# NEUROMUSCULAR VARIATIONS IN THE TOPOGRAPHY OF THE SCIATIC NERVE AND PIRIFORMIS MUSCLE: A MORPHOLOGICAL STUDY IN THE SLOVAK POPULATION WITH CLINICAL IMPLICATIONS FOR PIRIFORMIS SYNDROME

## Neuromuskulárne variácie v topografii n. ischiadicus a m. piriformis: Morfologická štúdia v slovenskej populácii s klinickými implikáciami pre piriformis syndróm

Marko VRZGULA[1], Slavomír POTIČNÝ[2], Natália HVIZDOŠOVÁ[1], Ema KERPČÁROVÁ[3], Ingrid HODOROVÁ[1]

[1]Department of Anatomy, Faculty of Medicine, Pavol Jozef Šafárik University, Košice, Head of Department prof. MUDr. I. Hodorová, PhD.
[2]Department of Neurosurgery, Faculty of Medicine, University of Ostrava, Czech Republic, Head of Department prof. MUDr. R. Lipina, PhD.
[3]Medical Faculty student, Pavol Jozef Šafárik University, Košice, Slovak Republic

**Abstract**
**Introduction.** Anatomical variations of the sciatic nerve (SN) and the piriformis muscle (PM) are associated with the clinical condition known as primary piriformis syndrome (PS). Topographically, six distinct variations in the positioning of the SN relative to the PM have been described, occurring with varying frequencies. The objective of this morphological study was to investigate neuromuscular variations within the greater sciatic foramen in the Slovak population. It aimed to improve understanding of the topographical relationships between the SN and PM, focusing on their clinical relevance.
**Material and Methods.** The study was conducted on 40 lower limbs from 10 female and 10 male adult cadavers. Detailed anatomical dissections of the SN and PM in the gluteal region were performed bilaterally. Dissections of the posterior femoral and popliteal regions were also carried out to identify the main branches of the SN.
**Results.** The SN, its main branches, and the PM were revealed on both sides in all cadaveric specimens. The SN typically passed through the infrapiriform foramen in 37 cases. However, atypical branching of the SN, with the common fibular nerve passing through the PM, was observed in 3 lower extremities.
**Conclusion.** Our study's findings indicate that an atypical course of the SN in relation to the PM is relatively common in the Slovak population. Such a course may lead to clinical discomfort, referred to as primary PS. Clinicians frequently miss this diagnosis, which should always be considered in the differential diagnosis for patients presenting with back and gluteal pain radiating to the lower limbs *(Fig. 5, Ref. 27). Text in PDF www.lekarsky.herba.sk.*
*KEY WORDS:* anatomical variation, dissection, piriformis muscle, piriformis syndrome, sciatic nerve.
Lek Obz 2025, 74 (6): 236-241

**Abstrakt**
**Úvod.** Anatomické variácie n. ischiadicus (SN) a m. piriformis (PM) môžu byť príčinou vzniku primárneho piriformis syndróm (PS). Topograficky bolo opísaných šesť rôznych variácií v polohe SN vzhľadom na PM, ktoré sa vyskytujú s rôznou frekvenciou. Cieľom tejto morfologickej štúdie bolo preskúmať neuromuskulárne variácie v oblasti foramen ischiadicum majus v slovenskej populácii a zlepšiť pochopenie topografických vzťahov medzi SN a PM so zameraním na ich klinický význam.
**Súbor a metódy.** Štúdia bola realizovaná na 40 dolných končatinách z 10 ženských a 10 mužských dospelých kadáverov. Bola vykonaná anatomická pitva SN a PM v gluteálnej oblasti bilaterálne, ako aj pitva zadnej femorálnej a popliteálnej oblasti s cieľom identifikovať hlavné vetvy SN.
**Výsledky.** SN, jeho hlavné vetvy a PM boli odpreparované na oboch stranách na všetkých kadáveroch. SN typicky prechádzal cez foramen infrapiriforme v 37 prípadoch. Atypické vetvenie SN, pri ktorom n. fibularis communis prechádzal cez PM, sa pozorovalo na troch dolných končatinách.
**Záver.** Výsledky našej štúdie naznačujú, že atypický priebeh SN vo vzťahu k PM je v slovenskej populácii relatívne bežný. Takýto priebeh môže viesť ku klinickým ťažkostiam, ktoré sa označujú ako primárny PS. V klinickej praxi sa táto diagnóza často prehliada. U pacientov s bolesťami chrbta a s bolesťami v gluteálnej oblasti, ktoré vyžarujú do dolných končatín, by sa na ňu vždy v rámci diferenciálnej diagnostiky malo myslieť *(obr. 5, lit. 27). Text v PDF www.lekarsky.herba.sk.*
*KĽÚČOVÉ SLOVÁ:* anatomická variácia, pitva, m. piriformis, piriformis syndróm, n. ischiadicus.

Lek Obz 2025, 74 (6): 236-241

## Introduction

The SN is the longest nerve in the human body. It originates from the anterior branches of the fourth lumbar to the third sacral spinal nerves, which converge at the lower border of the PM to form a single trunk. The SN enters the posterior pelvis through the greater sciatic foramen, passing beneath the PM via the infrapiriform foramen. After exiting the pelvis, it courses along the femur. It descends into the popliteal fossa, where it divides, at variable levels, into its terminal branches: the tibial and common fibular nerves (1). Immediately after exiting the greater sciatic foramen, the SN gives off sensory branches to the dorsal surface of the hip joint capsule. In the thigh, it provides motor branches to the semimembranosus and semitendinosus, as well as the long head of the biceps femoris muscle from the tibial portion. It also innervates the part of the adductor magnus, starting from the ischial tuberosity and inserting along the proximal border of the medial epicondyle of the femur, specifically at the adductor tubercle. The fibular portion of the SN gives sensory branches to the knee joint capsule and motor branches to the biceps femoris muscle's short head (2 – 4).

The PM is one of the deep posterior hip muscles and is the most cranially positioned among them. It originates from the anterior surface of the sacrum, including the lateral edges of the anterior sacral foramina and the borders of the greater sciatic notch. It also arises from the sacroiliac joint capsule and, occasionally, the sacrotuberous ligament. The muscle inserts onto the upper border of the greater trochanter. The PM functions as an abductor and external rotator of the hip joint, and it is innervated by motor fibers from the sacral plexus (5).

In specific instances, the PM can cause pathological compression of the SN or its terminal branches. This condition is known as PS, characterized by discomfort in the gluteal region and lower limb. From an etiopathogenetic perspective, the syndrome is classified into primary and secondary types. Primary PS is caused by anatomical variations in the SN and PM. Secondary PS results from an external insult or injury to the gluteal region (6).

The PM is well-recognized by orthopaedic and rehabilitation specialists but is less familiar to other physicians. For this reason, we conducted a detailed morphological study focusing on this muscle. The study aimed to identify potential anatomical variations of the PM and the SN, contributing to advancing knowledge in this field. Additionally, it provides a detailed analysis of the topography and variations of the deep gluteal region, which are essential for disciplines such as anatomy, radiology, and musculoskeletal or trauma-related pelvic surgery. Our goal was also to uncover previously unclassified anatomical variations. According to our information, no study with a similar focus has been performed specifically on the Slovak population.

## Material and Methods

The study was conducted on 40 lower limbs (20 lower limbs from 10 female cadavers, aged 62 – 88 years; and 20 lower limbs from 10 male cadavers, aged 49 – 82 years) used for educational and scientific research purposes at the Department of Anatomy, Faculty of Medicine of Pavol Jozef Šafárik University in Košice. All cadavers were obtained through the body donation program with proper informed consent from the donors. Consequently, our study did not require additional Ethics Committee approval from the Faculty of Medicine. All cadavers showed no noticeable macroscopic pathological changes and were preserved using standard alcohol-based solutions. For our research, the skin and subcutaneous tissue were removed bilaterally from the gluteal region, posterior femoral region, and popliteal fossa. After removing the gluteus maximus and gluteus medius, the SN and PM were identified. In all cadavers, the topography of the SN was noted. In the presence of an atypical finding, the course of its branches (the tibial nerve and common fibular nerve) in relation to the PM was also documented. Moreover, anatomical variations of the posterior deep hip muscles and potential variations of other neurovascular structures passing through the greater sciatic foramen were examined. To delineate the main branches of the SN, the tibial and common fibular nerves were dissected up to the popliteal fossa. In the popliteal fossa, the tibial nerve was recognized as the medial branch, and the common fibular nerve as the lateral branch.

## Results

Out of 40 lower limbs, the normal course of the SN through the infrapiriform foramen was observed in 37 cases (92.5%) (Fig. 1).

**Figure 1. Typical course of the SN below the PM, left side, posterior view, male cadaver. SN – sciatic nerve, PM – piriformis muscle.**

Atypical localization of the main branches of the SN was found in 3 lower limbs (7.5%). In all atypical findings, the variation involved the common fibular nerve piercing the PM, emerging from the posterior surface of the muscle. The tibial nerve was consistently positioned medially and caudally relative to the common fibular nerve and passed through the infrapiriform foramen. This observation was recorded unilaterally on both the right and left sides in two female cadavers (Figs 2, 3) and unilaterally on the right side in one male cadaver (Fig. 4). No other anatomical variations of the posterior deep hip muscles, vessels, or nerves in the gluteal region, whether known or previously unknown, were detected.

**Figure 2. Atypical course of the terminal branches of the SN, right side, posterior view, female cadaver.** TN – tibial nerve, CFN – common fibular nerve, PM – piriformis muscle.


**Figure 3. Atypical course of the terminal branches of the SN, left side, posterior view, female cadaver.** TN – tibial nerve, CFN – common fibular nerve, PM – piriformis muscle.

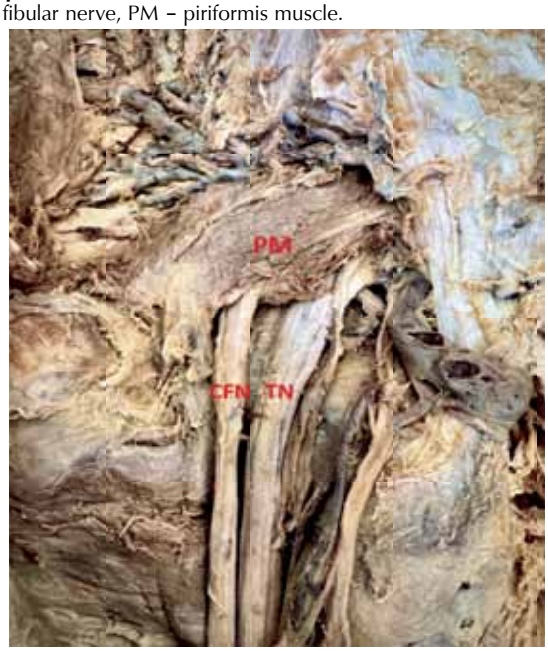
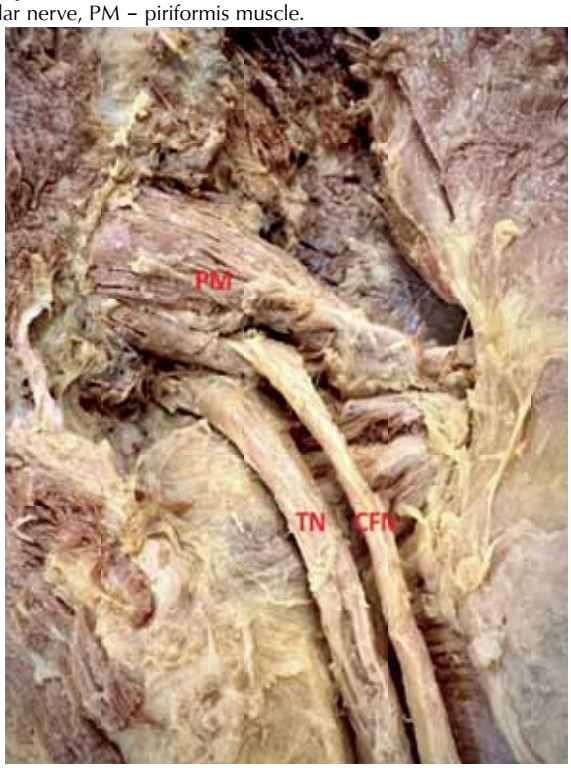



**Figure 4. Atypical course of the terminal branches of the SN, right side, posterior view, male cadaver.** TN – tibial nerve, CFN – common fibular nerve, PM – piriformis muscle.



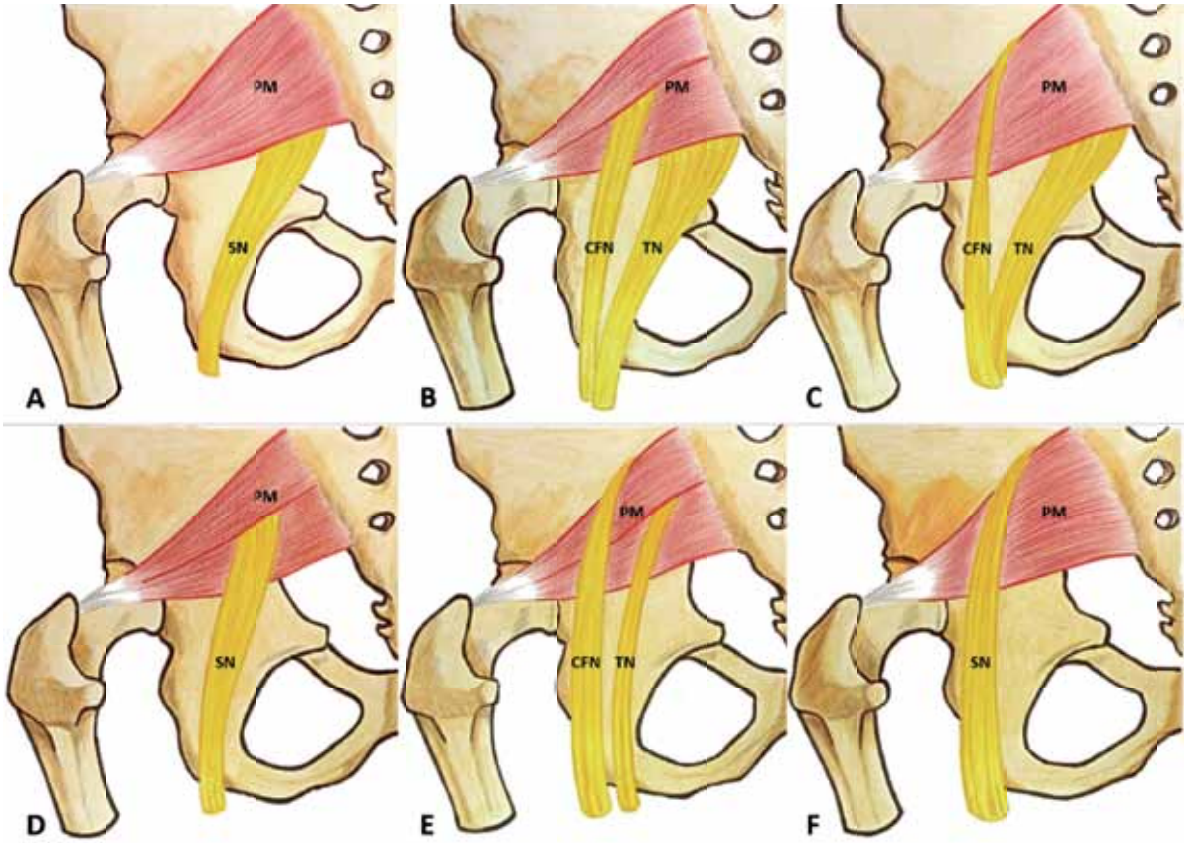

## Discussion

The SN consists of two large mixed nerves from the sacral plexus: the tibial and common fibular nerve. These nerves are closely located within the SN, each enclosed in its epineural sheath of fibrous tissue, and are separated by the Compton-Cruveilhier septum (7). The SN most commonly enters the posterior surface of the pelvis beneath the pear-shaped PM. The PM divides the greater sciatic foramen into the suprapiriform and the infrapiriform foramen. The superior gluteal vessels and the superior gluteal nerve pass through the suprapiriform foramen. Upon exiting the suprapiriform foramen, the superior gluteal nerve divides into superior and inferior branches (8). The inferior gluteal vessels, internal pudendal vessels, inferior gluteal nerve, pudendal nerve, posterior femoral cutaneous nerve, and SN pass through the infrapiriform foramen (2). After exiting the infrapiriform foramen, the SN descends beneath the lower edge of the gluteus maximus, located approximately halfway between the ischial tuberosity and the greater trochanter. In this region, it rests on the deep posterior hip muscles, which cover the hip joint and femoral neck posteriorly. The nerve then continues distally along the thigh axis, almost entirely covered by the long head of the biceps femoris muscle. It runs along the posterior surface of the adductor magnus into the popliteal fossa. At the top of the popliteal fossa, the nerve is bordered laterally by the tendon of the biceps femoris and medially by the tendons of the semitendinosus and semimembranosus muscles. At varying levels, the SN bifurcates into its two terminal branches, which

are already distinct within the popliteal fossa (9, 10). Several studies have confirmed various anatomical variations in the deep hip muscles (11 – 13). Similarly, other studies have documented variations in the topography of the SN. These include differences in its branching into the tibial and common fibular nerves at different locations between the pelvis and the popliteal fossa (14 – 16). The division of the SN into its terminal branches high on the thigh, above the popliteal fossa, is not rare. Other anatomical variations involve atypical localization of the SN in relation to the PM. In these cases, the nerve or its main branches may run above or below the muscle, or the nerve fibers may penetrate the PM. The most widely used classification, according to Beaton and Anson, lists six different neuromuscular topographic variations of the SN and the PM (Fig. 5).

An abnormal course of the SN or its main branches poses a potential risk during various surgical procedures involving the pelvis and thigh. Furthermore, SN blockade is a widely utilized technique for delivering analgesia and anaesthesia to the lower limb, with several different approaches available for targeting the SN (18). Topographical variations in the SN may lead to an insufficient block. In certain situations, anatomical variations in the SN and PM contribute to nerve compression, known as the primary PS (19). The specific type of anatomical variation determines the clinical manifestations of the compression syndrome. These variations result in compression of either the SN (types D and F of the Beaton and Anson classification) or the tibial and common fibular nerves (types B, C, and E of the Beaton and Anson classification), either within or above the muscle. The clinical manifestations resemble those of lumbar intervertebral disc disease, with primary symptoms including back, buttock, and thigh pain. Neurological signs, such as foot drop and paresthesia, may also be present (20). However, clinicians often fail to recognize this diagnosis (19). In the secondary PS, SN compression by the PM arises from diverse causes. The most common triggering factors include post-traumatic changes (e.g., a fall on the buttocks), surgical interventions involving the hip joint, pain-induced muscle spasms, or prolonged mechanical compression of the gluteal region, such as sitting on a wallet (6). PS is a clinical diagnosis, specifically a diagnosis *per exclusionem*, in which other potential causes of the patient's symptoms must be ruled out. As part of the differential diagnosis, it is essential to exclude conditions such as injuries to the posterior thigh muscles, dysfunction or injury of the sacroiliac joint, pathological changes in the

**Figure 5. Beaton and Anson's classification of the SN and PM topography.** PM-piriformis muscle, SN-sciatic nerve, CFN-common fibular nerve, TN-tibial nerve.
**The most common variation, referred to as type A, is characterized by the SN running below the PM through the infrapiriform foramen, which is considered a normal finding.** The common fibular nerve penetrates the PM in type B, while the tibial nerve is located beneath it. Type C involves the common fibular nerve running above the muscle and the tibial nerve below it. In type D, the undivided SN penetrates the PM. Type E occurs when the common fibular nerve exits the pelvis above the muscle, and the tibial nerve passes through the muscle. Finally, the undivided SN exits the pelvis above the muscle in type F (17).



lumbosacral spine, expansive processes in the pelvis, vasculopathy of the inferior gluteal region, and arteriovenous malformations. Imaging methods, including computed tomography, ultrasonography, and magnetic resonance imaging, are very helpful in diagnosing the abovementioned conditions (21). Treatment of PS includes the application of heat to the buttocks, stretching the hip muscles, and using muscle relaxants and anti-inflammatory medications. In some instances, pain and inflammation may be reduced through the local application of corticosteroids (6). In cases where conservative therapy, including rehabilitation, fails, surgical treatment is considered a last resort, enabling targeted release of nerve compression. It is important to note that the outcomes of surgical intervention are not always predictable, and in some patients, pain may continue despite surgical intervention (22). In our study, we revealed three occurrences of atypical branching of the SN, all of which were classified as type B according to the Beaton and Anson classification. The results of our study were compared with findings from other studies conducted across different populations, using the Beaton and Anson classification system. Vicente et al. reported six cases (15%) of non-standard SN courses among 40 lower limbs in a Brazilian population, corresponding to Type B variation (23). In contrast, Benzon et al. identified only one case (1.5%) of non-standard SN courses in 66 lower extremities of a North American population, classified as Type B (24). Furthermore, Muthu Kumar et al. found no variations in the course of the SN in 50 lower limbs examined in an Indian population (15). Similarly, Desalgen and Tesfay did not identify any Type B variations in 36 gluteal regions of a northern Ethiopian population (25). In the region of Central Europe, Pokorný et al. investigated the topographic variations of the SN and PM in the Czech Republic, identifying 13 cases (14.3%) of Type B variation in a sample of 91 gluteal regions (26). Finally, Okraszewska et al. identified two cases (5.6%) of Type B variation in 36 lower limbs of a Polish population (27). The results of this study are most consistent with ours.

Since our research was retrospective, we lacked anamnestic data or information regarding potential health concerns associated with the non-standard course of the main branches of the SN. However, we hypothesize that the manifestations of compression of the common fibular nerve, which passed through the PM, could be present in all affected individuals. Potential symptoms include, in addition to pain, paresthesias on the lateral surface of the lower leg and foot, as well as dysfunction of the lower leg's anterior and lateral muscles. These lower limb areas and muscle groups are innervated by fibers carried through the common fibular nerve.

## Conclusion

A thorough understanding of anatomical variations in the deep gluteal region is crucial for the precise execution of various medical interventions, especially those involving the pelvis and thighs. Our study demonstrates that an atypical course of the SN in relation to the PM, specifically the Type B variation according to Beaton and Anson's classification, is relatively common in the Slovak population. This variation shows the strongest correlation with its occurrence in the Polish population. Anatomical variations of the SN and PM may contribute to the development of primary PS. Due to the symptomatic overlap with other conditions, PS is frequently overlooked in clinical practice. Therefore, this condition should always be a part of differential diagnosis in patients with back and gluteal pain radiating to the lower extremities.*

* **Informed Consent Statement:** All cadavers used in this study were obtained from a body donation program officially recognized in the Slovak Republic. All donors provided informed consent for the use of their bodies for educational and research purposes.

Authors declare no conflict of interest regarding this article.

## References


1. CURRIN SS, MIRJALILI SA, MEIKLE G, et al. Revisiting the surface anatomy of the sciatic nerve in the gluteal region. Clin Anat 2015, 28 (1): 144 – 149.
2. SPINDLER V, WASCHKE J. Lower extremity. In: Waschke J, Böckers TM, Paulsen F, editors. *Sobotta Anatomy Textbook*. Elsevier GmbH: Munich 2019, pp. 195 – 249.
3. LAUMONERIE P, DALMAS Y, TIBBO ME, et al. Sensory Innervation of the Hip Joint and Referred Pain: A Systematic Review of the Literature. Pain Med 2021, 22 (5): 1149 – 1157.
4. FONKOUÉ L, BEHETS C, KOUASSI JEK, et al. Distribution of sensory nerves supplying the knee joint capsule and implications for genicular blockade and radiofrequency ablation: an anatomical study. Surg Radiol Anat 2019, 41 (12): 1461 – 1471.
5. CHANG C, JENO SH, VARACALLO M. Anatomy, Bony Pelvis and Lower Limb: Piriformis Muscle. In: StatPearls [Internet]. Treasure Island FL, 2024; StatPearls Publishing; Available online: https://www.ncbi.nlm.nih.gov/books/NBK519497/ (accessed on 10.12.2024).
6. WALTERS T, CORDOZA G. Rehab Science. 1st ed. Victory Belt Publ. Inc, 2023, pp. 344 – 346.
7. UGRENOVIC S, TOPALOVIC M, JONANOVIC I. Morphological and morphometric analysis of fascicular structure of tibial and common peroneal nerves. FU Med Biol 2014, 16: 18 – 22.
8. RAY B, D' SOUZA AS, SAXENA A, et al. Morphology of the superior gluteal nerve: a study in adult human cadavers. Bratisl. Lek Listy 2013, 114 (7): 409 – 412.
9. TRAN DQ, SALINAS FV, BENZON HT, et al. Lower extremity regional anesthesia: essentials of our current understanding. Reg Anesth Pain Med 2019. Doi.org/10.1136/rapm-2018-000019
10. KARMAKAR MK, REINA MA, SIVAKUMAR RK, et al. Ultrasound-guided subparaneural popliteal sciatic nerve block: there is more to it than meets the eyes. Reg Anesth Pain Med 2021, 46 (3): 268 – 275.
11. OLEWNIK L, ZIELINSKA N, KARAUDA P, et al. The quadratus femoris muscle anatomy: Do we know everything? Ann Anat 2024, 255: 152284.
12. ABDULHAMEED A, AHMED IM, BELLO SS. Bilateral absence: A rare anomaly of the gemelli muscles. Morphologie 2022, 106 (353): 132 – 135.

13. POLESELLO GC, QUEIROZ MC, LINHARES JPT, et al. Anatomical variation of piriformis muscle as a cause of deep gluteal pain: diagnosis using MR neurography and treatment. Rev Bras Ortop 2013, 48 (1): 114 – 117.
14. BERGSTEEDT BJ, CILLIERS K, GREYLING LM. Bifurcation of the sciatic nerve: A descriptive study on a South African cadaver cohort, Morphologie 2022, 106 (354): 155 – 162.
15. MUTHU KUMAR T, SRIMATHI ANANDA R, SUMATHI L. A cadaveric study of sciatic nerve and its level of bifurcation. J Clin Diagn Res 2011, 5 (8): 1502 – 1504.
16. VRZGULA M, HUDÁK V, LOVÁSOVÁ K, et al. Anatomical and Ultrasound Study of the Mid-Femoral Sciatic Nerve and Its Division. Acta Med Martiniana 2023, 23 (2): 51 – 57.
17. BEATON LE, ANSON BJ. The relation of the sciatic nerve and of its subdivisions to the piriformis muscle. Anat Rec 1937, 70: 1 – 5.
18. UZ A, APAYDIN N, CINAR SO, et al. A novel approach for anterior sciatic nerve block: cadaveric feasibility study. Surg Radiol Anat 2010, 32 (9): 873 – 878.
19. BOYAJIAN O'NEILL LA, MCCLAIN RL, COLEMAN MK et al. Diagnosis and Management of Piriformis Syndrome: An Osteopathic Approach JOM 2008, 108 (11): 657 – 664.
20. SMOLL NR. Variations of the piriformis and sciatic nerve with clinical consequence: a review. Clin Anat 2010, 23 (1): 8 – 17.
21. HICKS BL, LAM JC, VARACALLO M. Piriformis Syndrome. In: StatPearls [Internet]. Treasure Island FL, 2024; StatPearls Publishing; Available online: https://www.ncbi.nlm.nih.gov/books/NBK448172/.
22. NAZLIKUL H, URAL FG, ÖZTÜRK GT, et al. Evaluation of neural therapy effect in patients with piriformis syndrome. J Back Musculoskelet Rehabil 2018, 31 (6): 1105 – 1110.
23. VINCENTE EJD, VIOTTO MJS, BARBOSA CAA, et al. Study on anatomical relationships and variations between the sciatic nerve and piriform muscle. Rev Bras Fisioter 2007, 11 (3): 197 – 202.
24. BENZON HT, KATZ JA, BENZON HA, et al. Piriformis syndrome: anatomic considerations, a new injection technique, and a review of the literature. Anesthesiology 2003, 98 (6): 1442 – 1448.
25. DESALEGN M, TESFAY A. Variations of sciatic nerve its exit in relation to piriformis muscle in the Northern Ethiopia. Int J Pharma Sci Res 2014, 5: 953 – 956.
26. POKORNÝ D, JAHODA D, VEIGL D, et al. A. 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 2006, 28 (1): 88 – 91.
27. OKRESZEWSKA E, MIGDALSKI L, JEDRZEJEWSKI KS, et al. Sciatic nerve variations in some studies on the Polish population and its statistical significance. Folia Morphol (Warsz) 2002, 61 (4): 277 – 282.

Do redakcie došlo 20. 2. 2025.

**Address for correspondence:**
**MUDr. Marko Vrzgula PhD.**
Department of Anatomy, Faculty of Medicine UPJŠ
Šrobárova 2
041 80 Košice
E-mail: *marko.vrzgula@upjs.sk*