-normally distributed data were used to compare parameters between genders and sides. One-way ANOVA (for parametric test) or Kruskal-Wallis (for nonparametric test) was used to compare the difference of the presence of PB tendon tear in each type.

### **Ethical consideration**

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

## **RESULTS**

### **Characteristics, origin and the attachment of the SPR**

The SPR had a common origin which extended from the fibrocartilaginous 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. 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. 2 - 4). Type I consisted of double bands while type II and type III had single band. Details of the characteristic of each type are described in Table 1. However, type I could be divided into 2 subtypes: type Ia and type Ib based on the site of splitting into proximal and distal bands. The splitting site of type Ia was closed to its origin (Fig. 2A, B) while that of type Ib was at its middle part (Fig. 2C, D). The prevalence of each type is shown in Table 2. The most common was type Ib and the least common was type II. In addition, a symmetrical pattern was found in 29 (52.73%) cadavers with a prevalence of 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, characteristic features found in the cadavers were type Ib with type III, type Ia with type Ib, type Ia with type III, type Ia with type II and type Ib with type II with a prevalence of 12 (21.82%), 9 (16.36%), 2 (3.64%), 1 (1.82%) and 1 (1.82%), respectively. One cadaver with only one leg of type III was excluded from consideration of symmetrical pattern.

### **The width of SPR**

Width of the SPR was obtained from its origin ( $W_o$ ) and its insertion ( $W_i$ ). The SPR had a common origin at the lateral malleolus with an average width of  $18.37 \pm 4.13$  mm. The widest part of  $W_o$  was found in type Ib. In contrast, the widest part of  $W_i$  was found in type III. In addition, the average of  $W_i$  of SPR inserted on the lateral calcaneus was lesser than those inserted on the lateral intermuscular septum (Table. 3). Comparisons of the width of SPR between genders and sides in each type revealed that only the proximal and distal band of  $W_i$  of type Ia had a statistically significant difference between sides ( $p = 0.018$  and  $0.040$ , respectively).

### **The length of SPR**

Results of the length of SPR revealed that the mean length of those inserted on the posterior intermuscular septum and on the lateral wall of the calcaneus were  $22.05 \pm 3.99$  and  $28.41 \pm 5.49$  mm, respectively. The distal band of type Ib was the longest, while type III was the shortest. Comparisons of the length of SPR between genders and sides revealed no statistically significant difference. Detail of morphometric data is tabulated in Table 4.

### **The angle of SPR**

Results of the angle of the SPR revealed that most were acute angles, 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 mean upward angle of all type was  $10.02 \pm 5.80$  degrees. All distal bands coursed downward to their insertion on the lateral border of calcaneus. The mean downward angle of all type was  $40.75 \pm 18.98$  degrees. Details of the angle of SPR in each type are described in Table 4. Comparisons of the angle of SPR between genders and sides revealed no statistically significant difference.

### **The thickness of the SPR**

The thickness of the SPR was measured at its middle part. The average thickness of both proximal and distal bands in all types was  $0.47 \pm 0.20$  and  $0.38 \pm 0.19$  mm,

respectively. The thickest SPR was found in the proximal band of type III while the thinnest was found in the distal band of type Ib. Comparisons of the thickness of SPR between genders and sides showed no statistically significant difference (Table. 4).

### **Horizontal and vertical distances from the midpoint of origin and insertion of the SPR to the inferior tip of fibula**

In order to locate the precise attachment of the SPR, 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 type. Since the proximal band of Type I and the single band of type III inserted on the posterior intermuscular septum, the midpoint of insertion was always above the fibular tip. In contrast, the distal band of type Ia, Ib and II which inserted on the lateral wall of calcaneus was 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 5). The X-coordinate represents the horizontal distance from the tip of fibula and the Y-coordinate represents the vertical distance from tip of fibula. The average coordinates (X, Y) of origin in all types were  $7.26 \pm 3.15$  (0.87-15.15) and  $10.45 \pm 4.52$  (1.69-26.23) mm. The coordinates (X, Y) of the insertion could be divided into 2 categories according to the insertion site. Average coordinates of SPR which inserted on the posterior intermuscular septum were  $24.06 \pm 4.94$  and  $13.35 \pm 5.18$ , and those inserted on the lateral wall of calcaneus were  $21.45 \pm 7.88$  and  $13.59 \pm 6.73$  mm (Table 5 and Fig. 5). 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 vertical distance of type Ib at its origin and vertical distance of type III at its insertion were significantly different between sides ( $p = 0.003$  and  $0.014$ , respectively).

### **The PB tendon tears**

After cutting the SPR at its origin, the superior peroneal tunnel (SP tunnel) was exposed. The contents of the SP tunnel are generally composed of the PB and PL tendons. The PL tendon lied superficial to the PB tendon. The PB tendon tear occurred in 14 from 109 cases (12.84%). They were found in SPR type Ib (10 cases), type III (3 cases) and type 2a (1 case). 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 extension of PB tendon tear was from above the lateral malleolus to the entrance of inferior peroneal tunnel in most cases. However, there were 2 cases of PB tendon tears extended from the retromalleolar groove to the inferior peroneal tunnel.

The intra-tester reliability on data extraction indicated good to excellent reliability (ICC (3, 1) = 0.882 – 0.999).

## DISCUSSION

Morphology of the SPR has been described in standard textbook and previous reports [2, 6, 15, 21]. The origin of SPR observed in this study was from the fibrocartilaginous ridge of the lateral malleolus with an extension to the distal tip of the fibula which was in accordance with previous studies [2, 6, 15, 21]. The SPR had at least one insertion site either on the posterior intermuscular septum or lateral wall of the calcaneus. Insertion on the posterior intermuscular septum was in accordance with that described previously[21]. Moreover, 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[3]. However, we did not find insertion on the lateral border of the calcaneal tendon as reported by Davis et al., 1994[6]. Hence, we divided the SPR based on the insertion pattern into 3 types; the double band of type I with subtype Ia and Ib, and the single band of type II and III. The difference between subtype Ia and Ib was the site of splitting into proximal and distal band.

The average length of SPR inserted on the posterior intermuscular septum was approximately 23 mm. However, the length of type III was shorter than others. The length of distal band was similar in both type Ia and Ib. The average width of origin was in accordance with previous report[6]. Thickness of SPR reported in this study was lesser than previous study in MRI[16]. This might result from the difference in method and site of measurement.

The SPR plays an important role as the primary stabilizer of peroneal tendons to prevent the subluxation/dislocation [5, 18]. Insufficiency of the SPR could cause symptomatic tendon instability and tendon injury afterwards [5, 7, 24]. The



morphometric data showed that the site of splitting of type Ib 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. 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.

There are several surgical procedures for treatment of peroneal tendon instability including the SPR repair or reconstruction, bone block procedures, and retromalleolar groove deepening [4, 5, 7, 13, 18]. Reconstruction of SPR using either autologous graft including gracilis tendon and plantaris tendon or allograft including tensor fascia latae has been reported [9, 14, 20]. Groove deepening is classically recommended in peroneal tendon instability with flat or convex retromalleolar groove contour. However, anatomical SPR reattachment without groove deepening is reported to be effective in any types of retromalleolar groove contour [4]. Morphometric data of SPR including its length, width and thickness provided in this study would be beneficial for surgical planning of graft type and harvesting in SPR reconstruction with autograft or allograft. The knowledge of coordinate of midpoint of SPR origin measured from the fibular tip would provide the precise area for attachment of repaired or reconstructed SPR on the lateral malleolus. Furthermore, the angle of the SPR and the coordinate of horizontal and vertical distance from midpoint of SPR insertion measured from fibular tip reported here can be used to design the direction and also specify the precise area for SPR reattachment on the lateral wall of calcaneus.

SPR injury resulting in peroneal tendon instability can be associated with the calcaneal fracture, especially Sanders A type of calcaneus fracture [11, 12]. In this study, the SPR had at least one insertion site on the lateral wall of calcaneus, except type III. Type II of SPR inserted solely on the lateral wall of the calcaneus. Therefore, the SPR integrity and stability of peroneal tendon should always be evaluated in the treatment of calcaneal fractures.

Limitations of this study were the use of the formalin fixed cadaver which might affect the positions 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, embalmed cadaveric legs might yield different results from fresh or soft-embalmed cadaveric legs.

## CONCLUSIONS

Characteristics 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. Morphometric data provided in this study are beneficial for SPR surgical procedures including reattachment and reconstruction. Moreover, type Ib had a trend to be associated with PB tendon tear.

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## Conflict of interested statement

The authors declare that there is no conflict of interest in this research.

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**Table 1.** Description of the types of SPR

<b>Type</b>	<b>Definition</b>
Type I	<p>Type Ia The SPR originated from fibrocartilaginous ridge of the posterolateral surface of lateral malleolus and split near its origin into 2 bands: the proximal band coursed slightly upward and distal bands coursed slightly downward to insert on the posterior intermuscular septum and lateral wall of calcaneus respectively</p> <p>Type Ib The SPR originated from fibrocartilaginous 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 distal bands coursed slightly downward to insert on the posterior intermuscular septum and lateral wall of calcaneus respectively</p>
Type II	The SPR originated from fibrocartilaginous 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 from fibrocartilaginous 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 2.** Prevalence of the SPR — N (%)

<b>Type</b>	<b>Total</b>	<b>Left</b>		<b>Right</b>	
		<b>Male</b>	<b>Female</b>	<b>Male</b>	<b>Female</b>
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)

**Table 3.** Width of the SPR — mean  $\pm$  SD (range) [mm]

Type	Width at origin		<i>p</i> -value	Width at insertion		<i>p</i> -value
Type Ia						
Proximal band	Lt.	16.57 $\pm$ 4.03 (10.33-21.11)	0.278	10.93 $\pm$ 3.84 (6.31-17.42)		0.018*
	Rt.	19.59 $\pm$ 2.42 (14.98-21.74)		16.25 $\pm$ 3.47 (11.38-21.70)		
	Total	17.58 $\pm$ 3.36 (10.33-21.74)		13.59 $\pm$ 4.47 (6.31-21.70)		
Distal band	Lt.	NA	NA	8.96 $\pm$ 3.15 (4.59-14.17)		0.040*
	Rt.	NA		12.24 $\pm$ 2.08 (8.76-14.49)		
	Total	NA		10.60 $\pm$ 3.08 (4.59-14.49)		
Type Ib						
Proximal band	Lt.	18.91 $\pm$ 3.19 (13.17-27.71)	0.081	14.51 $\pm$ 3.74 (8.23-24.07)		0.926
	Rt.	20.23 $\pm$ 3.45 (15.37-28.98)		14.53 $\pm$ 4.05 (7.96-24.38)		
	Total	19.73 $\pm$ 3.40 (13.17-28.98)		14.52 $\pm$ 3.85 (7.96-24.38)		
Distal band	Lt.	NA	NA	10.22 $\pm$ 4.25 (5.65-29.94)		0.556
	Rt.	NA		10.25 $\pm$ 2.63 (6.14-18.46)		
	Total	NA		10.23 $\pm$ 3.53 (5.65-26.94)		
Type II						
Single band	Lt.	14.53 $\pm$ 5.54 (10.62-18.45)	NA	10.83 $\pm$ 7.00 (5.88-15.78)		NA
Type III						
Single band	Lt.	16.98 $\pm$ 4.37 (8.05-25.34)	0.656	14.86 $\pm$ 2.76 (10.54-21.12)		0.573
	Rt.	17.61 $\pm$ 4.97 (10.81-26.22)		14.26 $\pm$ 3.97 (5.64-21.02)		
	Total	17.31 $\pm$ 4.65 (8.05-26.22)		14.55 $\pm$ 3.42 (5.64-21.12)		
All cases of SPR based on insertion site						
Posterior intermuscular septum				14.34 $\pm$ 3.80 (5.64-24.38)		
Lateral wall of calcaneus				10.32 $\pm$ 3.42 (4.59-26.94)		

\*statistical significance

**Table 4.** Morphometric data of the SPR — mean  $\pm$  SD (range) [mm]

Type		Length	<i>p</i>	Thickness	<i>p</i>	Angle	<i>p</i>
Type Ia							
Proximal band	Lt.	22.34 ± 5.21 (16.51-32.83)	0.716	0.52 ± 0.22 (0.19-0.75)	0.217	13.95 ± 8.31 (4.67-26.00)	0.351
	Rt.	23.39 ± 5.26 (16.70-32.35)		0.37 ± 0.19 (0.15-0.68)		10.48 ± 4.55 (3.33-14.67)	
	Total	22.86 ± 5.06 (16.51-32.83)		0.45 ± 0.21 (0.15-0.75)		12.21 ± 6.69 (3.33-26.00)	
Distal band	Lt.	22.55 ± 5.56 (16.27-32.72)	0.381	0.54 ± 0.23 (0.27-0.82)	0.291	34.57 ± 18.47 (6.67-59.33)	0.332
	Rt.	24.91 ± 4.03 (17.16-29.94)		0.43 ± 0.16 (0.24-0.64)		24.95 ± 17.13 (2.33-48.33)	
	Total	23.73 ± 4.82 (16.27-32.72)		0.49 ± 0.20 (0.24-0.82)		29.76 ± 17.83 (2.33-59.33)	
Type Ib							
Proximal band	Lt.	23.01 ± 3.45 (18.45-31.15)	0.633	0.46 ± 0.18 (0.17-0.86)	0.954	10.32 ± 5.78 (0.00-19.00)	0.125
	Rt.	22.57 ± 2.93 (16.24-27.76)		0.46 ± 0.22 (0.20-0.98)		8.13 ± 3.58 (3.67-19.33)	
	Total	22.80 ± 3.18 (16.24-31.15)		0.46 ± 0.20 (0.17-0.98)		9.27 ± 4.92 (0.00-19.33)	
Distal band	Lt.	28.79 ± 4.71 (22.38-40.71)	0.073	0.29 ± 0.15 (0.08-0.63)	0.180	43.72 ± 15.36 (10.67-73.33)	0.910
	Rt.	30.83 ± 5.03 (22.50-39.44)		0.37 ± 0.19 (0.11-0.78)		44.33 ± 21.18 (3.67-83.33)	
	Total	29.77 ± 4.92 (22.38-40.71)		0.33 ± 0.17 (0.08-0.78)		44.02 ± 18.23 (3.67-83.33)	
Type II							
Single band	Lt.	26.39 ± 3.54 (23.89-28.89)	NA	0.73 ± 0.25 (0.55-0.91)	NA	18.69 ± 4.68 (15.38-22.00)	NA
Type III							
Single band	Lt.	20.30 ± 3.09 (15.68-26.60)	0.438	0.49 ± 0.22 (0.14-0.93)	0.707	10.27 ± 5.40 (0.00-18.33)	0.609
	Rt.	21.27 ± 4.92 (13.13-36.64)		0.46 ± 0.17 (0.22-0.76)		9.32 ± 6.76 (0.00-23.00)	
	Total	20.82 ± 4.15 (13.13-36.64)		0.47 ± 0.20 (0.14-0.93)		9.76 ± 6.11 (0.00-23.00)	

All cases of SPR based on insertion site			
Posterior intermuscular septum	22.05 ± 3.99 (13.13-36.64)	0.47 ± 0.20 (0.14-0.98)	10.02 ± 5.80 (0.00-26.00)
Lateral wall of calcaneus	28.41 ± 5.49 (16.27-40-71)	0.38 ± 0.19 (0.08-0.82)	40.75 ± 18.98 (2.33-83.33)

**Table 5.** Horizontal and vertical distances from mid-point of SPR to the inferior tip of fibula — mean ± SD (range) [mm]

Type	Origin				Insertion				
	X axis	<i>p</i>	Y axis	<i>p</i>	X axis	<i>p</i>	Y axis	<i>p</i>	
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		22.94 ± 8.00 (14.90-35.14)	0.909	14.48 ± 4.64 (7.20-22.38)	0.166
	Rt.	NA		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)		8.27 ± 2.56 (3.85-14.33)		23.27 ± 5.80 (10.46-35.67)		12.54 ± 4.39 (4.24-21.44)	
	Rt.	6.74 ± 2.56	0.749	10.70 ± 2.77	0.003	24.10 ± 3.96	0.56	14.68 ± 5.07 (5.32-	0.12

		(2.36-11.64)		(4.21-15.98)	*	(16.57-32.37)	8	22.64)	5
	Tota l	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		20.94 ± 8.39 (8.54-36.79)		14.19 ± 6.94 (0.00-27.69)	
	Rt.	NA	NA	NA	NA	20.95 ± 7.70 (11.17-38.66)	0.43 9	13.73 ± 7.19 (0.00-31.79)	0.82 4
	Tota l	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)		9.78 ± 3.57 (1.69-17.33)		21.90 ± 3.83 (13.85-29.14)		12.27 ± 5.37 (1.06-20.34)	
	Rt.	7.22 ± 3.39 (0.87-13.74)	0.587	9.79 ± 3.02 (4.62-17.28)	0.988	25.51 ± 4.81 (17.43-36.49)	0.01 4*	12.64 ± 4.00 (3.12-18.37)	0.79 0
	Tota l	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)	
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, \*statistical significance



**Table 6.** Prevalence of PB tendon tear and its association between types — N (%)

SPR	Peroneus brevis tendon tear		<i>p</i> -value
	Present	Absent	
Type Ia	1 (7.14)	13 (92.86)	
Type Ib	10 (20.83)	38 (79.17)	0.001*
Type III	3 (6.67)	42 (93.33)	

\*statistical significance

**Figure 1.** Illustration showing ankle supporting frame to maintain the foot in neutral position and measurement of all parameters in this position; **A.** Angle of the SPR to the horizontal axis; **B.** The width at the origin and insertion; **C.** The length of the SPR; **D.** The horizontal distance from mid-point of SPR origin and insertion to tip of fibula(\*); **E.** The vertical distance from mid-point of SPR origin and insertion to tip of fibula; **F.** The cutting line; Wo(prox.) - width at origin of proximal band; Wi(prox.) - width at the insertion of proximal band; Wi(dis.) - width at the insertion of distal band; Ho – horizontal distance from mid-point of origin to tip of fibula; Hi(prox.) - horizontal distance from mid-point of insertion of proximal band to tip of fibula; Hi(dis.) - horizontal distance from mid-point of insertion of distal band to tip of fibula; L(prox.) - length of the SPR proximal band; L(dis.) - length of the SPR distal band; SPR - superior peroneal retinaculum; IER - inferior extensor retinaculum

**Figure 2.** Photograph and illustration of type Ia (**A.** and **B.**) and Ib (**C.** and **D.**) of SPR. SPR (prox) and SPR (dis) inserted on the posterior intermuscular septum and lateral wall of calcaneus; IER - inferior extensor retinaculum; IPR - inferior peroneal retinaculum; LM - lateral malleolus; SER - superior extensor retinaculum; SPR -

superior peroneal retinaculum; SPR(prox) -superior peroneal retinaculum proximal band; SPR(dis) -superior peroneal retinaculum distal band

**Figure 3.** Photograph and illustration of Type II (**A.** and **B.**) of SPR with a single band inserted on lateral wall of the calcaneus; IER - inferior extensor retinaculum; IPR - inferior peroneal retinaculum; LM - lateral malleolus; SER - superior extensor retinaculum; SPR - superior peroneal retinaculum.

**Figure 4.** Photograph and illustration of Type III (**A.** and **B.**) of SPR with a single band inserted on posterior intermuscular septum; IER - inferior extensor retinaculum; IPR - inferior peroneal retinaculum; LM - lateral malleolus; SER - superior extensor retinaculum; SPR - superior peroneal retinaculum.

**Figure 5.** Illustrations of coordinates 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; **D.** Type III; SPR - superior peroneal retinaculum; IPR - inferior peroneal retinaculum; SER - superior extensor retinaculum.











