Anatomical Variations of the Piriformis Muscle Morphology and It's Relationship to the Sciatic Nerve

ความแปรผันทางกายวิภาคศาสตร์ของลักษณะทางสัณฐานวิทยาของกล้ามเนื้อ Piriformis และความสัมพันธ์ระหว่างเส้นประสาท Sciatic

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ABSTRACT

The piriformis (PM) is a triangular shaped muscle which is located deep in the gluteal region. Normally, the PM is positioned adjacent to the sciatic nerve (SN). The knowledge of the PM morphology and the anatomical relationship between the SN and PM is essential for clinical practices and relevant medical operations. This research aimed to study toward the PM morphology and its relationship to the SN. The gluteal regions from 102 cadavers were dissected. Six variations of the PM morphology have been observed. The most common morphology was triangular shape (67.65%). According to the classification of Beaton and Anson on the relationship of the SN and PM, the percentage of type a, type b and type c were 74.02%, 22.55% and 3.43% respectively. The result from this study is intended to be applied for the effectiveness of the piriformis syndrome diagnosis and treatment. Likewise, it is expected to have some benefits in reducing the number of the SN injuries when performing medical operations.

บทคัดย่อ

Piriformis (PM) คือ กล้ามเนื้อรูปสามเหลี่ยมบริเวณก้นชั้นลึก ปกติจะวางพาดทับเส้นประสาท sciatic (SN) ซึ่งเป็นเส้นประสาทไขสันหลังที่มีขนาดใหญ่ที่สุดในร่างกาย ความรู้เกี่ยวกับลักษณะทางสัณฐานวิทยาของ PM และความสัมพันธ์ทางกายวิภาคศาสตร์ระหว่าง SN และ PM มีความสำคัญทางคลินิกและการทำหัตถการที่เกี่ยวข้อง จึงเป็นที่มาของการศึกษาวิจัยครั้งนี้ ซึ่งมีวัตถุประสงค์เพื่อศึกษาลักษณะทางสัณฐานวิทยาของ PM และความสัมพันธ์ทางกายวิภาคศาสตร์ระหว่าง SN และ PM โดยทำการศึกษาจากร่างอาจารย์ใหญ่ 102 ร่าง พบลักษณะทางสัณฐานวิทยาของ PM 6 รูปแบบโดยรูปแบบที่พบมากที่สุดคือ กล้ามเนื้อเป็นรูปสามเหลี่ยม (67.65%) ประเภทความสัมพันธ์ระหว่าง SN และ PM ที่พบประกอบด้วย รูปแบบ a (74.02%), b (22.55%) และ c (3.43%) ตามการแบ่งของ Beaton และ Anson ผลที่ได้จากการศึกษาครั้งนี้คาดว่าจะช่วยป้องกันและลดจำนวนการบาดเจ็บของ SN ในการทำหัตถการทางการแพทย์บริเวณที่เกี่ยวข้อง รวมทั้งเพิ่มประสิทธิภาพของการวินิจฉัย และรักษาภาวะ piriformis syndrome ในอนาคต

Keywords: Piriformis muscle, Sciatic nerve, Anatomical variation

คำสำคัญ: กล้ามเนื้อ piriformis เส้นประสาท sciatic ความแปรผันทางกายวิภาคศาสตร์

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Introduction

The piriformis (PM) is a triangular shaped muscle which the origin is located on each side of ventral surface of sacrum and sacrotuberous ligament. It exits the pelvic cavity by sliding beneath the greater sciatic notch, then run diagonally downwards and attaches on the greater trochanter (Michel et al., 2013). It receives the innervation from anterior rami of first and second sacral spinal nerves. The PM is responsible for the external rotation and the abduction of the hip joint. It also helps to retain the head of femur in the acetabulum (Agur, Dalley II, 2009). The study by Haladaj et al. (2015) founded other morphology of piriformis muscle beside of triangle shape. The muscle was divided into two parts by the branch of the sciatic nerve which passed between them. This variation had been observed in 20% of their specimens. In 10% of sample, piriformis combined with gluteus medius muscle. Moreover, Nicholson suggested the possible fusion of the PM to gluteus minimus, gemellus superior, or obturator internus muscles (Nicholson et al., 2016). The sciatic nerve (SN) is the largest peripheral nerve in the body. It is originated by the combination of ventral rami of the spinal nerves from the fourth lumbar level to the third sacral level. Generally, the SN exits from the pelvis through the greater sciatic foramen and passes under the PM, travels between greater trochanter and ischial tuberosity to the back of thigh. Then, it terminates by bifurcating into the tibial (TN) and common fibular nerves (CFN) when it reaches the apex of the popliteal fossa. The SN serves a vital role in controlling the muscles of the back of the thigh, the leg and the foot. It is also responsible for the sensation of the skin of the entire lower leg, as well as the foot. Moreover, it provides articular branches to the joints of lower limb (Chung KW, Chung HM, 2012; Moore, 2014). 96% of population had normal relationship between the SN and the PM in which undivided SN passed below triangular shape PM (Boyajian-O'Neill et al., 2008). Beaton and Anson (1937) performed a study in 120 cadavers and classified the form of relationship between the PM and the SN into six types (Figure 1). The systematic review by Tomaszewski et al. (2016) in 45 studies and 7068 limbs founded 85.2% of type a, 9.8% of type b, and 1.9% of type c. Type d, f, and g were founded less than 1%.

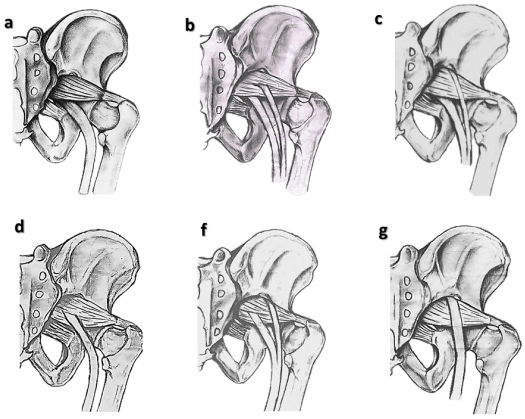

Figure 1 The six types of the anatomical relationship between the SN and the PM are from the classification of Beaton and Anson (1937).

The data of anatomical variation between the SN and the PM is importance, because it is more likely to be the cause of pathological condition, such as the sciatic nerve injuries during and after hip surgery (Pokorný et al., 2006; Kanawati, 2014; Tomaszewski et al., 2016) and piriformis syndrome (Boyajian-O'Neill et al., 2008; Hopayian et al., 2010). Piriformis syndrome is a group of symptoms that the patient has pain in the buttock, or the lower back,

and radiates to the back of thigh and legs along the distribution of sciatic nerve. The cause of piriformis syndrome is the SN compression by the PM. Proposed mechanism for piriformis syndrome includes predisposition to nerve compression by congenital variations of the SN or the PM, in which the SN or its division passes through the belly or tendinous portions of a normal muscle or the bellies of a bifid muscle. Previous study revealed that 16.2% of piriformis syndrome patients were associated with anatomical variation (Smoll, 2010).

Objectives of the study

The objective of this study was to classify the PM morphology and type of relationship between the SN and the PM according to the classification of Beaton and Anson in Thai cadavers.

Methodology

The study performed in the gluteal regions and posterior of thighs of Thai cadavers from the Department of Anatomy, Faculty of Medicine, Chulalongkorn University. Prior to commencing the study, ethical clearance was sought from The Institutional Review Board of the Faculty of Medicine, Chulalongkorn University. 204 formalin-fixed human lower limbs from 102 cadavers were used. 110 limbs were male and 94 limbs were female. The average age of the cadavers was 74.94 ±11.94 years. Subcutaneous fatty layer of gluteal region and the other unrelated structure have been removed to expose the PM and the SN under the layer of the gluteus maximus muscle. Observation of the PM morphology and the anatomical relationship between the SN and the PM were assessed. Data were recorded on the case record form and the photographs were taken.

Results

PM Morphology

The morphology of the PM was classified into six types according to its shape and division. Table 1 illustrates the detail of the finding.

Table 1 Piriformis muscle morphology

Characteristics of PM	Total (sides, %)	Left (sides, %)	Right (sides, %)	Male (sides, %)	Female (sides, %)
1.Typical morphology (pear-shaped)	138 (67.65%)	71 (34.80%)	67 (32.85%)	74 (36.28%)	64 (31.37%)
2.Piriformis muscles are divided into two parts with the common fibular nerve running between them	39 (19.12%)	22 (10.78%)	17 (8.33%)	19 (9.31%)	20 (9.80%)
3.The fusion of piriformis muscle with the gluteus medius muscle	19 (9.31%)	7 (3.43%)	12 (5.88%)	12 (5.88%)	7 (3.43%)
4.Piriformis muscles have two heads	4 (1.96%)	2 (0.98%)	2 (0.98%)	4 (1.96%)	0 (0%)
5.The lower edge of piriformis muscles have thick and curve tendon	3 (1.47%)	0 (0%)	3 (1.47%)	1 (0.49%)	2 (0.98%)
6.Piriformis muscle has accessory tendon between divided sciatic nerve	1 (0.49%)	0 (0%)	1 (0.49%)	0 (0%)	1 (0.49%)
Total	204 (100%)	102 (50%)	102 (50%)	110 (53.92%)	94 (46.08%)

As shown in figure 2 and Table 1, type I was the PM which had the typical morphology. The muscle was the pear or triangular shaped (Figure 2A). This type was observed in 138 specimens (67.65%). Seventy four limbs were males and 64 limbs were females. This study founded the special case in one sample. Some part of the PM was covered by gluteus medius muscle (Figure 2B, 2C). Type II, the PM was divided into two parts with the CFN running between them (Figure 3). This variation was found in 39 specimens (19.12%). Nineteen limbs were males and 20 limbs were females. A fusion of PM with the gluteus medius muscle was type III (Figure 4). The superior gluteal vessels and nerve run between fused muscle fibers. This study founded in 19 limbs (9.31%). 12 limbs were males and 7 limbs were females.

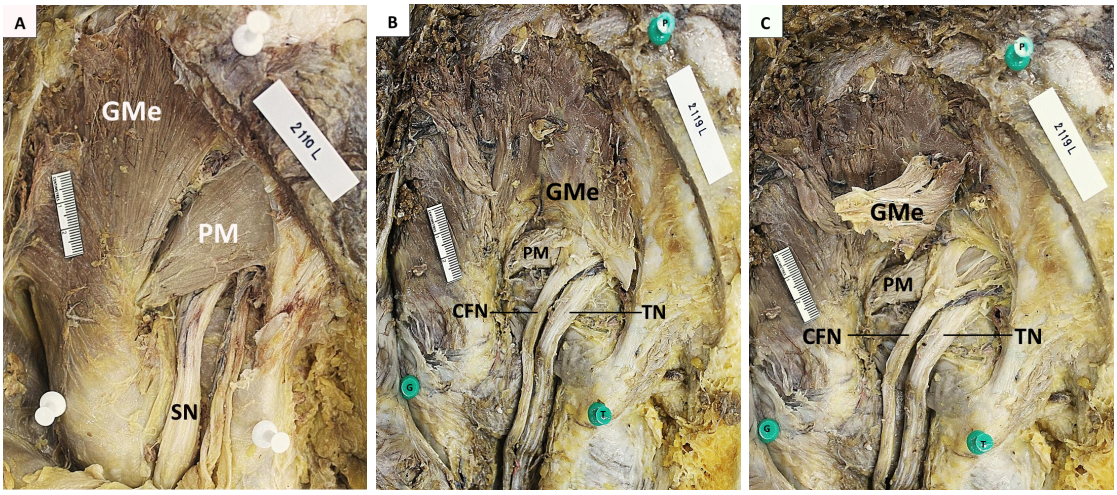

Figure 2 Photographs of gluteal dissection, demonstrating Type I PM morphology: A) Type I or Typical morphology which PM was the pear or triangular shaped; B) Gluteus medius muscle covered some part of typical PM; C) PM placed beneath gluteus medius which some part of its origin was cut and rolled up.

(GMe = gluteus medius muscle, PM = piriformis muscle, SN = sciatic nerve, CFN = common fibular nerve, TN = tibial nerve, P = PSIS, G = greater trochanter, T = Ischial tuberosity)

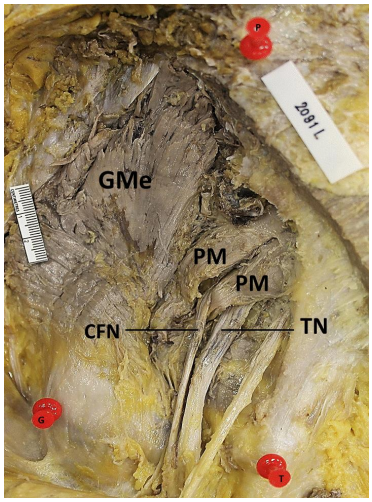

Figure 3 Type II: PM was divided into two parts with CFN running between them.

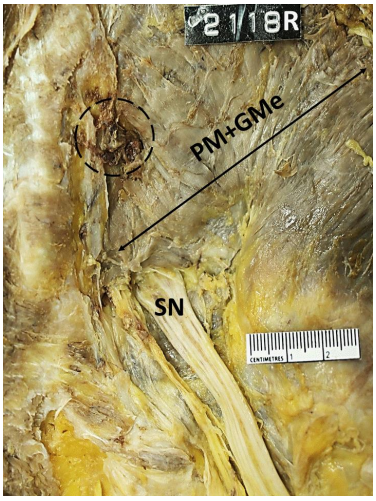

Figure 4 Type III: PM was fused with the gluteus medius muscle.

(GMe = gluteus medius muscle, PM = piriformis muscle, SN = sciatic nerve, CFN = common fibular nerve, TN = tibial nerve, P = PSIS, G = greater trochanter, T = Ischial tuberosity)

In addition, there were three types as shown in figures 5 that have never been reported before. In type IV (1.96%), the PM was divided into two heads. The superior gluteal nerve and vessels passed between them (Figure 5A). Type V (1.47%), the lower edge of the PM composed of a curve and thick tendon (Figure 5B). Lastly, in type

VI, there was an accessory tendon lied between the bifurcated nerves. This tendon was inserted to lesser trochanter (Figure 5C). This type was founded in only one limb of female.

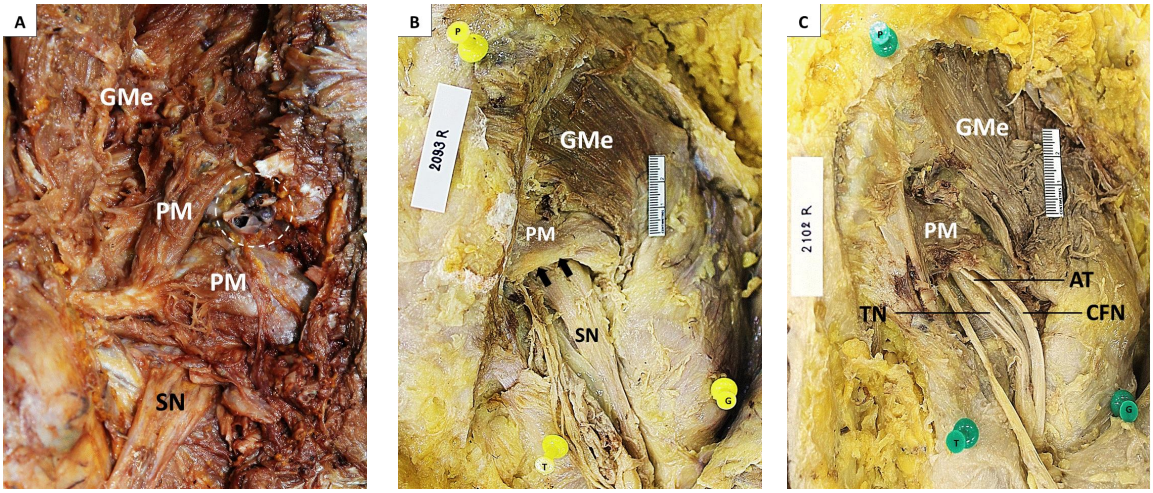

Figure 5 Photographs of gluteal dissection, demonstrating PM morphologies that have never been reported before: A) Type IV: PM had two heads with the superior gluteal nerve and vessels (white circle) running between them; B) Type V: PM had thick and curve tendon at the lower edge (black arrows); C) Type VI: PM had an accessory tendon lied between the bifurcated nerves.

(GMe = gluteus medius muscle, PM = piriformis muscle, SN = sciatic nerve, CFN = common fibular nerve, TN = tibial nerve, AT = accessory tendon, P = PSIS, G = greater trochanter, T = Ischial tuberosity)

Anatomical variation between SN and PM

In this study material, there were three types of relationship between the SN and the PM according to the classification of Beaton and Anson (Beaton, Anson, 1937) , these were type a, b and c. The details of each type were displayed in table 2. Type a or typical course of the SN, a single trunk of nerve passed through the infrapiriform foramen was observed in 151 limbs (74.02%) (Figure 6A). 82 of them were males and 69 were females. Type b in which the CFN passed between the spitted the PM and the TN passed under the PM was found in 46 limbs (22.55%) (Figure 6B).Twenty-four limbs were males and twenty-two limbs were females. Seven limbs were type c, in which the CFN passed above and the TN was below PM (Figure 6C). This variation was found in 4 male limbs and 3 female limbs. In this type, special features were found in 2 cases. In one case, the CFN formed by the combination of a branch passing above the PM and another branch below the PM (Figure 7A). In the other case, the CFN was originated from two branches above the PM and one branch below the PM (Figure 7B).

Table 2 The anatomical relationship between sciatic nerve and piriformis muscle.

Types	Number of limb	Left	Right	Male	Female
a	151 (74.02%)	75 (36.77%)	76 (37.26%)	82 (40.20%)	69 (33.83%)
b	46 (22.55%)	24 (11.76%)	22 (10.78%)	24 (11.76%)	22 (10.78%)
c	7 (3.43%)	3 (1.47%)	4 (1.96%)	4 (1.96%)	3 (1.47%)
Total	204(100%)	102 (50.00%)	102 (50.00%)	110 (53.92%)	94 (46.08%)

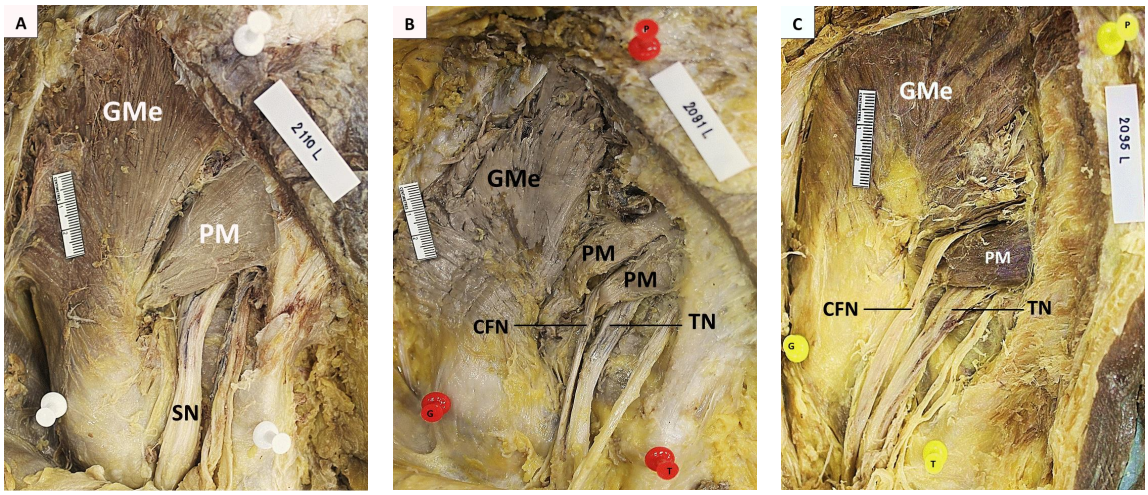

Figure 6 Posterior view of deep gluteal regions, showing anatomical relationship between the SN and the PM: A) Type a: The single trunk of the SN passed under the PM; B) Type b: the PM was divided into two parts with the CFN running between them; C) Type c: the CFN passed above and TN was below PM.

(GMe = gluteus medius muscle, PM = piriformis muscle, SN = sciatic nerve, CFN = common fibular nerve, TN = tibial nerve, P = PSIS, G = greater trochanter, T = Ischial tuberosity)

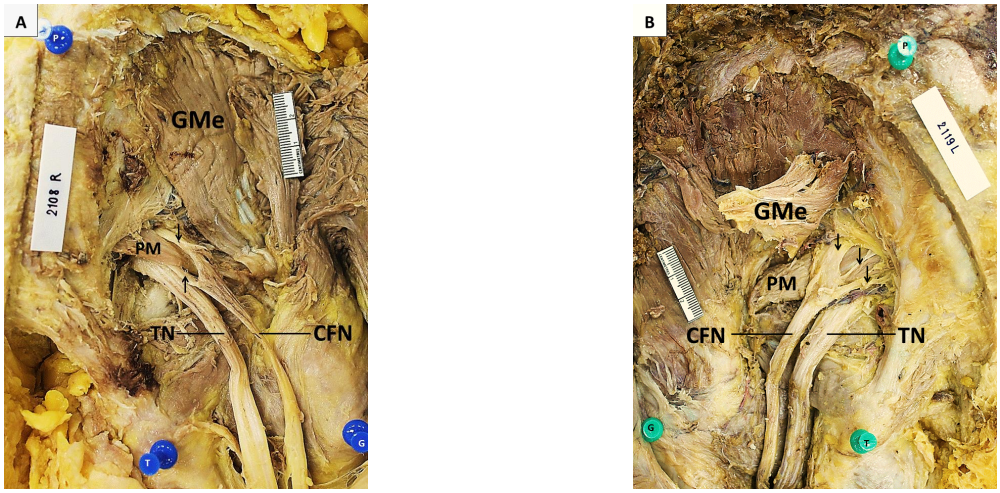

Figure 7 Photographs of gluteal dissection, displaying Type c with the special formation of the CFN: A) CFN was resulted from the combination of a branch above PM and a branch below PM (black arrows); B) CFN was originated from two branches above PM and one branch below PM (black arrows).
(GMe = gluteus medius muscle, PM = piriformis muscle, CFN = common fibular nerve, TN = tibial nerve, P = PSIS, G = greater trochanter, T = Ischial tuberosity)

In the issue of the symmetrical relationship between SN and PM (table 3), 77 cadavers or 75.49 % were symmetry: Sixty five cadavers were type a, 11 cadavers were type b. Only one cadaver was type c. Conversely, the other 25 cadavers or 24.51% were asymmetry. These were divided into 3 formats as shown in table 3.

Table 3 The symmetrical relationship between sciatic nerve and piriformis muscle.

Types	Frequency (cadaver)		Total (cadaver)	%
	Male	Female		
Symmetry				
a	35	30	65	63.73
b	5	6	11	10.78
c	1	0	1	0.98
total	41	36	77	75.49
Asymmetry				
a & b	12	8	20	19.61
a & c	0	1	1	0.98
b & c	2	2	4	3.92
total	14	11	25	24.51
Total	55	47	102	100

Discussion

The PM morphology has been reported in the literature. Haladaj et al. (2015) demonstrated three types of the PM. The results of this study confirmed the finding of previous studies (Haladaj et al., 2015; Nicholson et al., 2016). These morphologies were triangular shaped or typical morphology, divided muscle into two parts and fused with gluteus medius. One case of typical morphology is the PM was covered by gluteus medius muscle. The close relationship between the PM and gluteus medius might increase the pressure on the SN. This could be the cause of sciatic nerve compression. Moreover, the result of this study revealed three morphologies that had not been reported. Firstly, the PM had two heads. Secondly, the PM had a thick and curve tendon at the lower edge. The thick and curvy tendon was close to the SN which might be the cause of SN entrapment. Lastly, the PM had an accessory tendon between the bifurcated nerves.

The classification of the anatomical relationship between the SN and the PM by Beaton and Anson was used in this study (Beaton, Anson, 1937). Type a, b, and c were reported in this study. The most common relationship was type a followed by type b and type c was least. The total of atypical relationships was 25.98%. Forty-three point two percent of atypical relationship cases were symmetry. It is a possibility that if someone has anomaly on one side, he will also has on the other side. Table 4 displayed the frequency of anatomical variation between the SN and the PM in literatures. The variations were various from 9.5 to 35.8%. When compared the result of this study with other studies (Table 4), it was consistent with the findings of most studies, especially the study of Purnindhu (1983) in Thai cadavers and systematic reviewed by Tomaszewski in 2015. The subgroup analysis according to geography by

Tomaszewski showed that type b had a higher prevalence in Asian population when compared to American, Europe, and African population (Tomaszewski et al., 2016). Type b and c might cause primary piriformis syndrome because the nerves passed through the muscle fibers or tendon which could promote the nerve compression (Boyajian-O'Neill et al., 2008; Hopayian et al., 2010). In addition, Type b and c could be predisposing factor of tension injury from traction and manipulation and increase the risk of direct trauma on the CFN because SN had firmly relationship with muscles around hip joint and the position of CFN was superficial (Tomaszewski et al., 2016). Type b and c were found more than one-fourth of samples in this study. It is Interesting that this case was more common in male. Furthermore, the variation could be the cause of sciatic nerve palsy after hip surgery (Kanawati, 2014). In some cases of hip replacement surgery, the cutting of muscle's tendon (tenotomy) around pelvis which inserted at the trochanter was necessary to perform. This procedure could be the cause of muscle contraction and compression of the sciatic nerve or its branch (Pokorný et al., 2006). In 1995, Navarro et al. has suggested that anatomical variations are the primary cause of sciatic nerve palsy after surgery, especially in the posterior approach. It might be due to the muscle groups including the PM that are used to rotate the hip out, are cut which causes SN injuries (Navarro et al., 1995). Moreover, in the case of the sciatic nerve block, anesthetic could affect only one branch of the SN (Tomaszewski et al., 2016).

Although type d, f, and g were not record in this study, there were the finding of type d, f, g and other relationship in many studies. Pokorny et al. (2006) shown 2.2 % of type d and Natsis et al. (2014) reported 0.3%. Type f was discovered in the study of Nizankowski et al. (1972) and Lee and Tsai (1974). In addition, Lee and Tsai found out type g relationship in their specimens as well as Natsis et al. For other relationship, Anbumani et al. (2015) and Natsis et al. (2014) were report. The missing of these variations in this study may be resulted from small size of samples. However, the medical staffs should be aware of the possibility of these relationships.

Table 4 The studies of the anatomical relationship between sciatic nerve and piriformis muscle categorized as a form of Beaton and Anson.*

Investigator	Cadavers (Sides)	Nationality	Atypical type Cadavers (%) **		Types of relationship (Sides)							Total atypical limbs (%)
			Asymmetry	Symmetry	a	b	c	d	f	g	Other	
Trotter, 1932	232(464)	US	24	48(63.6)	400	-	-	-	-	-	-	20 (14.5)
Beaton and Anson,1937	60(120)	US	5	14(73.6)	101	14	4	1	0	0	-	64 (15.8)
Ming-Tzu, 1941	70(140)	Chinese	22	24(52.2)	92	46	0	2	0	0	-	48 (34.3)
Misra, 1954	150(300)	Indian	-	-	262	18	12	8	0	0	-	38 (12.7)
Nizankowski et al.,1972	100(200)	Polish	-	-	181	8	3	5	3	0	-	19 (9.5)
Lee and Tsai, 1974	84(168)	Taiwanese	-	-	118	33	7	3	2	5	-	50 (29.8)
Pecina, 1979	65(130)	Yugoslav	-	-	102	27	1	0	0	0	-	28 (21.5)
Buranindu, 1983	217(434)	Thai	50(64.1)	28 (35.9)	325	101	8	0	0	0	-	109 (25.1)
Chiba, 1992	257(511)	Japanese	-	-	328	173	10	0	0	0	-	183 (35.8)
Benzon et al., 2003	36(66)	US	1	0	65	1	0	0	0	0	-	1 (1.5)
Agur and Dalley, 2005	320(640)	-	-	-	557	79	3	0	0	0	-	82 (12.8)
Ugrenovic et al., 2005	100(200)	Serbian	-	-	192	5	3	0	0	0	-	8 (4.0)
Pokorny et al., 2005	91	Czech	-	-	72	13	4	2	0	0	-	19 cases (20.9)
Guvencer et al., 2009	25(50)	Turkish	-	-	38	8	4	0	0	0	-	12 (24.0)
Natsis et al., 2013	147(294)	Caucasian	-	-	275	12	1	1	0	1	4	19 (6.4)
Anbumani et al., 2015	25(50)	Indian	-	-	45	2	2	0	0	0	1	5 (10)
Tomaszewska et al, 2015	- 45 studies (7068) - 9 studies (637)	Review	-	(8.3)	85.2%	9.8%	1.9%	<1			-	-
Budhiraja et al, 2016	30(60)	Indian	-	-	41	8	11	0	0	0	-	19 (31.66)
This study, 2016	102 (204)	Thai	21(56.8)	16(43.2)	151	46	7	0	0	0		53 (25.98)

*Some data were compiled from the study of Smoll (2010).

**Total number of cadavers who have atypical type used as denominator

Conclusion

The results of this research showed six PM morphologies and three types of anatomical relationship between the SN and the PM. Understanding the anatomical variation of the SN and the PM might reduce the number of sciatic nerve injury and optimize the efficacy of diagnosis and treatment of piriformis syndrome.

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