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ORIGINAL ARTICLE

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

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ABSTRACT

Background: The sciatic nerve gave the motor branches supply to: 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 the 11 cadavers (4 females and 7 males) at the Department of Anatomy, Jagiellonian University Medical College Cracow.

Results: The motor branches of the sciatic nerve length, distance from piriformis muscle and number of all branches that exist from tibial nerve and common fibular nerve were measured. In most cases common fibular nerve gave off one branch to the short head of 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, 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

Keywords: motor branches, sciatic nerve, hamstring muscle complex

INTRODUCTION

Sciatic nerve (SN), also called ischiadic nerve, is the longest and thickest nerve of the human body and it is formed by the joining of anterior branches of L4–S3 spinal nerves [15]. SN is leaving 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 two terminal branches Common Peroneal Nerve (CPN), also known as the common peroneal nerve, external popliteal nerve, or lateral popliteal nerve and Tibial Nerve (TN) usually at the superior angle of popliteal fossa. It is a mixed nerve containing both motor and sensory fibers. The motor branches supply: biceps femoris long and short head, semitendinosus, and semimembranosus. (Fig. 1). These three 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 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 orthopedic knee surgery such as: anterior cruciate ligament reconstruction, 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 be a problem in a 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 gluteal region, penetrating injuries, surgical interventions, percutaneously anesthetic blocks, tumors in pelvis, improper hip injections usually applied to children and newborns, aneurysm of 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 SN, TN, CFN and its motor branches in both gluteal and posterior thigh regions. The aim of this study was to determine detailed depiction of 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 motor branches of the sciatic nerve were carefully dissected and examined in 20 cadaveric specimens (9 left and 11 right) from the 11 cadavers (4 females and 7 males) during the gross anatomy course at the Department of Anatomy, Jagiellonian University Medical College Cracow, 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, distance from piriformis muscle and number of all branches that exist from TN and CFN were measured. Branches to the knee joint form SN were excluded. Every measurement of the described nerve branches was made at least 3 times, using an electronic caliper (with an accuracy of one hundredth of a millimeter) and then the average was calculated. All variant data were recorded and analyzed. As the proximal hamstring tendon we considered any proximal tendinous part of hamstring muscles.

RESULTS

In the present study of 11 cadavers, a total of 20 cadaveric gluteal and posterior thigh regions were examined for variations, course, 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%) CFN passed through fibers of piriformis muscle and TN passed under the muscle.

In the study CFN innervated only the short head of biceps femoris (shBF) (Fig. 2). The rest of the hamstring muscles and adductor magnus (AM) were innervated by TN. In most cases (90%) CFN gave off one branch to shBF. In the femoral region TN gave off mostly 3 (45%) or 2 (40%) trunks (Table 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 CFN 211 mm under the piriformis muscle (Table 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% 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 branches arising from trunks are described in Table 3.

By the least number of branches were innervated shBF and AM. On the other hand the highest number of branches were innervating the semimembranosus muscle (ST) and lhBF (Table 4, Fig. 3). On average the longest branches were coming to the semimembranosus muscle (SM) and the shortest to the proximal hamstring tendon (Table 5).

DISCUSSION

Data about innervation of hamstring muscles and its variability seems to be highly limited in available literature. The necessity of expanding our knowledge in this area is emphasized 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 an aging population 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 involvedmuscle segment. Surgical treatment of avulsions with reattachement of avulsed tendon (or tendons) are gaining popularity as a method of treating the injury and preventing the occurance of hamstring syndrome [8, 14]. Symptoms of hamstring syndrome are usually described as the pain located in the upper buttock radiating to the posterior tight, which are commonly mistaken with sciatica and requires 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 etiology of lower back pain caused by cutaneous nerves entrapment [18, 19]. Hamstring syndrome is caused by ruptures and strains of hamstring muscles as well as may be induced by the scar tissue compressing the nearby nerve to which it 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 musculotendinous junction of LHBF and ST. The conjunction of tendons of LHBF and SHBF have similar morphological structure, however injuries in this region occur with lower prevalence [24]. Another field which requires further expertise and investigation is potential of transferring motor branches of sciatic nerve in management of high femoral nerve injuries, which might be the 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 high post-operative satisfaction rate (92.6% from 726 patients assessed their satisfaction level as “good”/”excellent” or “satisfied”/”very satisfied”), good functional outcomes, muscle strength restoration (at level of 87% compared to 460 patients with uninjured limb) and the “return to sport” rate at the level of 84.5% [14]. In order to sustain this trend or even improve the results, it seems necessary to establish standardized anatomical schemes (especially concerning the course of vessels and nerves, as well as possible anatomical variations) as well as further investigation of this area in order to facilitate the training of specialists willing to treat hamstring muscles 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, the M. Bretonnier et al. described 3 possible patterns of innervation of the lhBF (1, 2 or 3 branches to 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, 5 branches respectively in 10%, 35%, 25%, 25%, 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 before. Our observations regarding the innervation of the semitendinosus muscle were similar (1 branch in 55% cases or 2 branches in 45% cases described in cited article compared to our findings: 1 branch in 50%, 2 branches in 45% of cases and 3 branches in 5% of cases). The most differences we observed were within the innervation of the semimembranosus muscle. The authors of the paper we cited 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%, 20% of specimens. The differences between our studies could be attributed to a number of factors including the quantity, ethnicity and quality of the specimens studied. This indicates the importance of extending the study in order to develop a standardized innervation pattern of the muscles of the posterior group of the thigh [7].

Gustafson et al. reported that branch-free length (cm) of 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, biceps femoris (short head) was 13.3 ± 4.2 [12]. The literature has been ambiguous regarding the placement of motor branch entries to hamstring muscles established by measuring a distance from the ischial tuberosity. The long head of biceps femoris was 15.1 ± 3.4 cm and 14.1 ± 3.3 cm, the short head of 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 two motor branches from the sciatic nerve, which is running directly to the popliteal fossa [1, 3, 21, 22, 23, 27]. Our results are different from those above (Table 4). We find that the number of human motor branches of the sciatic nerve is 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 CFN gave off one branch to the short head of 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, the longest branches were coming to the semimembranosus and the shortest to the proximal hamstring tendon. This knowledge can surely be of great use for sports medicine, surgeons and orthopedics.

Article information and declarations

Data availability statement

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

Ethics statement

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

Author contributions

All authors contributed equally in an overall process of creating, planning and realizing research.

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Supplementary material

The supplementary material can be available on the special request.

Conflict of interest: None declared.

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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.

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.

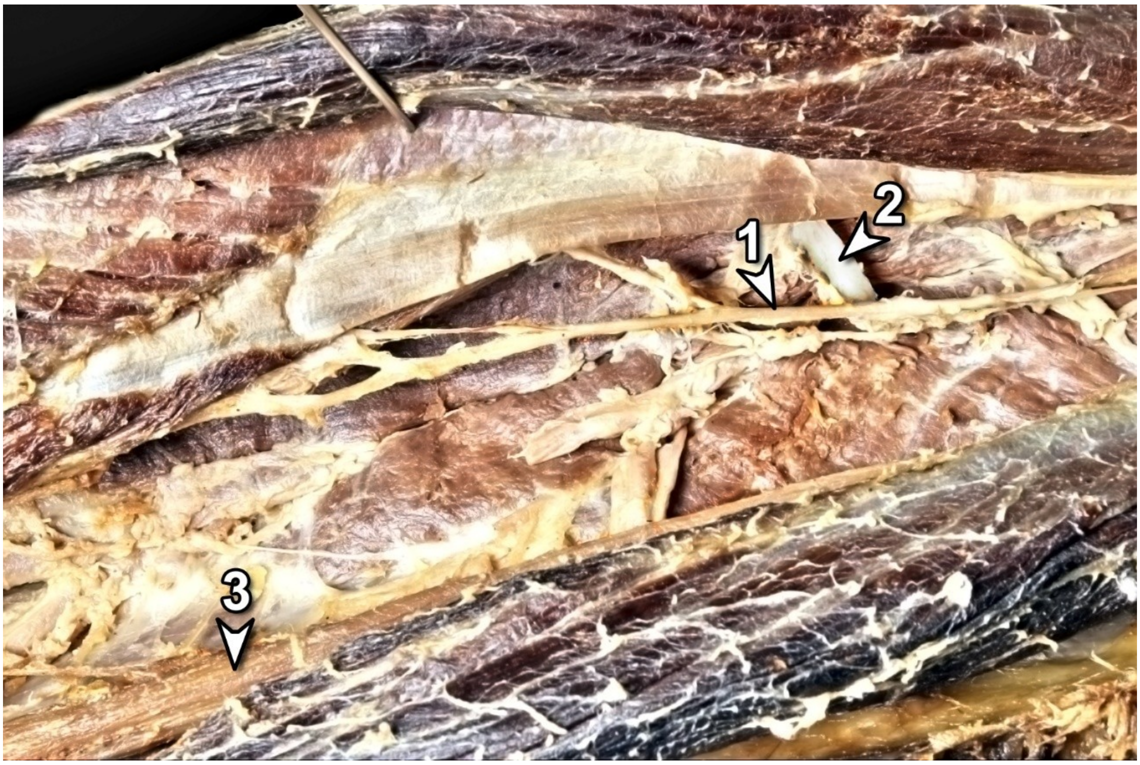

Figure 3. Terminal branches from the trunk from the sciatic nerve. 1 — branches to the semimembranosus muscle, 2 — branch to the adductor magnus muscle, 3 — sciatic nerve.

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

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%

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