Anatomical evaluation of the sciatic nerve innervation within the lower limb: A cadaveric study

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December 25th 2014
INTRODUCTION

Anatomically, the sciatic nerve is the largest peripheral nerve within the human body.\textsuperscript{1,2} This nerve is typically formed within the pelvis by the roots of the ventral rami of L4-S3.\textsuperscript{3,4} The sciatic nerve leaves the pelvis through the greater sciatic foramen, commonly below the piriformis, and descends between the bony landmarks of the greater trochanter and ischial tuberosity.\textsuperscript{3,4,5} This nerve consists of two major branches classified as tibial and common fibular nerve, both of which are usually seen separated within the popliteal fossa.\textsuperscript{1,3} Being a thick and prominent nerve of the lower limb, the sciatic nerve is a mixed nerve giving rise to both motor and sensory nerve fibers that supply the lower limb.\textsuperscript{1,2} The motor branches target the leg, foot and posterior compartment of the femoral region, in addition to hip and knee joint. The sensory fibers on the other hand supply the entirety of the leg and foot with exceptions to the anteromedial tibial region and medial margin of the foot.\textsuperscript{3}

Various literature has focused on the significance of the variations present within the sciatic nerve for its major clinical and surgical implications. It has been reported that such variations in nerve divisions span anywhere from the sacral plexus to the lower part of the popliteal fossa.\textsuperscript{1,3} With the lack of consistency of the sciatic nerve divisions, inadvertent injuries during operative procedures may lead to neurological deficits such as paralysis of the thigh muscles occasionally accompanied by inadequate sensory function.\textsuperscript{3,6,7} Clinically, the location of the sciatic nerve is essential for the implementation of deep intramuscular injections and sciatic nerve blocks, in addition to the interpretation of sciatic neuropathy such as piriformis syndrome, non-discogenic sciatica, coccygodynia, and muscular atrophy.\textsuperscript{1,3,6}

With such variability and its practical significance, it is critical to know the exact anatomy of such nerve structures. Thus, the aim of this study was to evaluate the branches, divisions and innervations of the sciatic nerve along the length of the lower limb. For this study, two cadaver lower limb segments were prosected. Segment 1 included the gluteal, femoral and popliteal regions (the segment ended inferior to the tibial tuberosity). Segment 2 consisted of the distal femoral region, knee joint and the remainder of the lower limb (leg and foot).
PROCEDURE

Segment 1

This cadaver segment was dissected in the prone position to expose the posterior femoral compartment in order to investigate the sciatic nerve. The segment was the right lower limb of a female donor that was cut transversely superior to the sacrum at the level of the iliac crest. Within the pelvic region, it was also cut midsagittally through the intergluteal cleft in addition to a transverse cut below the tibial tuberosity (Figure 1). A note should be made that the anterior compartment had already been dissected previously and most of the focus of this study was on the posterior compartment.

The segment was placed in a prone position to deliver a transverse incision immediately below the gluteal fold with the use of a scalpel. This cut was followed by a vertical incision that was made from the transverse cut to the end of the segment (popliteal region) (Figure 2). Incisions were made to be 2-3 millimeter deep to ensure that only the skin was cut and not the fascia lata (a broad connective tissue fully surrounding the thigh). Using toothed forceps and a scalpel, the skin of the femoral region was reflected medially and laterally. Next an oblique incision at a decline angle was made superior to the gluteal fold which was joined with the initial transverse incision made in the proximal femoral region (Figure 2). The skin on the gluteal region was reflected keeping most of the deep facia intact. However, medially, the fascia lata was strongly embedded with the skin and muscle fibers of the gluteus maximus which caused some of these fibers to be removed with the skin. The excess skin within the gluteal fold was removed to fully expose the gluteal and femoral regions of the thigh.

It was observed that there was an abundance of the adipose tissue in the proximal femoral, popliteal, and lateral gluteal regions.

The fascia lata was reflected by cutting along the same path as when the skin was reflected. A note should be made that the fascia in the gluteal region (over the gluteus maximus) was not removed completely as it was strongly embedded itself with the muscle fibers and attempt to reflect it would have damaged the muscle structure.

To further expose the structures within the gluteal region, the gluteus maximus was reflected. The gluteus maximus was identified and detached along its medial attachments of posterior ilium and dorsal sacrum with the use of a scalpel. Then from the superior border of the muscle, fingers and probes were pushed deep to the gluteus maximus to separate it from the deeper structures. The superior and
inferior arteries and nerves were palpated and cut for the purposes of effectively reflecting the gluteus maximus. At this point all structures deep to the gluteus maximus and fascia lata were effectively exposed (Figure 1).

**Segment 2**

Since the sciatic nerve is responsible for almost all portions of the leg and foot, the entirety of Segment 2 was dissected. This segment consisted of the distal femoral region, knee joint and the remainder of the lower limb (leg and foot) (Figure 3). Similar to Segment 1, incisions were made using a scalpel and were 2-3 millimeter deep to ensure that only the skin was cut and not the fascia lata or crural fascia (a broad connective tissue fully surrounding the leg). Two vertical incisions were made over the anterior and posterior aspects of the segment (Figure 4). On the anterior side, the cut spanned from the middle of superior portion of the segment (distal femoral over rectus femoris) which ran the length of the leg and continued onto the dorsum foot, stopping right before the metatarsophalangeal joints. Similarly, the posterior incision was synonymous to the anterior where the cut started from the middle top portion of the popliteal fossa that ran the length of the leg and continued from the heel to the plantar aspect of the foot. This cut as well ended before the region of metatarsophalangeal joints. Additionally, two circumferential incisions were made perpendicular to the initial vertical cuts. The first was performed at the level of the tibial tuberosity while the other at the level of the malleoli. Then two separate horizontal incisions were made at the ends of the vertical cuts of the dorsum and planum aspect of the foot. It was found that these two horizontal cuts were not in perfect line to perform a continuous incision (dorsal was much more posterior than the plantar). To make these cuts continuous, both medial and lateral sides were additionally connected but a cut that ran lateral and medial to the foot to produce a Z-shape.

Using toothed forceps and a scalpel, the skin was reflected medial and laterally from all incision intersection points. Since the cuts were circumferential, the skin on the segment was removed leaving with the fascia lata and crural fascia intact. Identical incision traces to the skin where made on the facia to reflect and remove it. This was done while preserving superficial structures embedded within the fascia such as greater saphenous vein, lesser saphenous vein, common fibular nerve, and superficial fibular nerve along with medial and lateral sural nerves.

It should be noted that there was an abundance of adipose tissue around the popliteal fossa and the plantar aspect of the foot with minimal amount seen in the leg region. There was also a scar tissue
formed posteriolateral to the calcaneal tendon (also known as Achilles tendon) near the calcaneus that was removed.

Once the muscles were revealed the deep muscle fasica was individually removed while separating muscles from one another with the use of a probe. The thigh muscles such as biceps femoris (BF), semimembranosus (SM), semitendinosus (ST), gracilis and sartorius were reflected either medially or laterally to reveal the sciatic nerve and popliteal blood vessels deep within the popliteal fossa. Within the lateral leg muscle compartment, the peroneus longus was cut at its origin (inferior border fibular head) and partially reflected to reveal the deep and superficial fibular nerve branches. Additionally, the calcaneal tendon was transected and reflected upwards to further examine the tibial nerve and its branches within the deep posterior leg compartment. It should be noted that a portion of the proximal soleus attachment at the soleal line was also cut for the purposes of tibial nerve examination. On the planum aspect of the foot, the plantar aponeurosis was cut from the posterior attachment and reflected anteriorly in order to reveal the muscular layers in addition to nerve branches of the foot. Similarly, the flexor digitorum brevis (FDB) was incised posteriorly and reflected anterolaterally while severing the supplied nerve and blood vessels for the purpose of observing the second and third layer of muscle layers.

MUSCULATURE

Segment 1

Starting from the gluteal region (Figure 5), the gluteus maximus was the most superficial muscle identified. The gluteus maximus had its insertions at the dorsal aspect of the sacrum and coccyx in addition to the posterior portion of the ilium. The muscle fibers traveled obliquely while spanning the width of the gluteal region to insert onto the iliotibial tract and gluteal tuberosity. Deep to the gluteus maximus, the gluteus medius was identified with its attachment at the superior border of the ilium. The fibers of gluteus medius traveled obliquely across the lateral surface of the coxal bone to be inserted on the superomedial aspect of the greater trochanter. Piriformis muscle was located inferior to the gluteus medius with its insertion also at the superomedial aspect of the greater trochanter (note: piriformis could not be followed to the origin). Inferior to the piriformis, quadratus femoris was distinguished as muscle fibers running horizontally from the lateral aspect of the ischial tuberosity to the medial border of the greater trochanter.
Three muscles were identified in the posterior compartment of the thigh (Figure 6); ST, SM, and BF. Medially, SM and ST attached at the inferiomedial and inferior border of the ischial tuberosity respectively. SM being medial, longer and larger, inserted on the medial tibial condyle while the ST converged as a thin tendon to be inserted onto the medial surface of the proximal tibia. It should be noted that the ST muscle was smaller, thinner and posterior to the SM. BF, the only lateral muscle of the posterior compartment, consisted of a long head (LH) and short head (SH) which bifurcated at the half point of the femoral diaphysis. LH being predominantly larger, attached at the inferiolateral border of the ischial tuberosity and followed vertically the length of the femur to insert onto the fibular head. The SH conversely originated from the linea aspera and lateral supracondylar line of the femur and blended with the long head at the halfway point of the femoral diaphysis.

Deep to the posterior compartment muscles, adductor magnus (AM) spanned and inserted at the full length of the femur while originating from the ischial tuberosity. Proximal aspects of the posterior leg compartment muscles were also recorded (Figure 7). Lateral and medial gastrocnemius (LG and MG) muscles were respectively attached to the lateral and medial aspects of the femoral condyles. Deep to the LG, plantaris muscle (PLAN) originated from the lateral supracondylar border and immediately converged into a thin tendon directed medially. Inferior to PLAN was the soleus muscles (SOL) spanning the width of the tibiofibular joint.

Segment 2

Starting from the anterior thigh region, the common quadriceps tendon converged rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius muscles onto the base of the patella which then connected to the tibial tuberosity through the patellar tendon. The distal end of the sartorius muscle was also identified as a strap like muscle attaching to the superior portion of the medial tibia. Additionally, the gracilis muscle of the medial compartment was investigated with its insertion at the superomedial surface of the tibia. It should also be noted that the posterior compartment muscles had identical insertions points at those mentioned in the first segment.

The posterior compartment of the leg was divided into the superficial and deep layer. Starting with the superficial layer, the medial and lateral gastrocnemii muscles were identifies with their origins at the medial and lateral femoral condyles respectively. Both these muscles traveled the length of the leg and converged at about the halfway point where they formed the calcaneal tendon that inserted at the posterior surface of the calcaneus (calcaneal tuberosity). Deep to the gastrocnemii muscles, SOL was
located with its insertions at the soleal line, middle third of the medial border of the tibia and posterior surface of the fibula. This muscle covered the width of the leg and converged onto the calcaneal tendon near the bottom third of the leg length. It should be duly noted that the PLAN was not directly inspected, but the tendon was located between the gastrocnemius and the SOL. The tendon stretched diagonally from underneath the lateral gastrocnemius and travelled with the medial border of the medial gastrocnemius which later merged with the calcaneal tendon near the insertion. Upon reflecting the superficial posterior muscles of the leg, the deep muscles were revealed as popliteus, flexor hallucis longus (FHL), flexor digitorum longus (FDL) and tibialis posterior (TP). These muscles were separated from the superior compartment via the intermuscular septum which was removed. The popliteus muscle was a short band that spanned from the lateral aspect of the distal femur to the posterior surface of tibia superior to the soleal line. FDL muscle, located medially, was attached to the posterior medial portion of the tibia inferior to the soleal line with its tendon running posterior to the medial malleoli and deep to the flexor retinaculum to the plantar aspect of the foot. The remainder could not followed due to the tendon stretching deep to the pedal muscular layers. Lateral to the FDL, FHL muscle originated at the posterior two thirds of the fibular surface and traveled the same path as the FDL, but only to insert at the base of the distal phalanx of the great toe (the tendon of which was identified in the second muscular layer of the planum foot). Lastly, the muscle deep to both FDL and FHL was TP. This muscle originated from the posterior surface of the tibia inferior to the soleal line in addition to the posterior surface of the fibula. TP also followed the same path as the other two deep muscles to insert at the plantar aspect of the foot (specifications on the insertion could not be determined).

The lateral compartment of the leg consisted of two muscles; peroneus longus (PL) and brevis. The more superficial of both, PL, originated from the inferior border of the fibular head and superior two thirds of the lateral fibular (note: some of these attachments were cut as mentioned for the purposes of examining the common fibular nerve divisions). This muscle traveled the length of the leg and posterior to the lateral malleoli to insert at the base of the foot (the tendon insertion was not identified specifically). Deep to this muscle the peroneus brevis arose from distal two thirds of the lateral surface of the fibula and inserted at the styloid process of the 5th metatarsal. Both of these muscle were held in place on the lateral aspect by the superior and inferior peroneal retinacula which inserted to the lateral surface of the calcaneus. It should be noted that the inferior peroneal retinaculum is an extension of the inferior extensor retinaculum whereas the superior peroneal retinaculum is its own structure.
Three muscle were identified in the anterior compartment of the leg; tibilais anterior (TA), extensor hallucis longus (EHL), and extensor digitorum longus (EDL)(note: fibularis tertius was not found). TA being medial originated from the lateral condyle and superior half of the lateral surface of the tibia. This muscle then traveled the length of the leg where the tendon passed onto the medioplantar surface of the foot. A smaller muscle lateral to TA and medial to EDL was the EHL which originated from the middle part of the anterior surface of the fibula. Its tendon traveled lateral to the TA and upon palpation was confirmed to insert onto the base of the distal phalanx of the great toe. The most lateral of the anterior muscles was the EDL which attached to the lateral condyle of the tibia along with the superior third of the medial surface of the fibula. This muscle bifurcated at the superior third portion, sending two separate tendons to the distal lateral four phalanges (determined through palpation). It should be kept in mind that the tendons of these muscles are held together by the superior and inferior extensor retinacula.

The dorsum of the foot consisted of two muscle that were deep to the tendons of the anterior leg compartment muscles. These muscle for the purpose of this experiments were not exposed completely, rather were inspected. The extensor hallucis brevis muscle being the most medial, spanned diagonally form the calcaleus to fuse with the long extensor tendon of the great toe. The extensor digitorum brevis also originated at the same location, but more laterally, fused with the extensor tendons of the phalanges.

On the plantar aspect of the foot, a broad connective tissue known as the plantar aponeurosis was distinguished which spanned from the calcaneus to the phalanges of the foot. A lateral band of this aponeurosis was also located which ran the length between the calcaneus and the styloid process at the base of the 5th metatarsal. Deep to this aponeurosis, the 1st layer of the plantar musculature was observed. This layer consisted of 3 muscles; abductor hallucis, FDB and abductor digiti minimi. Abductor digiti mini was the lateral most muscle that originated from the lateral surface of the calcaneus and inserted at the lateral base of the proximal phalanx. This muscle made the bulk of the lateral foot and ran superficial to the styloid process. Medial portion of the foot composed of the abductor hallucis which arose from the medial aspect of the calcaneus and inserted at the medial side of the proximal phalanx. In between these two muscles, FDB, a broad and flat muscle originated from the calcaneus and ran anteriorly and split into three tendons (fourth lateral tendon could not be found) which inserted to the plantar portion of the phalanxes. In the second muscular layer, two muscles were examined; quadratus plantae and the lumbricals. The quadratus plantae attached at the anterior surface of the
calcaneus and inserted by converging with the flexor digitorum longus muscle (insertion palpated, but not confirmed). The lumbrical muscles were not prominent and hard to locate. The only identification found was a lumbrical muscle that originated at the tendon of the 1st digitorum longus. Insertion according to literature is on the medial aspect of the expansion over lateral four digits (not found). By pulling aide the 2nd layer of muscle laterally, some of the 3rd muscular layer was exposed. This involved three muscles known as flexor hallucis brevis, adductor hallucis and flexor digiti minimi brevis. Flexor hallucis brevis and flexor digiti minimi brevis were easily located as they were directly inferior to abductor digiti minimi and abductor hallucis muscles respectively. Oblique head of the adductor hallucis was also identified. The origins and insertions of these muscle were not investigated. Lastly, the 4th muscular layer was not investigated as it was deep and exposing of which would require demolition of the previous 3 layers.

NEUROVASCULAR STRUCTURES

Please refer to table 1 for a summarized list of specific innervations of muscles

Segment 1

Starting at the gluteal region inferiomedial to the piriformis, three distinct nerves were identified. Posterior femoral cutaneous, inferior gluteal and the sciatic nerves were recognized medial to lateral (Figure 5).

The sciatic nerve being the largest nerve in the body was determined as a combination of two separate nerves (tibial medially and common fibular laterally) surrounded and enclosed by common connective tissue sheath. The nerve spanned from the inferior border of the piriformis and travelled vertically in-between the posterior compartment muscles to the end of the segment. The sciatic nerve traveled deep to the superior portion of the long head of the biceps femoris and bifurcated into its 2 separate branches at the distal third of the femoral length. It should be noted that the sciatic nerve was slightly laterally rotated in a sense to make the tibial nerve slightly posterior and the common fibular nerve slightly anterior. Additionally, a section of the sciatic nerve was naturally compressed and deformed at the proximal two-thirds of its length. It was also flat superior, and round inferior to the deformity.

The sciatic nerve gave rise to multiple branches that innervated the muscles of the posterior and medial compartments of the thigh (Figure 6). Starting at the superior third of the nerve, the tibial aspect
of the sciatic nerve gave rise to a branch which immediately bifurcated. One division ran parallel to the lateral border of LH of BF and deep to two blood vessels, supplying LH, to innervate the superior third of SH of BF. The other division was unexpectedly cut during the reflection of the gluteus maximus and the terminal branch innervation could not be located. Immediately inferior to these branches, a large branch protruded medially from the tibial aspect and followed parallel to the sciatic nerve. It traveled deep to LH of BF and innervated the deep aspect of the superior portion of this muscle. The remaining branch trifurcated at the medial border of LH of BF. Two of these divisions innervated the superior third of the long head while the last one spanned medially and innervated the superior portion of ST.

In the proximal two-third portion of the femoral length, only two branches protruded from the tibial aspect of the sciatic nerve (Figure 6). First (the superior one) branched medially and immediately divided into multiple branches where one ending innervated the AM deeply, another innervated the center of the ST muscle belly, and three innervated the lateral third of the SM. Second (the inferior one) was a thin tibial branch which traveled and inserted medially to the knee joint capsule. This branch was distinguished as the articular branch of the tibial nerve.

At the distal third of the length of the femur, the sciatic nerve separated into individual nerves by bifurcating into the common fibular laterally nerve and tibial nerve medially. The common fibular nerve travelled in parallel to the medial border of BF and eventually followed LG(Figure 7). It then passes over the posterior aspect of the head of the fibula (not followed completely in the dissection, but was palpable). The common fibular nerve also leads out three branches posteriorly that were superficial to the LG. These branches converged as lateral sural cutaneous nerve which trifurcated and were embedded within the fascia lata. The tibial branch travels vertically down the popliteal area in-between LG and MG. At the level of joint line, the tibial nerve lead out a branch posteriorly which immediately quadfurcated. Two of these branches innervated the superior aspect of MG while another traveled laterally and deep to LG to innervate PLAN. The final branch identified as the medial sural cutaneous nerve ran superficially and vertically to the end of the segment. Inferior to these branches, another spanned out laterally from the tibial nerve to innervate the superior aspect of the lateral gastrocnemius. Lastly, inferior to this branch a thick branch from the tibial nerve also ran laterally to innervate SOL.

**Segment 2**

Starting at the beginning of the segment, the sciatic nerve ran between the posterior compartment muscles (medial to BF while lateral to SM, and ST tendon) and posterior to the blood vessels(Figure 8).
This nerve sent two separate branches from its common fibular portion. The superior of which branched off at the start of the segment and ran laterally to innervate the BF and the lateral aspect of the knee capsule (termed as articular nerve). The second nerve branched from the anterior portion of the nerve which traveled down the segment until it penetrated through the blood vessels within the popliteal fossa and was suspected of supplying PLAN. The sciatic nerve bifurcated at the level of the femoral condyles into the medial tibial and lateral common fibular nerve.

The tibial nerve immediately after bifurcating from the sciatic nerve, trifurcated (Figure 8). The intermediate of these branches was identified as the medial sural nerve which travelled superficial to the center of the gastrocnemi muscle junction and later lateral to the calcaneal tendon. This nerve sent two branches from the bottom third of its length which went anterior to the calcaneal tendon and were later identified as calcaneal branches. The sural nerve then traveled the lateral aspect of the foot deep to the superficial venous vessels where four branches supplied the lateral heel, two branches supplied the lateral region posterior to the styloid process and two branches supplied the metatarsalphalangeal area (Figure 9). Medial of the three branches of the tibial nerve sent a branch which bifurcated to supply the superior third of MG. The lateral of the branches was the major continuation of the tibial which sent a branch laterally to supply the superior third of LG. The tibial nerve as it traveled towards SOL sent a branch which innervated the mid-posterior part of SOL. The remainder of the tibial nerve entered the deep posterior leg muscle compartment via the hiatus created by the tendinous arch of SOL.

While the tibial nerve was passing through the hiatus, it protruded three branches (origins were not locatable) two of which supplied the middle anterior portion of the SOL while the last one traveled to about a third the length of the tibia to supply the superior third of TP (Figure 10). In the deep posterior compartment, the tibial nerve ran central to FDL and FHL. Starting at the superior third of the nerve length, the tibial nerve sent out a branch medially which traveled to and innervated the superior third of the FDL. At the two thirds length of the tibial nerve, a medial branch innervated the superior third of the FHL. At the half length point of the tibial nerve, a final medial branch is sent out that divide into five individual branches to innervate the top two third of the FHL. At the inferior third of the tibial nerve length four additional branches (three at the same level and one superior to the rest) are sent to the posterior calcaneal region.

The tibial nerve exited the deep posterior leg compartment by travelling medially and inferior to the medial malleoli underneath the flexor retinaculum. The nerve then wraps around the heel to enter the plantar aspect of the foot (Figure 11). This nerve bifurcated into medial and lateral plantar nerve
which was seen between the first and second plantar muscular layers. It should be noted that there was branch of the nerve that supplied the posterior aspect of FDB which was cut to effectively reflect the muscle. The medial plantar nerve traveled to the anterior aspect of the foot (lateral to abductor hallucis) and bifurcated. The medial branch followed the abductor hallucis towards the 1st metatarsophalangeal joint. The second splits into three branches which ran towards the second and third metatarsophalangeal joints in addition to the webbed space between them. The superficial portion of the lateral plantar nerve travelled diagonally to the lateral portion of the foot (medial to the abductor digiti minimi). This nerve trifurcated to supply the fourth and fifth metatarsophalangeal joints along with the webbed space in between. It should be noted that a deep branch of the plantar nerve was spotted, but not confirmed.

The common fibular nerve post sciatic bifurcation followed the medial border of the biceps femoris and over LG to the posterior border of the fibular head. At the region of the lateral condyle, the lateral sural nerve branches medially (Figure 12). This nerve travels superficial to LG where it thinned into four major branches. The common fibular nerve then passed deep to the PL where it split into four observable branches (Figure 13). The most anterior of these branches was distinguished as the articular branch that lead to the tibiofibular joint. The branch adjacent to this was termed as the deep fibular nerve that passed onto the anterior compartment to innervate the muscles within. The third branch identified as the superficial fibular nerve ran parallel (not completely followed due to muscle attachments) and deep to PL fibers and exited anteriorly at half length of the muscle. The remainder of the nerve traveled over the extensor retinaculi to supply the dorsum of the foot (Figure 14). It should be noted that many minor branches were cut for the purposes of reflecting the skin from the foot and only three main branches were preserved (near the great toes, the 3rd metatarsophalangeal joint and true ankle joint). The last of the four branches that was most posterior was identified as a nerve that was supplying PL. Only two branches were spotted that innervated the superior third of the muscle while the rest could not be followed due to the attachment of the muscle.

The deep fibular nerve emerged within the anterior compartment between EDL and TA which ran the entire length of the leg (Figure 15). At the superior third of the nerve, three branches emerged (one medial and two lateral). The medial branch traveled under blood vessels to innervate TA (Figure 16) at the halfway point of its length. The superior of the lateral branches innervated around half length and distal third of EDL (Figure 16). The remaining lateral branch supplied the superior third of EHL. Lastly, at the inferior third length of the deep fibular nerve, another lateral branch split, both supplying the
inferior third length of the EHL (Figure 16). The remainder of the deep fibular nerve travelled underneath the extensor retinaculi where it could not be followed further or located at the dorsum of the foot.

Saphenous nerve of the femoral nerve was identified as a thin single nerve branch that travelled medial and superficial to the tibia to supply the medial aspect of the foot (Figure 17).

**BLOOD VESSELS**

*Segment 1*

Examining the blood supply of the cadaver segment was not the focus of this study, however main blood vessels and branches that supplied the sciatic nerve were recorded. The superior and inferior gluteal arteries were located as being superior and inferior to the prisiformis respectively. A distinct perforating artery was identified protruding posteriorly from AM at the half length of the femoral region (Figure 18). This artery trifurcated to supply the sciatic nerve at its half length mark. Notably, both the popliteal artery and vein enclosed in a common sheath protruded medially from the adductor hiatus at the half point of the femoral length medial to the femur. These blood vessels ran medially and deeper to the sciatic nerve until the end of the segment. It should be noted that the branch of the small saphenous vein was also identified superficially to the vessel structures.

*Segment 2*

The popliteal blood vessels travelled down from the start of the segment to follow the tibial nerve where it bifurcated into posterior tibial vessels medially and fibular vessel laterally (could not be followed after it went under FHL). Both sural nerves were also accompanied by blood vessels. The small saphenous vein emerged between the sciatic bifurcation and traveled down the leg laterally. The great saphnous was identified medially where it traveled from the start of the segment to the foot. Both the saphenous veins were connected on the dorsal aspect of the foot by the dorsal venous arch. A few centimeters superior to sciatic bifurcation, three blood vessels of the sciatic nerve where supplying the anterior aspect of the large nerve (Figure 18).
DISCUSSION

The purpose of this study was to evaluate the branches, divisions and innervations of the sciatic nerve along the length of the lower limb. Within the stages of embryological development, nerves contributing to the lower limb are formed from a combination of lumbar and sacral plexuses. As development progresses, these nerves protrude into the limb and subdivide into dorsal and ventral components to supply musculature within respective compartments. The formation of the sciatic nerve occurs when the dorsal component of the sacral plexus (common fibular nerve) is accompanied by the ventral component (tibial nerve) which travel lower into the limb. These nerves typically follow the lower limb while being embedded within the same fascia (termed sciatic) that bifurcates into their two separate nerves anywhere from the gluteal to the popliteal region. Smoljanovic reported that out of sample of specimens, 28.46% of cases demonstrated no fusion of the separate nerves, even when traveling in close proximity. In the remainder, bifurcation was seen within the upper posterior compartment in 16.15% of cases as well as in middle posterior thigh region, with 39.23% demonstrating the split within the lower portion or in the popliteal region. In the current study, both Segment 1 and Segment 2 are considered within the majority of cases since the bifurcation occurred in the lower thigh/ popliteal region. In addition, the sciatic nerve in Segment 1 entered the gluteal region medial and inferior to the piriformis which falls within the 70 – 85% incidence range. This location of entry into the gluteal regions serves important clinical significance. In cases where the nerves enters through or above the piriformis muscle may be responsible for complications related to hip arthroplasties, implementation of nerve blocks, intramuscular injections, occurrences of piriformis syndrome, non-discogenic sciatica, coccygodynia and muscular atrophy.

Investigating the innervation pattern within the posterior muscle compartment, SM in this study did not meet the classical neural innervation anatomy according to Woodley. It is described that the primary innervations of SM occurs within the superior and inferior third of the muscle belly through two primary branches. Segment 1 however, demonstrated two separate branches innervating the middle portion of the muscle (outside the superior and inferior boundaries). However, it should be noted that few cases have reported this region giving rise to secondary or even tertiary branches from the tibial nerve that innervate subdivision of the whole muscle as seen within Segment 1. Additionally, the innervation of the AM through a SM branch was found to be consistent with literature findings. The innervation pattern of the ST is in agreement with Woodley’s model of two primary nerves branching separately to innervate the superior and middle portion of the muscle. In agreement with various
reports\textsuperscript{8,9,10}, LH of BF in Segment 1 is supplied with only one primary branch. It is suggested that the primary branch divides into two branches both supplying LH, but Segment 1 demonstrated three branches instead.\textsuperscript{8,10} However, reports\textsuperscript{8,10} have suggested that high levels of variability, such as those demonstrated within the current study, could be accounted for examining a smaller sample size. SH innervation within the study were consistent from literature with only one nerve supply.\textsuperscript{8,9,10} However, Segment 2 demonstrated a small distal branch towards the short head not mentioned in previous reports.

The anatomical placements of the sciatic, tibial and fibular nerves were all corresponding to Ellis’s\textsuperscript{11} description of popliteal, leg and foot nerves. Within the deep posterior compartment, Segment 2 followed a type 1 Apaydin’s model\textsuperscript{12} where 55.6 % of cases showed separate branches to each muscles within the compartment. Additionally, SOL anterior and posterior innervations examined within Segment 2 were identical to Loh’s\textsuperscript{13} description with the exception of two entry points on the anterior aspect. Additionally, the deep fibular nerve patterns observed within Segment 2 were consistent with major findings from previous reports\textsuperscript{14}. Table 2 summarizes our findings when compared with the literature.

Although not the primary focus of this study, arterial supply to the sciatic nerve was additionally investigated. The initial part of the sciatic nerve generally is accompanied by sciatic arteries that supply nutrients to the vessel.\textsuperscript{15} These arteries, also referred to as arteria comitans nervi ischiadici, are typically expected to supply four to eight nutritional branches that arise from inferior gluteal, medial circumflex femoral, perforating and popliteal arteries.\textsuperscript{15} While examining Segment 1, three perforating artery branches were seen supplying the sciatic nerve anteriorly at the half length of the femoral region. In Segment 2, three separate sciatic arteries branching from popliteal arteries were supplying the sciatic nerve superior to the bifurcation. Since the sciatic arteries within the study either branched from perforating or popliteal arteries, expected origins as reported within literature are demonstrated. 70 % of lower limb records show blood supply to sciatic nerve in the gluteal region.\textsuperscript{15} However, the presence of such structures could not be examined as they were cut to reflect the gluteus maximus. These arteries serve a significant role during operative treatment to prevent iatrogenic or ischemic damage to the sciatic nerve.\textsuperscript{15}

The study consisted of various limitations that should be taken into consideration. Firstly, the separate lower limb segments were not in their entirety, rather were specific sections with only the knee joints that could be compared. Without the whole lower limb present, it becomes difficult to
compare our sample size to the literature. Also the sample size within this study was small (n=2) which made it difficult to form any statistically significant comparative conclusions. Additionally, the gender and the ethnicity of the segments was inconsistent. Ogeng’o\textsuperscript{6} found that 30% of sciatic nerve anatomy cases in Kenyans varied from the classical population description with higher levels of divisions, low incidences of piriformic course and unusual connections between common fibular and tibial nerves.\textsuperscript{6} With all these factors being uncontrolled for, research implication of this study becomes a challenge. That being said, the primary aim for this project was to prospect with precision to isolate all sensory and motor branches of the sciatic nerve for educational purposes. Due to this aim, minor branches that detailed anatomical structures were preserved which are not typically seen in literature.

There is reassuring evidence that points towards high inter-patient variability of sciatic nerve which can lead to many medical impediments seen both operatively and clinically. For the reality of structure discrepancy, preoperative nerve imaging accompanied by operative diligence to precisely locate the sciatic nerve within the gluteal and posterior thigh region are recommended to prevent various complications.\textsuperscript{3,6} Further investigations are encouraged for the development of feasible interventions and instrumentations that help in locating nerve placement and origin.

**ADDITIONAL WORK**

The anterior portion of *Segment 1* was additionally dissected. The pelvic cavity was cleaned where the iliopsoas muscle group (iliacus and psoas major) was identified. Within the pelvic cavity lateral femoral cutaneous, femoral and obturator nerves were located (Figure 19). Deep to the inguinal ligament, the femoral nerve branched into multiple segments ad supplied the anterior compartment muscles. Additionally, the iliac vessels that are later femoral vessels were examined (Figure 19).

**ACKNOWLEDGEMENTS**

I would like to thank Dr. Alimohammadi and Dr. Doroudi for giving me the opportunity to further my knowledge in anatomy. I would also like to mention Dr. Lien Vo for her help during lab.
APPENDIX

Figure 1: Posterior view of Segment 1, including gluteal, femoral and popliteal region (Left). Posterior view of Segment 1 with gluteus maximus reflected (Right).

Figure 2: Skin incision path of Segment 1 is demonstrated with the dotted line. Direction of reflection is demonstrated by the direction of arrows.
Figure 3: Lateral (left) and medial (right) view of Segment 2

Figure 4: Skin incision path of Segment 2 is demonstrated with the dotted line. Direction of reflection is demonstrated by the direction of arrows.
Figure 5: Gluteal region of Segment 1 demonstrating sciatic, inferior gluteal and posterior cutaneous nerves entering medial and inferior to the piriformis.

Figure 6: Femoral region of Segment 1 showing the pathway of the sciatic nerve and its various branches innervating the posterior compartment muscles.
Figure 7: Popliteal region of Segment 1 demonstrating the bifurcation of the sciatic nerve into tibial (medial) and common fibular nerve (lateral). Additional innervations of the proximal leg muscles are shown.

Figure 8: Popliteal region of Segment 2 demonstrating the bifurcation of the sciatic nerve into tibial (medial) and common fibular nerve (lateral). Additional innervations of the proximal leg muscles are shown.
Figure 9: Continuation of the sural nerve onto the lateral aspect of the foot and traveling deep to superficial venous structures

Figure 10: Continuation of the tibial nerve into the deep posterior compartment muscles. Innervations of TA (top arrow), FDL (bottom arrow), and FHL are demonstrated.
Figure 11: First layer of the foot revealed with the plantar aponeurosis reflected anteriorly (Left). Deep to the first layer, lateral and medial plantar nerves are demonstrated as a continuation of the tibial nerve.
Figure 12: Medial and lateral sural nerves from tibial and common fibular nerves respectively shown on the posterior aspect of Segment 2.

Figure 13: Common fibular nerve quadfurcation is shown (Middle) in addition to the superficial fibular nerve (depicted by the probe on Left)
Figure 14: Continuation of the superficial fibular nerve onto the dorsum of the foot

Figure 15: Pathway of deep fibular nerve along with its innervation patterns
Figure 16: Pathway of deep fibular nerve along with its innervations on TA (Left), EDL (Middle), and EHL (Right)

Figure 17: Saphenous nerve and great saphenous vein running on the medial side of Segment 2
Figure 18: Blood supply to the sciatic nerve in Segment 1 (Left) and Segment 2 (Right)

Figure 19: Iliopsoas group muscles along with lateral femoral cutaneous, femoral and obturator nerves (Left). Continuation of the femoral nerve on top the anterior compartment of the thigh (Right)
Table 1: *Segment 1* and *Segment 2* innervations and locations

<table>
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<tr>
<th>Muscle</th>
<th>Innervations</th>
<th>Location</th>
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<td>LH of BF</td>
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</tr>
<tr>
<td>SH of BF</td>
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<tr>
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<td>M</td>
</tr>
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<td>M</td>
</tr>
<tr>
<td>LG</td>
<td>1</td>
<td>S</td>
</tr>
<tr>
<td>MG</td>
<td>2</td>
<td>S</td>
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</tr>
<tr>
<td>PLAN</td>
<td>1</td>
<td>M</td>
</tr>
</tbody>
</table>

Number of innervation points of each muscle along with specific location from the sciatic nerve is recorded within this table. Location of the entry point is depicted as either superior third (S), middle third (M) or inferior third (I).

Table 2: *Segment 1* and *Segment 2* innervations patterns when compared to literature

<table>
<thead>
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<th>Consistency</th>
<th>Muscle</th>
<th>Consistency</th>
</tr>
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<td>SOL</td>
<td>✓</td>
</tr>
<tr>
<td>SH of BF</td>
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<td>~</td>
</tr>
<tr>
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<td>TP</td>
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<tr>
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<td>×</td>
<td>FHL</td>
<td>~</td>
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<tr>
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<td>✓</td>
<td>PL</td>
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</tr>
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<td>~</td>
</tr>
<tr>
<td>LG</td>
<td>~</td>
<td>EDL</td>
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</tr>
<tr>
<td>MG</td>
<td>~</td>
<td>EHL</td>
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</tr>
</tbody>
</table>

Each muscle innervation examined within this study when compared to literature. Consistency of entry points is distinguished by a checkmark while inconsistency is determined by a cross. ~ refers to general nerve pattern consistency without specific entry points congruency.
REFERENCES


