

Anatomic considerations and the relationship between the piriformis muscle and the sciatic nerve

Mustafa Güvençer · Pınar Akyer · Cihan İyem · Süleyman Tetik · Sait Naderi

Received: 22 January 2008 / Accepted: 20 March 2008 / Published online: 6 May 2008
© Springer-Verlag 2008

Abstract

Stating background The piriformis syndrome is one of the non-discogenic causes of sciatica. It results from the compression of the sciatic nerve (SN) by the piriformis muscle (PM) in the neutral and piriformis stretch test position. The evidence of the increase in pain in the test position requires a detailed anatomical study addressing the changes that occurred in the SN and PM anatomy during the test position. The aim of this study is to examine this relationship morphometrically.

Materials and methods A total of 20 right and left lower limbs of ten adult cadavers were examined. The SN and the PM were made visible. The location of the SN was evaluated with respect to the consistent bony landmarks, including the greater and the lesser trochanter of the femur, the ischial tuberosity, the ischial spine of the hip bone, the posterior inferior iliac spine of the hip bone and the posterior superior iliac spine of the hip bone. The study was done in both neutral and test positions (i.e., 30° adduction 60° flexion and approximately 10° medial rotation position of the hip joint).

Results The width of the greater sciatic notch was 63.09 ± 13.59 mm. The length of the lower edge of the PM was 95.49 ± 6.21 mm, and whereas the diameter of the SN where it emerged from the infrapiriforme was 17.00 ± 3.70 mm, the diameter decreased to 11.03 ± 2.52 mm at the level of the lesser trochanter of the femur. The SN

intersected the PM most commonly in its medial second quarter anatomically. The vertical distance between the medial edge of the SN–PM intersection point and the ischial tuberosity was 85.62 ± 17.23 and 72.28 ± 7.56 mm ($P < 0.05$); the angle between the SN and the transverse plane was $66.36^\circ \pm 6.68^\circ$ and $71.90 \pm 8.48^\circ$ ($P < 0.05$); and the vertical distance between the medial edge of the SN and the apex of the ischial spine of the hip bone was 17.33 ± 4.89 and 15.84 ± 4.63 mm ($P > 0.05$), before and after the test position, respectively.

Conclusion This study provides helpful information regarding the course and the location of the SN. The presented morphometric data also revealed that after stretch test position, the infrapiriforme foramen becomes narrower; the SN becomes closer to the ischial spine of the hip bone, and the angle between the SN and the transverse plane increases. This study confirmed that the SN is prone to be trapped in the test position, and diagnosis of this situation requires dynamic MR and MR neurography study.

Keywords Piriformis muscle · Sciatic nerve · Sciatica · Piriformis syndrome · Gluteal region

Introduction

Sciatica commonly defines a painful state resulting from the compression of the nerves forming the sciatic nerve (SN) by intervertebral disc herniation. This state may also occur as a result of non-discogenic disorders. Piriformis syndrome (PS) is one of the major causes of non-discogenic sciatica.

The SN is the thickest nerve in the body and innervates the posterior compartment of the thigh and all compartments of the lower leg and foot. It is formed in the pelvis

M. Güvençer (✉) · P. Akyer · C. İyem · S. Tetik
Department of Anatomy, School of Medicine,
Dokuz Eylül University, 35340 Balçova/İzmir, Turkey
e-mail: mustafa.guvenecer@deu.edu.tr

S. Naderi
Department of Neurosurgery, School of Medicine,
Yeditepe University, İstanbul, Turkey

from the ventral rami of the L4–S3 spinal nerve roots, and enters the lower limb via the greater sciatic foramen below the piriformis together with the posterior cutaneous, pudendal, obturator internus and inferior gluteal nerves. It descends between the greater trochanter and the ischial tuberosity [25]. In the pelvis, the nerve descends inferior and posterior to the piriformis muscle (PM), one of the deep muscles of the gluteal region. The PM arises from the anterior surface of the sacrum. It also arises from the gluteal surface of the ilium near the posterior inferior iliac spine, from the capsule of the adjacent sacroiliac joint. The PM passes out of the pelvis through the greater sciatic foramen and inserts into the medial side of the upper border of the greater trochanter of the femur via a rounded tendon [18, 25].

The PM belongs to the group of the pelvi-trochanteric muscles. Within the pelvis, the anterior surface of the PM is related to the rectum, the sacral plexus of the nerves and the branches of the internal iliac vessels. Its posterior surface lies against the sacrum. Outside the pelvis, its anterior surface is in contact with the posterior of the ischium and the hip joint capsule and its posterior surface with the gluteus maximus. Its upper border is in contact with the gluteus medius and the superior gluteal vessels and nerve, and its lower border with coccygeus and gemellus superior [18, 25]. Obturator internus, gemelli and quadratus femoris share common insertions with the PM and can compensate for a loss of its function [19].

The relationship between the PM and the SN is variable. The undivided nerve may emerge above the muscle or through the muscle. The major divisions of the nerve may lie on either side of the muscle, or (the most common variation) one division either above or below [4, 5, 21, 22].

This close relationship requires knowledge of the anatomical and the morphometrical aspects of the SN and the PM. The aim of this study was to define the location and the anatomical relationships of the PM and the SN, the relation between the anatomical structures restricting infrapiriforme foramen and the SN, as well as to compare the results obtained in the static position with those obtained after PM stretch test.

Materials and methods

Ten adult male cadavers with no pathology were used for this study. Totally, 20 right and left lower limbs were examined. The SN and the PM were exposed after deep dissection of the gluteal region, and the consistent bony landmarks surrounding the SN and the PM were determined (Figs. 1, 2). The location of the SN was evaluated with respect to the location of the greater trochanter of the femur, the lesser trochanter of the femur, the ischial

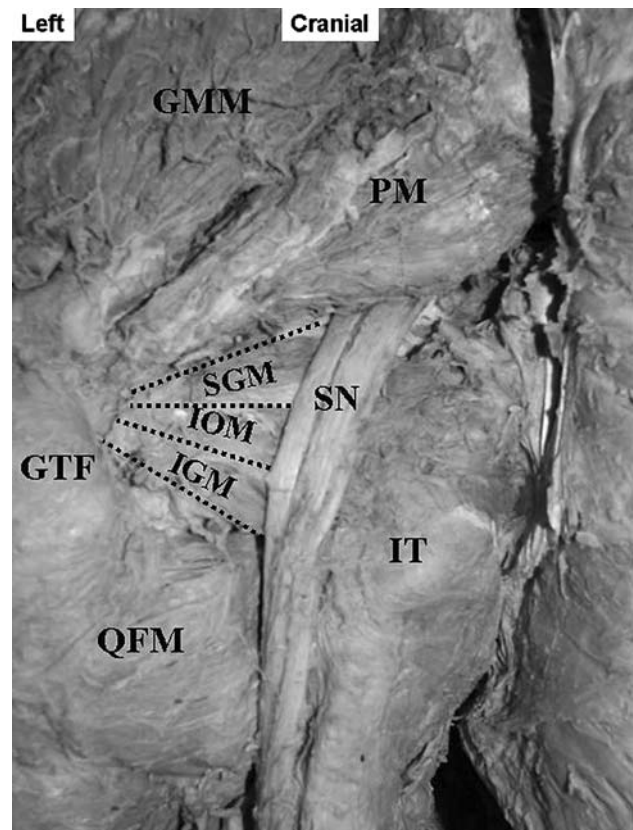


Fig. 1 The piriformis muscle (PM) and the sciatic nerve (SN) localization in the left gluteal region. GMM gluteus maximus muscle, SGM superior gemellus muscle, IGM inferior gemellus muscle, IOM internal obturator muscle, QFM quadratus femoris muscle, GTF greater trochanter of the femur, IT ischial tuberosity

tuberosity, the ischial spine of the hip bone, the posterior inferior iliac spine of the hip bone and the posterior superior iliac spine of the hip bone (Fig. 3). To get the best orientation, the distances between the bony landmarks were also measured. Morphometric characteristics of the SN and the PM, the relation between the SN and the PM (Figs. 4, 5) and their distance to consistent bony landmarks were measured. (Table 1).

To expose the relation between the SN and the PM, the lower edge of the PM, from the apex of the greater trochanter of the femur to the greater sciatic notch, was divided into four equal parts, and the positions of both medial and lateral edges of the SN with respect to each quarter were determined (Fig. 6).

The distances were measured with Mitotoyo digital caliper (Aurora, IL, USA) accurate to 0.01 mm, and the angles were measured with a goniometer accurate to 1°.

The measurements were made first in the anatomical position and then in a position simulating the PM stretch test (i.e., 60° flexion, 30° adduction and 10° internal rotation of the pelvis joint) [12] (Fig. 7).

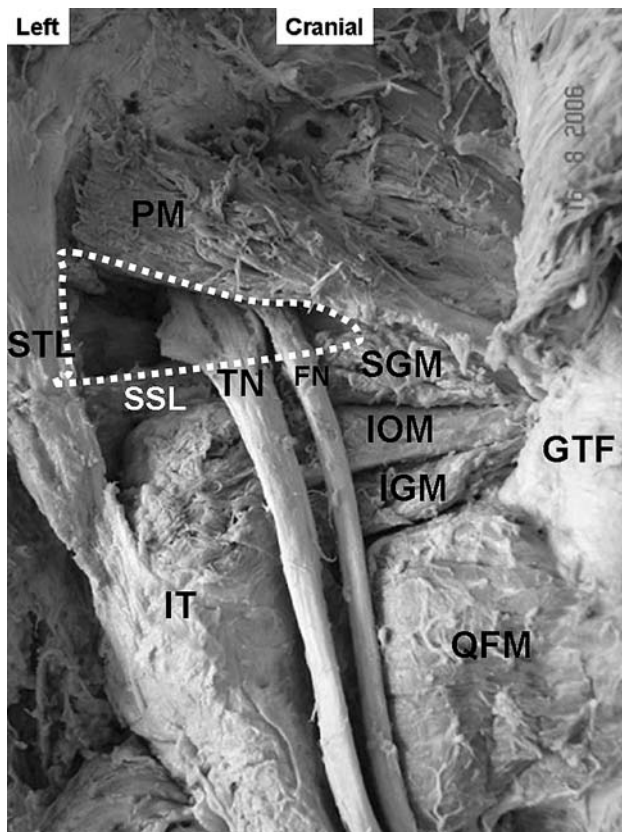


Fig. 2 High division of the sciatic nerve and the infrapiriforme foramen in the right gluteal region. *PM* piriformis muscle, *SGM* superior gemellus muscle, *IGM* inferior gemellus muscle, *IOM* internal obturator muscle, *QFM* quadratus femoris muscle, *GTF* greater trochanter of the femur, *IT* ischial tuberosity, *STL* sacrotuberous ligament, *SSL* sacrospinous ligament, *TN* tibial nerve, *FN* fibular nerve

The differences with respect to the anatomical position were evaluated and analyzed using student's *t* test.

Results

In 20 gluteal regions, parameters related with the dimensions of the pelvis in the gluteal region, the trace of the SN and the position of the SN in the infrapiriforme foramen were measured and evaluated (Table 1).

The data related to the dimensions of the pelvis in the gluteal region

On cadavers that were all male, the distances between the landmark points were measured in order to define the dimensions of the pelvis. Parameter 2 (AB) was measured as 125.91 ± 15.17 mm, parameter 3 (BC) as 74.16 ± 5.04 mm and parameter 4 (AC) 117.96 ± 13.71 mm for these distances (Table 2).

Of these parameters, parameter 2 (AB) and parameter 3 (BC) were also measured during the PM stretch test as the

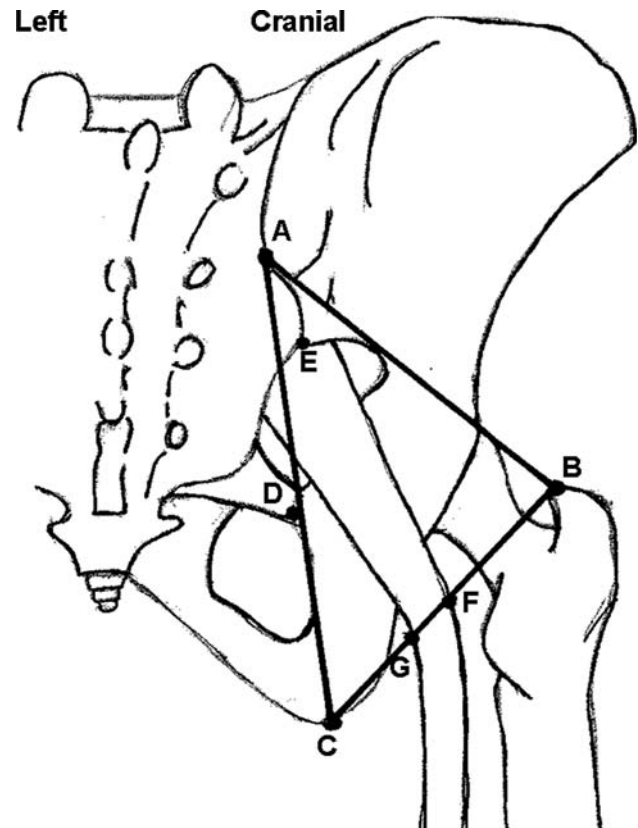


Fig. 3 Parameters 1: the relation between the sciatic nerve and the bone landmark. 1. The width of the greater sciatic notch (*ED*). *E* the posterior inferior iliac spine, *D* the iliac spine. 2. The distance between the posterior superior iliac spine of the hip bone (*A*) and the greater trochanter of the femur (*B*) (*AB*). 3. The distance between the apex of the greater trochanter of the femur (*B*) and the ischial tuberosity (*C*) (*BC*). 4. Distance between the posterior superior iliac spine of the hip bone and the ischial tuberosity (*AC*). 5. The distance between the lateral edge of the sciatic nerve (*F*) and the apex of the greater trochanter of the femur (*BF*). 6. The distance between the medial edge of the sciatic nerve (*G*) and the ischial tuberosity (*GC*)

hip joint moved. Parameter 2 (AB) was found significant statistically according to the anatomic position ($P < 0.05$; Table 2).

The data related to the trace of the SN in the gluteal region

The diameter of the SN was measured as 17.00 ± 3.70 mm in the infrapiriforme foramen (Parameter 7) and as 11.03 ± 2.52 mm in the lesser trochanter level (Parameter 8; Table 3).

On the ischial tuberosity–greater trochanter line, the distance between the SN and the greater trochanter (Parameter 5 BF) was measured as 42.83 ± 4.41 mm and the distance between the SN and the ischial tuberosity (Parameter 6 GC) was 22.03 ± 4.20 mm. The angle between the SN and the transverse plane of the upper lesser trochanter of the femur

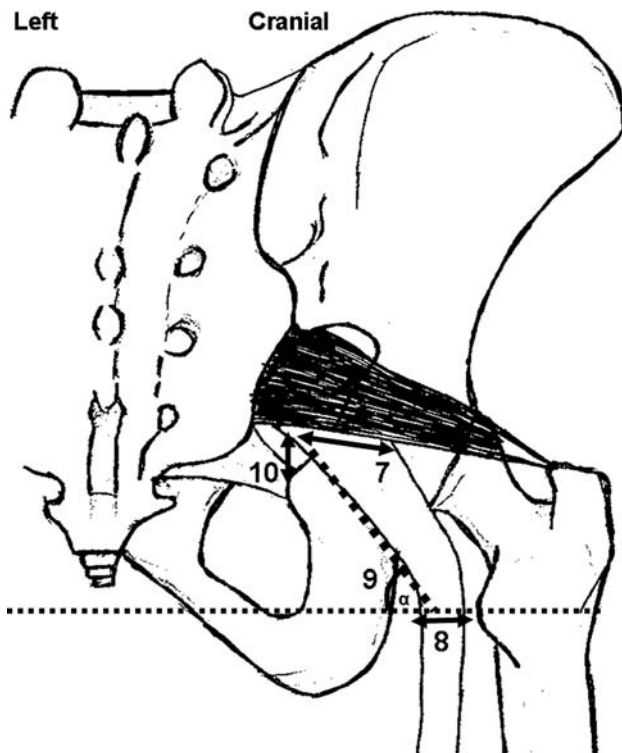


Fig. 4 Parameters 2: 7 the diameter of the sciatic nerve where it emerged from the infrapiriforme foramen, 8 the diameter the sciatic nerve at the level of the lesser trochanter of the femur, 9 the angle between the sciatic nerve and the transverse plane (upper lesser trochanter of the femur) α , 10 the vertical distance between the medial edge of the sciatic nerve and the apex of the ischial spine of the hip bone

with the SN leading from the gluteal region to the thigh (Parameter 9) was $66.36 \pm 6.68^\circ$ (Table 3).

Of these parameters, parameters 5, 6 and 9 were measured during the PM stretch test and only Parameter 9 was found to be significant statistically ($P < 0.05$; Table 3).

The data related to the position of the SN in the infrapiriforme foramen

The SN lies laterally to the posterior cutaneous nerve of the thigh when it passes from the infrapiriforme foramen. The diameter of the SN in the infrapiriforme foramen was measured as 17.00 ± 3.70 mm. The width of the greater sciatic notch (Parameter 1 ED), which forms the lateral border of the infrapiriforme foramen was measured as 63.09 ± 13.59 mm. The sacrospinal ligament, which is attached to the ischial spine forms the inferior border of the infrapiriforme foramen. The distance between the SN and the apex of the ischial spine (Parameter 10) was measured as 17.33 ± 4.89 mm. Parameter 12, which was the highest distance of the foramen was measured as 17.81 ± 5.31 mm. At this height, the distance between the medial side of the SN and the ischial tuberosity (Parameter 11) was measured



Fig. 5 Parameters 3: 11 the vertical distance between the sciatic nerve–piriformis muscle intersection point and the apex of the ischial tuberosity, 12 the vertical distance between the lower edge of the piriformis muscle and the apex of the ischial spine of the hip bone, 13 the length of the lower edge of the piriformis muscle

as 85.62 ± 17.23 mm. The lower side of the PM forms the superior side of the foramen. The lower side of the PM (Parameter 13) was measured as 95.49 ± 6.21 mm (Table 4). On this side, in order to define the position of the SN, the inferior side of the PM was divided into four equal parts. The quadrants in which the medial and the lateral sides of the SN existed were evaluated. In the second quadrant, the ratio was 79.58% for the lateral side and 85.72% for the medial side (Table 5).

Parameters 10, 11 and 12 were measured during the PM stretch test. Only Parameter 11 was significant statistically ($P < 0.05$; Table 4).

Discussion

The piriformis syndrome is the most important cause of non-discogenic sciatica. It was described first by Yeomen in 1928, and was called “piriformis syndrome” by Robinson in 1947 [3, 6, 7, 10, 21, 24]. Three main theories were reported to be responsible for this syndrome, including (1) traumatic adhesion of the PM by Robinson, (2) compression of the SN within the tendinous part of the PM during the leg internal rotation maneuver by Pecina, and (3) myofascial

Table 1 Parameters

1. The width of the greater sciatic notch (ED)
2. The distance between the posterior superior iliac spine of the hip bone and the greater trochanter of the femur (AB)
3. The distance between the apex of the greater trochanter of the femur and the ischial tuberosity (BC)
4. The distance between the posterior superior iliac spine of the hip bone and the ischial tuberosity (AC)
5. The distance between lateral edge of the sciatic nerve and the apex of the greater trochanter of the femur (BF)
6. The distance between the medial edge of the sciatic nerve and the ischial tuberosity (GC)
7. The diameter of the sciatic nerve where it emerged from the infrapiriforme foramen
8. The diameter the sciatic nerve at the level of the lesser trochanter of the femur
9. The angle between the sciatic nerve and the transverse plane (upper lesser trochanter of the femur) α
10. The vertical distance between the medial edge of the sciatic nerve and the apex of the ischial spine of the hip bone
11. The vertical distance between the sciatic nerve–piriformis muscle intersection point and the apex of ischial tuberosity
12. The vertical distance between the lower edge of the piriformis muscle and the apex of the ischial spine of the hip bone
13. The length of the lower edge of the piriformis muscle
14. Location of the sciatic nerve on the lower aspect of the piriformis muscle (from medial to lateral)

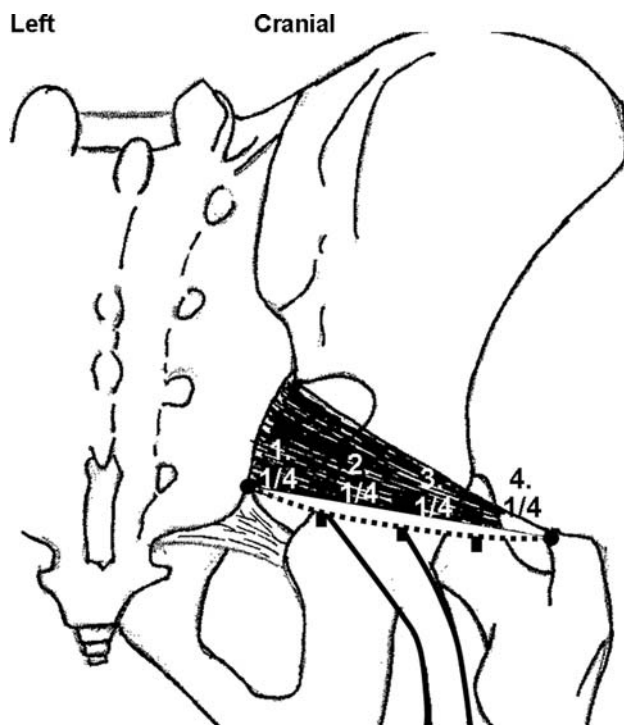


Fig. 6 To expose the relation between the SN and the PM, the lower edge of the PM, from the apex of the greater trochanter of the femur to the greater sciatic notch, was divided into four equal parts, and the positions of both medial and lateral edges of the SN with respect to each quarter were determined

pain secondary to traumatic focal irritation of the PM by Pace and Nagle [18].

On the other hand, on the lateral side of the SN, the posterior cutaneous nerve of the thigh passes from the infrapiriforme foramen with the SN, which may explain

that pain could radiate to the posterior thigh down to the knee. This may cause a situation like sciatica.

Many factors were reported in the etiology of the piriformis syndrome, including long-term sitting, pregnancy, gluteal traumas, PM hypertrophy and spasticity in athletes, PM inflammation [10, 11, 18, 21, 24], PM fibromyositis [10], compression of the PM by the myofascial bands [10], early branches of the SN in the pelvis and passing of the tibial and the fibular nerves in different tunnels [1, 2, 8, 13, 14, 16, 17, 27], as complication of total hip arthroplasty [22, 26] or as complication of cesarean section under spinal anesthesia [28]. Beaton and Anson classified variations of the PM and SN in 240 specimens in 1938. The six possible anatomical relationships between the PM and the SN are found in literature [5, 19, 21].

The clinical, radiologic and neurophysiological diagnosis of piriformis syndrome needs special attention [3, 7, 9–11, 15, 18].

Freiberg test has been used to reveal piriformis syndrome. During this test, the physician performs flexion adduction and medial rotation of the hip in the supine position. An increase in pain during this stretch test assists in the diagnosis of piriformis syndrome by the physician [3, 6, 7, 10, 12, 18]. MR [11], Tc99 scintigraphy [18] and MR neurography [9, 15] may reveal the compression of the PM.

The piriformis syndrome has six cardinal features: history of trauma, pain in the region of the sacro-iliac joint causing difficulty walking, acute exacerbation of pain with lifting and moderately relieved by traction, palpable sausage-shaped mass over the PM, positive Laségue sign and possible gluteal atrophy [19].

Fig. 7 Piriformis stretch test position in cadaver. **a** Lateral aspect, **b** posterior aspect

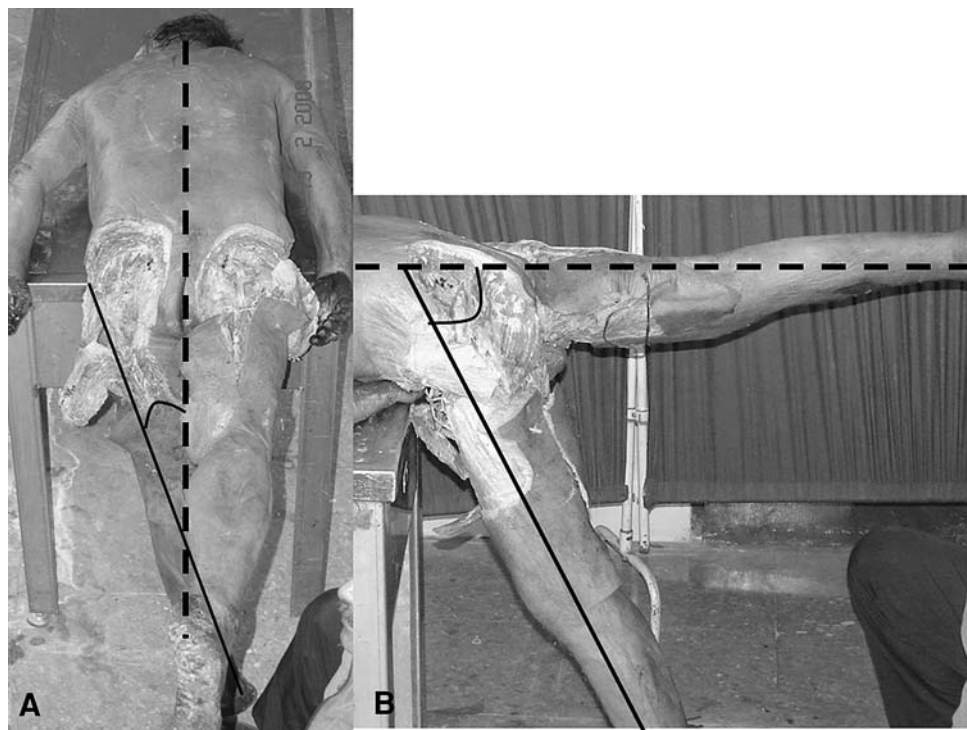


Table 2 Data related to the dimensions of the pelvis in the gluteal region

	Anatomic position	Piriformis stretch test position	<i>P</i>
2	125.91 ± 15.17	139.31 ± 12.20	0.010
3	74.16 ± 5.04	74.88 ± 7.71	0.792
4	117.96 ± 13.71		

2: Distance between the posterior superior iliac spine of hip bone and the greater trochanter of femur (AB); 3: distance between the apex of the greater trochanter of the femur and the ischial tuberosity (BC); 4: distance between the posterior superior iliac spine of the hip bone and the ischial tuberosity (AC)

P < 0.05 significant statistically

In the treatment of piriformis syndrome different methods are used, particularly injection with local anesthetic and steroid or with botulinum toxin under either fluoroscopic or CT guidance. Responses to these injections are favorable with 75–100% of significantly lower pain scores at 3 months after injection [6, 23]. Moreover, some authors perform a minimally invasive surgery by a transgluteal approach with resection of the piriformis muscle and neuroplasty of both the sciatic nerve and the posterior femoral cutaneous nerve [9].

The close relationship between the SN and PM has led many researchers to study this anatomical topic [5, 6, 10, 11, 17, 24]. All these studies focused on the static relationship between the SN and PM, but not on the morphometry and the anatomy occurring after the PM stretch test. To our knowledge, this is the first anatomical

Table 3 Data related with the trace of SN in the gluteal region

	Anatomic position	Piriformis stretch test position	<i>P</i>
5	42.83 ± 4.41 mm	42.12 ± 6.95 mm	0.674
6	22.03 ± 4.20 mm	21.36 ± 5.29 mm	0.692
7	17.00 ± 3.70 mm		
8	11.03 ± 2.52 mm		
9	66.36 ± 6.68°	71.90 ± 8.48°	0.022

5: The distance between the lateral edge of the sciatic nerve and the apex of the greater trochanter of the femur (BF); 6: the distance between medial edge of the sciatic nerve and the ischial tuberosity (GC); 7: the diameter of the sciatic nerve where it emerged from the infrapiriforme foramen; 8: the diameter of the sciatic nerve at the level of the lesser trochanter of the femur; 9: the angle between the sciatic nerve and the transverse plane (upper lesser trochanter of the femur) \hat{x}

P < 0.05 significant statistically

study in literature that addresses the change in anatomy after the PM stretch test.

Most of the findings obtained from the static part of our study are in line with those published before. This study found that the width of the greater sciatic notch, a notch forming the pelvic side of the infrapiriforme foramen and the point of exit of the SN from the pelvis, was 63.09 ± 13.59 mm. The width of this notch was reported by Patriquin [20] to be 43.03 ± 4.99 mm in white males, and 36.96 ± 4.62 mm in black males. The PM traverses through this notch and forms a location between the anterior surface of the sacrum and the greater trochanter.

Table 4 Data related with the position of the SN in the infrapiriforme foramen

	Anatomic position (mm)	Piriformis stretching test position (mm)	<i>P</i>
1	63.09 ± 13.59		
10	17.33 ± 4.89	15.84 ± 4.63	0.206
11	85.62 ± 17.23	72.28 ± 7.56	0.046
12	17.81 ± 5.31	15.34 ± 5.21	0.068
13	95.49 ± 6.21		

1: The width of the greater sciatic notch (ED); 10: the vertical distance between the medial edge of the sciatic nerve and the apex of the ischial spine of the hip bone; 11: the vertical distance between the sciatic nerve–piriformis muscle intersection point and the apex of the ischial tuberosity; 12: the vertical distance between the lower edge of the piriformis muscle and the apex of the ischial spine of the hip bone; 13: the length of the lower edge of the piriformis muscle

P < 0.05 significant statistically

Table 5 Location of the sciatic nerve on the lower aspect of the piriformis muscle (from medial to lateral)

	First quarter (%)	Second quarter (%)	Third quarter (%)	Fourth quarter (%)
Lateral edge of the sciatic nerve	–	79.58	21.42	–
Medial edge of the sciatic nerve	7.14	85.72	7.14	–

On the other hand, the diameter of the SN in the infrapiriforme foramen was reported to be 15.0 ± 0.3 mm by Benzon [6]. The SN diameter was found to be 17.00 ± 3.70 mm in the present study.

This location and musculoskeletal relationship should be taken into consideration during the evaluation for the piriformis syndrome. Any increase in the volume of the PM may cause stenosis of the notch and in turn compress the SN [10, 11, 18, 21, 24]. The presence of the SN abnormalities such as early branching may also complicate the state.

Besides the static causes, dynamic compressions may also occur. It is remarkable that the piriformis stretch test leads to changes, primarily in the position of the bones with respect to each other. All other changes that occurred in the position of the PM and the SN are secondary to changes in the bony morphometry.

This study reveals that anterior and external displacement of the greater trochanter of the femur during the test position results in a significant increase in the distance between the posterior superior iliac spine of the hip bone and the greater trochanter of the femur (*P* = 0.010). Similarly, the same reasons led to increase in the distance between the apex of the greater trochanter of the femur and the ischial tuberosity (*P* > 0.05), resulting in a decrease in

the distance between the trochanter major and the SN, and decrease in the vertical distance between the SN–PM intersection point and the apex of the ischial tuberosity (from 85.62 ± 17.23 mm in neutral position to 72.28 ± 7.56 mm in the test position). In other words, the potential space in the notch decreases after the PM stretch test position.

The changes secondary to the PM stretch test position are not limited to the aforementioned changes. During the test position, the vertical distance between the lower aspect of the PM and the structures forming the lower aspect of the infrapiriforme foramen (i.e., spina ischiatica and sacrospinal ligament), as well as the vertical distance between the ischial spine and the SN decreases. This may compress the medial border of the SN (tibial nerve) between the lower aspect of the PM and the ischial spine.

On the other hand, the α angle increases during the PM stretch test position, when compared to the neutral position. Despite anterior displacement of the greater trochanter during the test position, increase in the α angle leads to the decrease in the distance between the greater trochanter of the femur and the lateral aspect of the SN. This, as a result, may compress the lateral aspect of the SN (common fibular nerve) between the PM lower aspect and the greater sciatic notch during the test position.

Conclusion

This study provides helpful information regarding the course and the location of the SN. The presented morphometric data also revealed that after the stretch test position, the infrapiriforme foramen becomes narrower; the SN becomes closer to the ischial spine of the hip bone, and the angle between the SN and the transverse plane increases. This study confirmed that the SN is prone to be trapped in the test position, and diagnosis of this situation requires dynamic MR and MR neurography study. This requires adding dynamic MR imaging to preoperative workup of such cases.

References

1. Arifoğlu Y, Sargon MF, Tanyeli E, Yazar F (1997) Double superior gemellus together with double piriformis and high division of the sciatic nerve. *Surg Radiol Anat* 19:407–408
2. Babinski MA, Machado FA, Costa WS (2003) A rare variation in the high division of the sciatic nerve surrounding the superior gemellus muscle. *Eur J Morphol* 41(1):41–42
3. Barton PM (1991) Piriformis syndrome: a rational approach to management. *Pain* 47:345–352
4. Beaton LE, Anson BJ (1937) The relation of the sciatic nerve and of its subdivisions to the piriformis muscle. *Anat Rec* 70(supp1):1–5

5. Beaton LE, Anson BJ (1938) The sciatic nerve and the piriformis muscle: their interrelation a possible cause of coccygodynia. *J Bone Joint Surg* 20:686–688
6. Benzon HT, Katz JA, Benzon HA, Iqbal MS (2003) Anatomic considerations, a new injection technique and a review of the literature. *Anesthesiology* 98:1442–1448
7. Broadhurst NA, Simmons N, Bond MJ (2004) Piriformis syndrome: correlation of muscle morphology with symptoms and signs. *Arch Phys Med Rehabil* 85:2036–2039
8. Chen WS (1994) Bipartite piriformis muscle: an unusual cause of sciatic nerve entrapment. *Pain* 58:269–272
9. Filler AG, Haynes J, Jordan SE, Prager J, Villablanca P, Farahani K, McBride DQ, Tsuruda JS, Morisoli B, Batzdorf U, Johnson JP (2005) Sciatica of nondisc origin and piriformis syndrome: diagnosis by magnetic resonance imaging with outcome study of resulting treatment. *J Neurosurg Spine* 2:99–115
10. Foster MR (2002) Piriformis syndrome. *Orthopedics* 25(8):821–825
11. Jankiewicz JJ, Hennrikus WL, Houkom JA (1991) The appearance of the piriformis muscle syndrome in computed tomography and magnetic resonance imaging. *Clin Orthop Relat Res* 262:205–209
12. Kendall FP, Kendall McCreart E, Geise PP (1993) *Muscles testing and function*, 4th edn. Williams & Wilkins, Baltimore, pp 219, 333, 365
13. Kırıcı Y, Ozan H (1999) Double gluteus maximus muscle with associated variations in the gluteal region. *Surg Radiol Anat* 21(6):397–400
14. Kırıcı Y, Yazar F, Ozan H (1999) The neurovascular and muscular anomalies of the gluteal region: an atypical pudendal nerve. *Surg Radiol Anat* 21(6):393–396
15. Kosukegawa I, Yoshimoto M, Isogai S, Nonaka S, Yamashita T (2006) Piriformis syndrome resulting from a rare anatomic variation. *Spine* 31(18):E 664–6
16. Mas N, Özekşi P, Özdemir B, Kapakin S, Sargon MF, Çelik HH, Yener N (2003) A case of bilateral high division of the sciatic nerves, together with a unilateral unusual course of the tibial nerve. *Neuroanatomy* 2:13–15
17. Ozaki S, Hamabe T, Muro T (1999) Piriformis syndrome resulting from an anomalous relationship between the sciatic nerve and piriformis muscle. *Orthopedics* 22(8):771–772
18. Papadopoulos EC, Khan SN (2004) Piriformis syndrome and low back pain: a new classification and review of the literature. *Orthop Clin Am* 35:65–71
19. Parziale JR, Hudgins TH, Fishman LM (1996) The piriformis syndrome. *Am J Orthoped* 25(12):819–823
20. Patriquin ML, Steyn M, Loth SR (2005) Metric analysis of sex differences in South African black and white pelvis. *Forensic Sci Int* 147:119–127
21. Pecina M (1979) Contribution to the explanation of the piriformis syndrome. *Acta Anat* 105:181–187
22. Pokorny D, Jahoda D, Veigl D, Pinskerova V, Sonsa A (2006) Topographic variations of the relationship of the sciatic nerve and the piriformis muscle and its relevance to palsy after total hip arthroplasty. *Surg Radiol Anat* 28(1):88–91
23. Porta M (2000) A comparative trial of botulinum toxin type A and methylprednisolone for the treatment of myofascial pain from chronic muscle spasm. *Pain* 85:101–105
24. Sayson SC, Ducey JP, Maybrey JB, Wesley RL, Vermilion D (1994) Sciatic entrapment neuropathy associated with an anomalous piriformis muscle. *Pain* 59:149–152
25. Standring S (editor-in-chief) (2005) *Gray's anatomy The anatomical basis of clinical practice*, 39th edn. Elsevier, Amsterdam, pp 1403, 1404, 1446, 1447
26. Uchio Y, Nishikawa U, Ochi M, Shu N, Takata K (1998) Bilateral piriformis syndrome after total hip arthroplasty. *Arch Orthop Trauma Surg* 117:177–179
27. Uluutku MH, Kurtoğlu Z (1999) Variations of nerves located in deep gluteal region. *Okajimas Folia Anat Jpn* 76(5):273–276
28. Vallejo MC, Mariano DJ, Kaul B, Sah N, Ramanathan S (2004) Piriformis syndrome in a patient after cesarean section under spinal anesthesia. *Reg Anesth Pain Med* 29(4):364–367