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The anatomy of the motor branches of the sciatic nerve: an anatomical study with clinical implications

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Background: *The sciatic nerve gives the motor branches supply to the biceps femoris long and short head, semitendinosus, semimembranosus, and adductor magnus muscles. The anatomy of these motor branches is highly variable. The aim of this study was to estimate the anatomy and morphometry of hamstring muscles innervation.*
Materials and methods: *The motor branches of the sciatic nerve were dissected from both sides from 20 cadaveric specimens (9 left and 11 right) from 11 cadavers (4 females and 7 males) at the Department of Anatomy, Jagiellonian University Medical College, Kraków.*
Results: *The motor branches of the sciatic nerve length, distance from the piriformis muscle, and number of all branches that exist from the tibial nerve and common fibular nerve were measured. In most cases the common fibular nerve gave off one branch to the short head of the biceps femoris, and in most cases the proximal hamstring tendon was innervated only by the first trunk, the highest number of branches were innervating the semimembranosus and the long head of biceps femoris, the longest branches were coming to the semimembranosus and the shortest to the proximal hamstring tendon*
Conclusions: *The present study shows that there are various innervation types of the posterior group of thigh muscles. Knowledge of possible innervation patterns could be of utmost value to operators performing surgeries on the posterior region of the thigh.* (Folia Morphol 2024; 83, 4: 823–829)

Keywords: motor branches, sciatic nerve, hamstring muscle complex

INTRODUCTION

The sciatic nerve (SN), also called the ischiadic nerve, is the longest and thickest nerve of the human body, and it is formed by the joining of the anterior branches of the L4–S3 spinal nerves [15]. The SN leaves through the greater sciatic foramen below the piriformis muscle and descends between the greater trochanter and ischial tuberosity in the gluteal region [1]. The nerve is divided into 2 terminal branches: the common peroneal nerve (CPN), the external popliteal nerve, or lateral popliteal nerve, and the tibial nerve (TN), usually at the superior angle of

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Figure 1. Innervation of the proximal part of hamstring muscles. 1 — branches to the proximal hamstring tendon, 2 — common trunk from the sciatic nerve, 3 — sciatic nerve, 4 — branch to the long head of biceps femoris.

popliteal fossa. It is a mixed nerve containing both motor and sensory fibres. The motor branches supply: biceps femoris long and short head, semitendinosus, and semimembranosus (Fig. 1). These 3 muscles are collectively referred to as the hamstring muscles [4]. Moreover, the adductor magnus muscle is innervated by both obturator and sciatic nerves [25]. The hamstring muscles function as an extension of the hip and flexion of the knee when the foot is not in contact with the ground [7]. All motor innervation to the posterior thigh derives from the tibial division of the sciatic nerve except for the short head of the biceps femoris, which is innervated by the peroneal division of the sciatic nerve [13]. Semitendonous tendon is commonly used in orthopaedic knee surgery such as anterior cruciate ligament reconstruction and collateral ligament reconstruction. Moreover, hamstring complex injury is typical in athletes who are running, jumping, or climbing [4]. Their prevalence is estimated to reach 12–15% among professional football players [10, 11], but it can also be a problem in the general population [17]. Furthermore, the proximal motor branches of the sciatic nerve may be transferred as donor nerves to repair high femoral nerve injury [9]. Fractures and dislocations in the gluteal region, penetrating injuries, surgical interventions, percutaneously anaesthetic blocks, tumours in the pelvis, improper hip injections usually applied to children and newborns, and aneurysms of the internal iliac artery and its branches may injure sciatic nerve and the branches of this nerve along the posterior thigh [15]. Therefore, it is very important to know the course of the SN, TN, CFN and their motor branches in both the gluteal and posterior thigh regions. The aim of this study was to determine a detailed depiction of the topography of the motor branches of the SC concerning the motor branches to the hamstring complex muscle and adductor magnus muscle. The information was based on dissections of the subgluteal region and posterior thigh region.

MATERIALS AND METHODS

The anatomy of the motor branches of the sciatic nerve were carefully dissected and examined in 20 cadaveric specimens (9 left and 11 right) from 11 cadavers (4 females and 7 males) during the gross anatomy course at the Department of Anatomy, Jagiellonian University Medical College, Kraków, Poland. Further stages of the study were carried out in accordance with the approved guidelines [2]. The specimens were without any grossly evident pathologies or surgical procedures in the leg region. All the cadavers were routinely fixed in 5% formalin solution. The motor branches of the sciatic nerve length, the distance from the piriformis muscle, and number of all branches that exist from the TN and CFN were measured. Branches to the knee joint from the SN were excluded. Each measurement of the described nerve branches was made at least 3 times, using an electronic caliper (with an accuracy of one hundredth of a millimetre) and then the average was calculated. All variant data were recorded and analysed. We considered any proximal tendinous part of hamstring muscles as the proximal hamstring tendon.

Figure 2. Innervation of the short head of biceps femoris. 1 — branch to the knee joint, 2 — branch to the short head of biceps femoris, 3 — sciatic nerve.

Table 1. Number of trunks from the sciatic nerve.

Branches	1	2	3	4
Tibial nerve overall (20)	1 (5%)	10 (50%)	7 (35%)	2 (10%)
Common fibular nerve overall (20)	18 (90%)	2 (10%)	–	–

Table 2. Motor nerve trunks from the sciatic nerve.

Nerve exits	Overall	Left	Right	Male	Female
From TN average	117.99 ± 0.74	118.90 ± 0.74	117.27 ± 0.74	119.56 ± 0.68	115.86 ± 0.81
From TN highest	86.87 ± 0.85	87.80 ± 0.99	86.12 ± 0.73	87.73 ± 0.77	85.58 ± 0.96
From TN lowest	141.19 ± 0.65	142.15 ± 0.57	140.41 ± 0.72	146.09 ± 0.51	133.85 ± 0.86
From CFN average	211.41 ± 0.93	181.89 ± 0.68	231.85 ± 1.10	206.42 ± 0.74	219.31 ± 1.23

RESULTS

In the present study of 11 cadavers, a total of 20 cadaveric gluteal and posterior thigh regions were examined for variations, course, and length of the motor branches of the SN. In 19 cases (95%) the sciatic nerve passed undivided under the piriformis muscle, and in one case (5%) the CFN passed through fibres of the piriformis muscle and the TN passed under the muscle.

In the study the CFN innervated only the short head of the biceps femoris (shBF) (Fig. 2). The rest of the hamstring muscles and adductor magnus (AM) were innervated by the TN. In most cases (90%) the CFN gave off one branch to the shBF. In the femoral region TN gave off mostly 3 (45%) or 2 (40%) trunks Tab. 1). The average level of the exit of trunks from TN was 87 mm for the highest trunk, 141 mm for the lowest, and from the CFN 211 mm under the piriformis muscle Tab. 2).

In most cases the proximal hamstring tendon was innervated only by the first trunk, in one case both by the first and the second trunk, and once only by the second trunk. In 65% of cases the first trunk innervated only the proximal hamstring tendon. The second most common (20%) type of innervation provided by the first trunk was innervation of the proximal hamstring tendon and the long head of biceps femoris (lhBF). Distribution of the rest of the branches arising from trunks are described in Table 3.

The fewest branches were innervated shBF and AM. On the other hand, the highest number of branches were innervating the semimembranosus muscle (ST) and lhBF Tab. 4, Fig. 3). On average, the longest branches were coming to the semimembranosus

Table 3. Trunks of motor branches of the sciatic nerve.

Branches	1 TN	2 TN	3 TN	4 TN	1 CFN	2 CFN
Short head biceps femoris muscle	0%	0%	0%	0%	91.67%	8.33%
Long head biceps femoris muscle	30.36%	64.28%	5.36%	0%	0%	0%
Proximal hamstring tendon	95.56%	4.44%	0%	0%	0%	0%
Semitendinosus muscle	9.68%	51.61%	29.03%	9.68%	0%	0%
Semimembranosus muscle	3.33%	46.67%	40%	10%	0%	0%
Adductor magnus muscle	4%	52%	40%	4%	0%	0%

Table 4. Number of motor branches of the sciatic nerve.

Branches	1	2	3	4	5
Short head biceps femoris muscle	80%	20%	0%	0%	0%
Long head biceps femoris muscle	10%	35%	25%	25%	5%
Proximal hamstring tendon	30%	35%	25%	0%	10%
Semitendinosus muscle	50%	45%	5%	0%	0%
Semimembranosus muscle	5%	35%	35%	5%	20%
Adductor magnus muscle	75%	25%	0%	0%	0%

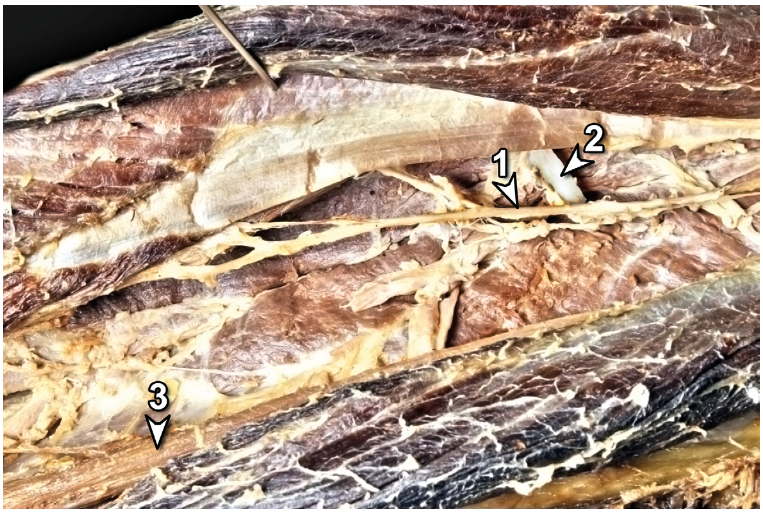

Figure 3. Terminal branches from the trunk from the sciatic nerve. 1 — branches to the semimembranosus muscle, 2 — branch to the adductor magnus muscle, 3 — sciatic nerve.

muscle (SM) and the shortest to the proximal hamstring tendon Tab. 5).

DISCUSSION

Data about innervation of hamstring muscles and its variability seems to be highly limited in the available literature. The necessity of expanding our knowledge in this area is emphasised by the fact that the hamstring muscles are one of the most frequently injured muscle groups among professional sports athletes (an estimated 12% to 26% of all injuries occurring during sports activities). Furthermore, hamstring muscle injuries are becoming more common among the aging population who are increasingly engaging in recreational physical activities [8]. The vast majority of injuries are strains of the muscle or myotendinous junction, which can be treated non-invasively through physical rehabilitation with positive outcome. Less common muscle tears or avulsions from ischial tuberosity are, however, associated with significant impairment in mobility and sharp pain above the involved muscle segment. Surgical treatment

Table 5. Length (mm) of motor branches of the sciatic nerve.

Branches	Overall	Left	Right	Male	Female
Short head biceps femoris muscle	51.21 ± 0.72	56.93 ± 0.73	46.37 ± 0.71	62.28 ± 0.67	37.52 ± 0.83
Long head biceps femoris muscle	79.73 ± 0.70	74.96 ± 0.73	83.82 ± 0.68	83.64 ± 0.65	71.48 ± 0.80
Proximal hamstring tendon	28.73 ± 0.73	27.11± 0.83	29.86 ± 0.66	27.47 ± 0.76	32.19 ± 0.65
Semitendinosus muscle	90.44 ± 0.67	101.65 ± 0.69	81.33 ± 0.66	91.58 ± 0.71	88.57 ± 0.62
Semimembranosus muscle	120.52 ± 0.74	126.9 ± 0.69	115.03 ± 0.79	118.81 ± 0.54	122.51 ± 0.97
Adductor magnus muscle	76.93 ± 0.87	80.94 ± 0.90	73.49 ± 0.85	69.86 ± 0.71	88.23 ± 1.13

of avulsions with reattachment of avulsed tendon (or tendons) are gaining popularity as a method of treating the injury and preventing the occurrence of hamstring syndrome [8, 14]. Symptoms of hamstring syndrome are usually described as the pain located in the upper buttock radiating to the posterior part of tight, which are commonly mistaken with sciatica and require a different therapeutic approach [20]. Similar symptoms might be observed in different sciatica-like conditions involving sciatic nerve compression such us piriformis syndrome or even abnormalities of fascia in lumbar region, which might be a potential aetiology of lower back pain caused by cutaneous nerve entrapment [18, 19]. Hamstring syndrome is caused by ruptures and strains of hamstring muscles or may be induced by scar tissue compressing the nearby nerve to which it has adhered [5]. For the reasons mentioned above, the establishment of a universal pattern of innervation of hamstring muscles seems to be of utmost importance from the point of view of a physician diagnosing the cause of pain and motor impairments affecting this region. In particular, this knowledge appears to be crucial in therapy aimed at preventing long-term disability and restoring athletes to their pre-injury performance as well as improving the quality of life of other patients suffering from similar causes [26]. Most of the injuries are observed in the musculotendinous junction of the LHBF and ST. The conjunction of tendons of the LHBF and SHBF have similar morphological structure; however, injuries in this region occur with lower prevalence [24]. Another field that requires further expertise and investigation is the potential of transferring motor branches of the sciatic nerve in the management of high femoral nerve injuries, which can be a complication of hip arthroplasty, lumbar operations, or traffic accidents. However, there is a need for further expertise on this subject [9, 28].

A systematic review with meta-analysis on outcomes following surgical management of proximal hamstring tendon avulsions carried out by R. Hillier--Smith et al. shows that surgical treatment has a high post-operative satisfaction rate (92.6% of 726 patients assessed their satisfaction level as "good"/ /"excellent" or "satisfied"/"very satisfied"), good functional outcomes, muscle strength restoration (at the level of 87% compared to 460 patients with uninjured limbs) and the "return to sport" rate at the level of 84.5% [14]. To sustain this trend or even improve the results, it seems necessary to establish standardised anatomical schemes (especially concerning the course of vessels and nerves, as well as possible anatomical variations) and further investigation of this area to facilitate the training of specialists willing to treat hamstring muscle injuries.

During our research we found some differences in innervation patterns described and proposed by other authors in comparison to our findings. Based on 20 specimens, M. Bretonnier et al. described 3 possible patterns of innervation of the lhBF (1, 2, or 3 branches to the lhBf, respectively, in 35%, 50%, and 15% of cases). In our research work, we have observed higher diversity within the innervation of the lhBF. According to our findings, we have described up to 5 branches reaching the long head of the biceps femoris muscle (1, 2, 3, 4, and 5 branches, respectively, in 10%, 35%, 25%, 25%, and 5% of specimens). However, the variant with 2 branches was the most common in our study as well as in the scientific paper we mentioned previously. Our observations regarding the innervation of the semitendinosus muscle were similar (one branch in 55% of cases or 2 branches in 45% of cases described in the cited article compared to our findings: one branch in 50% of cases, 2 branches in 45% of cases, and 3 branches in 5% of cases). The greatest number of differences we observed were within the innervation of the semimembranosus muscle. The authors of the cited paper described only 2 variants of SM innervation (by 1 or 2 branches) while we observed variants having 1, 2, 3, 4, or 5 branches reaching the SM, respectively, in 5%, 35%, 35%, 5%, and 20% of specimens. The differences between our studies could be attributed to several factors, including the quantity, ethnicity, and quality of the specimens studied. This indicates the importance of extending the study to develop a standardised innervation pattern of the muscles of the posterior group of the thigh [7].

Gustafson et al. reported that the branch-free length (cm) of the sciatic nerve of semitendinosus was 9.5 ± 1.6, biceps femoris (long head) was 10.7 ± 3.5, adductor magnus was 6.9 ± 3.7, semimembranosus was 14.7 ± 3.8, and biceps femoris (short head) was 13.3 ± 4.2 [12]. The literature is ambiguous regarding the placement of motor branch entries to hamstring muscles, established by measuring the distance from the ischial tuberosity. The long head of the biceps femoris was 15.1 ± 3.4 cm and 14.1 ± 3.3 cm, the short head of the biceps femoris was 20 cm and 19.1 ± ± 2.3 cm, primary semitendinosus was 4.75 ± 1.4 cm and 7.0 ± 2.2 cm, secondary semitendinosus was 14.47 ± 2.6 cm and 20.3 ± 2.9 cm, and semimembranosus was 21.1 ± 3.3 cm [3, 21, 27]. Based on the results from the other author, the semimembranosus and long/short head of biceps femoris are supplied by one motor branch, while the semitendinosus receives 2 motor branches from the sciatic nerve, which runs directly to the popliteal fossa [1, 3, 21–23, 27]. Our results are different from those above Tab. 4). We found the number of human motor branches of the sciatic nerve to be much more variable.

Knowledge of possible innervation patterns could be of utmost value to operators performing surgeries on the posterior region of the thigh, and further investigation of this topic might be crucial for improving diagnostics and developing the surgical approach on hamstring muscles and tendon injuries or even show the usefulness in the possible use of the posterior motor branches of the sciatic nerve in transplantology. Hamstring muscle injuries can involve the disruption of innervation by damaging motor nerve branches. The nerve conduction velocity in injured hamstrings is significantly lower than in uninjured muscles [16].

CONCLUSIONS

The present study shows that there are various innervation types of the posterior group of thigh muscles. In most cases the CFN gave off one branch to the short head of the biceps femoris; in most cases the proximal hamstring tendon was innervated only by the first trunk, the highest number of branches were innervating the semimembranosus and the long head of biceps femoris, and the longest branches were coming to the semimembranosus and the shortest to the proximal hamstring tendon. This knowledge can be of great use for sports medicine, surgeons, and orthopaedics.

ARTICLE INFORMATION AND DECLARATIONS

Data availability statement

The data of this study are available upon request from the corresponding author.

Ethics statement

The research protocol was submitted for evaluation and approved by the Jagiellonian University Bioethics Committee, Kraków, Poland.

Authors' contributions

All authors contributed equally to the overall process of creating, planning, and carrying out the research.

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Supplementary material

The supplementary material is available upon special request.

Conflict of interest

None declared.

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