Original Article

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Anatomical Variants of the Sciatic Nerve Division in the Pelvis, the Gluteal Region and the Thigh: A Cadaveric Study

Anatomy Section

AZZA I FARAG[1], RASHA M SALAMA[2]

ABSTRACT

Introduction: Anatomical dissimilarities can be found in any part of the body and is pertinent to identify patients who are not treated successfully with standard medical care. Anatomical variants of the Sciatic Nerve (SN) were defined many years ago, and may have consequences in certain diseases, as sciatica. Specialised care may be required to these patients due to their unique anatomy.

Aim: To study the cadaveric anatomical variants of the SN divisions in the pelvis, the gluteal region and the thigh and also to describe its linkage to the Piriformis Muscle (PM).

Materials and Methods: This descriptive study was conducted from June 2021 to September 2021 in the Department of Anatomy of Qassim University, Saudi Arabia. Total 30 lower limbs and gluteal regions of formalin fixed male cadavers were used to study the anatomical variants of the SN division into its terminal branches and its relation to the PM. Numbers and percentages of the specimens falling in the groups were calculated and tabulated.

Results: Out of 30, 3 specimens (10%), showed division of the SN in the pelvis, where both Tibial Nerve (TN) and Common Fibular Nerve (CFN) course separately below the piriformis muscle. While, 8 specimens (26.66%) showed division of the SN in the pelvis, where CFN pierces the piriformis muscle, and tibial nerve lies below it. About 5 specimens (16.66%), showed division of the sciatic nerve into tibial nerve and CFN in the gluteal region at the level of the obturator internus muscle. Additionally, 9 specimens (30%) showed division of the sciatic nerve into tibial nerve and CFN occurred in the upper of the posterior aspect of the thigh. Lastly, 5 specimens (16.66%), revealed division of the sciatic nerve into tibial nerve and CFN in the middle of the posterior aspect of the thigh.

Conclusion: The most prevalent level of bifurcation of the SN in the present study was the upper part of the posterior aspect of the thigh (30%), while the least common level of the SN bifurcation was in the pelvis, before its exits in the gluteal region, where TN and CFN course separately below PM (10%).

Keywords: Common fibular nerve, Obturator internus muscle, Piriformis muscle, Tibial nerve

INTRODUCTION

The Sciatic Nerve (SN) is the bulkiest and largest nerve in the body, nearly it is 0.5 cm thick and 2 cm wide at its origin, it is composed of a bundle of two nerves, the Common Fibular Nerve (CFN) and Tibial Nerve (TN) tied together by a common sheath as they track down the posterior thigh. The SN is branching from the sacral plexus, from the L4-S3 segments of the sacral plexus, for sensory and motor innervation of the lower extremities. Classically, the SN, departing the pelvis, by emerging from the greater sciatic foramen below the Piriformis Muscle (PM) and descends along the posterior aspect of the thigh to supply posterior compartment of the lower limb. Proximally, it is accompanied by the inferior gluteal artery and posterior femoral cutaneous nerve. While distally, it is passed by the long portion of the biceps femoris muscle and rests on the adductor magnus muscle [1].

About the tip of the popliteal fossa at the distal third of the femur, the SN bifurcates into two parts, CFN and TN [2,3]. However, a novel research found a connection between CFN and TN in their cadavers after bifurcation [4].

Tibial nerve supplies muscles in the posterior aspect of the thigh and leg in addition to muscles of the sole of the foot. While, CFN supplies muscles of the lateral and anterior aspects of the leg, the dorsum of the foot and the short head of biceps femoris with providing the leg and the foot with sensory supply [5].

Many anatomical variants of SN division in relation to the PM have been reported chiefly the high divisions in the gluteal region in which the CFN courses above the PM and the TN exits inferior to the PM [2,3].

Piriformis muscle allows lateral rotation and abduction of the hip joint and forms a tunnel with the superior gemellus muscle to pass the SN. It originates on the pelvic aspect of the sacrum between the 2nd and 4th foramina and connects to the top of the greater trochanter [5].

Classically, SN exits entirely below the PM, but in some cases one of its divisions pierces the muscle or passes above it [1]. The anatomical variants of the SN have been elaborated synchronous with gluteal surgical interventions, as a trigger for piriformis syndrome, and other clinical approaches [6,7].

Piriformis syndrome was characterised by entrapment of the SN as it emits from the greater sciatic notch [8]. It is a common reason of buttock and leg pain. Effective diagnosis and proper management of this clinical syndrome is still poorly understood. Variants in the SN anatomy might be a possible undetermined aetiology in the piriformis syndrome by some researchers [9].

In addition, postoperative sciatic palsy, a rare result after hip joint surgery, is considered another clinical importance of these anatomical variants, where stretching of the nerve or its branches represents high risk during surgical operation. The posterior paratrochanteric portal (posterior portal) is another clinical significance during arthroscopic surgery [10]. Sciatic nerve division in the popliteal fossa may be responsible for unsuccessful SN blocks [11].

The aim of the study was to throw light on the cadaveric anatomical variants of the SN divisions in the pelvis, the gluteal region and the thigh and its linkage to the PM to increase the awareness of surgeons about these variations which have clinical importance and to achieve better treatment outcomes.

MATERIALS AND METHODS

This descriptive study was conducted from June 2021 to September 2021 in the Department of Anatomy, Qassim University, Buraidah, Saudi Arabia. In the present study, appropriate ethical principles were followed under strict Institutional Ethics Committee of the Institution (EIC no-11/2021 ANT2)

Inclusion criteria: Thirty lower limbs and gluteal regions of formalin fixed male cadavers without any gross pathology following their use in anatomy education were included in the study.

Exclusion criteria: The pathological cadavers were excluded from the study.

Data Collection

The levels of the SN bifurcation into TN and CFN parameters in all thirty lower limbs and gluteal regions were photographed and documented following their use in anatomy education.

Depending upon the level of the SN division into TN and CFN, this study was categorised into five groups [12,13]-

Group I: SN divides in the pelvic region, before its exits to the gluteal region, where both TN and CFN course separately below the PM.

Group II: SN divides in the pelvic region, before its exits to the gluteal region, where CFN pierces the PM, and TN lies below the PM.

Group III: SN divides into TN and CFN in the gluteal region at the level of the obturator internus muscle.

Group IV: SN divides into TN and CFN in the upper part of the posterior aspect of the thigh.

Group V: SN divides into TN and CFN in the middle part of the posterior aspect of the thigh.

STATISTICAL ANALYSIS

Numbers and percentages of the lower limbs and the gluteal regions falling in the groups were calculated and tabulated accordingly. The findings were analysed statistically by using Microsoft Office Excel 2016.

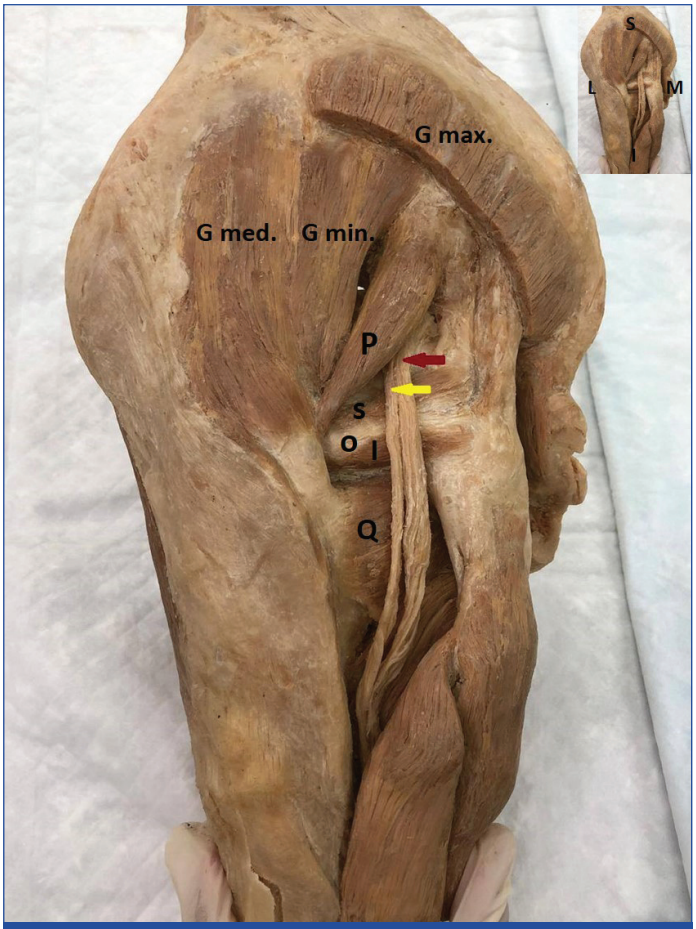
RESULTS

As shown in [Table/Fig-1], 30 specimens of the lower limbs and the gluteal regions were used in the present study and were categorised into five groups.

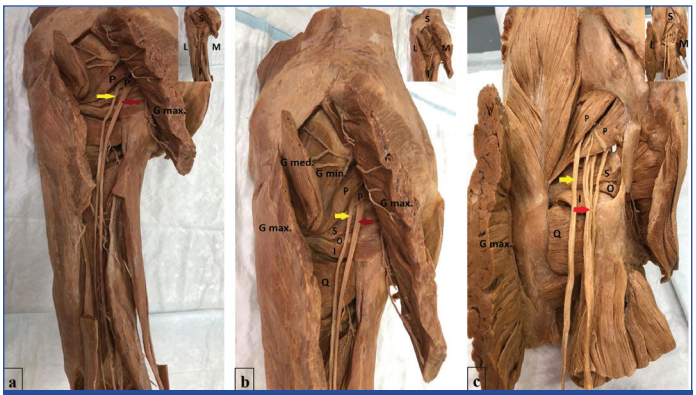
Groups	Anatomical variants of sciatic nerve division into its terminal branches	Number of specimens, (%)
Group I	Division of SN in the pelvic region, before its exits to the gluteal region, where both TN and CFN course separately below the PM.	3 (10%)
Group II	Division of SN in the pelvic region, before its exits to the gluteal region, where CFN pierces the PM, and TN lies below the PM.	8 (26.66%)
Group III	Division of SN in the gluteal region at the level of obturator intemus muscle.	5 (16.66%)
Group IV	Division of SN in the upper part of the posterior aspect of the thigh.	9 (30%)
Group V	Division of SN in the middle part of the posterior aspect of the thigh.	5 (16.66%)

[Table/Fig-1]: The number and percentage of the anatomical variants of the Sciatic Nerve division.

Three specimens (10%) fall in Group I, showed division of the SN in the pelvis, before its exits to the gluteal region, where both TN and CFN course separately below the PM [Table/Fig-2]. In Group II, 8 specimens (26.66%) revealed division of the SN in the pelvis, before its exits to the gluteal region, where CFN pierces the PM, and TN lies below the PM [Table/Fig-3]. Five specimens (16.66%) fall in Group III, exhibited division of the SN into TN and CFN in the gluteal region at the level of the obturator internus muscle [Table/Fig-4].

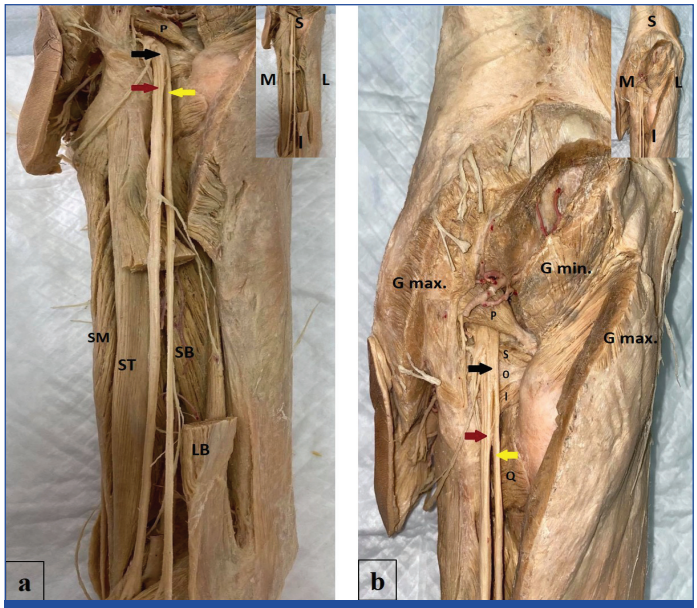


[Table/Fig-2]: A specimen of the dorsal aspect of the left gluteal region in group I, showing bifurcation of the SN, in the pelvis, into tibial nerve (red arrow) and common fibular nerve (yellow arrow) coursing separately below piriformis muscle (P), and crossing superior gemellus (S), obturator internus (O), inferior gemellus (I) and quadratus femoris (Q) muscles. Note the surrounding muscles; gluteus maximus (G max.), gluteus medius (G med.), and gluteus minimus (G min.). The insert shows the orientation of the image; superior (S), inferior (I), medial (M) and lateral (L).

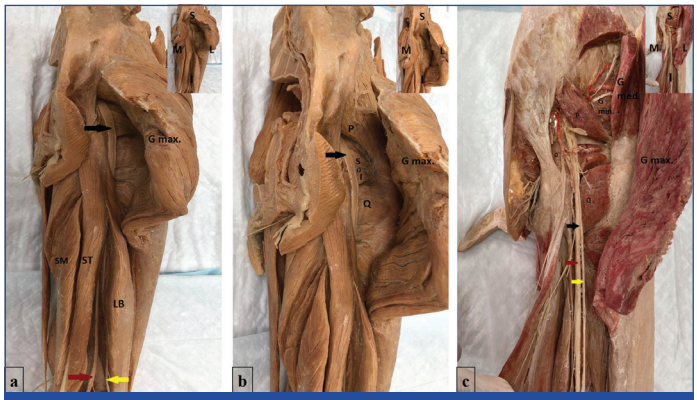


[Table/Fig-3]: (a) A specimen of the dorsal aspect of the left lower extremity in group II, showing bifurcation of the SN in the pelvis, before its exits in the gluteal region, into common fibular nerve (yellow arrow) pierces the piriformis muscle (P), and tibial nerve (red arrow) passes below it. Note, the covering gluteus maximus muscle (G max.); (b) Close-up photography of specimen (a), showing common fibular nerve (yellow arrow) passes through piriformis muscle (P), and tibial nerve (red arrow) lies below it and the two nerves crossing superior gemellus (S), obturator internus (O), inferior gemellus (I) and quadratus femoris (Q) muscles. Note, the covering muscles; gluteus maximus (G max.), gluteus medius (G med.) and gluteus minimus (G min.); (c) Another specimen of the dorsal aspect of the left gluteal region in group II, exhibiting higher SN division in the pelvis, into common fibular nerve (yellow arrow) splits piriformis muscle (P), and tibial nerve (red arrow) lies below piriformis muscle (P), and the two nerves crossing superior gemellus (S), obturator internus (O), inferior gemellus (I) and quadratus femoris (Q) muscles. Note, the surrounding gluteus maximus muscle (G max.). The insert showed orientation of the images; superior (S), inferior (I), medial (M) and lateral (L).

Group IV, contained 9 specimens (30%) that showing division of SN into TN and CFN in the upper part of the posterior aspect of thigh [Table/Fig-5]. Lastly 5 specimens (16.66%) related to Group V, exhibited division of the SN into TN and CFN in the middle part of the posterior aspect of the thigh [Table/Fig-6].



[Table/Fig-4]: (a) A specimen of the dorsal aspect of the right lower extremity in group III, showing the exit of Sciatic Nerve (black arrow) below piriformis muscle (P) and its two terminal branches common fibular nerve (yellow arrow) and tibial nerve (red arrow). Note, the surrounding muscles in the thigh; short head of biceps femoris (SB), long head of biceps femoris (LB), semitendinosus (ST), and semimembranosus (SM) muscles; (b) Close-up photography of the upper part of specimen (a), showing the exit of Sciatic Nerve (black arrow) below piriformis muscle (P) and its bifurcation into common fibular nerve (yellow arrow) and tibial nerve (red arrow) in the gluteal region at the level of obturator internus muscle (O) between superior gemellus (S), and inferior gemellus (I) muscles. Note, the surrounding gluteus maximus (G max.), gluteus minimus (G min.) and quadratus femoris (Q) muscles. The insert showed orientation of the images; superior (S), inferior (I), medial (M) and lateral (L).



[Table/Fig-5]: (a) A specimen of the dorsal aspect of the right lower extremity in group IV, showing Sciatic Nerve (black arrow) and its bifurcation in the upper part of the posterior aspect of the thigh into common fibular nerve (yellow arrow) and tibial nerve (red arrow). Note, the covering gluteus maximus muscle (G max.) and the surrounding long head of biceps femoris (LB), semitendinosus (ST), and semimembranosus muscles in the thigh; (b) Close-up photography of specimen (a), showing the exit of Sciatic Nerve (black arrow) below piriformis muscle (P) crossing superior gemellus (S), obturator internus (O) inferior gemellus (I) and quadratus femoris (Q) muscles. Note, the covering gluteus maximus muscle (G max.); (c) Another specimen of the dorsal aspect of the right gluteal region in group IV, showing Sciatic Nerve (black arrow) exit below piriformis muscle (P) crossing superior gemellus (S), obturator internus (O) inferior gemellus (I) and quadratus femoris (Q) muscles. Then bifurcates in the upper part of the posterior aspect of the thigh into common fibular nerve (yellow arrow) and tibial nerve (red arrow). Note, the surrounding gluteus maximus (G max.), gluteus medius (G med.), and gluteus minimus (G min.) muscles. The insert showed orientation of the images; superior (S), inferior (I), medial (M) and lateral (L).

The upper part of the posterior aspect of the thigh was the most prevalent level of bifurcation of SN in this study (30%) and the least common level of SN bifurcation was in the pelvis, before its exits in the gluteal region, where TN and CFN course separately below the PM (10%).

DISCUSSION

Normally, the SN leaves the pelvis through the greater sciatic foramen, between the greater trochanter (laterally) and the ischial tuberosity (medially) [14].

[Table/Fig-6]: A specimen of the dorsal aspect of the right lower extremity in group V, showing Sciatic Nerve (black arrow) exit below the piriformis muscle (P) and bifurcates in the middle of the posterior aspect of the thigh into common fibular nerve (yellow arrow) and tibial nerve (red arrow). Note, the surrounding short head of biceps femoris (SB), and semimembranosus (SM) muscles in the thigh. The insert showed orientation of the images; superior (S), inferior (I), medial (M) and lateral (L).

In the present, five anatomical variants of the SN divisions were detected in thirty specimens of the lower limbs and the gluteal regions. A 36.66% of specimens (Group I and II), showed division of the SN in the pelvis, before its exits to the gluteal region. About 16.66% of specimens (Group III) showed division of the SN in the gluteal region, while 46.66% of specimens (Group IV and V) showed division of the SN in the posterior aspect of the thigh. These results are nearly similar to types A, B and G of Tomaszewski KA et al., who included a total of 45 studies (n=7068 lower limbs) in a meta-analysis and classified the SN variations with respect to the PM into seven types (A-G): Type A where SN exits the pelvis undivided below the PM. Type B where SN divides in the pelvis, CPN pierces the PM, and TN lies below the PM. Type C where SN divides in the pelvis, CPN courses over the PM, and TN lies below the PM. Type D where SN exits the pelvis undivided piercing the PM. Type E where SN divides in the pelvis, CPN courses over the PM, and TN pierces the PM. Type F where SN exits the pelvis undivided coursing over the PM. Type G where SN divides in the pelvis, both CPN and TN coursing separately below the PM [1]. In contrast, types C, D, E and F of Tomaszewski KA et al., were not detected in the present study [1].

Group I and II in the present study, showed 11 specimens (36.66%) with early SN division inside the pelvic cavity, into its two terminal branches, before passing through the greater sciatic notch. Three specimens of group I (10%) showed the two branches passed separately below the PM similar to type G of Tomaszewski KA et al., [1].

The other 8 specimens of group II (26.66%) showed the CFN pierces the PM and the TN passes below it, this is in accordance with type

B of Tomaszewski KA et al., and the anatomical variant that was reported in one cadaver bilaterally by Pokorný D et al., who carried out his study on about 91 cadavers [1,15].

Moreover, group III, IV, and V in the present study proved that 63.32% of specimens, the SN passes undivided inferior to the PM, then divides into TN and CFN at different levels, this is nearly the same as detected in type A of Tomaszewski KA et al., [1]. High division of SN in the gluteal region in group III was detected in 16.66% of specimens, while division of the SN in the upper part of the back of the thigh in group IV was found in 30% of specimens and in the middle of the back of the thigh in group V was discovered in 16.66% of specimens. These results are similar to the findings of Pais D et al., who detected three cadavers with sciatic anatomical variations, two of them with bilateral high division in the inferior gluteal regions and the findings of İkiz ZAA et al., who observed bilateral variations in one cadaver [16,17]. Moreover, Prakash AK et al., and İkiz ZAA et al., documented SN division in the upper part of the back of the thigh in one lower limb [13,17]. However, their studies recorded also 40.7% SN division in the lower part of the posterior aspect of the thigh, and 34.9% SN division in the popliteal fossa, which weren't detected in the present study.

Also the findings in the present study are in harmony with another cadaveric study that was performed by Smoll NR over about 3000 cadavers, where he detected only six anatomical variants between the SN and the PM [18], similar to types A to F described by Tomaszewski KA et al., where type A represented the highest incidence (83.1%), while types E and F were the lowest (0.08 %) [1]. Moreover, a systematic review, searched 30 textbooks and 6 databases to report about variants of the PM and the SN with clinical consequence, was performed by Smoll NR in which he found that the gluteal anomalies were between 35.8% and 9.5% [18]. But İkiz ZAA et al., reported that the SN variations were 15% of both gluteal regions and lower limbs and 10% in only gluteal region [17].

In contrast to the results in this study, Pais D et al., found that the SN divides in the pelvis, where the CFN passing above the PM [16], and the TN lies below it, this was the same as type C of Tomaszewski KA et al., study [1]. In addition, İkiz ZAA et al., listed this variant unilaterally in one cadaver [17]. This type of high separation may be a reason of atypical sciatic compressive syndrome due to intervention of one of the terminal branches in sciatica.

A new subtype of variant B, type B previously mentioned in Tomaszewski KA et al., study, was reported by Cassidy LA et al., in which a small accessory PM with a separate tendon was found between the CFN and the TN [1,19], while the SN itself passes below the PM [17]. Delabie A et al., also recorded the entity of the accessory PM with the peroneal nerve passing between two heads in 9.6% in a random study of 52 patients using MRI [20]. However, this new variant wasn't noted in the present study.

An unusual anatomical variants of the SN was reported by Dupont G et al., where the SN separated just inferior to the piriformis on each side of the ischial tuberosity, and İkiz ZAA et al., found two nerve divisions passed above and below the piriformis to form the CFN on the right side of one specimen, it was the first time to report this type of nerve variation and it was not detected in the present study [3,17]. This puts the nerve division passing above the muscle at risk of compression by the piriformis or injury during intragluteal injections as it was not in the safe region for injections, which lies above the line from the posterior superior iliac spine to the greater trochanter of the femur [5].

Anatomical variations of the SN in which the nerve or part of it perforate the PM put the nerve in danger of palsy during the posterior hip arthroplasty. This is due to detachment or retraction of the tendons of the lateral rotator muscles of the hip including the piriformis from the greater trochanter [18].

Different cadaveric studies were conducted to detect the different anatomical variants of the PM and the SN to elucidate possible causes of piriformis syndrome. Although there is a strong opinion suggesting the relationship between the piriformis syndrome and these anatomical variations, there are other studies which did not support this opinion. One of these studies performed by Broadhurst NA et al., who reported three variations on the unaffected side after examining 27 patients complaining of piriformis syndrome with ultrasound of the buttock [21]. Also, Kirschner JS et al., stated that these variations were found in some asymptomatic patients [22].

As the SN can divide into its two terminal branches at variable levels starting from the sacral plexus till the popliteal fossa; identifying these anatomical variations can help clinicians in performing nerve blocks in the popliteal fossa which is frequently performed in cases of postoperative pain blockage for surgical operation below the knee [11,23].

Sciatica is a painful condition causing chronic pain, mostly affects persons in the 4th and 5th decades of life. The most common causes of sciatica are spinal radiculopathies, degenerative disc disorders or osteoarthritic changes affecting the spinal canal and neural foramen [24]. However, if the exact cause is not known, entrapment of the SN in the gluteal region (formerly called pyriformis syndrome) may account for up to 6-8% of sciatica, this entrapment results from the SN compression by the PM in cases of anatomical variations between the muscle and the nerve and usually diagnosed through determination of the pain source [25,26].

Michel F et al., purposed different maneuvers to test the PM and a clinical scoring method to score patients according to their pain [27]. The maneuvers included Freiberg maneuver to stretch the PM, Flexion-Adduction-Internal Rotation (FAIR) maneuver, the Heel-Contralateral Knee maneuver (HCLK) and the Beatty test for limited contraction. After each maneuver, it was reported that if the case exhibited instant pain or not. The authors concluded that these procedures could suggest piriformis entrapment as the most likely cause of sciatica, as they produce sciatic pain in non discogenic reasons of the sciatica. In addition, the clinical pain scoring method suggested that, scores more than or equal 8, mostly indicate piriformis syndrome. Pain scoring system depends on emphatic agents of the pain due to contraction or expansion of the piriformis. This supports the idea that variations of the SN anatomy in relation to the PM play a fundamental part in the pain triggered in the piriformis syndrome [7].

Limitation(s)

The insufficient sample size specimen according to the lab facilities with restricted statistical measurements and the age distribution of the cadavers were not done. Such limitations will be addressed in the future research.

CONCLUSION(S)

During surgical approaches and other clinical procedures in the gluteal region, anatomical variants of the SN division and its relation to the PM should always be kept in mind. Such variations and differences must be detected anatomically and understood clinically in order to plan them to increase the awareness of surgeons about these variations which have clinical importance and to achieve better treatment outcomes.

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PARTICULARS OF CONTRIBUTORS:
1. Faculty of Medicine, Department of Human Anatomy and Embryology, Zagazig University, Zagazig, Egypt.
2. Faculty of Medicine, Department of Anatomy and Embryology, Menoufia University, Alexandria, Egypt.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Rasha M Salama,
14 May Street, Smouha Alexandria, Alexandria, Egypt.
E-mail: drrashasalama@yahoo.com

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