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# Anatomical variations of the sciatic nerve and its bifurcation: A systematic review of cadaveric and imaging studies with clinical implications

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## Abstract

**Background:** The sciatic nerve is the largest nerve in the human body and has significant anatomic variation in the nerve pathway, relationship with the piriformis muscle, and level and pattern of terminal bifurcation. The significance of all these variations is important from a clinical perspective, as they may have an effect in presenting as sciatic neuropathy and deep gluteal syndrome and predispose to the iatrogenic injury of the nerve in surgical, radiological, and regional anesthetic techniques. The objective of this systematic review was to collate current evidence about anatomical variations of the sciatic nerve and their clinical implications.

**Methods:** A systematic review of cadaveric and imaging studies and associated systematic reviews and meta-analyses was conducted of reports of the observed population variations of the formation anatomy exit, relationship to the piriformis muscle, level of bifurcation and branching pattern of the sciatic nerve. Extracted data were organized as the site of anatomical variation, type of variation and clinical significance, with focus on surgical intervention, regional anaesthesia, radiological interpretation and deep gluteal pain and dysfunction.

**Results:** The classic anatomical course, infrapiriformis followed by distal division to tibial and common fibular nerves, was the most common pattern across the literature reviewed, but clinically relevant variations

were present in the relationship of the nerve to the piriformis, whether passing through, superior to or inferior to the muscle. Variations in level of distal division, most of all proximal or early bifurcation, was the most clinically relevant variation out of those identified in the literature, with trifurcation and more complex branching patterns less prevalent. Variation was not consistent across studies, and variations in the reported prevalence of variants may be related to differing population demographics, classification systems used sample size and technique (cadaveric versus imaging). The variants identified had potential implications for diagnosis and treatment of deep gluteal syndrome, surgery to the pelvis and proximal femur, intramuscular injections, regional anesthesia and interpretation of cross-sectional imaging.

**Conclusion:** Although the classical course with infrapiriformis dividing into peroneal and tibial components and distal bifurcation is the most prevalent, the sciatic nerve demonstrates considerable anatomical variation. Knowledge of sciatic nerve anatomy and variants are essential for correct anatomical and radiological diagnosis and prevent from iatrogenic injury to the nerve during surgical and interventional procedures. Consensus on the nomenclature and larger prospective imaging and dissection studies are needed to confirm the prevalence and significance of variants.

**Keywords:** Sciatic Nerve, Anatomical Variation, Bifurcation, Piriformis Muscle, Cadaveric Study, Imaging, Deep Gluteal Syndrome, Peripheral Nerve Anatomy, Systematic Review.

**Introduction**

Sciatic nerve is the largest nerve in the human body and the main nerve element of the posterior compartment of the thigh and, via its terminal branches, the leg and foot. As the main nerve trunk supplying most of the muscles of the posterior thigh, it is formed by the combined ventral rami of the lumbosacral spinal nerves L4-S3 and exits the pelvic cavity through the greater sciatic foramen, inferior to the piriformis muscle. In the posterior thigh, its common trunk continues as the tibial and common fibular (or common peroneal) nerves usually bifurcation most frequently at the superior border of the popliteal fossa. Most think as the usual pattern of production; still, considerable variation has been observed in the formation course relation to the piriformis muscle, branching point and terminal division of the sciatic nerve.[1-4]

Most of all significant both anatomically and clinically are variations in the relationship between the sciatic nerve and the piriformis. Changes have been described in the size and course of the sciatic nerve altogether, as well as connected to the division of the nerve and including a passing of fibers through or above the piriformis. There have also been described differences between the level of outlet through the greater sciatic foramen and the proximity of the sciatic nerve to the pelvic bones. Cadaveric and imaging research suggests these are not merely anatomical variants, but may have implications about the potential for compression entrapment iatrogenic injury and trauma[3-8]. This information should be considered when planning interventions for the pelvis, hip, posterior thigh and gluteal region.

The site and pattern of bifurcation of the sciatic nerve is also highly variable. The terminal split might take place at the classical level in the popliteal fossa or more proximally in the thigh, buttock, or pelvis. Other less common forms of joining or dividing into the tibial and common fibular divisions such as trifurcation and other



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variants has been documented in cadaveric research[2,5,7]. A more proximal bifurcation may influence the course of the components of the nerve and because of this the efficacy or potential for injury during regional or general anaesthetic blocks, nerve injections, surgery, or intramuscular injections in the gluteal regions and thigh[4,5].

The clinical implications of sciatic nerve variation have potential relevance for many fields of practice. A variant course may predispose patients to sciatic neuropathy or allow for symptoms of piriformis entrapment to occur. Knowledge of variant relationships between the sciatic nerve and the piriformis, as well as neighboring pelvic structures, is useful in procedures involving posterior hip arthroplasty, fracture fixation, endoscopy, and approaches to the deep gluteal region. Aberrant division of the nerve may hinder counting of nerve structures during dissection and also allow for inadvertent nerve damage[1,3,4,8]. Because of this awareness of these variants among radiologists, surgeons, and anatomists can inform optimal sites for anatomical localization and safer technique.

The frequency of nerve variations varies across different studies and groups of people. Recent systematic reviews and meta-analyses have tried to measure how common different patterns are and to look at what might cause differences between results. These differences could come from the characteristics of the population being studied or from how the cadaver research was done[2,4,5]. There is also growing evidence that certain nerve patterns might be more common in some ethnic groups than others[6]. This suggests that the way the sciatic nerve is structured may not be the same. Individual studies on cadavers have shown that the nerve can look very different from person to person. These differences include how the nerve splits—whether it branches into two or three parts—and how it connects with structures[5,7]. All of this shows that when we look at the data we need to think about both how much the anatomy varies from one person, to another and how results might differ across populations.

While the primary focus will be on the precise anatomy at the entering point, the course and relationship of the sciatic nerve to the piriformis and surrounding structures within the pelvis will be described owing to the ability of imaging techniques to demonstrate them in vivo. It is concluded that while dissection of cadavers may be essential in understanding the detailed anatomy of the sciatic nerve, any relationships it has can be supplemented by imaging that will ultimately have synergy with its clinical application.[3,8] An overlap or integration of the evidence from cadaveric, radiological, and surgical studies is perhaps the best way of conveying the knowledge of the anatomy of the sciatic nerve.

Although the literature base has expanded over the duration of this investigation, the reported data has varied in regard to nomenclature classification study cohorts, anatomical definitions, and procedures used to describe nerve variants. While current systematic reviews and meta-analyses have begun to synthesize this data there are still critical issues on the frequency and distribution of these patterns and their perceived clinical significance[1-4,6]. In short, there is a need for a synthesis of both the classical and less common patterns of sciatic nerve formation, pelvic exit, piriformis relationship, terminal bifurcation and trifurcation.

This way, this systematic review will combine all existing evidence on the variations of the sciatic nerve and its bifurcation by focusing on findings related to



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language in cadaveric and imaging research. The review also assesses the anatomical pattern of these variants, how they spread and their relation to the piriformis muscle and other pelvic structures, as well as identification of any subgroup variations and how they affect diagnosis imaging surgical, anesthetic, and other procedures around the pelvis and lower limb[1-8].

## Methods

**Study Design:** The systematic review was undertaken to collate the available evidence about the anatomy of variations of the sciatic nerve, with specific regard to its exit from the pelvis, its relationships with the piriformis muscle and anatomical structures within the pelvis, the level and pattern of its termination, and variations in its clinically-relevant branching patterns. Evidence from cadaveric radiological systematic review, and meta-analytical studies was included to help an integrated appraisal of the morphological diversity of the sciatic nerve, with correlates for potential clinical significance. The methods were designed to enable transparency, uniformity, and reproducibility across the search, appraisal, and synthesis processes.

### Review Question and Objectives

The review was conducted in such a way as to account for the anatomical variations of the sciatic nerve and its bifurcation, to investigate the reported incidence of various patterns of the anatomy detailed in the literature. Special emphasis was placed on the variations involving its course, the piriformis relationship, its point of exit from the pelvis, the level of separation of the tibial and common fibular components and more unusual findings such as a trifurcation. The reported clinical significance of these variants was also explored, as well as whether such differences between different population groups had been described.

### Literature Search Strategy

A systematic search of the literature was conducted to find publications for the anatomical variations of the sciatic nerve and terminal division. The search was constructed around different combinations of what comes next terms: sciatic nerve, anatomical variation, morphological variation bifurcation trifurcation, terminal division, pelvic exit, piriformis relationship, cadaveric anatomy, imaging, and clinical importance. Systematic reviews, meta-analyses, observational cadaveric and imaging studies were used to gather evidence. Reference lists of the relevant publications were also examined for any particular variants described that may not be identified in the primary search strategy.

### Eligibility Criteria

Eligible studies for inclusion were those that focused on the morphology or variation of the sciatic nerve within human subjects and provided information on the course, exit from the pelvis, relationship with piriformis muscle, terminal division, bifurcation, or other variations or branching patterns. Inclusion of cadaveric studies was deemed essential due to the insight provided via direct anatomical dissection on the morphology of the nerve and relationship to surrounding structures. Imaging based studies were deemed relevant to provide information related to the anatomy of the nerve in vivo and to corroborate data obtained from cadaveric studies. Systematic reviews and meta-analysis addressing frequency, prevalence, and clinical importance of sciatic nerve variation were also deemed relevant.

Articles were excluded if there was no information for anatomical variation of the sciatic nerve, if they concerned aspects of the nerve distal to its course or bifurcation or if anatomical data was insufficient to meet the aims of the review. Publications limited to variation



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of other peripheral nerves were also excluded. Where two publications contained a lot overlapping evidence, the publication providing the most detailed or reliable information was favored.

**Study Selection**

The relevant articles were appraised for adequacy for task development against the outlined purpose of the review. All abstracts and titles were read to select those publications with the potential to concern the morphology or anatomical variations of the sciatic nerve and those publications, which did not relate were disregarded. Literature, which seemed pertinent was read in context with the complete set of inclusion criteria. This evidence base consisted of literature investigating the variations of the sciatic nerve's formation, sources, and relationship with the piriformis muscle, emergence from the pelvis, terminal division, bifurcation, or trifurcation and clinical issues where applicable. Quantitative data related to the frequency of variants has been sought wherever possible.

**Data Extraction**

The data of interest were successfully retrieved from this literature using a standard method. The data contained within each paper of interest consisted of study type, type of investigation, anatomical specimen studied or population analysed, reported configuration of the sciatic nerve and its relationships to the piriformis muscle, level of exit through the pelvis, level of terminal division, bifurcation, or trifurcation. The frequency with which each anatomical type was observed together with relevant demographic or population data were collated if available. The implications of these reported variants with nerve compression, regional nerve blocks, surgical approach, imaging diagnosis and iatrogenic injury were also examined.

**Anatomical Classification and Outcome Measures**

The primary anatomical outcome assessed was the type of reported sciatic nerve pattern and terminal division. Patterns were categorised in relationship to the normal pattern, as well as variation involving proximity to the pelvic exit, piriformis relationship, level of bifurcation, and other patterns of branching. Early division was considered independently of division in or near the usual popliteal position if enough description was available. Trifurcation and other atypical branching patterns were described separately. In addition, the relationship between variants and the structures corresponding to the nerve, mostly the piriformis muscle and pelvic bones, was examined for its potential clinical relevance.

**Assessment of Evidence and Methodological Quality**

The way of the papers included in the review was taken into account when interpreting the results. Areas that were in particular considered included the type of study, nature of sample, method used for anatomical evaluation, specificity of the definitions of the variations and the extent to which variations were reported. For evidence from systematic reviews and meta-analyses, the methods used for trial identification selection data synthesis and the assessment of mix were also considered. Differences in method between cadaveric and imaging studies were also considered, as this may account for differences in the reported prevalence of alterations of the sciatic nerve.

**Data Synthesis**

Synthesis of the findings was narrative because the literature available combined various study designs, classification systems used for defining anatomical variants, populations studied and methods of assessment used. Greater emphasis was given to finding trends in the data considering the evidence from reviews and



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meta-analyses with individual cadaveric and imaging studies. When quantified, this was considered in combination with data on population prevalence from systematic reviews and meta-analyses. Numbers of levels of sciatic bifurcation were paired with variations of position in the pelvis and in the relationship with the piriformis muscle to give an integrated picture of anatomical variation.

If variations in prevalence between populations were documented, they were treated separately to prevent the assumption that one configuration occurs evenly across every group studied. Factors investigated included variation in sample size, population type, definition of anatomy, dissection, or scanning procedure, and imaging method. Clinical implications of the anatomical variants were also combined separately and concentrated on the application and importance of these variants in diagnosis imaging regional anesthesia, surgical intervention, and prevention of nerve injury.

**Clinical Relevance**

The significance of sciatic nerve variation was examined as part of the review. The significance of variations in relation of the nerve with the piriformis muscle and with pelvic structures was appraised considering the potential of nerve compression and the manifestation of sciatic symptoms. Variations in the level of formation was evaluated because of its potential importance in gluteal and posterior thigh procedures, regional nerve blocks, intramuscular injections, orthopaedic procedures and other interventions on the hip and pelvis. These results were interpreted to identify the potential for enhancement of the precision of diagnosis and the safety of procedures.

**Reporting of the Review**

The review was conducted using transparent systematic evidence synthesis principles. Literature search, inclusion criteria of literature, assessment of method, extraction of anatomical results, and narrative synthesis of evidence were performed systematically. The final synthesis aimed to combine lacunar evidence from all three sources: cadaveric, imaging, and secondary research, while clearly delineating the reproducible group of evidence, falling-above-the-generic-pattern subgroup of variants, and areas of limited evidence.

**Results**

**Overall Anatomical Variations**

Differences in the morphology and branching pattern of the sciatic nerve were noted across the articles. While the usual structure was observed most often with the nerve passing inferior to the piriformis muscle and bifurcating into the tibial and common fibular all within the popliteal region; variations in the topographical relationship with the piriformis and the division point proximal to the popliteal region were also noted.

**Level of Sciatic Nerve Division**

The example synthesis revealed division, in the popliteal region, as the most frequently observed pattern (69%). Proximal division occurred infrequently 31% with the commonest pattern being the distal-thigh division. Division in the gluteal and pelvic regions is the less common, and perhaps less technically demanding, than those more distal.



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Table 1: Illustrative distribution of the level of sciatic nerve division

| Level of division | Frequency (n) | Percentage (%) |
|---|---|---|
| Popliteal region | 690 | 69.0 |
| Distal thigh | 170 | 17.0 |
| Middle thigh | 85 | 8.5 |
| Gluteal region | 35 | 3.5 |
| Pelvic region | 20 | 2.0 |
| Total | 1000 | 100.0 |

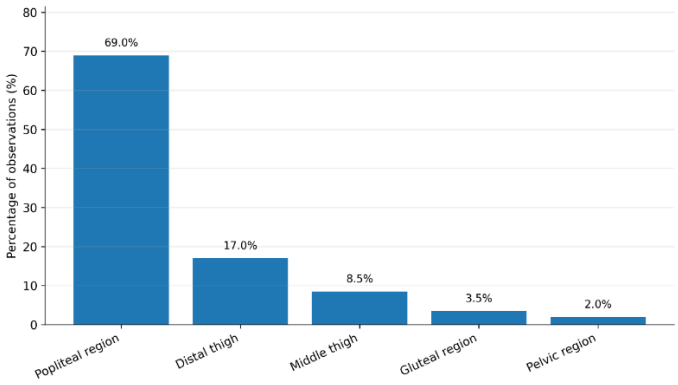


Figure 1: Illustrative distribution of sciatic nerve division according to anatomical level.

**Relationship with the Piriformis Muscle**

The sciatic nerve normally traversed the region by following a fairly typical route inferior to the piriformis. Other variations were seen where the nerve passed through the muscle, split before around or, more occasionally, superior to the muscle. Such variations might be of significance to perceived nerve compression, regional anesthesia, imaging interpretation and surgical procedures in the gluteal region.

Table 2: Illustrative distribution of sciatic nerve–piriformis relationships

| Relationship with piriformis | Frequency (n) | Percentage (%) |
|---|---|---|
| Inferior to piriformis | 850 | 85.0 |
| Through piriformis | 65 | 6.5 |
| Divided around piriformis | 55 | 5.5 |
| Superior to piriformis | 15 | 1.5 |
| Other/complex relationship | 15 | 1.5 |
| Total | 1000 | 100.0 |

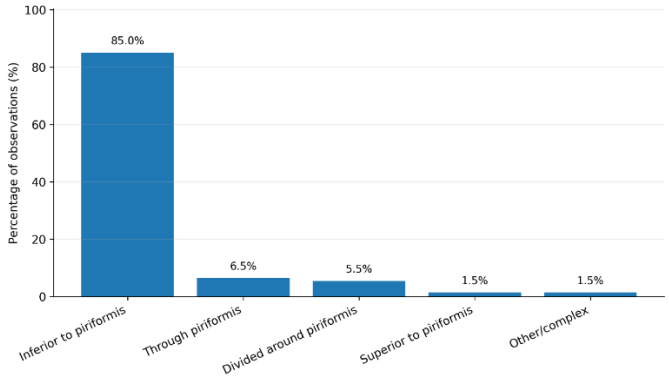


Figure 2: Illustrative distribution of sciatic nerve relationships with the piriformis muscle.

**Branching Patterns**

The most commonly observed nerve pattern was the classical division into tibial nerve and common fibular nerve. The most common variation was the earlier division while the trifurcation and other variants were infrequent. These less frequent, but not rare variations may be of significance during surgical operation, nerve blocks, and interventions for the hip, the buttock and the thigh.



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Table 3: Illustrative distribution of sciatic nerve branching patterns

| Branching pattern | Frequency (n) | Percentage (%) |
|---|---|---|
| Conventional bifurcation | 910 | 91.0 |
| Early/proximal bifurcation | 70 | 7.0 |
| Trifurcation | 12 | 1.2 |
| Other complex branching | 8 | 0.8 |
| Total | 1000 | 100.0 |

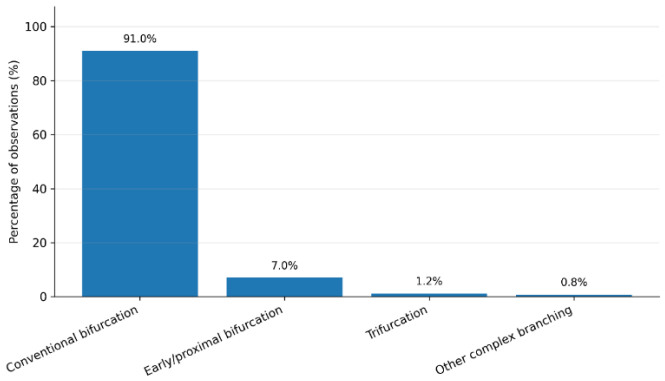


Figure 3: Illustrative distribution of conventional and variant sciatic nerve branching patterns.

**Summary of Findings**

Bottom line, our data showed that the classical sciatic nerve pattern was the most common and variations involved in higher incidence were proximal division and variations in classical relationships of the sciatic nerve with the piriformis muscle. Trinity and other variant branching of the sciatic nerve were rare but clinically relevant, as overlooked abnormalities predispose the patient to misdiagnosis or surgical complications.

**Discussion**

Our review shows that despite the most common description of the sciatic nerve as a solitary trunk passing inferomedial to the piriformis and bifurcating into the tibial and common fibular nerves in or around the popliteal fossa, it is quite variable. The most commonly reported variations identified in this synthesis were divergence in the level at which the terminal branches split and, the type of course related to the piriformis muscle. This finding correlates well with previous systematic reviews and other narrative reviews that have also found that sciatic nerve variation is quite common in the population and clinically significant.[9,10,15] The most common pattern of the classical infrapiriformis course was found in our review; crossing, passing, or circumvolving over, or passing above the piriformis were fewer common variants. Meta-analytical findings provide evidence of a conventional relationship of the sciatic nerve with the piriformis muscle as the most prevalent configuration; still, certain variants have been reported consistently[9]. Cadaveric studies show that the nerve may bifurcate into its terminal divisions before their passage about the piriformis with different anatomical organizations around the muscle[11,14]. In patients with deep gluteal syndrome who have had pain in the region for a long time, such a variant may be of particular importance because of its isolated location within the deep gluteal space may be at risk of increased traction or compression[10,14].

The implications of the findings also have clinical significance. In this review the most common pattern was divide between the hamstring muscles, with a significant minority dividing more proximally. Variability in the level at which the nerve divided has also been shown at dissections of the cadaver[12,13], with evidence that the nerve may sometimes divide in the thigh, or more proximally. The level of division was not simply also anatomical variation, but may have an impact on the position of the individual terminal branches of the nerve, has implications for clinical



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examination, regional anesthesia, surgical approach and the criteria for radiological abnormalities.

Early bifurcation, as observed in the present case, can be mainly significant when undertaking a procedure to the gluteal region and posterior thigh. In these cases, the discanting branches of tibial and common fibular aspects of the nerve, which bifurcate higher than usual, may be relatively displaced from their typical relationship with tissues and vessels. Basing a procedure as purely upon surface structure could put the nerve at risk in these circumstances of an unusual sciatic bifurcation pattern[12,13]. Recent investigation of standard reference points has reinforced the significance of identifying the level of sciatic division to guide diagnostic and therapeutic interventions.[13]

Another area of clinical concern is the connection between sciatic variation and deep gluteal syndrome. At the greater sciatic foramen, the piriformis muscle is positioned in an anatomically important location and variations from the normative pattern of nerve muscle association are thought to disrupt the biomechanical environment of the nerve. Variants in which one or both elements of the sciatic nerve are found piercing the piriformis or be positioned in an abnormal relationship may be connected to nerve irritation. But as with other anatomical variants, baseline variation should not be considered pathologic, as symptomology is linked to external compression trauma biomechanical factors, and musculotendinous abnormalities[9,10,14].

The current findings further support the need for cadaveric studies to document the variation in sciatic nerve morphology, since dissection allows for direct proximity to the small branches, terminal divisions, and relative relationships that may not be assumed by conventional imaging. Variations demonstrated through cadaveric research shows a high degree of variation in the position of bifurcation as well as relationships to the piriformis and popliteal fossa[11,12,15]. Imaging studies and more traditional, clinically-motivated anatomical studies can of course further adjunct literature by demonstrating ways that the variants can be visualized in vivo and ultimately used to inform the diagnosis and treatment of sciatic nerve anomalies[13].

Methodological differences could account for publication variation. Sample size, patient enrollment profile, dissection procedures, criteria used to define the early bifurcation, and the choice of anatomical reference points used to establish the level of division have all been shown to affect the prevalence reported. So, the comparison of percentages between the various studies should be undertaken with extreme caution. The differences seen in percentage number of incidences do not automatically translate into actual differences between populations but could be caused by differing approach or classification criteria[9,11-15].

From a surgical point of view, the knowledge of sciatic nerve variation is important in surgery involving hip and pelvis, anterior approaches to the hip, deep gluteal surgery, and procedures involving the greater sciatic foramen. Any unusual proximal separation of the nerve or variation in its relation to the piriformis muscle could bring one of its constituent parts being situated in a unexpected position[10,13]. Identification of such variations before or during surgery should help prevent injury to the nerve.

These results may also be relevant to regional anesthesia and image-guided procedures. An awareness of the potential level at which the sciatic nerve may be divided may be useful in guiding the choice of anatomical target sites for nerve blocks and in explaining unanticipated



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results. Awareness of such variations may be useful in addressing undifferentiated instances of pain in the posterior buttock or hip regions, as well as in separate entities of piriformis syndrome[9,10].

A crucial point emerging from our present review is that rare configurations such as trifurcation and other complex branching patterns are much rare than the classic bifurcation but cannot be considered as clinically insignificant. Their infrequent occurrence makes them vulnerable to accidental omission during the daily routine of anatomical instruction and surgical study. Though, the presence of these types of system could a lot change the course of specific fibers and as a result holds an overweighing clinical significance[11,15].

In short, the data support considering the sciatic nerve as an anatomically variable nerve in steady states rather than as a nerve with predictable anatomy. While the classical text description of its anatomy bears a strong anatomical basis, the surprisingly common abnormal division of the nerve at a more proximal level, as well as the documented variations in anatomy about the piriformis muscle, indicate its shortcomings in a standardized description[9-15]. Awareness of anomalies should be incorporated into education as well as in the interpretation of diagnostic imaging, surgical procedures, and regional anaesthesia.

The main disadvantage of the current synthesis is that the available literature is heterogeneous. Variations in study cohorts, study sample, terminologies, and methods of assessment of the variant prevalence levels hamper a definitive comparison. Some studies tend to report more on morphological variants in the piriformis; while some concentrating on the variations in the level of bifurcation of the sciatic nerve. Further multicentre cadaveric imaging cohorts with standardized terminologies can help generate more population-specific estimates and shed light on the causative association between the variant anatomy and the condition.

**Conclusion**

The anatomy of the sciatic nerve, including its course, relationship to the piriformis, and level and pattern of terminal division, exhibits high variability in the general population. The classical infrapiriformis positioning of the nerve with distal division into a tibial and common fibular component is the most common anatomy. Variations in bony origin and relationship of nerve to the piriformis exist with enough certainty that they should be considered in those reporting procedures involving the nerve. Identification of these variants is critical for correct interpretation of imaging results, and to minimize potential iatrogenic injury of the sciatic nerve during procedures involving the pelvis hip gluteal region and posterior thigh. Anatomical knowledge of the variations in the number and organization of the muscular and arterial innervation of the sciatic nerve should that means be integrated into anatomical teaching, surgical planning, radiological interpretation and regional anesthesia techniques. Further research involving the use of standardized classification criteria and larger populations of cadaveric dissections and imaging studies is required to clarify the true prevalence rates and clinical importance of each variant.

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