The sciatic nerve division in the gluteal region in a South African population: An anatomical study

by

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DECLARATION

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ABSTRACT

The sciatic nerve is repeatedly involved in the daily medical practices of anaesthesia, neurology, orthopaedics and rehabilitative medicine. The sciatic nerve, and its branches, are some of the most frequently injured nerves within the human body. A possible reason for injury could be related to an inadequate knowledge of the anatomical variations of this nerve. Adequate understanding of the anatomical variability within the gluteal region is vital for appropriate diagnosis, potential treatment of gluteal pathology and pain and population-specific anomalies.

To the author's best knowledge, no previous study has described the anatomical variations in relation to the piriformis and sciatic nerve bifurcation within the South African population. Therefore, the aim of the study is to report the prevalence of anatomical variations within the course of the sciatic nerve in relation to the piriformis muscle. Additionally, to report the prevalence of the variations in the level of the sciatic nerve bifurcation. Lastly, to analyse the typical sciatic nerve and piriformis morphomety. The results obtained will be a comparison between sides, sexes, and population groups.

For the purpose of this study, lower limbs ($N = 340$) from 170 South African cadavers were selected for dissection and morphological analysis. These specimens consisted of 191 males and 149 females, and comprised of three South African subpopulation groups, namely, White/Caucasian ($n = 232$), Mixed race ($n = 78$) and South African Black ($n = 30$). The variations were recorded, classified and described. Piriformis and sciatic nerve parameters were measured morphometrically using a digital sliding calliper, and statistically analysed.

Analysis of the relationship between piriformis and the sciatic nerve resulted in 43 (12.65%) specimens that presented variations in the morphology, while 297 (87.35%) specimens presented normal anatomical features. Variations of these structures occurred predominantly in the South African White/Caucasian population. The bifurcation of the sciatic nerve occurred mainly in the popliteal fossa proper (79.6%). The width of the sciatic nerve was significantly larger in the White/Caucasian group ($p < 0.05$), in comparison to the other two groups. The mean length of the sciatic nerve was significantly larger in the male specimens ($p < 0.05$) in comparison to the female specimens.

It was found that the sciatic nerve commonly entered the gluteal region as a single trunk, through the infra-piriform space, inferior to the piriformis muscle. However, variations in the anatomy of the sciatic nerve are common, and are vital in assessing clinical risk, and avoiding debilitating injury or incorrect pain diagnoses. To maintain best possible clinical practices requires regularly updated clinical skills in relation to accurate and relevant new anatomical

knowledge. It is for this reason that studies, such as this one, ensure that vital research contributions are available for best clinical practice. Clear uniform landmarks for morphometric analysis of the sciatic nerve and piriformis needs to be established in order to create uniformity and understanding of results. Additionally, there is a need for the increase in published literature for the South African subpopulation groups in order to strengthen comparisons and conclusions of reported research. Researchers also need to research variations in larger groups within the South African population.

OPSOMMING

N. ischiadicus is dikwels betrokke in mediese praktyke soos narkose, neurologie, ortopedie en rehabilitasie geneeskunde. N. ischiadicus, sy vertakkings, is ook die senuwee in die menslike liggaam wat die meeste beseer word. Onvoldoende kennis oor anatomiese variasies van die senuwee is ’n moontlike rede tot beserings. Dit is van kardinale belang om voldoende kennis van die anatomiese variasies in die gluteale gebied op te doen, vir korrekte diagnose en potensiële behandeling van gluteale patologie en -pyn, asook van bevolkingspesifieke anomalieë.

Geen vorige studies wat die verskille in die verhouding tussen m. piriformis en bifurkasie van n. isciadicus beskryf, bestaan, sover die navorser kon bepaal, vir die bevolkingsgroepe in Suid-Afrika nie. Die doel van hierdie studie was dus om verslag te doen oor die voorkoms van anatomiese variasies in die verloop van n. ischiadicus in verhouding tot m. piriformis. Die voorkoms van variasies op die vlak van bifurkasie van n. ischiadicus is ook bestudeer. Laastens is ‘n tipiese n.ischiadicus en m. piriformis morfometries geanaliseer. Die resultate is tussen linker en regter kante van die liggaam, geslagte en bevolkingsgroepe vergelyk.

Vir die doel van hierdie studie is onderste ledemate ($N = 340$) van 170 Suid-Afrikaanse kadawers vir disseksie en morfologiese analise, geselekteer. Die liggame wat bestudeer is, het bestaan uit 191 mans en 149 vroue, en is oor drie Suid-Afrikaanse bevolkingsgroepe versprei, naamlik Wit ($n = 232$), Kleurling ($n = 78$) en Swart ($n = 30$). Verskille is bestudeer, geklassifiseer en beskryf. Morfometriese afmetings van m. piriformis- en n. isciadicus is met behulp van ’n digitale gly-meetpasser gedoen en statisties geanaliseer.

Na analise van die verhouding tussen m. piriformis en n. ischiadicus, is bevind dat in 43 (12.65%) van die liggame daar morfologie verskille is, terwyl in 297 (87.35%) van die liggame ‘n normale anatomies patroon vertoon. Daar is bevind dat verskille in morfologie van die strukture hoofsaaklik in die Wit Suid-Afrikaanse bevolkingsgroep voorgekom. Bifurkasie van n. ischiadicus het hoofsaaklik in die popliteale fossa self (79.6%) voorgekom. Die breedte van n. ischiadicus was noemenswaardig groter in die Wit bevolkings groep wat bestudeer is ($p < 0.05$) in vergelyking met die ander twee bevolkings groep is. Die gemiddelde lengte van n. ischiadicus was noemenswaardig langer in die manlike groep ($p < 0.05$), teenoor die van die vroulik groep.

N. ischiadicus gaan gewoonlik as ’n enkele stam die gluteale gebied binne. Die senuwee beweeg inferior tot m. piriformis. Variasies in die anatomie van n. ischiadicus kom algemeen voor. Kennis van hierdie wariasies is klinies belangrik om risiko’s te beperk en om debiliterende

beserings of foutiewe diagnose van pyn te voorkom. Ten einde die handhawing van die beste moontlike kliniese praktyk te verseker, vereis dit dat kliniese vaardighede, met betrekking tot akkurate en relevante anatomiese kennis, op ’n konstante basis verfyn word, en gereeld opgedateer word. Dit is om hierdie rede dat studies soos hierdie belangrike bydraes lewer vir die beste kliniese uitkomste. Duidelike, uniforme landmerke vir die morfometriese analise van n. ischiadicus en m. piriformis moet bepaal word om sodoende uniformiteit te verseker. Daarbenewens is daar ook ’n behoefte vir meer gepubliseerde literatuur oor Suid-Afrikaanse bevolkingsgroepe, sodat vergelykings en gevolgtrekkings wat gerapporteer word, ondersteun kan word. Daar is ook ‘n behoefte vir groter studies om beter verteen woordigig van verskillende bevolkings groepe in Suid Afrika te beskryf.

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"True love is selfless. It is prepared to sacrifice"

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ABBREVIATIONS

CPN	Common fibular nerve
GM	Gluteus Medius
GM&PM	Fused gluteus medius and piriformis
GMin	Gluteus minimus
GMx	Gluteus maximus
GT	Greater trochanter
IG	Inferior gemellus
IGV	Inferior gluteal vessels
IT	Ischial tuberosity
LWP	Lateral width of piriformis
MWP	Medial width of piriformis
OI	Obturator internus
P	Common fibular nerve
PIBL	Piriformis inferior border length
PM	Piriformis muscle
PM_1	Superior piriformis belly
PM_2	Inferior piriformis belly
PSBL	Piriformis superior border length
QF	Quadratus femoris
SG	Superior gemellus
SGV	Superior gluteal vessels
SN	Sciatic nerve
SNBLI	Sciatic nerve bifurcation level index
SNL	Sciatic nerve length
SNW	Sciatic nerve width

SP	Sacral plexus
SU	Stellenbosch University
STL	Sacrotuberous ligament
T	Tibial nerve
TCox	Triceps coxae muscle group
TL	Thigh length
TN	Tibial nerve
TNB_1	Tibial nerve branch one
TNB_2	Tibial nerve branch two
UCT	University of Cape Town
UP	University of Pretoria
Wits	University of the Witwatersrand

MATHEMATICAL SYMBOLS AND UNITS

$\cong$	Approximately equal to
$=$	Equal to
$\frac{x}{y}$	Fraction (division)
$>$	Greater than
$<$	Lesser than
$\leq$	Lesser than or equal to
$\times$	Multiply
%	Percentage
$\pm$	Plus / minus
cm	centimetre
mm	Millimetre

CHAPTER ONE: INTRODUCTION

The sciatic nerve is constantly involved in the daily medical practices of anaesthesia, neurology, orthopaedics, and rehabilitative medicine (Brooks *et al*., 2011). The sciatic nerve, and its branches, are also the most frequently injured nerves within the human body (Kumar *et al*., 2011; Budhiraja *et al*., 2016). This nerve is unique because of its extensive course throughout the gluteal region, and lower limbs (Kotian *et al*., 2015). This intricately long course makes the nerve vulnerable to injury from various medical causes (Prakash *et al*., 2010; Kotian *et al*., 2015; Budhiraja *et al*., 2016). Another reason for injury could be related to an inadequate knowledge regarding anatomical variations of the nerve (Budhiraja *et al*., 2016; Kiros & Woldeyes, 2015). Therefore, knowledge of the nerve, and its variations, are of vital concern in clinical science (Prakash *et al*., 2010; Ogeng'o *et al*., 2011).

The anatomy of the sciatic nerve has been described extensively in literature (Kanawati, 2014). However, this is not the case for the variations of the sciatic nerve, as well as the subsequent variations of structures closely related to, and innervated by this nerve, within the gluteal region (Budhiraja *et al*., 2016). One such association, which is of increasing concern, is the close relationship between piriformis and the sciatic nerve (Brooks *et al*., 2011). The interest in this relationship is largely due to its possible involvement in producing sciatic-related pain and discomfort. The existence of variations in the anatomy of the sciatic nerve only increases the risk of damage to this nerve during clinical and surgical procedures (Smoll, 2010). Several authors have identified variations of the levels of the sciatic nerve bifurcations into its tibial and common fibular branches. The branching variation could occur proximally, close to its origin from the sacral plexus, or more distally, within the popliteal fossa proper. Should the branching occur superiorly, proximal to the piriformis, there is a possibility of variations in the morphology of piriformis itself. These anatomical variations could give rise to a number of possible debilitating conditions within the region innervated by the sciatic nerve. Sufficient knowledge about the variations of the sciatic nerve, and its bifurcation, are fundamental in the prevention of injury to the nerve (Ogeng'o *et al*., 2011). A number of techniques performed in, and out, of the operating theatre often require access to this region. If complications within the gluteal region occur, resulting from surgical complications or the presence of unknown variations within the region, there could be considerable and permanent impairment to the structures of the lower limb. These complications range from general irritation, to loss of sensation in the posterior compartment of the thigh, foot, or the entire lower limb (Kiros & Woldeyes, 2015).

Variations of the sciatic nerve, and its bifurcation, occurs with varying prevalence (Tomaszewski *et al*., 2016) amongst different population groups across the world. While extensive research on the sciatic nerve is done in Northern and Western regions of the world, this is not the case for the African continent. Upon reviewing literature, only six academic papers were found from medical universities in Africa, namely: Kenya, Ethiopia, Uganda, and Nigeria (Ogeng'o *et al*., 2011; Kiros & Woldeyes, 2015). Considering the lack of research on variations of the sciatic nerve for the African population (Ogeng'o *et al*., 2011), this research hopes to address some of the problems by looking at the prevalence of sciatic nerve variations, and related variations of the piriformis muscle, in a South Africa population. Dissected cadaver lower limbs will be used for the study. According to Prakash *et al.* (2010), the cadaver is the best means to study anatomy at this level, even with advances in medical technology (Smoll, 2010; Brooks *et al*., 2011).

CHAPTER TWO:

LITERATURE REVIEW

2.1 REGIONAL ANATOMY

The gluteal region is the prominent area located posterior to the pelvis, inferior to the level of the iliac crest. It extends laterally to the posterior margin of the greater trochanter. The gluteal region covers the greater trochanter of the femur laterally, and then extends anteriorly towards the anterior superior iliac spine, a bony projection of the iliac bone, providing attachment for the inguinal ligament and sartorius muscle, but is also an important landmark in surface anatomy. Medially, within the left- and right gluteal regions is the intergluteal cleft, which is the groove that separates the buttocks from one another (Moore *et al*., 2017). The gluteal muscles dominate the bulk of the gluteal region (Figure 2.1) (Drake *et al*., 2015). The gluteal fold demarcates the inferior boundary of the buttocks and the superior boundary of the thigh region of the lower limb.

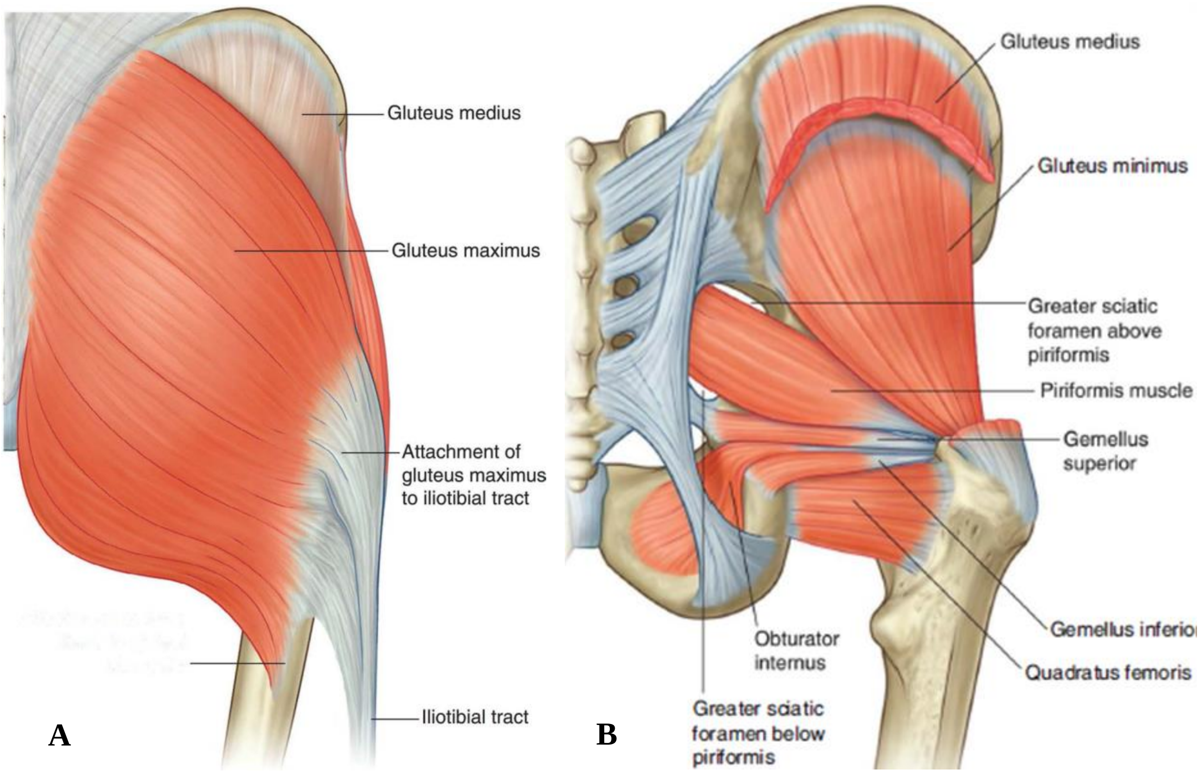

Figure 2.1: The superficial (A) and deep (B) muscles of the gluteal region (Drake *et al*., 2015).

2.1.1 Muscles of the Gluteal Region

The muscles of the gluteal region (Figure 2.1) share a common compartment, but are organised into two layers, namely the superficial- and deep layers (Moore *et al*., 2017). The superficial layer of muscles of the gluteal region consists of the three large overlapping glutei – the gluteus maximus, medius, and minimus. The last muscle in this layer is the tensor fasciae latae (Moore *et al*., 2017). The latter is closely associated with gluteus maximus as both muscles' fibres join and attach to a common insertion structure, known as the iliotibial tract. The superficial gluteal muscles are all proximally attached to the posterolateral surface and margins of the ala of the ilium, and have common insertion points on various sites of the proximal femur, or iliotibial tract, laterally (Hansen, 2014). The glutei muscles are mainly responsible for abduction and extension of the hip, and extension, abduction, and medial rotation of the thigh (Drake *et al*., 2015).

The deep layer of muscles in the gluteal region consists of smaller muscles, such as piriformis, obturator internus, superior and inferior gemelli, and quadratus femoris. The inferior half of gluteus maximus covers them all (Hansen, 2014). These muscles all have distal attachments on or adjacent to the intertrochanteric crest of the femur. These muscles are lateral rotators of the thigh, but they also stabilize the hip joint, working with the strong ligaments of the hip joint to steady the femoral head in the acetabulum (Moore *et al*., 2017).

2.1.2 Sub-gluteal Space

The sub-gluteal space, also known as the deep gluteal space, represents the cellular and fatty tissue located between the middle and deep gluteal aponeurosis layers (Hernando *et al*., 2015). The sub-gluteal space largely represents the space deep to the belly of gluteus maximus (Byrd, 2015). The inferior margin of the sub-gluteal space is continuous with the superior contents of the posterior compartment of the thigh, with the proximal attachment of the hamstring muscles at the ischial tuberosity structurally demarcating this border (Park *et al*., 2016). The lateral lip of the linea aspera and gluteal tuberosity of the proximal femur mark the most lateral boundary of this space, along with the lateral fusion of both the middle and deep gluteal aponeurosis layers, which extend up to tensor fascia latae via the iliotibial tract. The posterior surface of the femoral neck, associated posterior acetabular column, hip joint capsule, and the greater- and lesser trochanters of the femur all contribute in forming the anterior limit of this space (Martin *et al*., 2015). The inferior margin of the superior aspect of the sciatic notch forms the superior boundary. Lastly, the sacrotuberous ligament and the falciform fascia jointly create the medial limit of the sub-gluteal space (Figure 2.2) (Hernando *et al*., 2015).

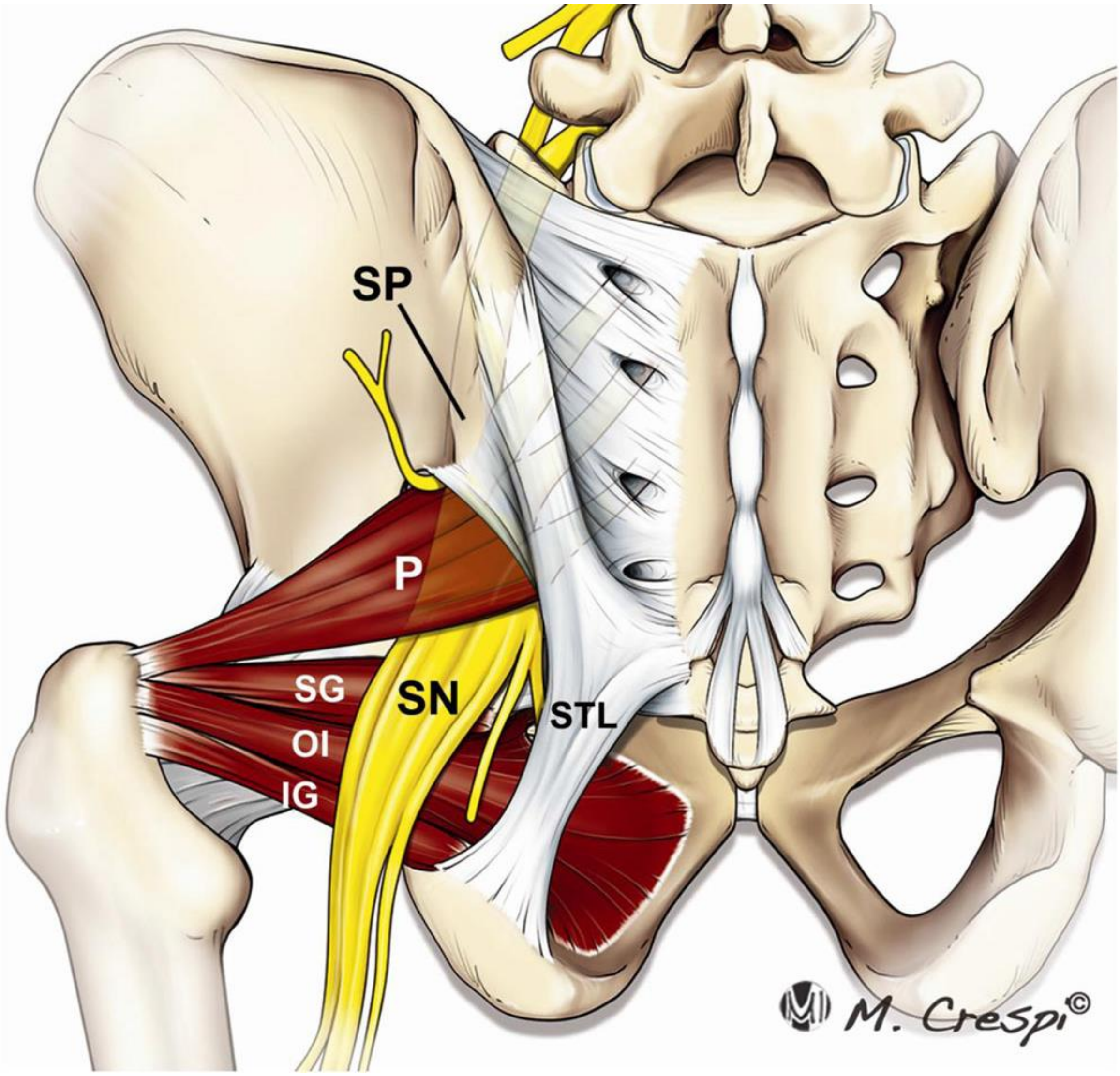

Figure 2.2: The normal anatomy of the subgluteal space. The diagram illustrates the main osteology, ligamentous, muscle, and tendinous structures located in the subgluteal space, in a posterior view. SP – sacral plexus, SN – sciatic nerve, STL – sacrotuberous ligament, P – piriformis, SG – superior gemellus, OI – obturator internus, IG – inferior gemellus (Hernando *et al*., 2015).

The medial margin of the sub-gluteal space is comprised of the greater- and lesser sciatic foramina. The superior boundary of the greater sciatic foramen is the lateral edge of the sacrum and greater sciatic notch, and inferiorly boundary is the sacrospinous ligament. The limits of the lesser sciatic foramen are the lesser sciatic notch externally, the lower border of the sacrospinous ligament superiorly, and the superior part of the sacrotuberous ligament inferiorly (Martin *et al*., 2015). The greater sciatic foramen contains the piriformis muscle, as it runs through the opening, and into the gluteal region (Hernando *et al*., 2015). Since the sciatic nerve is closely related to piriformis in this region, this is an important association of these structures.

Table 2.1: Contents of the sub-gluteal space.

Contents
• Superior and inferior gluteal nerves
• Superior and inferior gluteal blood vessels
• Ischium
• Sacrotuberous- and sacrospinous ligaments
• Sciatic nerve
• Piriformis
• Obturator Internus
• Obturator Externus
• Gemelli
• Quadratus femoris
• Hamstring muscle group

The sub-gluteal space contain an array of structures, ranging from vascular and neural to muscular tissue (Park *et al*., 2016). The contents of the sub-gluteal space are listed above, in table 2.1 (Byrd, 2015). In the sub-gluteal space, the sciatic nerve enters the pelvic region through the greater sciatic foramen, to pass inferior to piriformis (Knudsen, Mei-Dan & Brick, 2016). The sciatic nerve has a significant mobility associated with overall hip movement (Coppieters *et al*., 2006). According to Coppieters *et al*. (2006), the sciatic nerve has a range of 28 mm of displacement during hip flexion (Martin *et al*., 2015). Under normal circumstances, the sciatic nerve is able to stretch and glide to accommodate moderate strain or compression associated with joint movement (Martin *et al*., 2010). However, this motion is affected by anatomical variations in both the sciatic nerve and piriformis in 16.2% of the population, as reported by Smoll (2010). Any of the contents of the sub-gluteal space, and the wide range of variability in displacement of the sciatic nerve in this space, can cause sciatic nerve entrapment-related syndromes (Park *et al*., 2016).

2.1.3 Piriformis

Piriformis is a flat, triangular muscle. It belongs to the deep muscle group within the gluteal region, where piriformis is the most superiorly placed muscle of the group (Drake *et al*., 2015). In the gluteal region, piriformis is located deep to the large gluteus maximus and proximal to the obturator internus, where the obturator internus is part of the triceps coxae group, along with the superior and inferior gemelli (Pecina *et al*., 2001). Piriformis arises from the ventrolateral surface of the S2-S4 sacral vertebrae, gluteal surface of the ileum, and sacroiliac joint capsule (Pérez-Carro *et al*., 2016). It runs laterally, exiting the pelvic region by coursing through the greater sciatic foramen (Tubbs *et al*., 2015). Thereafter, piriformis runs diagonally downwards through the gluteal region, becomes tendinous, and inserts on the piriformis fossa at the medial aspect of the greater trochanter of the femur (Drake *et al*., 2015). At its termination, the now tendinous piriformis is often partly blended with the common tendon of the triceps coxae muscle complex (Pérez-Carro *et al*., 2016).

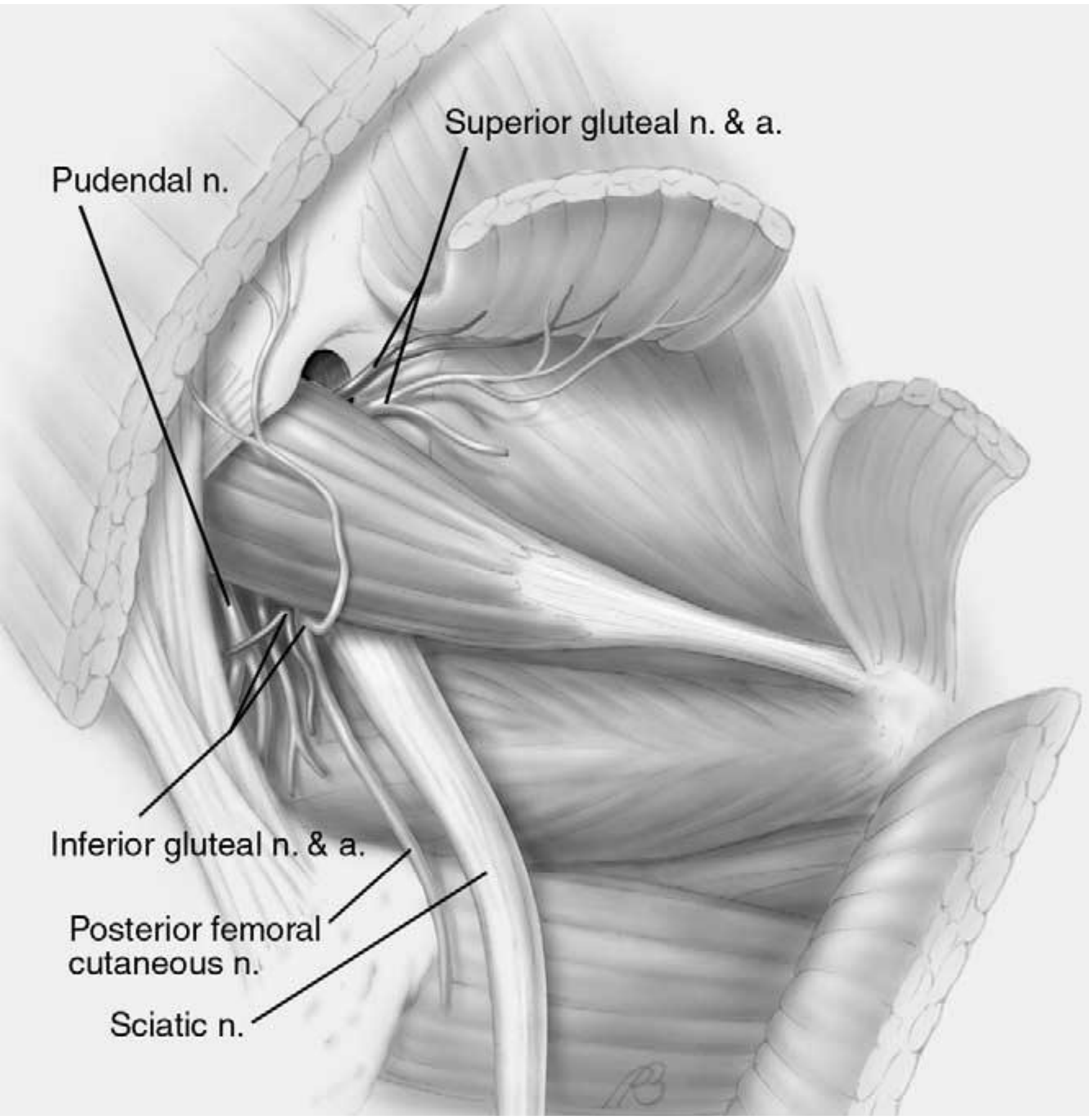

Figure 2.3: The Piriformis muscle, along with important structures in the gluteal region (Byrd, 2015).

The main functions of the piriformis involve abduction of the flexed thigh, and lateral rotation of the extended thigh (Moore *et al*., 2017). During walking, abduction of the flexed thigh is important, because it shifts the body weight to the opposite side of the body and ultimately prevents falling (Siddiq *et al*., 2017). Additionally, piriformis stabilizes the femoral head in the acetabulum. This stabilization is essential for postural stability during ambulation, as well as standing (Tubbs *et al*., 2015).

Due to the muscle's central position in the area, piriformis is the landmark structure of the gluteal region (Moore *et al*., 2017). Consequently, piriformis provides the key to understanding relationships in the pelvic region, and gluteal region. Additionally, piriformis demarcates the two zones of structural passage within the gluteal region. The passage superior to piriformis, through which the superior gluteal nerve and vessels course, is known as the supra-piriform space. Conversely, the passage inferior to piriformis, in the gluteal region, is infrequently referred to as the infra-piriform space (Knudsen *et al*., 2016). Piriformis thus determines the nomenclature of the vessels and neurovascular structures in the region, depending on the course of these vessels in relation to piriformis (Pérez-Carro *et al*., 2016). While the superior gluteal nerves and vessels traverse the supra-piriformis space, the inferior gluteal and pudendal nerves, and the sciatic nerve passes through the infra-piriformis space (Michel *et al*., 2013). For these various reasons, the relationship shared by the sciatic nerve and piriformis becomes a focal point in the gluteal region.

2.1.4 The Sciatic Nerve

The sciatic nerve is the largest nerve in the human body, as well as in many other animals (Saritha *et al*., 2012). There are two reasons for this; one being that there are numerous neural fibres that gather to produce this nerve, and secondly, due to the extensive size of the gluteal region and lower limb, in other words, the regions innervated by this nerve (Figure 2.4) (Saleh *et al*., 2009). The sciatic nerve develops from the lumbo-sacral plexus, from the fourth lumbar to the third sacral (L4-L5 and S1-S3) spinal nerves. The nerve often has a maximum width of two centimetres (cm) or more, and can reach a diameter of over 0.5 cm, as it passes posterior and inferior to piriformis (Saleh *et al*., 2009). The sciatic nerve is described as the nerve with the largest diameter in the body. The nerve carries both motor and sensory fibres. The sciatic nerve enters the gluteal region, through the lower part of the greater sciatic foramen, below piriformis, as a single nerve encompassed by a single epineural sheath (Kotian *et al*., 2015), and thereafter continues into the lower limb. The sciatic nerve is the chief innervator of the posterior compartment of the thigh, the anterior, lateral and posterior compartments of the lower leg, and dorsal and plantar regions of the foot. Generally, this nerve terminates in approximately the distal third of the posterior compartment of the thigh, to branch into the common fibular and tibial nerves. These two terminal branches are important innervators for normal functioning of the foot (Kukiriza *et al*., 2010).

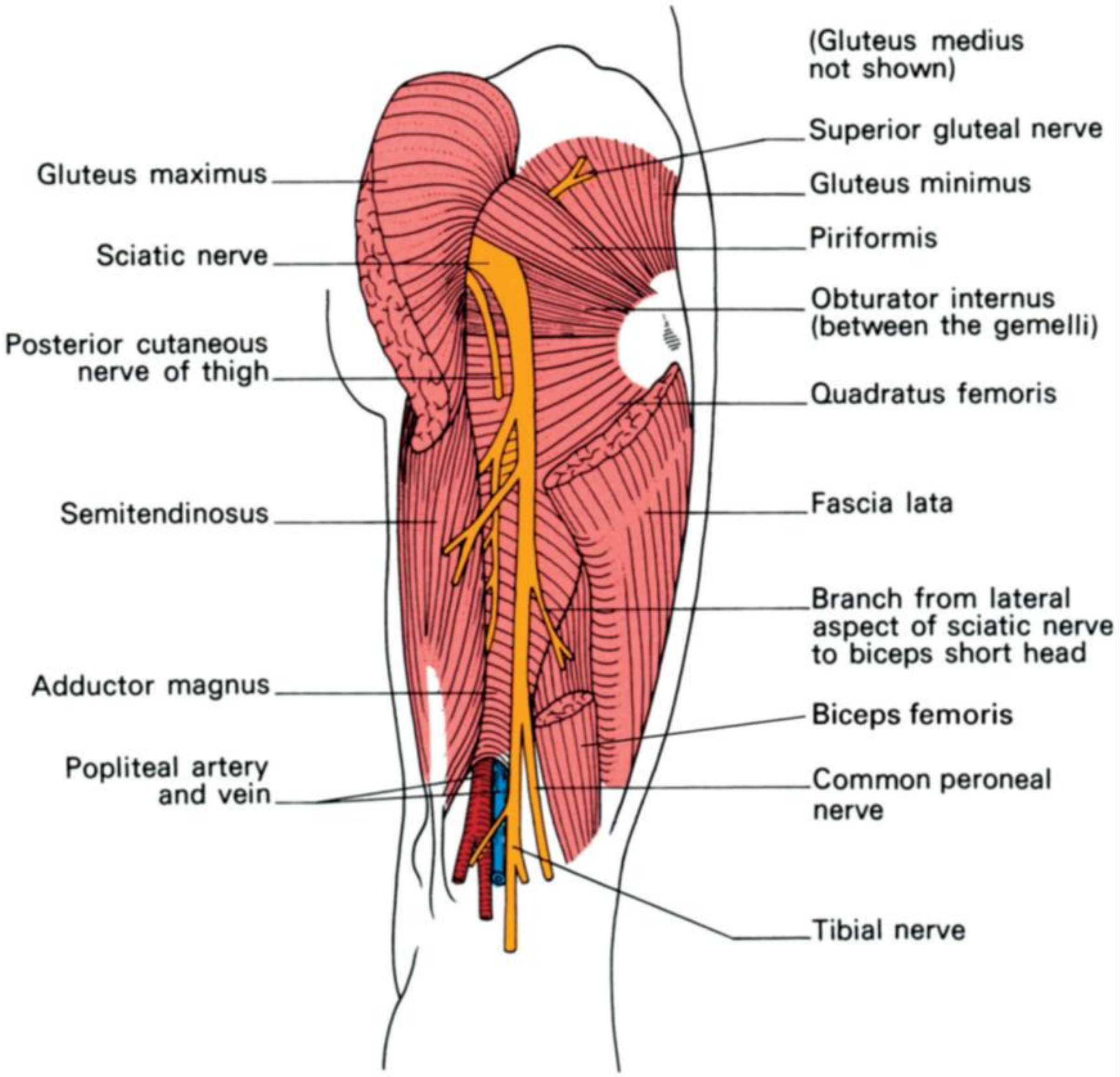

Figure 2.4: The course of the sciatic nerve and its terminal branches within the gluteal region, posterior compartment of the thigh, and popliteal fossa proper (Moore *et al*., 2017).

While there is a large body of literature reinforcing the depicted path of the sciatic nerve (Figure 2.4), there has also been a subsequent increase in literature that speaks to the variability of this anatomy (Smoll, 2010). Therefore, it is important to understand the variations of this anatomy, in a population group, which is being catered for medically.

2.2 ANATOMICAL VARIATIONS WITHIN THIS REGION

2.2.1 The Relationship between the Sciatic Nerve and Piriformis

Piriformis is closely related to the sciatic nerve, as mentioned previously (Kirschner *et al*., 2009). According to traditional literature, the sciatic nerve is expected to emerge from the pelvic region by passing posterior and inferior to piriformis (Moore *et al*., 2017). However, this "normal" representation of the course, in relation to piriformis, through the infra-piriformis space does not always occur. There are several possible paths that the sciatic nerve might follow while coursing through the gluteal region and, as a result, influencing the morphology of adjacent structures (Haladaj *et al*., 2015.).

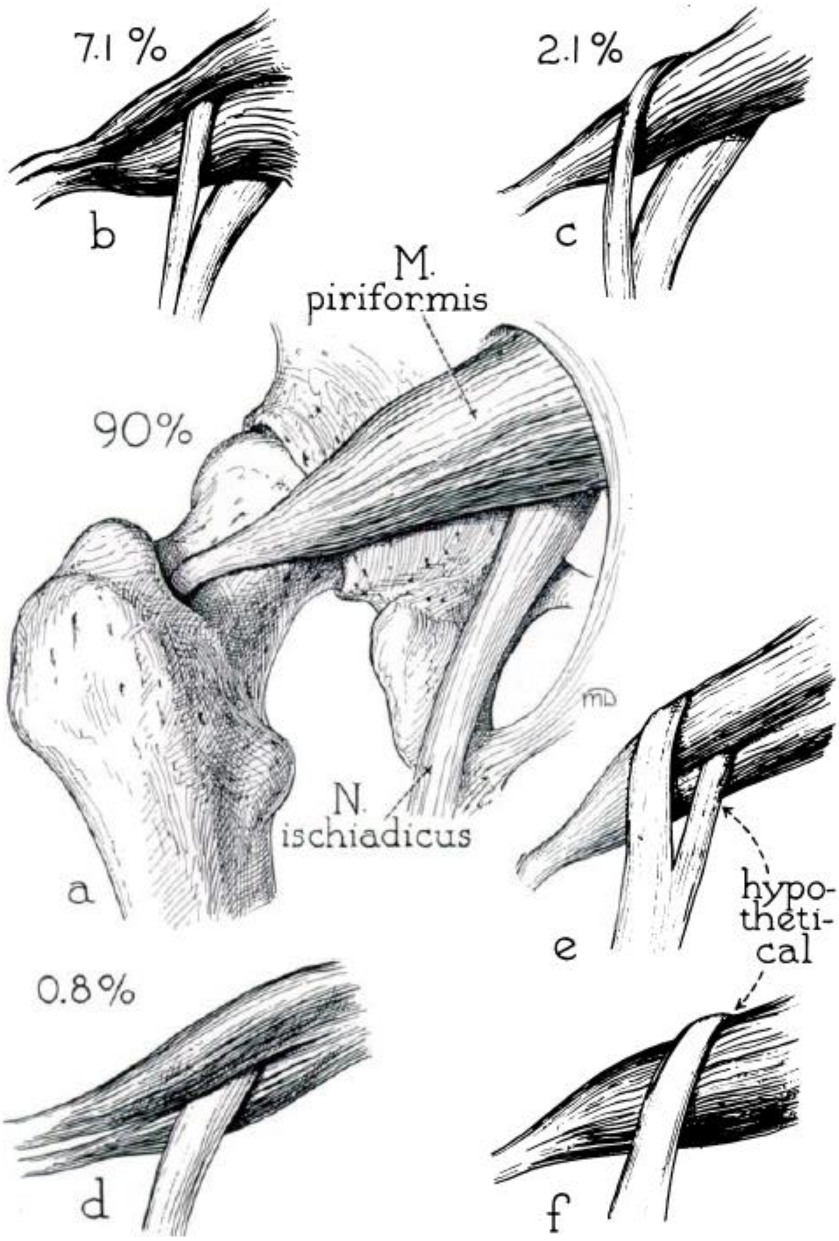

Figure 2.5: The six variations of the sciatic nerve, or its subdivisions, in relation to piriformis, arranged in the order of frequency from the study in 1938 (Beaton & Anson, 1938).

In 1937, Beaton and Anson were the first researchers to categorise the variations in the relationship between piriformis and sciatic nerve. At the time, the system devised to identify and classify each variation, was composed of six major variations (Figure 2.5). There were four variations directly observed in this study (Beaton & Anson, 1937), while the other two were hypothetical variations that have since been identified and described in subsequent literature (Tomaszewski *et al.*, 2016). This original classification has since been modified to include additional variations that are possible within the region (Figure 2.6). However, the classification created by Beaton and Anson (1937) remains the basis when studying these variations.

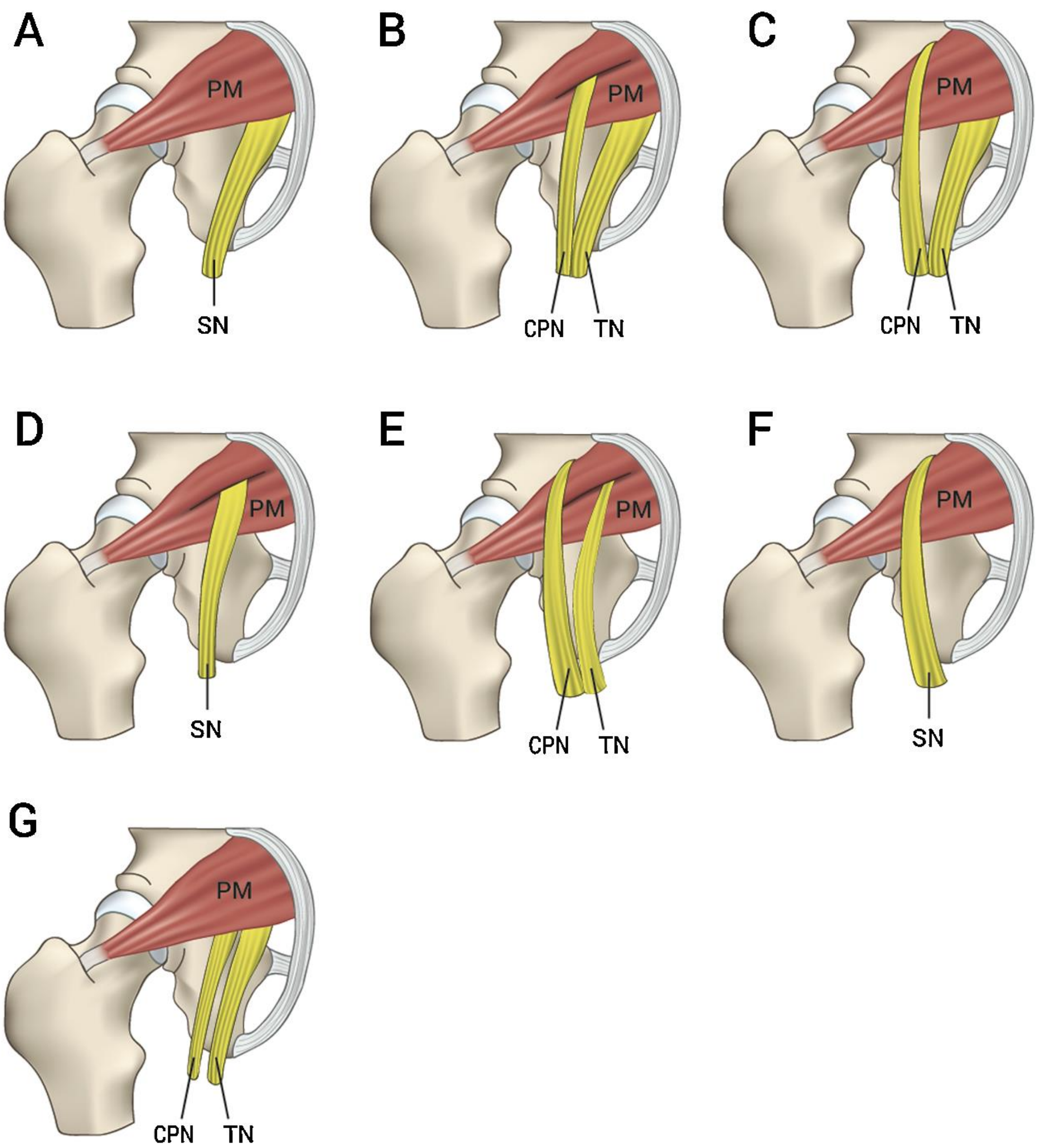

Figure 2.6: The variations in the relationship between piriformis and the sciatic nerve, within the gluteal region (types A–G). SN – sciatic nerve, PM – piriformis, CPN – common fibular nerve, TN – tibial nerve (Tomaszewski *et al.*, 2016).

The variations categorized in the literature (Figure 2.6), can broadly be subdivided into two groups. The first group comprises of variations where the sciatic nerve enters the gluteal region, posterior and inferior to piriformis, as a single common trunk, comprised of the common fibular and tibial nerves. The second group is categorised by a sciatic nerve that has bifurcated proximally, within the pelvic region, into its terminal branches, the common fibular and tibial nerves (Tomaszewski *et al*., 2016). The most important aspect about the two subgroups is how the bifurcated sciatic nerve exits in relation to piriformis (Guvencer *et al*., 2008). It is for this reason that the aforementioned classifications (Figure 2.6) rely heavily on how structural morphology impacts on neighbouring structures (Natsis *et al*., 2014).

The classification, type A (Figure 2.6), is generally the most common morphological representation of these structures, where the sciatic nerve enters the gluteal region as a single entity, posterior and inferior piriformis, which is also a single, undivided muscle. According to a meta-analysis conducted by Tomaszewski *et al.* (2016), this occurrence had a pooled prevalence of 85.2% in 7068 lower limbs investigated. This is accurately visualised in figure 2.7, where a typical course of the sciatic nerve passes posteriorly and inferior to a typical piriformis muscle.

Type B, is a variation that has a pooled prevalence of 9.8%, far less than that of type A (Tomaszewski *et al*., 2016). In this version of the variation, the sciatic nerve is already bifurcated, where both the common fibular and tibial nerves exit the pelvis as separate entities within the gluteal region. Furthermore, the common fibular nerve is piercing piriformis, which is now split into two different bellies of the same muscle, with the same origin and insertion points. Moreover, the tibial nerve courses below piriformis, which is the expected course for the undivided sciatic nerve (Figure 2.6). This is also depicted in figure 2.8, by Haladaj *et al*. (2015), where the common fibular nerve is clearly seen piercing piriformis, thereby separating piriformis into two bellies. In this image, the larger tibial division of the sciatic nerve is passing posterior and inferior to the smaller, inferiorly placed belly of piriformis (Figure 2.8). Furthermore, additional variations that have occurred in the right gluteal region of this lower limb can be observed, as a result of the variation of the sciatic nerve and piriformis (Haladaj *et al*., 2015). In this image (Figure 2.8), a black arrowhead is used to indicate the tendon of superior gemellus, which has fused with the piriformis tendon. While this tendon would traditionally attach to the trochanteric fossa of the femur, distally (Moore *et al*., 2017), as can be seen in figure 2.7, this is not the case in figure 2.8, where piriformis and sciatic nerve variations have subsequently effected other structures in this region.

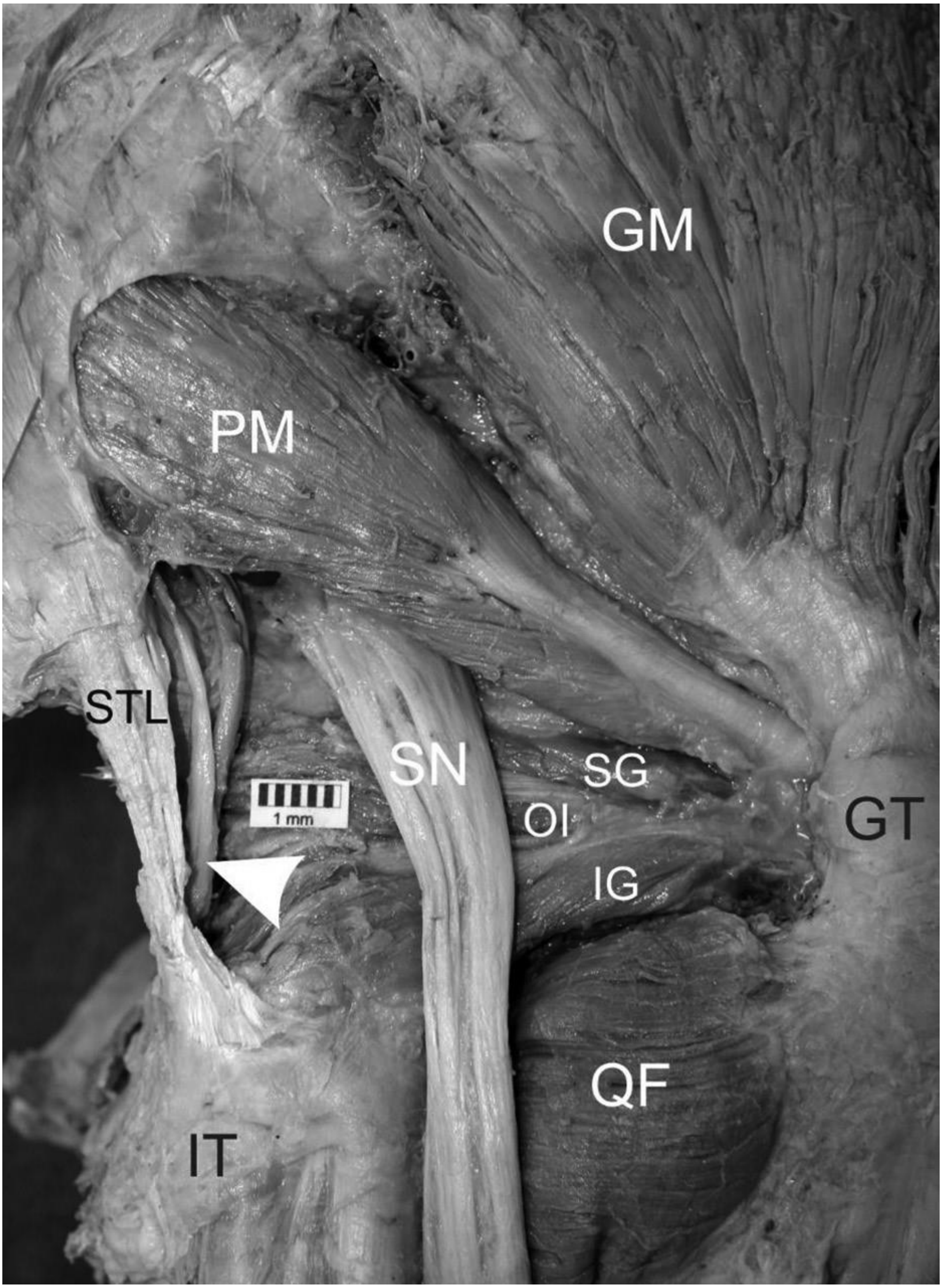

Figure 2.7: A typical morphology of piriformis and typical course of the sciatic nerve in the infra-piriform space. The white arrowhead indicates the pudendal nerve. GM – gluteus medius, GT – greater trochanter, IG – inferior gemellus, IT – ischial tuberosity, OI – obturator internus, PM – piriformis, QF – quadratus femoris, SN – sciatic nerve, SG – superior gemellus, STL – sacrotuberous ligament (Haladaj *et al*., 2015).

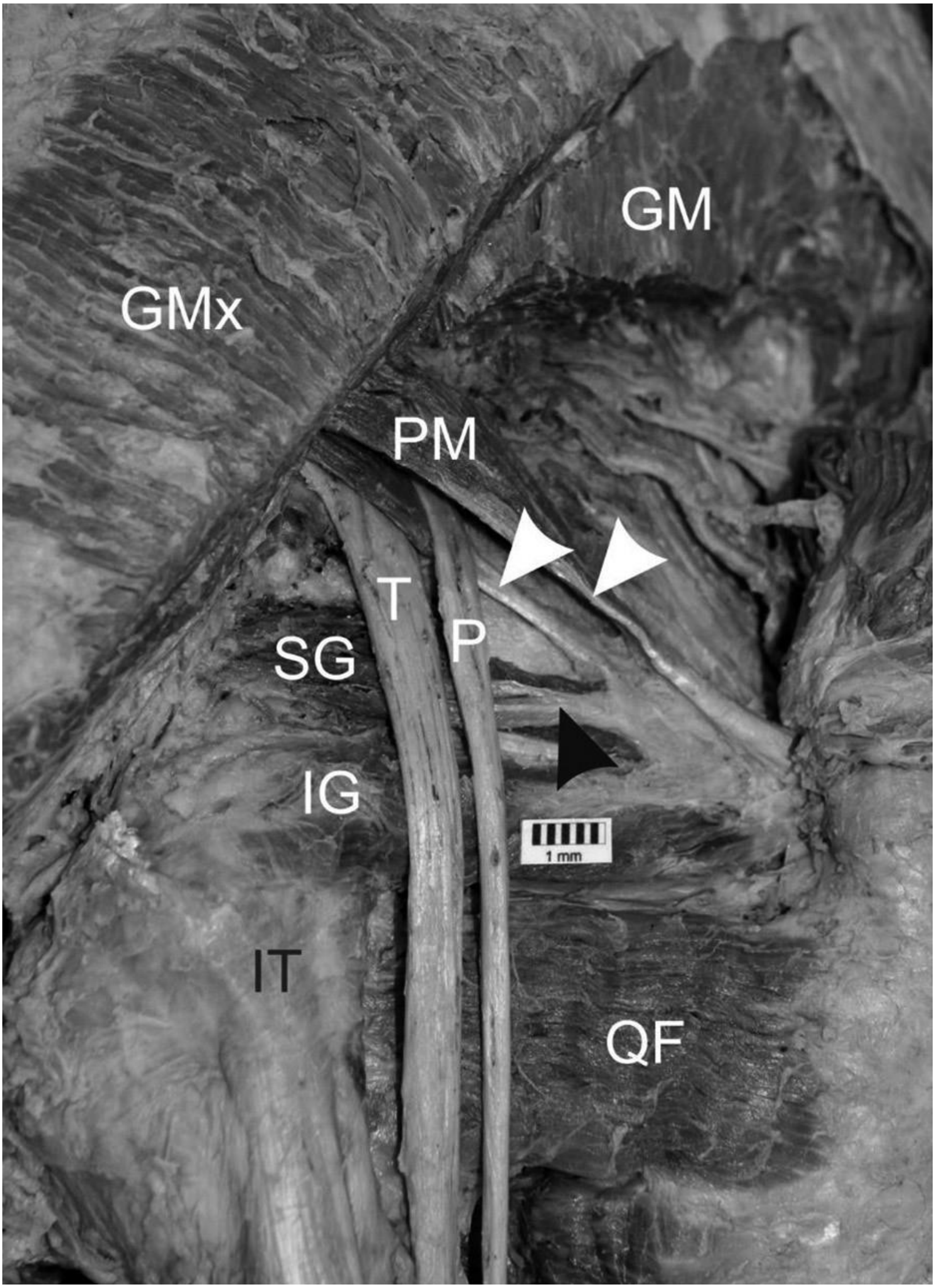

Figure 2.8: The common fibular nerve piercing piriformis. The white arrowheads indicate two bellies of piriformis with the common fibular nerve running between them. The black arrowhead indicates a tendon of the superior gemellus fused with piriformis tendon. GM – gluteus medius, GMx – gluteus maximus, IG – inferior gemellus, IT – ischial tuberosity, P – common fibular nerve, PM – piriformis, QF – quadratus femoris, SG – superior gemellus, T – tibial nerve (Haladaj *et al*., 2015).

The third variation in the series, type C, is where the sciatic nerve has bifurcated prior to exiting the pelvis (Figure 2.9). In this instance, the common fibular nerve exits along with the superior gluteal vessels, in the supra-piriform space, before proceeding to travel inferiorly, into the lower limb. The tibial nerve, on the other hand, exits within the infra-piriform space, as is traditionally expected from a common sciatic nerve, as seen in the most frequently occurring type A. Therefore, the two terminal branches of the sciatic nerve wrap around a complete piriformis without piercing the muscle.

In type D, the sciatic nerve pierces piriformis. Here, there are two bellies of piriformis, with the same origin and insertion points. The sciatic nerve remains unbranched, but does not travel posterior and inferior to piriformis, though the infra-piriform space, as expected. Instead, the defining feature of type C is that the intact sciatic nerve pierces piriformis. Therefore, the nerve will travel through piriformis, before traveling inferior, to the posterior compartment of the thigh, where it will proceed to bifurcate into its terminal branches, the common fibular and tibial nerves (Figure 2.5).

Type E has many similarities to the second variation (type B). Once again, this type of variation presents the terminal branches of the sciatic nerve entering the gluteal region separately. The common fibular nerve enters through the supra-piriform space with the superior gluteal vessels, and crosses piriformis before traveling inferiorly, towards the posterior compartment of the thigh. The tibial nerve exits the pelvic region and pierces piriformis, thereby creating two muscle bellies (Figure 2.5). In this variation, no sciatic nerve branch runs posterior and inferior to piriformis, through the infra-piriform space.

Type F is another variation where the sciatic nerve does not branch in the pelvic region. Rather, the sciatic nerve enters the gluteal region unbranched, but travels through the supra-piriform space, accompanied by the superior gluteal vessels (Figure 2.5). The sciatic nerve enters the gluteal region superior to piriformis, crosses piriformis, and then proceeds to follow its expected route inferiorly towards the posterior compartment of the thigh.

The last variation expected in the gluteal region is type G (Figure 2.5). This variation is not too different from type A. However, in this instance the sciatic nerve has already bifurcated into terminal branches when it exits the pelvic region. Thus, the structures entering the gluteal region include the common fibular and tibial nerves. These bifurcated terminal branches of the sciatic nerve do not pierce piriformis. None of the two branches enters the gluteal region through the supra-piriformis region, and instead course posterior and then inferior to piriformis, as two separate nerves, through the infra-piriform space.

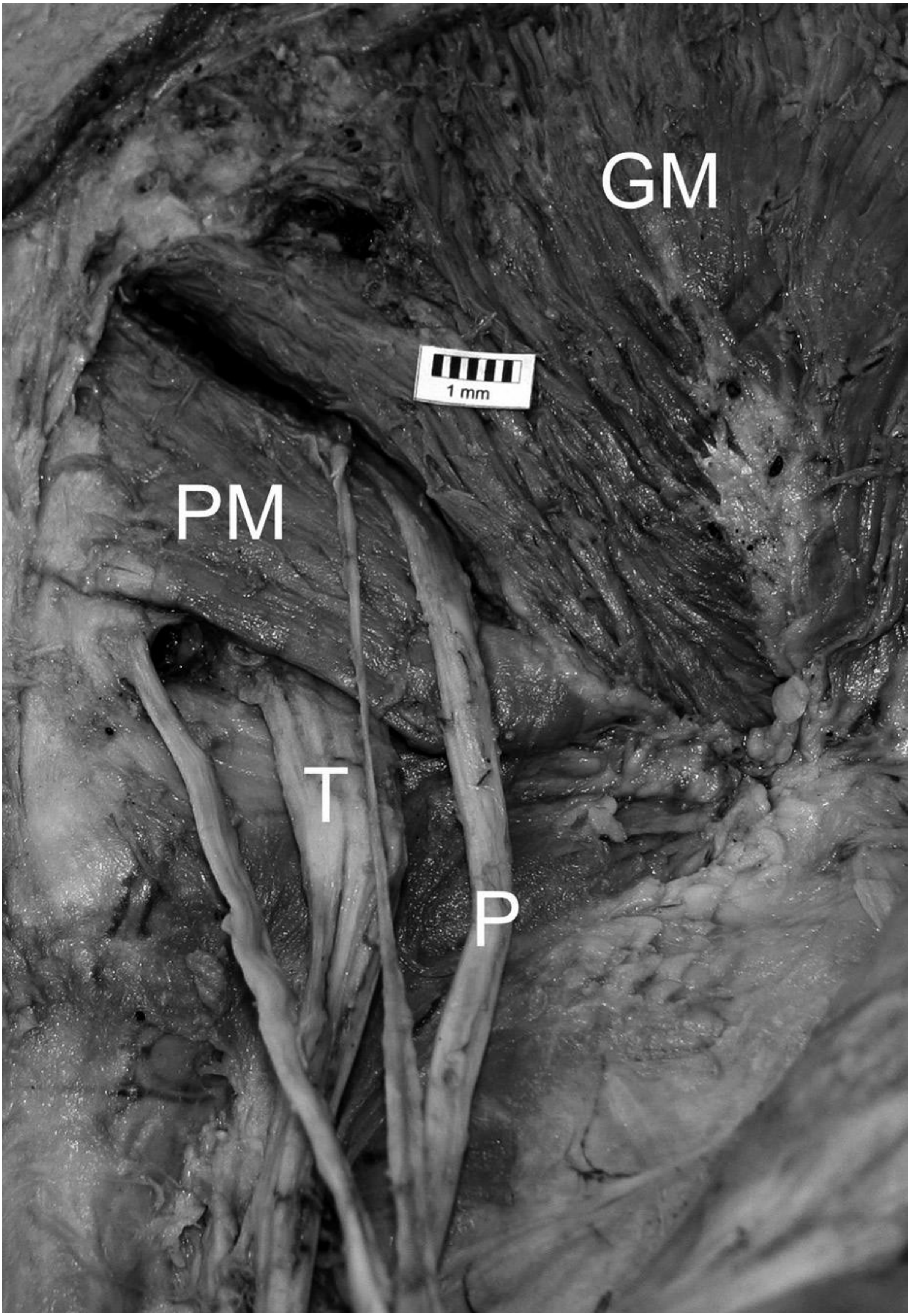

Figure 2.9: Common fibular nerve running through the supra-piriform space. The tibial nerve proceeds to course through the infra-piriform space as expected. GM – gluteus medius, P – common fibular nerve, PM – piriformis, T – tibial nerve (Haladaj *et al*., 2015).

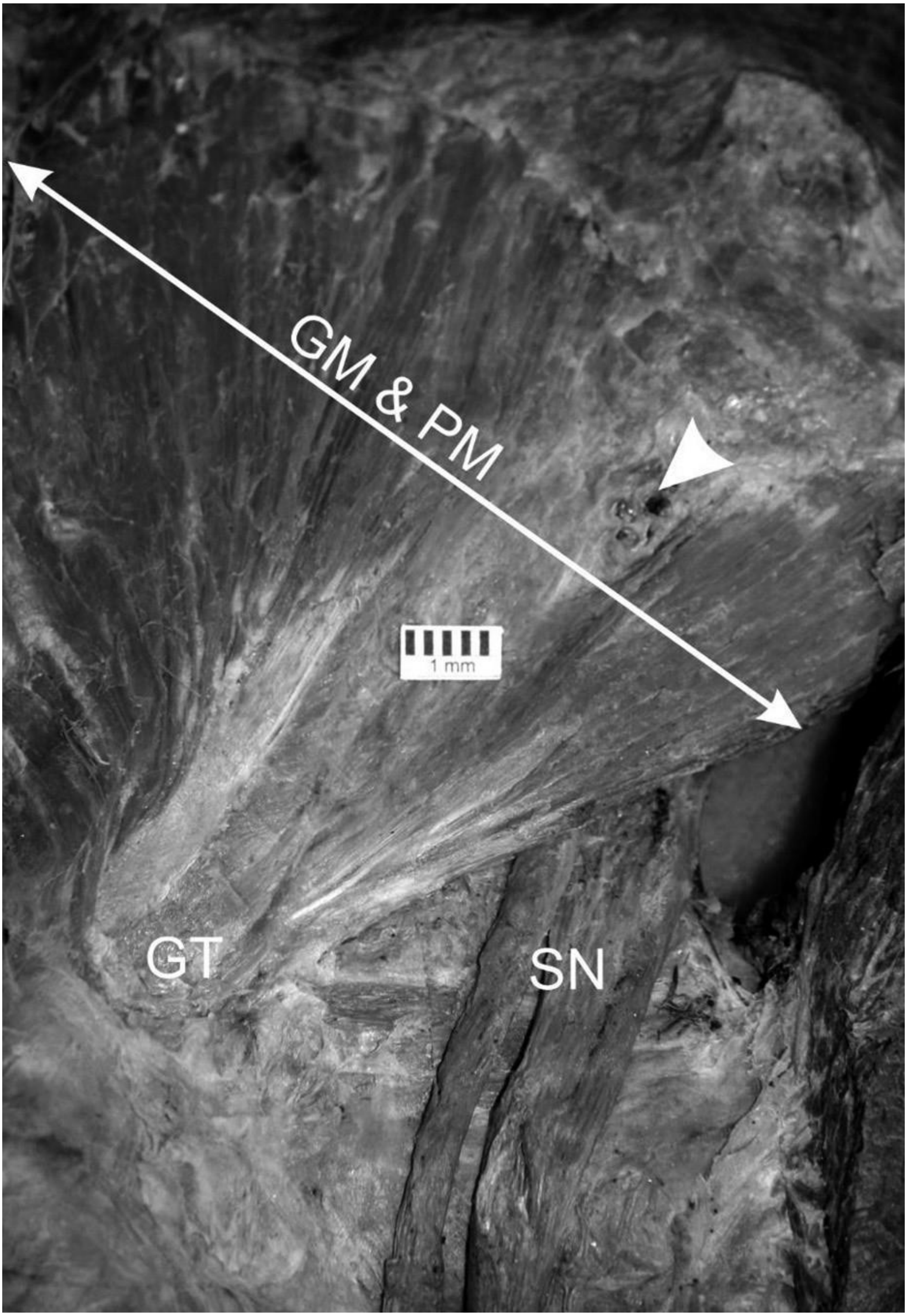

Figure 2.10: Fusion of piriformis and gluteus medius. The white arrowhead indicates the superior gluteal vessels, running between fibres of the fused muscle belly. GM & PM – fused gluteus medius and piriformis, GT – greater trochanter, SN – sciatic nerve (Haladaj *et al*., 2015).

An additional variation, not described in previous literature, can occur in the gluteal region. This variation involves gluteus medius and piriformis, and is not part of the standard classification of sciatic nerve variations in the gluteal region, as seen in figure 2.5. This variation occurs when gluteus medius fuses with piriformis, resulting in one continuous muscle layer that occupies a large area within the deeper layer of the gluteal region and deep to gluteus maximus. This variation is important because it has a significant effect on the gluteal vessels that enter the gluteal region. Once the muscles are fused, the supra-piriform space is eliminated. This means that there is no room for the superior gluteal vessels to course though the opening that would normally be present between gluteus medius and piriformis. Therefore, the superior gluteal vessels runs along the middle of this fused muscle. Recently, the variation was mentioned by Haladaj *et al*., in 2016, and can be seen in figure 2.10. Furthermore, should any one of the types A-G occur in conjunction with the fused gluteus medius and piriformis, the sciatic nerve or its terminal branches, will be affected, along with the superior gluteal vessels.

The types A, B and C have been reported frequently in literature. According to Tomaszewski *et al*. (2016), types D, E, F, and G are rarer, and reported in less than 1% of the populations studied. In the study conducted by Beaton and Anson, in 1938, the types E and F were only hypothesized, and not seen in their study sample. Moreover, type G was not found and described by Beton and Anson (1937), but was added as a modification of the different types of variations at a much later stage (Guvencer *et al*., 2008). The possible variations that can occur in the gluteal region, namely types A-G, and shown in figure 2.5, have been summarised in table 2.2, below.

Table 2.2: Summary of the possible variations in the relationship between the sciatic nerve and piriformis.

Types[1]	Variations
A	The sciatic nerve emerges in the gluteal region undivided and passes through the infra-piriform space, inferior to piriformis ("normal").
B	The sciatic nerve bifurcates in the pelvic region, with common fibular nerve piercing piriformis, and tibial nerve passing through the infra-piriform space, inferior to piriformis.
C	Sciatic nerve bifurcates in the pelvic region, with common fibular nerve passing through the supra-piriform space, superior to piriformis, and tibial nerve passes through the infra-piriform space, inferior to piriformis.
D	The undivided sciatic nerve pierces piriformis.
E	Sciatic nerve bifurcates in pelvic region, with common fibular nerve passing through the supra-piriform space, superiorly to piriformis, and tibial nerve piercing piriformis.
F	The undivided sciatic nerve passes through the supra-piriform space, superior to piriformis.
G	Sciatic nerve bifurcates in piriformis, and both common fibular nerve and tibial nerve pass through the infra-piriform space, inferior to piriformis.

The relationship between piriformis and the sciatic nerve is emphasized repeatedly because the structures are integral in morphological appearances in the gluteal region, when one structure affects the morphological appearance of another structure. The relationship between piriformis and sciatic nerve is largely variable. While these variations have since been documented in many regions across the world (Table 2.3), the same cannot be said for studies published within the continent of Africa.

[1] The categories used in table 2.2, A-G, are to categorise the variations that occur as a result of the relationship between the sciatic nerve and piriformis, and should not be confused with the categories A-F, used in table 2.4.

Table 2.3: Shows basic details of previous studies conducted on the sciatic nerve variations in relation to piriformis.

Authors	Year Published	Number of lower limbs dissected	Country of publication
Beaton & Anson	1937	120	United States of America
Beaton & Anson	1938	120	United States of America
Guvencer *et al.*	2008	20	Turkey
Guvencer *et al.*	2009	50	Turkey
Haladaj *et al.*	2015	30	Poland
Windisch *et al.*	2007	112	Austria
Patel *et al.*	2011	86	India
Uluutku & Kurtoglu	1999	25	Japan
Desalegn *et al.*	2014	26	Ethiopia
Kotian *et al.*	2015	60	India
Shylaja *et al.*	2017	40	India
Lewis *et al.*	2016	102	United States of America
Pokorny *et al.*	2006	182	Czech Republic
Vicente *et al.*	2007	40	Brazil
Natsis *et al.*	2015	294	Greece
Budhhiraja *et al.*	2016	60	India
Delabie *et al.*	2013	104	France
Sulak, Sakalli, & Ozguner,	2014	400 (foetus)	Turkey
Trotter,	1932	464	America
Saritha *et al.*	2012	50	India
Kumar *et al.*	2011	50	India
Brooks *et al.*	2011	40	Brazil
Chukwuanukwu *et al.*	2007	52	Nigeria
Ogeng'o *et al.*	2011	164	Kenya
Chiba *et al.*	1994	514	Japan
Ugrenovic *et al.*	2005	200 (foetus)	Serbia
Pecina	1979	130	Yugoslavia (Croatia)
Benzon *et al.*	2003	72	United States of America

2.2.2 The Level of Sciatic Nerve Division

There are many ways in which the sciatic nerve can present itself within the gluteal region, and within the lower limb. Research repeatedly suggests that anatomical structures vary between population groups across the world (Patel *et al*., 2011). Generally, the bifurcation of the sciatic nerve into its two major divisions occurs at the inferior aspect of the posterior compartment of the thigh. The sciatic nerve becomes the tibial nerve and common fibular nerve at the superior angle of the popliteal fossa proper (Patel *et al*., 2011). However, this is not always the case, since the sciatic nerve has considerable variation at the point where it bifurcates into its two terminal divisions (Nayak *et al*., 2014).

These variations have been categorised into six types (Kiros & Woldeyes, 2015). In type A, the sciatic nerve bifurcates proximally to its exit into the gluteal region. In type B, it bifurcates in the gluteal region. In types C, D, and E, it bifurcates within the proximal, middle, and distal regions of the posterior compartment of the thigh, respectively. In the last group, type F, the sciatic nerve bifurcates in the popliteal fossa proper (Table 2.4). This A-F classification provides a platform to quantify the level of bifurcation of the sciatic nerve in a given population.

Table 2.4: The level of sciatic nerve division in the lower limb.

Types[2]	**Level of division**
A	In the pelvic region.
B	In the gluteal region.
C	In the proximal third of the posterior compartment of the thigh.
D	In the middle third of the posterior compartment of the thigh.
E	In the distal third of the posterior compartment of the thigh.
F	Within the popliteal fossa proper.

It is reported that in approximately 12% of the cases studied, the common fibular nerve and tibial nerve emerge from the pelvis as two separate structures proximal to piriformis (Brooks *et al*., 2011). This has its own implications on the structure and variation of the piriformis muscle.

[2] The categories used in table 2.4, A-F, are to categorise the variations that occur as a result of the bifurcation of the sciatic nerve, and should not be confused with the categories A-G, used in table 2.2.

2.2.3 Literature in Africa

Africa is currently home to over one billion people (Cohen, 2006). Between 2015 and 2050, it is projected that the populations of 28 African countries will more than double (Hussain & Bhat, 2018). While the population is increasing, there is currently still very little research done to customise practices in the health services to be best suited to the African population. Africa is still subjected to medical practices designed for European conditions.

While extensive research has been conducted on the variations of the sciatic nerve in relation to piriformis, this is not entirely true for the continent of Africa. According to Ogeng'O *et al*. (2011), data from African population groups remain scarce. Chukwuanukwu *et al*. (2007), in Nigeria, and Kukiriza *et al*. (2010), in Uganda, reiterate this scarcity of proper data. There have only been four studies conducted on the relationship between the structures in the gluteal region, and a further three publications that address the level of the bifurcation of the sciatic nerve (Figure 2.11).

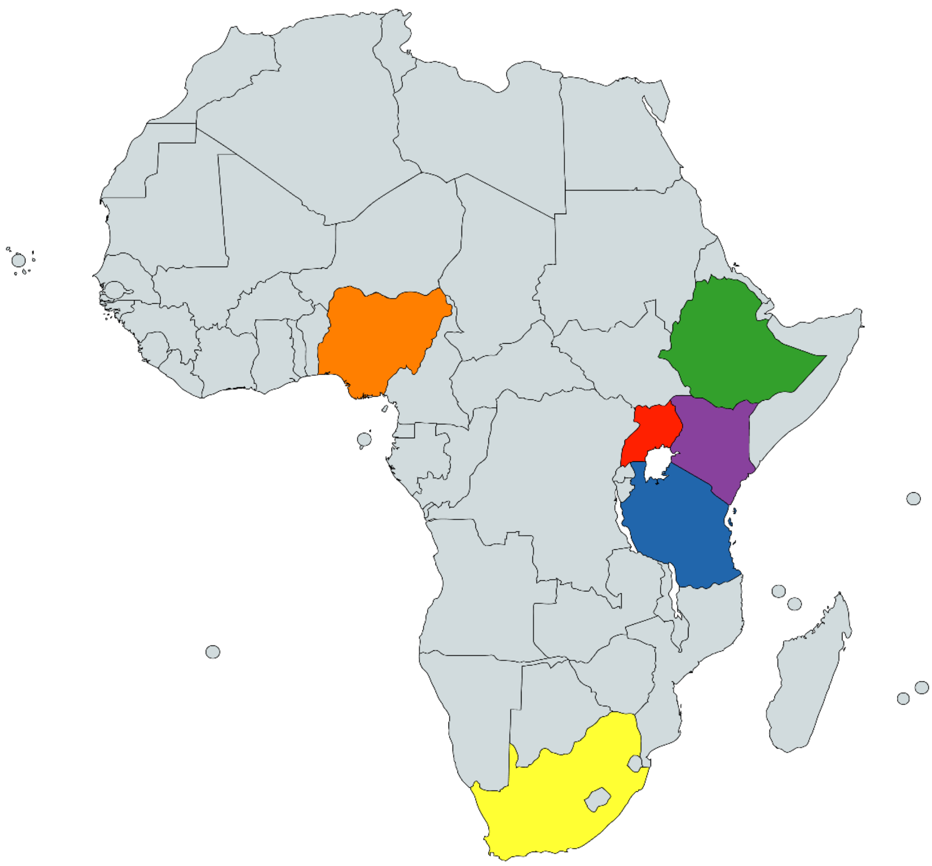

Figure 2.11: Map depicting countries in Africa where previous sciatic nerve and piriformis variation related research have been published. Green – Ethiopia, Purple – Kenya, Red – Uganda, Blue – Tanzania, Orange – Nigeria, Yellow – South Africa.

As depicted in the map (Figure 2.11), there have only been seven publications produced in Africa, which add to the overall literature on piriformis and sciatic nerve variations. These countries include Ethiopia, where three known studies have been conducted, and Kenya, Uganda, Tanzania, and Nigeria with one publication each, at the time the present study was conducted (Figure 2.11). It should be noted that South Africa has been highlighted on the map to indicate where the current study is being conducted.

In studies published on Ethiopian, Kenyan, and Nigerian population groups, where sciatic nerve and resultant piriformis variations were observed, only 156 cadavers were assessed across the three studies. This sample size is far smaller in relation to research conducted elsewhere in the world (Ogeng'o *et al*., 2011). While a prevalence for variations between the structures in the pelvic- or gluteal region is reported to be between 10-20% for the European population (Pokorny *et al*., 2006; Natsis *et al*., 2014; Delabie *et al*., 2013), the prevalence of this varied association was far less, at only 3.8% in the Nigerian population (Chukwuanukwu *et al*., 2007). Comparatively, there is still a lack of data that speaks to the variations in an African population compared with that elsewhere. It is for this reason that the current study aims to add meaningful data to existing literature for the South African population.

Piriformis is closely related to the sciatic nerve, which makes it possible that trauma and inflammation in piriformis might be clinically represented by sciatic-related pain (Hopayian *et al*., 2010). The clinical setting requires that there is an accurate knowledge of the sciatic nerve, which is important for the purpose of multiple procedures performed in this area. It is paramount that variations are documented extensively. It is for this reason that the variations are prone to develop into case specific pathologies in patients. No patient wants to live through pain and surgical intervention on a continued basis. Due to the aforementioned, literature regarding clinical conditions related to the sciatic nerve and piriformis will be reviewed; namely how this nerve is fundamental in producing debilitating and even chronic sources of pain in and around the gluteal region if not handled effectively. Literature will also focus on sciatic nerve blocks, intramuscular injections and the role that the sciatic nerve and muscles of the gluteal region play in piriformis syndrome.

2.3 CLINICAL CONSIDERATION

2.3.1 Pain

Pain is a major global health problem (Goldberg & McGee, 2011), and it has been estimated that 1 in 5 adults suffer from pain. Another 1 in 10 adults are diagnosed with chronic pain each year. Chronic pain has recently been highlighted as the leading cause for disability across the globe (Cooper *et al*., 2016). The high prevalence of chronic pain and the negative effect on society provides justification for regarding chronic pain as a public health priority (Häuser *et al*., 2015). Subsequently, this is one of the most debated issues in public health worldwide (Hoy *et al*., 2014). This information demands continued research with the focus on pain.

Pain can progressively become worse, resulting in chronic pain. Chronic pain can be described as pain that perseveres past what is considered 'normal' healing time (Treede *et al*., 2015). The result of this is a condition that is debilitating, and places the patient on medication and/or rest for extended periods at a time. Similar to many other chronic non-communicable diseases, chronic pain is typically accompanied by somatic and mental comorbidities (Goldberg & McGee, 2011). Therefore, the burden of chronic pain in terms of health care or unemployment could be confounded with one of these associated diseases (Dominick *et al*., 2012). Thus, there is a need for further research in this area (Häuser *et al*., 2015). If anything is to change, pain needs to be clearly defined as being of disease status on itself, rather than as a symptom of a disease (McGee *et al*., 2011).

One of the largest contributors to disability (Dunn *et al*., 2013), particularly in the Western world, is chronic musculoskeletal conditions (Stubbs *et al*., 2014). The results of the 2010 Global Burden of Disease study confirms that the prevalence and burden from musculoskeletal conditions are exceptionally high throughout the world (Hoy *et al*., 2014). Gore *et al*. (2012), maintain that lower back pain is the most prevalent musculoskeletal condition. According to Gouveia *et al*. (2015), lower back pain is defined as pain in the back area, from the lower margin of the twelfth ribs to the lower gluteal folds, with or without pain referred to the lower limbs. At its most extreme, lower back pain can present itself as an extremely severe and persistent pain in some patients, leading to chronic low back (Overaas *et al*., 2017).

Pain affects all population groups, regardless of age, sex, income, ethnicity, or geography (Goldberg & McGee, 2011). The prevalence rate for pain is expected to increase as people continue to live longer (Reid *et al*., 2015). According to Stubbs *et al*. (2014), and Leopoldino *et al*. (2016), older populations are increasing worldwide. By 2035, an estimated one quarter of the population in the European Union will be aged 65 or older (Reid *et al*., 2015). Williams *et* *al*. (2015) notes that with the rapid growth in numbers of older adults in low and middle-income countries, the back- and musculoskeletal pain burden will grow significantly in the coming decades. Therefore, the public health impact of pain is ever rising. This data only emphasises the urgency to identify the cause of musculoskeletal-related pain, and ensure accurate diagnoses when treating patients.

Pain in the gluteal region is becoming far more recognised by clinicians, and is an ever increasing complaint encountered in orthopaedic practices (Martin & Sekiya, 2008; Martin *et al*., 2014), with an estimated prevalence of between 10-25% amongst the population of industrialised nations (Meknas *et al*., 2011). According to Battaglia, D'Angelo and Kettne (2016), hip- and gluteal pain is common and effects approximately 14% of the population over the age of 60 years. Since people over 65 years-of-age account for 65% of admissions to hospitals, and 40% of primary care expenditure, it is important for clinicians to adjust to this reality (Abdulla *et al*., 2013). The possible causes of pain in the gluteal region are extensive (Hartvigsen *et al*., 2013; Martin *et al*., 2014), and might include referred symptoms from lumbosacral spine, sacroiliac joint (Buijs, Visser & Groen, 2007), the hip joint, or extra-articular structures of the hip region (Frank *et al*., 2010). The deep rotators of the hip joint (Cox & Bakkum, 2005; Meknas *et al*., 2003), the hamstring group (Puranen & Orava, 1988; Frank *et al*., 2010), tendinopathy of gluteus medius and gluteus minimus (Kingzett-Taylor *et al*., 1999), or an entrapment of the pudendal or sciatic nerves (Martin *et al*., 2010), could be extra-articular sources of gluteal pain. Entrapment of the sciatic nerve can present itself in many different forms within the gluteal region and lower limb, namely; an abnormal anatomical relationship between the sciatic nerve and vascular tissue found in the deep gluteal region (Martin *et al*., 2010), the muscle and tendon complexes of piriformis (Freiberg, 1934; Robinson, 1947; Lee *et al*., 2016) obturator internus and gemelli (Cox & Bakkum, 2005; Meknas *et al*., 2003), or proximal hamstrings (Puranen & Orava, 1988; Martin *et al*., 2010). Due to the many sources of gluteal pain from various intra- and extra-articular structures found in relation to the sciatic nerve, it can be difficult to determine the specific source through a clinical examination (Buijs *et al*., 2007). Therefore, it is paramount that there is adequate knowledge of the anatomical variations within the region for appropriate diagnosis, and potential treatment of the pain (Grassi *et al*., 2003; Martin *et al*., 2014).

2.4.2 Sciatic Nerve Block

Significant advances have been made in regional techniques for localised nerve blocks. This has primarily been driven by the need to produce effective analgesia during the postoperative period (Murray *et al*., 2010). Additionally, modern medical care practices demand a shorter hospital stay, early mobilisation of the individual, and overall improved patient experiences (Murray *et al*., 2010).

Regional anaesthesia has become increasingly popular for procedures performed on the lower limb because this improves the quality of pain relief postoperatively (di Benedetto *et al*., 2001). The sciatic nerve block is frequently used for anaesthesia or analgesia when performing procedures on the lower limb (Karmakar *et al*., 2007). This procedure is well established, and is performed using a variety of different techniques and approaches. The nerve can be blocked at any point along its course within the lower limb, provided there is sufficient ultrasound images to guide this procedure (Marhofer *et al*., 2010).

Although the sciatic nerve has the largest cross-sectional diameter in the human body, its ultrasonography imaging can, however, not be easy to interpret (Moayeri *et al*., 2010). Imaging of the sciatic nerve can be challenging for a number of reasons. There are many other surrounding structures within the gluteal region, which means that the large amount of muscle and adipose tissue around the nerve can impair its visualisation (Marhofer *et al*., 2010). Moreover, inadequate probe manipulation has the potential to cause serious complications to the patient. The risk of injury caused by the intraneural injection is increased, as multiple redirections of the needle would often be required in order to deposit the anaesthetic solution correctly near the deeply situated nerve (Yamamoto *et al*., 2014). It is common for most of the techniques currently in use to rely on anatomical landmarks identified on the surface, which is largely unreliable and has the potential for many errors. While these anatomical landmarks are correct in providing clues to where the sciatic nerve is situated, it is by no means accurate, and these landmarks are only a guide. These landmarks do not work for all patients, as they do not make provision for anatomical variations, or varying body sizes (Karmakar *et al*., 2007). Most importantly, the effective identification of this nerve within the gluteal region requires extensive knowledge of the topography of the gluteal region, and internal architecture of the nerves and vessels within adjacent structures (Moayeri *et al*., 2010).

As discussed previously, the sciatic nerve anatomy has been described in many medical textbooks used throughout the world. However, as with many other structures in the body, there are varieties of different ways that the sciatic nerve is distributed within the gluteal region. The bifurcation of this nerve proximal to the gluteal region may lead to subsequent failure of regional anaesthetic techniques (Murray *et al*., 2010). The sciatic nerve bifurcates into two large terminal branches. While this bifurcation typically takes place approximately 6.6 cm proximal to the popliteal crease (Vloka *et al*., 2001), the bifurcation could also occur as proximal as the level of piriformis, or even before that. This superiorly placed bifurcation means that there could be an incomplete or failed nerve block when the variation goes undetected (Clendenen *et al*., 2008). Therefore, adequate knowledge of population-specific variations that occur within the gluteal region is necessary for the success of many procedures performed on the lower limb.

2.4.3 Intramuscular Injections

The sciatic nerve can receive debilitating damage when injured by an intramuscular injection into the buttock, or gluteal region (Mishra & Stringer, 2010). An intramuscular injection is an important procedure used by many clinicians for administering a variety of medications (Ramtahal *et al*., 2006). This is especially so for administering local anaesthetic, as compared to the longer lasting general anaesthetic. While often underestimated, intragluteal injections is one of the most frequent causes of sciatic nerve injury and overall lower limb nerve injury in children (Senes *et al*., 2009). In several cases, the injury generally presents itself clinically as a drop foot (Mishra & Stringer, 2010). This is due to the deficits in movements involving dorsiflexion and eversion of the foot. However, more often the manifestation of sciatic nerve injury in the lower limb is incorrectly interpreted as a congenital defect or related to disease of the spinal cord (Senes *et al*., 2009).

Intramuscular injections are an integral part of drug administration in the nursing practice. Subsequently, the teaching of this technique has become an integral part of nursing syllabi around the world (Roger & King, 2000). Unfortunately, injury to the sciatic nerve, resulting from a misplaced intramuscular injection in the gluteal region, is a problem that persists worldwide and affecting patients in both economically thriving and underdeveloped countries alike (Mishra & Stringer, 2010). Consequently, safe injection practices should be a priority in every health sector, and is a concern for all health professionals. In economically poorer countries, children make up the greatest number of casualties of traumatic injection neuropathy (Fatunde & Familusi, 2001). In countries such as Pakistan, India, and Nigeria, the administration of intramuscular injections by inadequately trained staff seems to be the most predominant cause for neural damage (Adetunji *et al*., 2005; Pandian *et al*., 2006; Tak *et al*., 2008).

Recovery has been poor in this important, preventable, type of peripheral nerve injury (Combes *et al*., 1960). The extent of recovery depends on the severity of the initial injury. Overall, many patients are not able to make a full recovery, even when there has been attempted microsurgical repair of the area (Mishra & Stringer, 2010). An increasing realisation is that nursing staff are reluctant to use better-quality sites for intramuscular injections. This is because there is inadequate and/or conflicting research about these sites, and the variations present (Small, 2004). This only emphasises the importance of sound anatomical knowledge of a region, which relates to an emphasis on the high-risk nature of clinical techniques performed on structures within these regions.

Due to the dangers associated with piriformis and the sciatic nerve, piriformis is often injected with the assistance of numerous medical techniques. These techniques include computed tomography, magnetic resonance imaging, ultrasound, or electromyography. These techniques are beneficial when injecting the muscle, because of the relative small size of piriformis, proximity to many neurovascular structures, and its deep location within the gluteal region. However, these techniques are not always reliable because of the variability in depth of the sciatic nerve and other related structures, as previously mentioned (Marhofer *et al.*, 2010). Additionally, these techniques are not affordable, especially in developing countries, where they are frequently unavailable, or there are no physicians trained to use these techniques (Gonzalez *et al.*, 2008). This is why a study assessing the prevalence of population-specific variation is highly advantageous for the region-specific medical application.

2.4.4 Piriformis Syndrome

Piriformis syndrome remains a controversial and unformulated diagnosis within the field of clinical medicine (Papadopoulos & Khan, 2004). This can be ascribed, primarily, to an unclear consensus on the definition and pathophysiology of the syndrome (Jawish *et al.*, 2010; Kirschner, *et al.*, 2009). Piriformis syndome is a condition that is rarely considered in the event of differential diagnosis for patients who present with pain in the lower limb (Halpin & Ganju, 2009). It is often mistaken for conditions that occur more commonly in the lower back and gluteal regions, such as conditions affecting spinal nerve entrapment and herniated discs (Windisch *et al.*, 2007). As a result, piriformis syndrome is an underdiagnosed condition, which includes lower back or buttock pain amongst its collection of symptoms (Benzon *et al.*, 2003). For years, the diagnosis of piriformis syndrome has been elusive, commonly taking the role of diagnosis due to exclusion of other causes by many clinicians (Kirschner *et al.*, 2009). However, there is adequate evidence suggesting that noteworthy sciatic pain is not necessarily spinal in nature (Fishman *et al.*, 2002). Too often, diagnosis is left to the decision and agreement as to whether piriformis syndrome is a stand-alone clinical entity (Kirschner *et al.*, 2009). The syndrome has been described as “difficult to substantiate” (Dawson & Hallett, 1990), due to the lack of clarity surrounding its pathogenic mechanisms (Fishman *et al*., 2002). Piriformis syndrome has really caused controversy amongst peripheral nerve experts because a precise definition has not been established for its symptoms. This ambiguity is due to the overwhelming number of pain conditions involving the gluteal region and lower limb that have to be ruled out before piriformis syndrome is even considered as a diagnosis (Halpin & Ganju, 2009).

Initially, periarthritic manifestations of the anterior sacroiliac ligament were hypothesized to be the source of changes presented in piriformis and related fascia due to inflammation (Halpin & Ganju, 2009). It was Yeoman, in 1928, who linked these changes and clinical manifestations to the presentation of a condition referred to as sciatica in the region. Due to the close relationship of structures in the gluteal region, namely, piriformis, sciatic nerve, and sacroiliac joint, there was a move to understand the presence of lower limb pain in the absence of any pathology below the gluteal region (Cassidy *et al*., 2012). Sciatica was the preferred term presented to describe such pain. This term was first introduced in fifteenth-century in Florence, and was associated to anomalies present at the ischium (Fishman *et al*., 2002). Sciatica is used clinically to describe pain present along the course of the sciatic nerve, and pain associated with structures closely related to this nerve (Chen, 1994). It was around 10 years later, when Freiberg and Vinke presented three manifestations of piriformis-induced sciatica (Fishman *et al*., 2002). These included: (1) tenderness at the sciatic notch, (2) a positive Lasègue's sign[3], and (3) improvement with non-surgical treatment (Freiberg, 1937). This was aligned with a move to cement an etiological explanation for sciatica. Piriformis syndrome was first mentioned, and described, by Robinson, in 1947. He attested piriformis syndrome as having six key characteristics: (1) a history of trauma or direct fall to the buttock; (2) gluteal or sacroiliac pain radiating down the leg that often limits ambulation; (3) gluteal atrophy; (4) a palpable sausage-shaped mass present above piriformis; (5) positive Lasègue sign; and (6) exacerbation of pain with bending or lifting objects (Robinson, 1947). However, there are flaws with both these definitions, attempting to define piriformis syndrome (Papadopoulos & Khan, 2004). While Robinson's (1947) list only picks a fraction of the many piriformis syndrome cases that are clinically identifiable, Freiberg (1937) included problems other than piriformis syndrome in his criteria, such as intramuscular injections and sacroiliac joint derangement, to name two. However, anatomical variations should not be overlooked when trying to characterise the aetiology of piriformis syndrome (Windisch *et al*., 2007)

[3] Lasègue sign is a straight lower limb raise test that has diagnostic significance as a sign constantly present in sciatica. The patient lies in the supine position, and the involved lower limb is raised with the knee extended. The manoeuvre is repeated, with the leg flexed at the knee while the thigh is flexed at the pelvis. The sign is present if the first manoeuvre evokes sciatic pain and the second does not (Maranhão-Filho & Vincent, 2018).

There were six common anatomical variations, originally described by Beaton and Anson, in 1937, which defined the intricate relationship between the piriformis and sciatic nerve (Beaton & Anson, 1937). This is noteworthy because of the nerve's manipulation of the muscle, and the subsequent clinical manifestations due to the presence of a variation. In a later study, undertaken by Beaton and Anson in 1938, another 120 cadaver specimens were examined, increasing their study sample to 240 specimens. In this study, 0.8% of the specimens showed sciatic nerves that exited the gluteal region through the midsubstance of the piriformis (Beaton & Anson, 1938). In these specimens, the piriformis syndrome is the result of a sciatic nerve that is compressed because it runs between the two bellies of piriformis that have been created because of this variation (Beaton & Anson, 1937). This is notable because these specimens present rare cases of piriformis syndrome due to variations, which could be treated surgically (Kosukegawa *et al*., 2006).

However, despite a number of publications, it is still largely unclear as to whether the pathology of piriformis syndrome is due to the presence of these anatomical variations in the region (Cassidy *et al*., 2012). This is because there have been reported cases where patients with variations have been asymptomatic, and conversely, there have been symptomatic patients who did not have any structural variations (Kirschner *et al*., 2009). Numerously, anatomical variations have been considered as a cause of piriformis syndrome (Cassidy *et al*., 2012). While considering the causes for piriformis syndrome, Windisch *et al.* (2007) again looked at the anatomical variations. Here, an intricate set of parameters were considered, such as the nature of the musculotendinous junction, shape of the muscle, diameter, insertion, and fusion of the piriformis tendon with other tendons. Upon completing the observation of 112 cadaver specimens for the study, the authors concluded that a purely anatomical cause for piriformis syndrome was rare (Windisch *et al*., 2007). This was because of the extensive variability described for each of the parameters measured. This lead to a consensus that although other causes would need to be considered to determine the cause of piriformis syndrome (Windisch *et al*., 2007), anatomical variations were still a noteworthy contribution to its aetiology (Cassidy *et al*., 2012). Ozaki *et al*. (1999) were in agreement that sciatic nerve and piriformis variations play a major role in piriformis syndrome. In their study, a previously unreported variation was observed and reported. In this case, a patient presented a bifurcated sciatic nerve that coursed superior to piriformis, in the supra-piriform space. This 22-year-old Japanese woman presented with lower back and pelvic pain due to a compression of the sciatic nerve between the superior border of piriformis and superior margin of the greater sciatic foramen (Ozaki *et al*., 1999). In a case report by Babinski *et al*., 2003, another rare variation of the sciatic nerve bifurcation was described. In this case, the tibial nerve passed inferior to the superior gemellus, while the common fibular nerve passed superior to this muscle. The conclusion here was that such variations might be conducive to the prevalence of piriformis syndrome (Babinski *et al*., 2003). In yet another rare case report, a similar type of variation was observed, namely, piriformis, which had been divided into two bellies, compressed the entire sciatic nerve. Upon intervention, the piriformis muscle was resected, resulting in the disappearance of the pain (Kosukegawa *et al*., 2006). Once again, Kosukegawa *et al*. (2006) highlighted the definitive contribution that anatomical variations have on the clinical manifestation of piriformis syndrome.

Scientific specialists in the field have studied the detection of piriformis and sciatic nerve related variations. These variations can be identified by the use of radiological techniques, and in almost all operative procedures within the gluteal region. However, it is important to remember that, even with increased technological advances, the cadaver is the best means to study the anatomy of the sciatic nerve and piriformis, along with the prevalence of variations in the morphology of these structures (Smoll, 2010; Prakash *et al*., 2010).

CHAPTER THREE:

AIMS AND OBJECTIVES

3.1 PROBLEM STATEMENT

The intricacy of the sciatic nerve and piriformis variations have been discussed in detail, and the clinical implications resulting from these variations have been looked at as well. Following the review of literature, it is clear that it is important to understand the sciatic nerve, along with the variations that are most prevalent. While the variations of piriformis and the sciatic nerve have been documented in the past, there is a need for population specific data. This is the case for the Americas, Europe, and Asia. As far as it is understood, there have been very few studies of this calibre undertaken or published on the African continent. Moreover, to the author's knowledge, there have been no formal publications of this kind within South Africa to date. The primary aim of the present study is to describe and document the anatomical and morphological variations of piriformis in relation to the sciatic nerve bifurcation within the South African population. Additionally, to morphometrically analyse normal parameters of the sciatic nerve and piriformis muscle. Furthermore, the secondary aim of the present study is to assess the level of bifurcation of the sciatic nerve within the lower limbs of the South African population. Thereafter, comparisons of the variations described will be made between right and left lower limbs, male and female specimens, and between the three population groups available, namely; White/Caucasian, Mixed Race and South African Black groups, within South Africa. Although there is extensive diversity amongst the smaller subpopulation groups within South Africa, this research will speak to the South African population as a whole. Furthermore, the researcher will attempt to provide detailed results for the South African population groups and their variation classifications where statistically possible.

3.2 AIMS

The aims of the present study are to:

(1) Report on the prevalence of anatomical variations in the course of the sciatic nerve in relation to piriformis;

(2) Report on the prevalence of variations in the level of sciatic nerve bifurcation into the tibial and common fibular nerves either within the pelvic region, gluteal region, posterior compartment of the thigh, or popliteal fossa proper, within the lower limb;

(3) Analyse morphometric measurements for the typical sciatic nerve and piriformis morphology;

(4) Compare results found between right and left lower limbs, male and female specimens, and in the three South African subpopulation groups.

3.3 OBJECTIVES

In order to achieve the aims of this study, the following objectives were set:

i. To observe the variations of the sciatic nerve in relation to piriformis variation
   a. Sciatic nerve exits the pelvic region and continues undivided, below piriformis.
   b. Sciatic nerve bifurcates in the pelvic region, with the common fibular nerve piercing piriformis, and the tibial nerve emerging below piriformis.
   c. Sciatic nerve bifurcates in the pelvic region, with the common fibular nerve coursing inferiorly across piriformis, and tibial nerve emerging below piriformis.
   d. Sciatic nerve exits the pelvic region undivided, piercing piriformis.
   e. Sciatic nerve bifurcates in the pelvic region, with the common fibular nerve coursing inferiorly across piriformis, and the tibial nerve piercing piriformis.
   f. Sciatic nerve exits the pelvic region undivided, coursing through the supra-piriform space and then inferiorly across piriformis.
   g. Sciatic nerve bifurcates in the pelvic region, with both the common fibular nerve and tibial nerve coursing separately below piriformis.

ii. To observe the level of sciatic nerve bifurcation within the lower limb:
   a. Within the pelvic region, proximal to piriformis;
   b. Within the gluteal region;
   c. In the proximal first third of the posterior compartment of the thigh;
   d. In the middle third of the posterior compartment of the thigh;
   e. In the distal third of the posterior compartment of the thigh;
   f. Within the popliteal fossa proper.

iii. Take morphometric measurements of selected piriformis and sciatic nerve parameters;

iv. Analyse datasets of the sciatic nerve and piriformis between:
   a. right and left lower limbs,
   b. male and female specimens
   c. cadavers from the three different South African population groups.

CHAPTER FOUR: MATERIALS AND METHODS

4.1 ETHICAL APPROVAL

Ethical approval was obtained from the Stellenbosch University's Health Research Ethics Committee; reference number S18/02/032. The Health Research Ethics Committee complies with the South African National Health Act No. 61 2003, sections 61 to 64 as it allows the use of cadavers for research purposes and medical training (National Health Act, 2003). Additionally, this act pertains to health research and adheres to the United States Code of Federal Regulations Title 45 Part 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

4.2 ACQUISITION OF CADAVERS

For this research project, cadavers were sourced from three universities within South Africa: Division of Clinical Anatomy, at Stellenbosch University (SU), School of Anatomical Sciences, at the University of the Witwatersrand (Wits), and the Division of Clinical Anatomy and Biological Anthropology, at the University of Cape Town (UCT).

The departments and divisions obtained cadavers primarily by making use of two methods. Firstly, cadavers are sourced through informed consent. Prior to death, a person provides consent that their body is donated for the purpose of medical research and education. Secondly, cadavers that are not claimed from the state by relatives within a 30-day period are automatically donated to a university within the region for the purpose of medical research and education. Concerning the latter arrangement, consent is not formally given, instead consent is granted by the inspector of anatomy for the Western Cape, on behalf of the person, their family, and government. Furthermore, a detailed account of the cadaver's location is kept. In both instances, no personal information regarding cadavers is made available.

Cadavers will each receive a university-specific number for storage and identification purposes, with the inclusion of basic cause and date of death, sex and age. No personal or medical information regarding any of the cadavers were used when conducting this present study. The cadavers will remain anonymous throughout the entirety of the study.

4.3 STUDY MATERIAL

For the purpose of the present study, 170 ($N = 340$ lower limbs) embalmed cadavers were used. The researcher conducted this study during routine dissection of the lower limb by medical students, at the three medical universities mentioned earlier. The specimens were acquired randomly, as all the cadavers used for the medical dissection programs at the universities were included in the study. Both right and left lower limbs were used from all 170 cadavers. Therefore, every right lower limb has a corresponding left lower limb. Previous studies excluded specimens where damage to piriformis or the sciatic nerve was observed. However, in this study, no damage was observed and all the specimens could be used and measured.

The 340 lower limbs consisted of male (n=190) and female (n=150) specimens. The ages were between 24 and 101 years at the time of death (with an average of 67 years). The specimens were distributed over three South African population groups, namely; White/Caucasian (n=232), Mixed race (n=78), and South African Black (n=30) specimens. Table 4.1, below, summarises this.

Table 4.1: Basic information regarding the specimens used in the present study.

	Categories	Total	Percentages
Total		340	-
Side	Right	170	50.0%
	Left	170	50.0%
Sex	Male	190	55.9%
	Female	150	44.1%
Population Group	White/Caucasian	232	68.2%
	Mixed Race	78	23.0%
	South African Black	30	8.8%
Variations	Total	43	12.0%
	Bilateral	28	8.2%
	Unilateral	15	3.8%

The present study is descriptive and observational in nature. The emergence of the sciatic nerve, in relation to piriformis, within the gluteal region, was observed and documented. Subsequently, the anatomical relationship between the sciatic nerve and piriformis was classified according to the adjusted Beaton and Anson (1937) classification, into the seven known types (Table 2.2). Additionally, the lower limbs were observed in order to study the sciatic nerve, and its level of bifurcation into the tibial and common peroneal nerves. This was categorised into six separate classifications (A-F) (Table 2.4), depending on the level of bifurcation of the sciatic nerve into its branches. Figure 4.1 depicts a summary of this methodology for the study. Specimens were collected and grouped according to the two overarching variations observed: the variation in the relationship between piriformis and the sciatic nerve, and the variation in the level of bifurcation of the sciatic nerve.

Dissection and classification of variations were done as follows: if students at specific institutions were not dissecting this region, the researcher performed the dissection on the gluteal regions and lower limbs. Where these regions were dissected as part of the curriculum, the students dissected these regions under constant supervision of the primary researcher. In this way, although various individuals were responsible for dissection, the methodology stayed the same. The researcher was solely responsible for the classification of any variation discovered within the gluteal region or at the level of bifurcation.

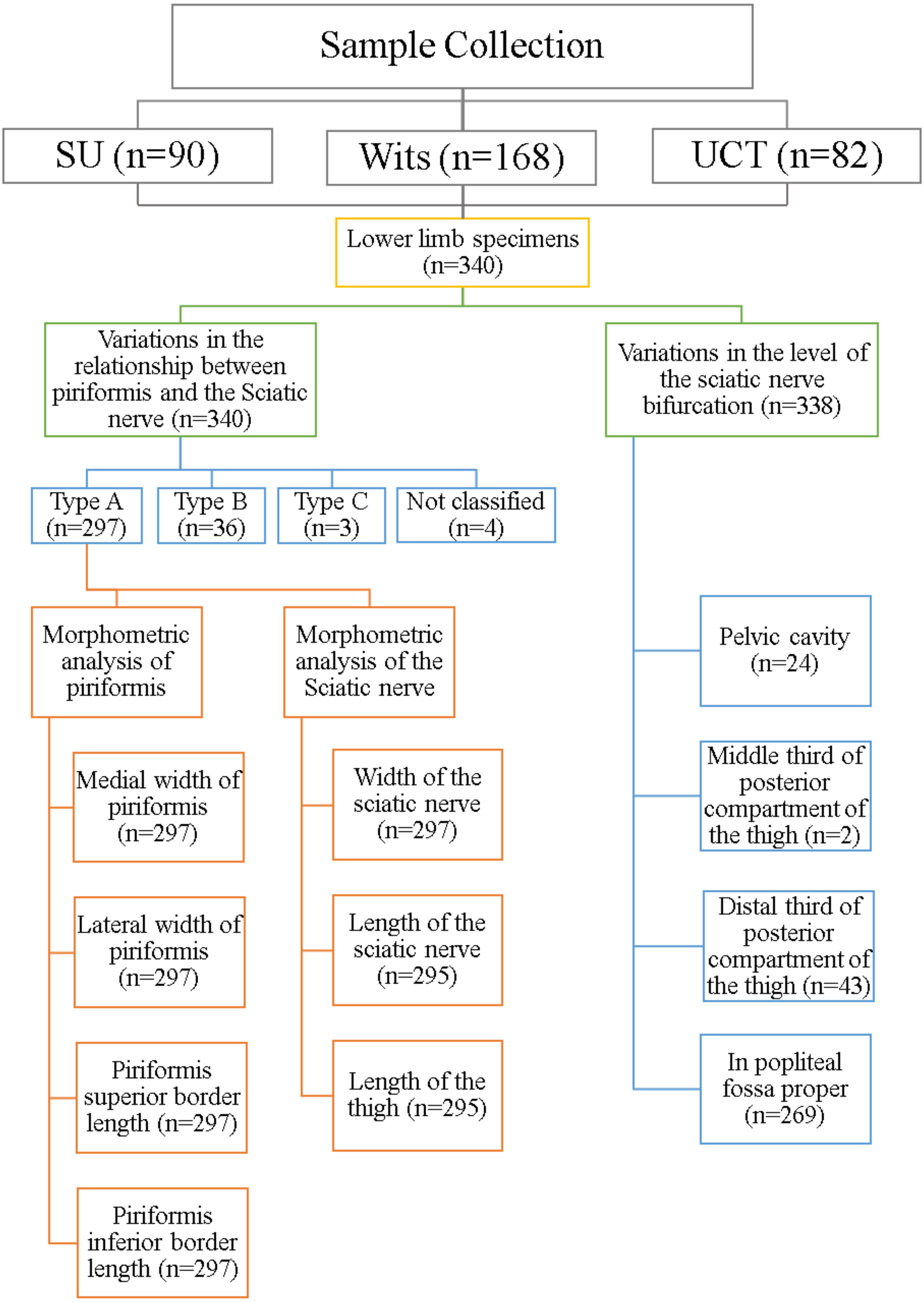

Figure 4.1: Summary of methodology. Specimens were collected and grouped according to the two overarching variations observed: the variation in the relationship between piriformis and the sciatic nerve, and the variation in the level of bifurcation of the sciatic nerve.

4.4 MEASUREMENT OF THE STRUCTURES

Measurements were taken for all the relevant structures in the gluteal region, but only if the structures conformed to the normal anatomy within the gluteal region. This meant that only the limbs that resembled type A, in figure 2.4, qualified for morphometric analysis. Table 4.2, below, presents a summary of these measurements. Additionally, figure 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, and 4.8 depict these measurements recorded on a specimen, followed by the description of these measurements later in the chapter.

Table 4.2: Parameters of the morphometric measurements.

No.	Measured Parameter	Designation
1	Medial width of piriformis	MWP
2	Lateral width of piriformis	LWP
3	Length of the superior border of piriformis	LSBP
4	Length of the inferior border of piriformis	LIBP
5	Width of the sciatic nerve, as it emerges below the inferior border of piriformis	SNW
6	Length of the sciatic nerve	SNL
7	Length of the thigh	TL

4.4.1 Piriformis muscle

The normal piriformis, recognised as type A in the Beaton and Anson (1937) classification, was measured for statistical purposes. The extra-pelvic medial width of piriformis was measured, as the muscle became visible within the gluteal region (the width was measured directly parallel to the length of the sacrotuberous ligament) (Figure 4.2). A lateral width of piriformis was also measured, at the middle of the extra-pelvic piriformis belly (Figure 4.3). The extra-pelvic superior length of piriformis was measured from where the muscle appeared in the gluteal region, at the sacrotuberous ligament and ending at the tendinous insertion at the piriformis fossa on the medial aspect of the greater trochanter of the femur (Figure 4.4). The extra-pelvic inferior length of piriformis was also measured from where the muscle appeared in the gluteal region, at the sacrotuberous ligament and ending at the tendinous insertion at the piriformis fossa on the medial aspect of the greater trochanter of the femur (Figure 4.5). The above measurements were obtained using a 300mm VINCA DCLA-1205 quality electronic digital Vernier calliper, with an accuracy of ±0.04mm.

Figure 4.2: Measurement of the medial width of piriformis, using the sliding digital calliper.

Figure 4.3: Measurement of the lateral width of piriformis, at the middle of the muscle belly. This measurement was taken using a sliding digital calliper.

Figure 4.4: Measurement of the superior border of piriformis, using the sliding digital calliper.

Figure 4.5: Measurement of the inferior border of piriformis, using a sliding digital calliper.

4.4.2 Sciatic nerve

The width of the sciatic nerve was measured for all unbranched nerves that entered the gluteal region. The width measurement was taken uniformly for all sciatic nerves, as the nerve passes inferior to the piriformis, and became visible within the gluteal region (Figure 4.6). This measurement was also obtained using a 300mm VINCA DCLA-1205 quality electronic digital Vernier calliper, with an accuracy of ±0.04mm.

Figure 4.6: Measurement of the width of the sciatic nerve, as the nerve becomes visible at the inferior border of piriformis.

The length of the sciatic nerve was measured, from the level of the inferior border of piriformis, to the level at which the nerve bifurcates into the common fibular and tibial nerves (Figure 4.7).. The length of the thigh was measured from the most proximal point on the greater trochanter, to the middle of the popliteal fossa, posterior to the knee joint (Figure 4.8). This measurement was used in conjunction with the length of the sciatic nerve in order to quantify the level of the sciatic nerve bifurcation.

Figure 4.7: Measurement of the length of the sciatic nerve, from the level of the inferior border of piriformis, to its terminal bifurcation in the posterior compartment of the thigh.

Figure 4.8: Measurement of the thigh length, from the most proximal point on the greater trochanter of the femur, to the middle of the popliteal fossa proper.

4.4.3 Sciatic nerve bifurcation level index

The length of sciatic nerve and the length of the thigh were measured in both lower limbs. The measurement of the sciatic nerve length was done as described in 4.4.2. Therefore, no measurements were recorded for terminal branches. Measurements were recorded depending on where the bifurcation occurred. Additionally, the researcher recorded the thigh length using clearly demarcated landmarks for both proximal and distal ends. The measurement started proximally, at the most proximal point on the greater trochanter of the femur, which is also the common attachment site for the lateral rotator muscles. This measurement ended distally, at the middle of the popliteal fossa, at a line connecting the distal ends of the medial and lateral femoral epicondyles.

Subsequently, these two measurements were used to develop a new index that attempts to quantitatively classify the level at which the sciatic nerve terminates. For the purpose of this study, the index will be termed the sciatic nerve bifurcation level (SNBL) index. The SNBL index can be calculated by obtaining the product of the ratio of the sciatic nerve length and the length of the thigh. This can be visualised in the equation:

$$SNBLI = (\frac{SNL}{TL}) \times 100$$

The percentages calculated were then used to categorise where, in the lower limb, the sciatic nerve bifurcated into the common fibular and tibial nerves. The researcher divided the lower limb into five sections, represented in the index (Table 4.3). The proximal first 25% of the measurement represents the gluteal region, while the most distal 15% represents the popliteal fossa proper. The remaining 60% is equally divided into the second, third, and fourth intervals of the index that represent the proximal, middle, and distal thirds of the posterior compartment of the thigh, respectively. Importantly, the gluteal region is represented by 25% of the thigh length, and popliteal fossa by 15% of this length, as the gluteal region makes up a larger portion of the lower limb. Theoretically, this index can be used for objective classification of the sciatic nerve bifurcation, and will remain constant for individuals of various lengths. Using the index created, the researcher was able to quantify, and categorise the level at which the sciatic nerve bifurcated into its terminal branches.

Table 4.3: Theoretical summary of the sciatic nerve bifurcation level index.

Ratio brackets	Description	Correlating level of bifurcation	Classification type
$\leq 0.0\%$	Less than or equal to 0.0%.	In the pelvic region.	A
$> 0.0\%\ but \leq 25\%$	Greater than 0%, but less than or equal to 25%.	In the gluteal region.	B
$> 25\%\ but \leq 45\%$	Greater than 25%, but less than or equal to 45%.	Proximal third of the posterior compartment of the thigh.	C
$> 45\%\ but \leq 65\%$	Greater than 45%, but less than or equal to 65%.	Middle third of the posterior compartment of the thigh.	D
$> 65\%\ but \leq 85\%$	Greater than 65%, but less than or equal to 85%.	Distal third of the posterior compartment of the thigh.	E
$> 85\%\ but \leq 100\%$	Greater than 85%, but less than or equal to 100%.	In the popliteal fossa proper.	F

4.5 DOCUMENTATION OF THE VARIATIONS

The parameters of the sciatic nerve and piriformis were measured for every cadaver in the sample group, regardless of whether a variation was present or not. Images were only taken of the lower limb if the specimens presenting anatomical variations. A Canon 600D 18.0 megapixel camera was used for capturing all the images. The lens has four-stop image stabilizer technology, which improves performance during low-light conditions, as can be expected in an artificially lighted dissection hall.

4.6 STATISTICAL ANALYSIS

For statistical analysis, a biostatistician, Professor Martin Kidd, at the Centre for Statistical Consultation, Department of Statistics and Actuarial Sciences, Stellenbosch University, was consulted for quantitative and descriptive statistics of the study data. Statistical analysis was conducted with Statistica® version 13.2 (Dell, 2014, USA) software. Comparisons were made between the left and right sides of the lower limbs, sex, and population groups.

CHAPTER FIVE:

RESULTS

5.1 OVERVIEW

The following chapter will provide descriptive, statistical, and graphical representation of the morphology of piriformis and the sciatic nerve, as well as the prevalence of anatomical variations of these two structures, within a South African sample population. In the present study, the researcher studied 340 lower limbs in order to assess the anatomy of piriformis and its relation to the sciatic nerve. This included an equal number of right and left lower limbs from 170 cadavers. The researcher interpreted the results for the variations of the piriformis, variation in the level of sciatic nerve bifurcation, and the morphometric measurements of the "normal" anatomy.

5.2 ANATOMICAL VARIATIONS OF PIRIFORMIS

5.2.1 Overview

The researcher classified specimens into two overarching subgroups. The first subgroup made up the total number of specimens that presented with no variation in the sciatic nerve and piriformis within the gluteal region. This group consisted out of 297 (87.35%) lower limbs. Additionally, the investigator classified them under type A, according to the modified classification, created by Beaton and Anson, in 1937. The researcher recorded morphometric measurements of the sciatic nerve, the piriformis, and the length of the thigh for these specimens.

The second subgroup consisted of the remaining 43 (12.65%) lower limbs that showed variation in the sciatic nerve and piriformis anatomy within the gluteal region. As these specimens presented anatomical variations, they did not conform to the standard criteria needed for the morphometric measurements. The researcher will proceed to discuss the different variation classifications within this subgroup, namely types B and C, as well as variations that do not conform to the standard classification system, along with respective prevalence. Table 5.1, below, provides a summary of the seven different classification categories, descriptions, and findings of the present study.

Table 5.1: A summary of piriformis and sciatic nerve variations found in the study, along with additional sample characteristics.

Type	Description	Specimens (n)	Percentage (≅)	Side		Sex		Population group		
				Right	Left	Male	Female	White/ Caucasian	Mixed race	South African Black
A	The sciatic nerve emerges in the gluteal region undivided and passes through the infra-piriform space ("normal").	297	87.35%	150	147	168	129	192	76	29
B	The sciatic nerve bifurcates in the pelvic region, with common fibular nerve piercing piriformis, and tibial nerve passing through the infra-piriform space, inferior to piriformis.	36	10.59%	16	20	16	20	36	-	-
C	Sciatic nerve bifurcates in the pelvic region, with common fibular nerve passing through the supra-piriform space, superiorly to piriformis, and tibial nerve passes through the infra-piriform space, inferior to piriformis.	3	0.88%	2	1	3	-	2	-	1
D	The undivided sciatic nerve pierces piriformis.	-	-	-	-	-	-	-	-	-
E	Sciatic nerve bifurcates in the pelvic region, with common fibular nerve passing through the supra-piriform space superior to piriformis, and tibial nerve piercing piriformis.	-	-	-	-	-	-	-	-	-
F	The undivided sciatic nerve passes through the supra-piriform space, superior to piriformis.	-	-	-	-	-	-	-	-	-
G	Sciatic nerve bifurcates in the pelvic region, and both common fibular and tibial nerves pass through the infra-piriform space, inferior to piriformis.	-	-	-	-	-	-	-	-	-
Not classified	Variation that are not part of the existing classification system.	4	1.18%	2	2	4	-	2	2	-
Total	Total sample size used in current study	340		170	170	191	149	232	78	30

5.2.2 Type A

Type A is the first variation type described in Beaton and Anson's (1937) classification. This variation includes the typical morphology of the pyramidal-shaped piriformis, along with an undivided sciatic nerve that courses posterior, and then inferior to this muscle (Figure 5.1 & 5.2). In this study, 297 (88.35%) specimens shared this common morphology. Type A made up the majority in this study. Of these, 168 specimens were male, and 129 were female. The population group breakdown was as follows: 192 White/Caucasian, 76 Mixed race, and 29 South African black (Table 5.1).

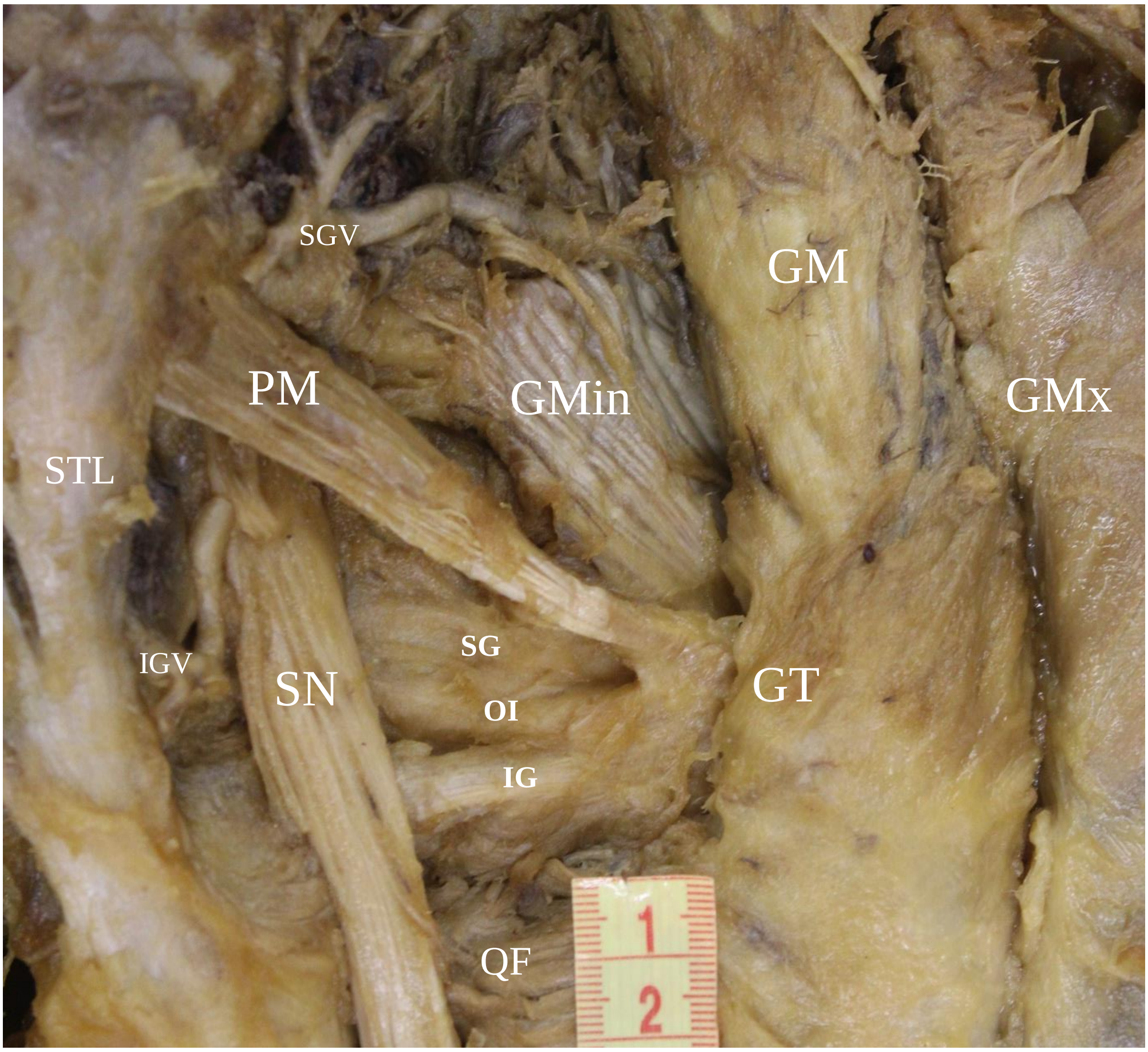

Figure 5.1: The typical morphology of piriformis and course of the sciatic nerve, in a right gluteal region. The three muscles comprising the triceps coxae group are visible: superior gemellus, obturator internus, and inferior gemellus. GMx – gluteus maximus, GM – gluteus medius, GMin – gluteus minimus, GT – greater trochanter, IG – inferior gemellus, IGV – inferior gluteal vessels, OI – obturator internus, PM – piriformis, QF – quadratus femoris, SG – superior gemellus, SGV – superior gluteal vessels, SN – sciatic nerve, STL – sacrotuberous ligament.

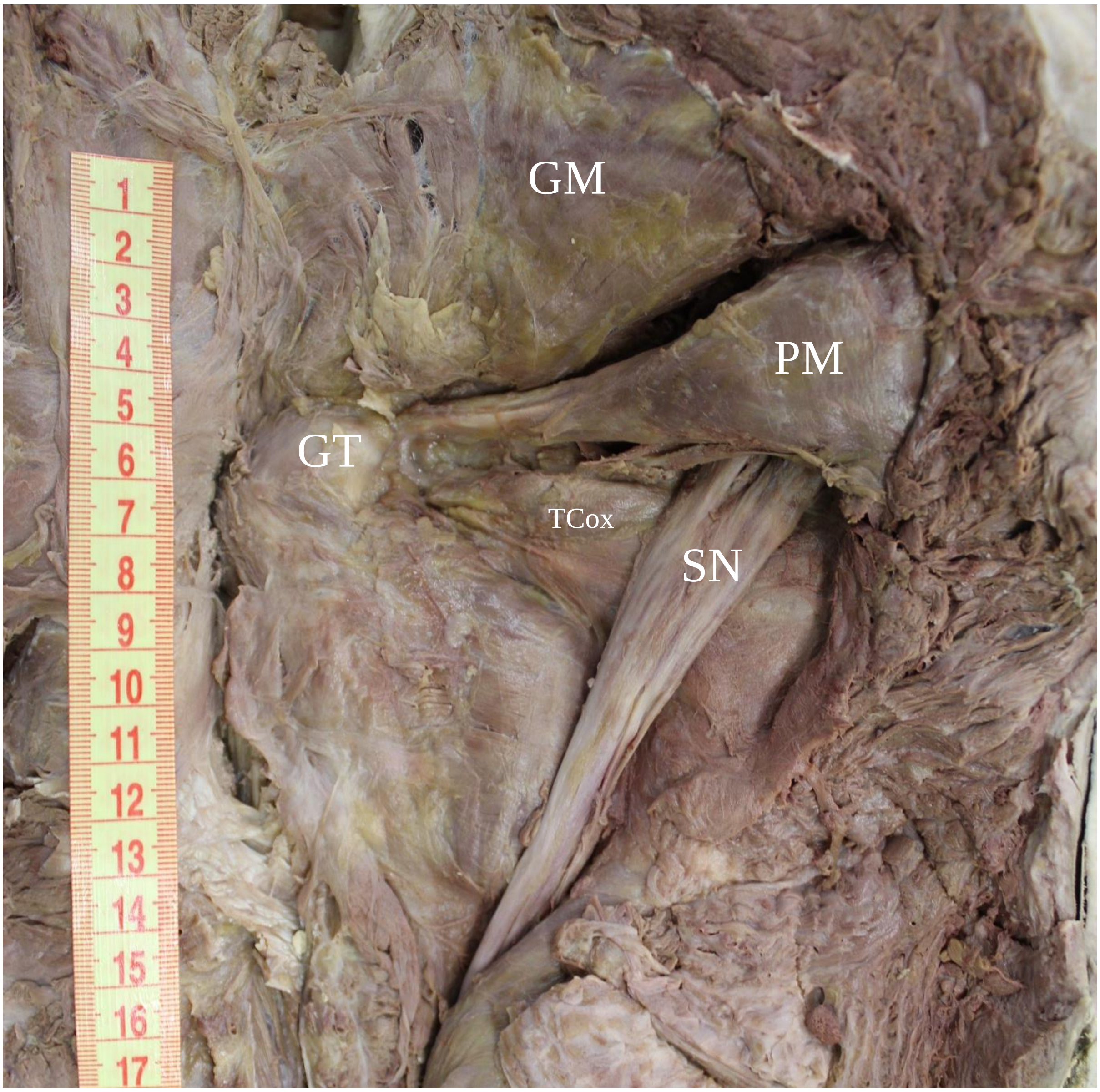

Figure 5.2: The typical morphology of piriformis and typical course of the sciatic nerve in the infra-piriform space. In this specimen, the common attachment point, greater trochanter, is clearly visible, along with defined gluteus medius and piriformis. GM – gluteus medius, GT – greater trochanter, PM – piriformis, SN – sciatic nerve, TCox – triceps coxae muscle group.

Within this category, there were further morphological variations of the structures of importance in the gluteal region. Figure 5.1 depicts a much smaller piriformis that is largely tendinous in nature. However, this was not the case in figure 5.2, where the same muscle had a clearly defined, large muscular belly, becoming tendinous distally, at its attachment at the piriformis fossa on the medial aspect of the greater trochanter of the femur. With the aid of morphometric analyses, these and other parameters, within the gluteal region, will be assessed and quantified (Table 5.3).

5.2.3 Type B

The second variation in the classification, type B, includes the variation where piriformis divides into two bellies: superior and inferior. The muscle presented with this morphology when the sciatic nerve bifurcated proximally, within the pelvic region, superior to piriformis. In this instance, the common fibular nerve pierced piriformis as it coursed through the gluteal region, dividing the muscle into two separate bellies (Figure 5.3). The tibial nerve left the pelvic region as was expected, running inferior to piriformis. This variation was present in 36 specimens, which makes up 10.59% of the total sample in this study. This is the most prevalent variation from the "normal" morphology. There were 16 (8.38%) male and 20 (13.42%) female specimens in this group (Table 5.1).

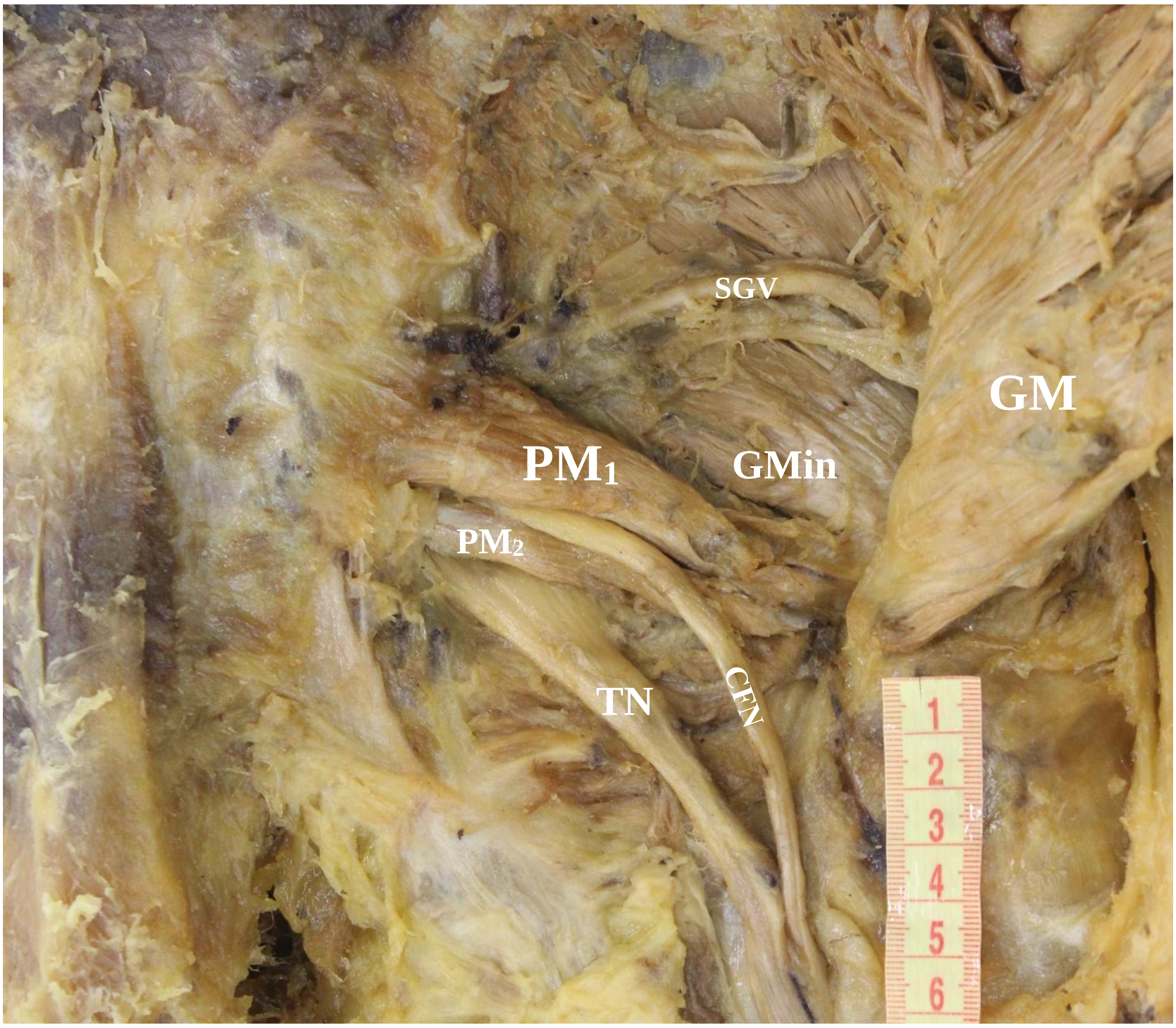

Figure 5.3: The common fibular nerve piercing piriformis. Subsequently, piriformis divides into two bellies. The tibial nerve runs through the infra-piriform space, as expected. CFN – common fibular nerve, GM – gluteus medius, GMin – gluteus minimus, PM_1 – superior piriformis belly, PM_2 – inferior piriformis belly, SGV – superior gluteal vessels, TN – tibial nerve.

Additionally, investigating this group further, the following was noticed; there was a variety of entry points at which the common fibular nerve pierced the piriformis. This had two effects on the piriformis and the sciatic nerve. Firstly, there was variability in the level at which the common fibular nerve entered the gluteal region. Secondly, the two split bellies of piriformis muscle had different sizes. Depending on the level at which the muscle was pierced by the nerve, the superior belly of the muscle was either larger than, equal to, or smaller in size than the inferior belly.

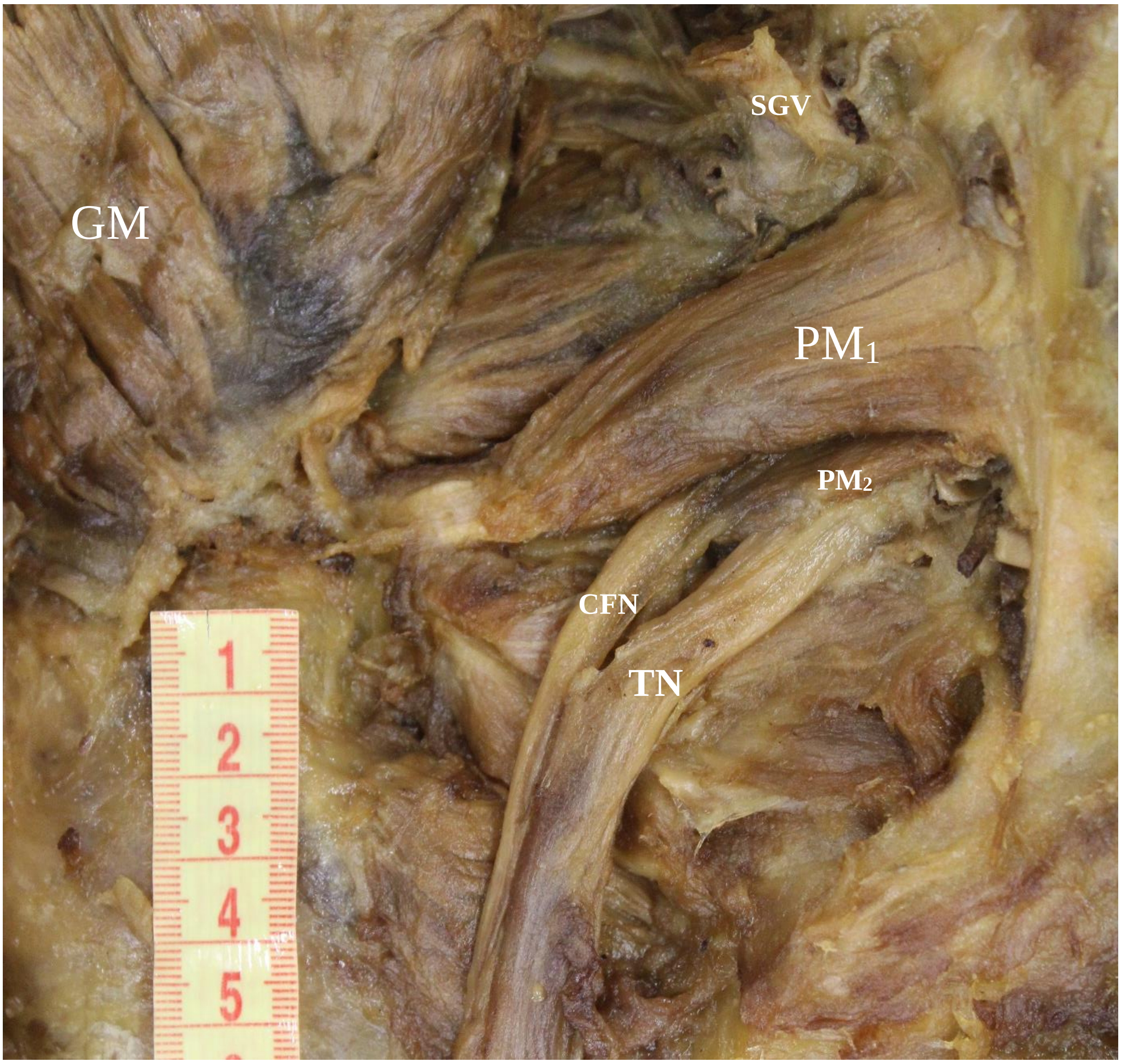

Figure 5.4: The common fibular nerve piercing piriformis. In the same cadaver as Figure 5.3, the left piriformis also divides into two bellies. CFN – common fibular nerve, GM – gluteus medius, GMin – gluteus minimus, PM_1 – superior piriformis belly, PM_2 – inferior piriformis belly, SGV – superior gluteal vessels, TN – tibial nerve.

This variation was depicted in two lower limbs of the same cadaver. In figure 5.3, the inferior belly of piriformis is larger in this right lower limb. In figure 5.4, the inferior belly of piriformis is much smaller than the larger superior section of the same cadaver. In contrast, the combined size of piriformis in figures 5.3 and 5.4 are the same as that in figure 5.5.

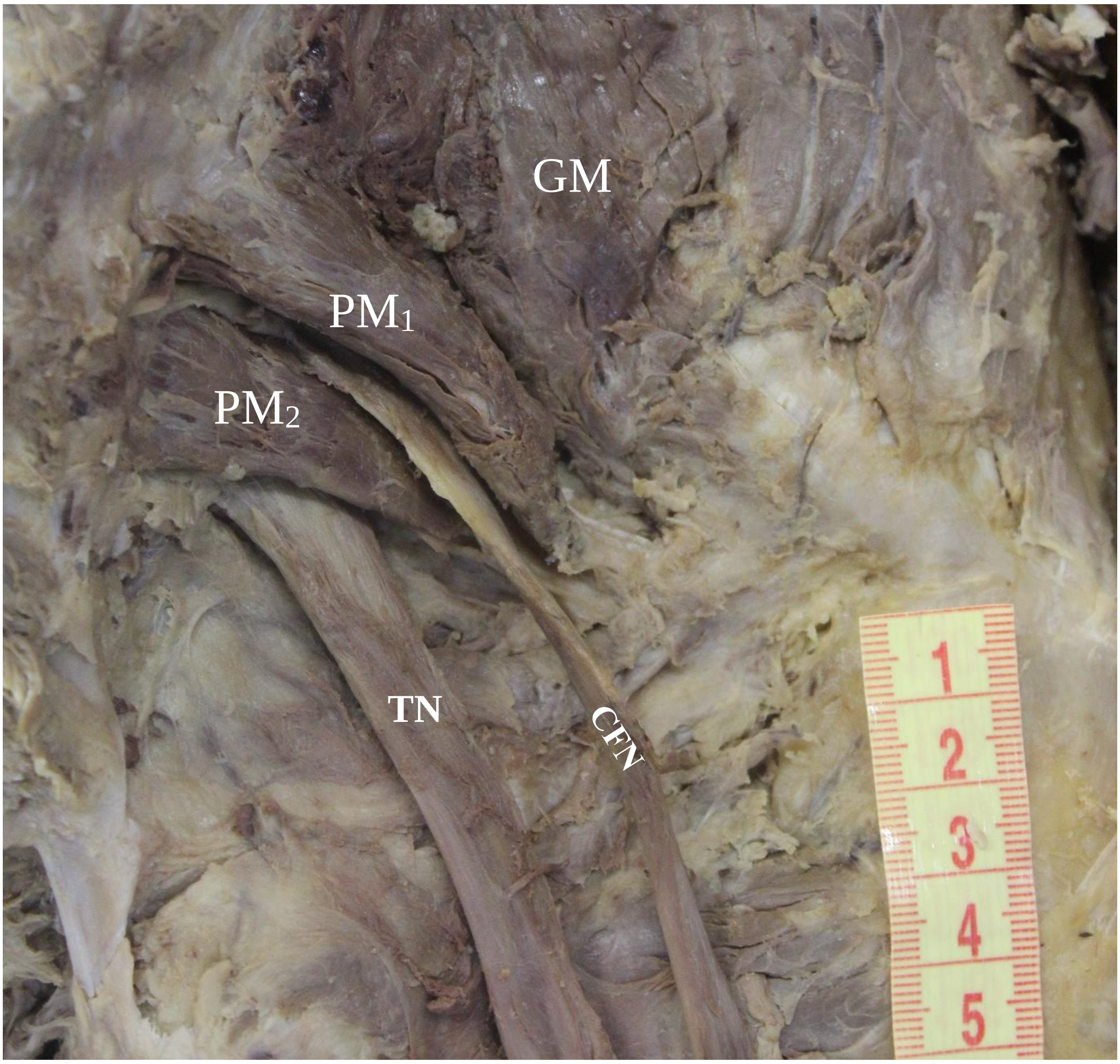

Figure 5.5: The common fibular nerve piercing piriformis. In this specimen, the two bellies of piriformis are relatively equal in size. CFN – common fibular nerve, GM – gluteus medius, PM1 – superior piriformis belly, PM2 – inferior piriformis belly, TN – tibial nerve.

5.2.4 Type C

When the sciatic nerve divides in the pelvis, there can be a resultant effect on the morphology of piriformis. In a situation where this nerve bifurcates in the pelvic region, the common fibular nerve and tibial nerve course though the gluteal region, running inferiorly towards the posterior compartment of the thigh. However, piriformis might remain unchanged by this early bifurcation. In the third possible variation, type C, the common fibular nerve enters the supra-piriform space and courses superiorly across piriformis. Additionally, the tibial nerve courses through the gluteal region as expected, through the infra-piriform space. Importantly, the defining feature of this type is that piriformis remains single and undivided. In the current study, only three (0.88%) specimens depicted the type C variation (Table 5.1), making this the most rare of the classified variations that occurred in the study.

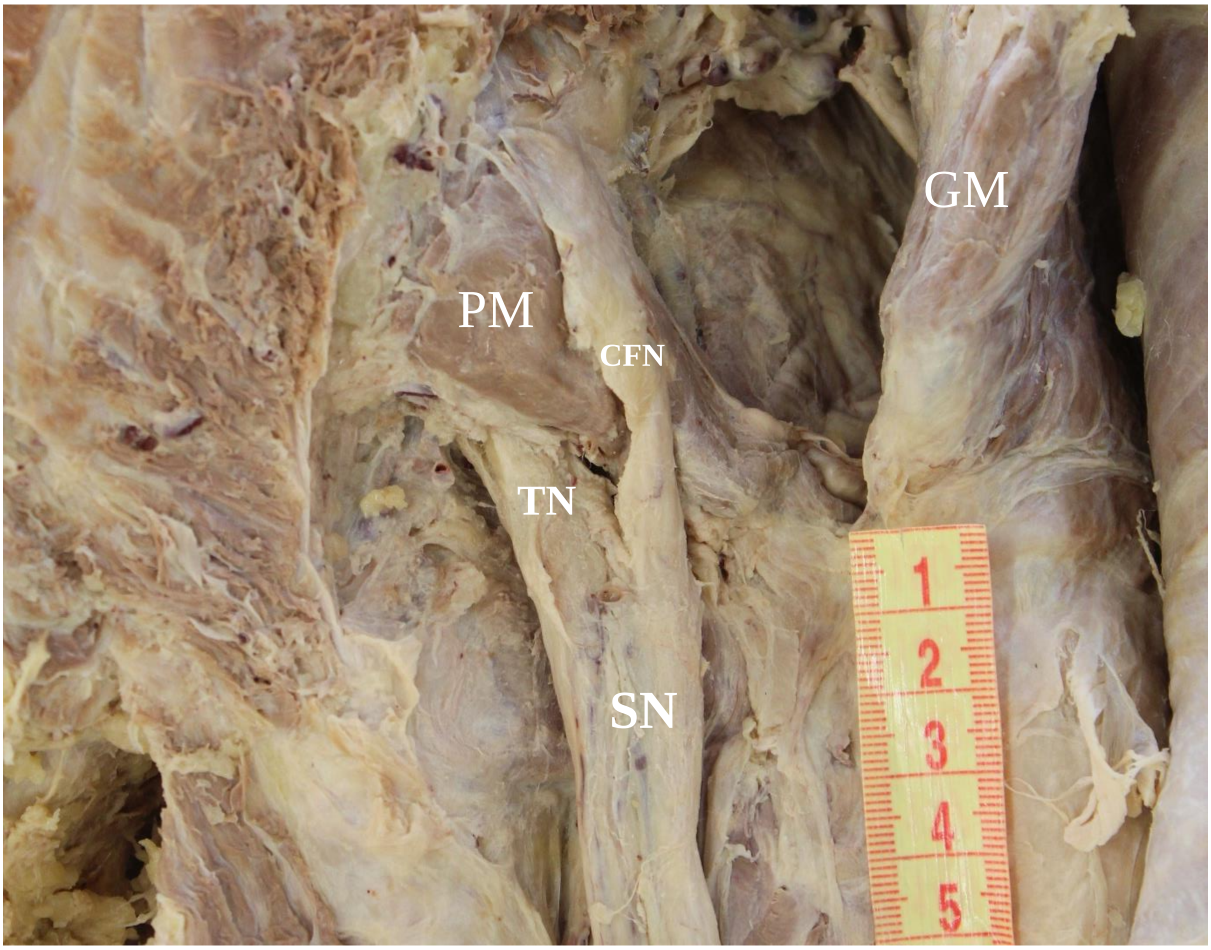

Figure 5.6: The common fibular nerve runs through the supra-piriform space. The nerve then runs across piriformis and inferiorly, to join the tibial nerve. Additionally, the terminal branches of the sciatic nerve re-join to form the sciatic nerve, before coursing through the gluteal region, to the posterior compartment of the thigh. CFN – common fibular nerve, GM – gluteus medius, PM – piriformis, SN – sciatic nerve, TN – tibial nerve.

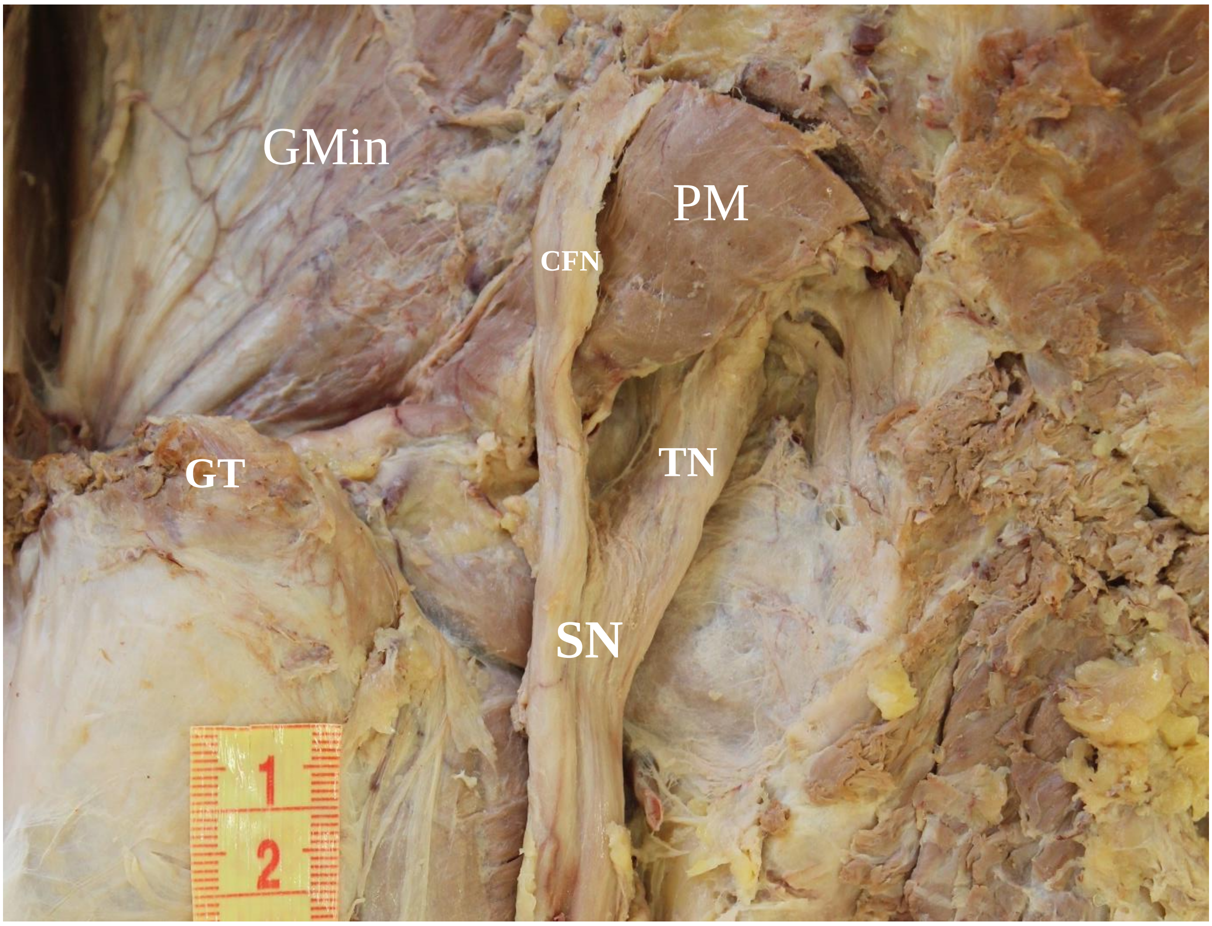

Figure 5.7: The common fibular nerve runs through the supra-piriform space. The nerve crosses piriformis, and passes inferiorly, to join tibial nerve inferiorly. CFN – common fibular nerve, GMin – gluteus minimus, GT – greater trochanter, PM – piriformis, SN – sciatic nerve, TN – tibial nerve.

This variation occurred in two limbs of the same individual, a 71-year-old White/Caucasian female, with bilateral symmetry in the variation between piriformis and the sciatic nerve (Figure 5.6 & 5.7). The remaining one specimen is that of a right lower limb that belonged to a South African black male, aged 37 years at the time of death (Figure 5.8). This cadaver did not present with bilateral symmetry, and the left limb is categorised under type A, as its anatomy depicts a normal piriformis and sciatic nerve morphology.

As shown in figures 5.6, 5.7, and 5.8, piriformis remains unseparated, despite the fact that the sciatic nerve bifurcated in the pelvis. In addition, the common fibular nerve and tibial nerve re-join in both left and right gluteal regions (Figure 5.6 & 5.7), to course through the respective lower limbs as unbranched sciatic nerves. In the remaining specimen (Figure 5.8), the sciatic nerve terminates in the pelvic region, and its terminal branches, the common fibular and tibial nerves, course superficial and deep to piriformis, and into the posterior compartment of the thigh, as two distinct entities.

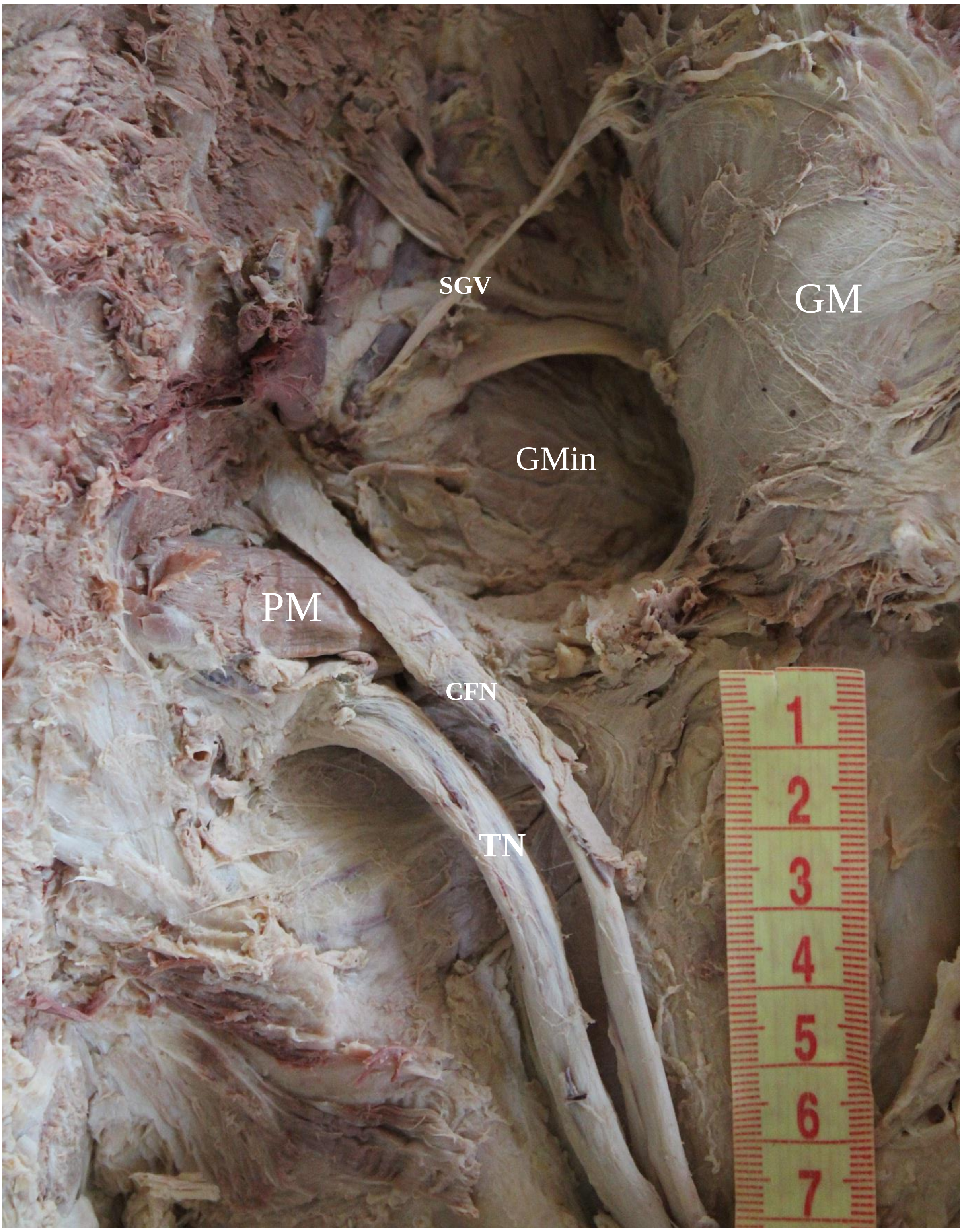

Figure 5.8: The common fibular nerve runs through the supra-piriform space. The nerve then runs across piriformis and inferiorly, to join the tibial nerve. The tibial nerve runs through the infra-piriform space, as expected. In this specimen, the terminal branches do not join to form a single sciatic nerve, and remain two structures throughout their course. CFN – common fibular nerve, GM – gluteus medius, GMin – gluteus minimus, PM – piriformis, SGV – superior gluteal vessels, TN – tibial nerve.

5.2.5 Additional Variation

One specimen showed a rare variation, not represented in the classification by Beaton and Anson (1937). Still classified as type B, this variation involved the common fibular nerve piercing piriformis, creating two separate bellies of the muscle. However, additional anomalies were present. Not only did the common fibular nerve pierce piriformis, and enter the gluteal region between the two muscular bellies, but the same was true for the inferior gluteal nerve. This nerve shared the entrance into the gluteal region, with the common fibular nerve, before travelling inferiorly, to innervate the gluteus maximus (Figure 5.9). Furthermore, while a sciatic nerve proper did not appear in the gluteal region, its terminal branches, the tibial and common fibular nerves, were present. Additionally, the tibial nerve was seen inferior to piriformis as two trunks. In literature, this is described as two separate anterior divisions of ventral rami L4-S3. A single combined tibial nerve will then continue its course inferiorly, towards the posterior compartment of the thigh. This variation was not seen in any other specimen.

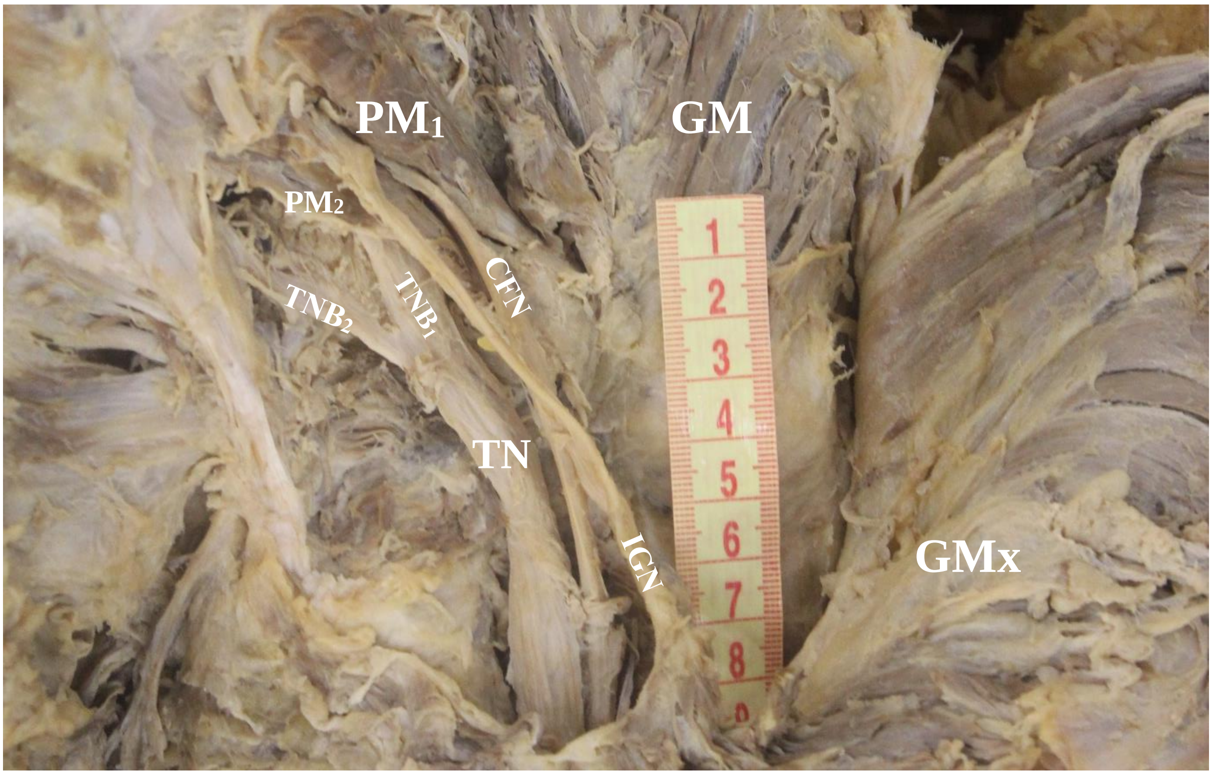

Figure 5.9: The common fibular nerve runs through the supra-piriform space. The inferior gluteal nerve ran between the two bellies of piriformis, before supplying the gluteus maximus. Additionally, two neural branches converged to form the tibial nerve inferior to piriformis. CFN – common fibular nerve, GMx – gluteus maximus, GM – gluteus medius, IGN – inferior gluteal nerve, PM_1 – superior piriformis belly, PM_2 – inferior piriformis belly, SGV – superior gluteal vessels, TN – tibial nerve, TNB_1 – tibial nerve branch one, TNB_2 – tibial nerve branch two.

5.2.6 Fused piriformis muscle and gluteus medius muscle

Lying deep to gluteus maximus are the deep muscles of the gluteal region. These include piriformis and gluteus medius, among others. However, in this category, the gluteal region did not contain a separate piriformis or gluteus medius. Rather, these muscles were fused and present as one large muscle mass. This fused muscle occupied the majority of the space deep to gluteus maximus. In this study, four (1.88%) specimens presented this varied morphology (Table 5.1). The four lower limbs came from two cadavers, where both showed bilateral symmetry in this variation. The specimens were from a Mixed race male, aged 30 at the time of death (Figures 5.10 & 5.11), and the other from a 76-year-old White/Caucasian male (Figures 5.12 & 5.13). No variations in the bifurcation of the sciatic nerve were present in these specimens.

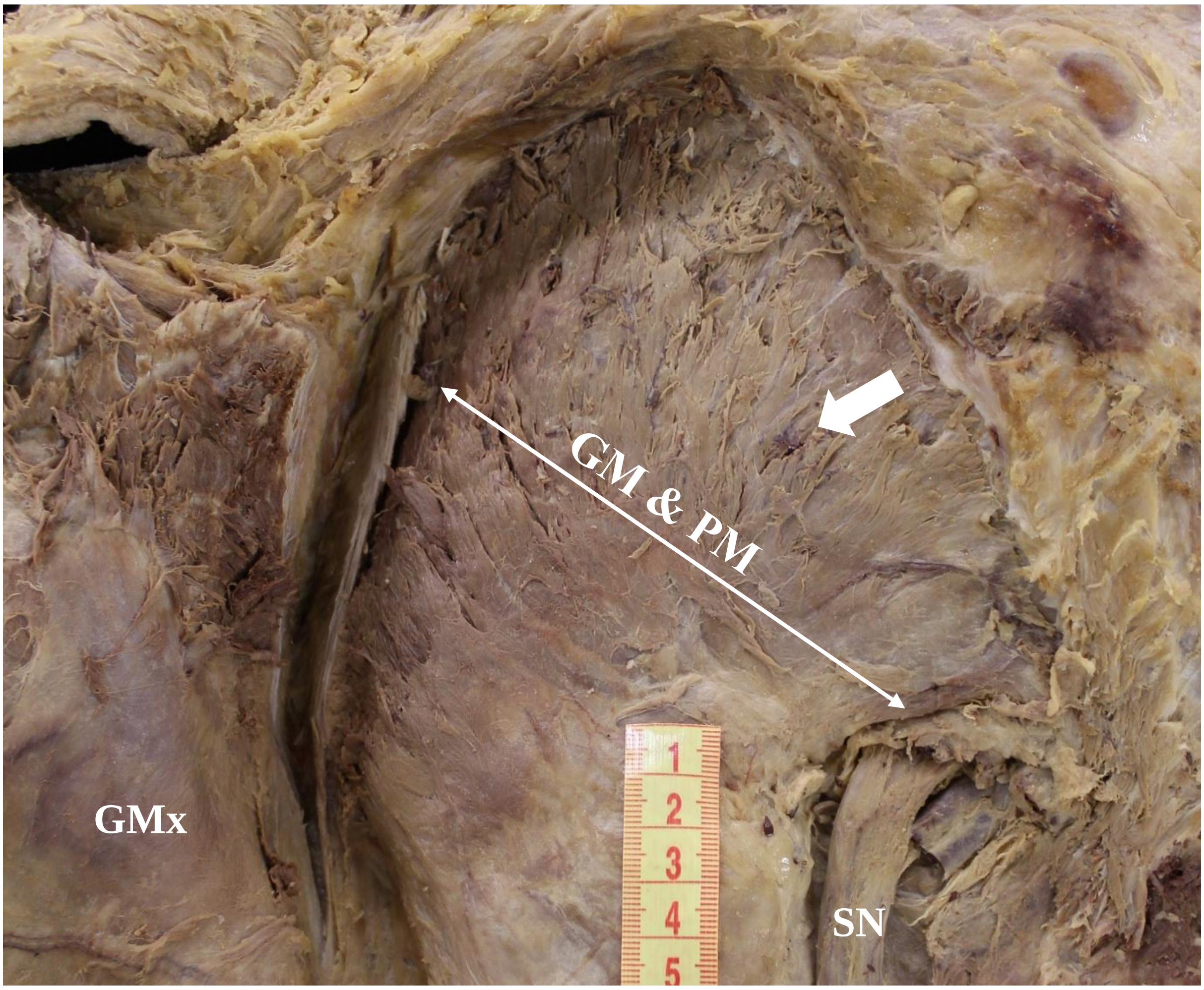

Figure 5.10: Fusion of piriformis and gluteus medius in the left gluteal region. The white arrowhead represents the superior gluteal vessels, running between the fibres of the fused muscle mass. GMx – gluteus maximus, GM & PM – fused muscle, SN – sciatic nerve.

This anatomical variation will influence other structures closely related to the two muscles. Since there was no defined piriformis or gluteus medius, it meant that there was no longer a supra-piriform space present, which would have been between the two muscle bellies. Therefore, the superior gluteal vessels, which traverse this space, pierced the combined muscle at various points. The white arrowheads, in figures 5.10, 5.11, 5.12 and 5.13, depict this.

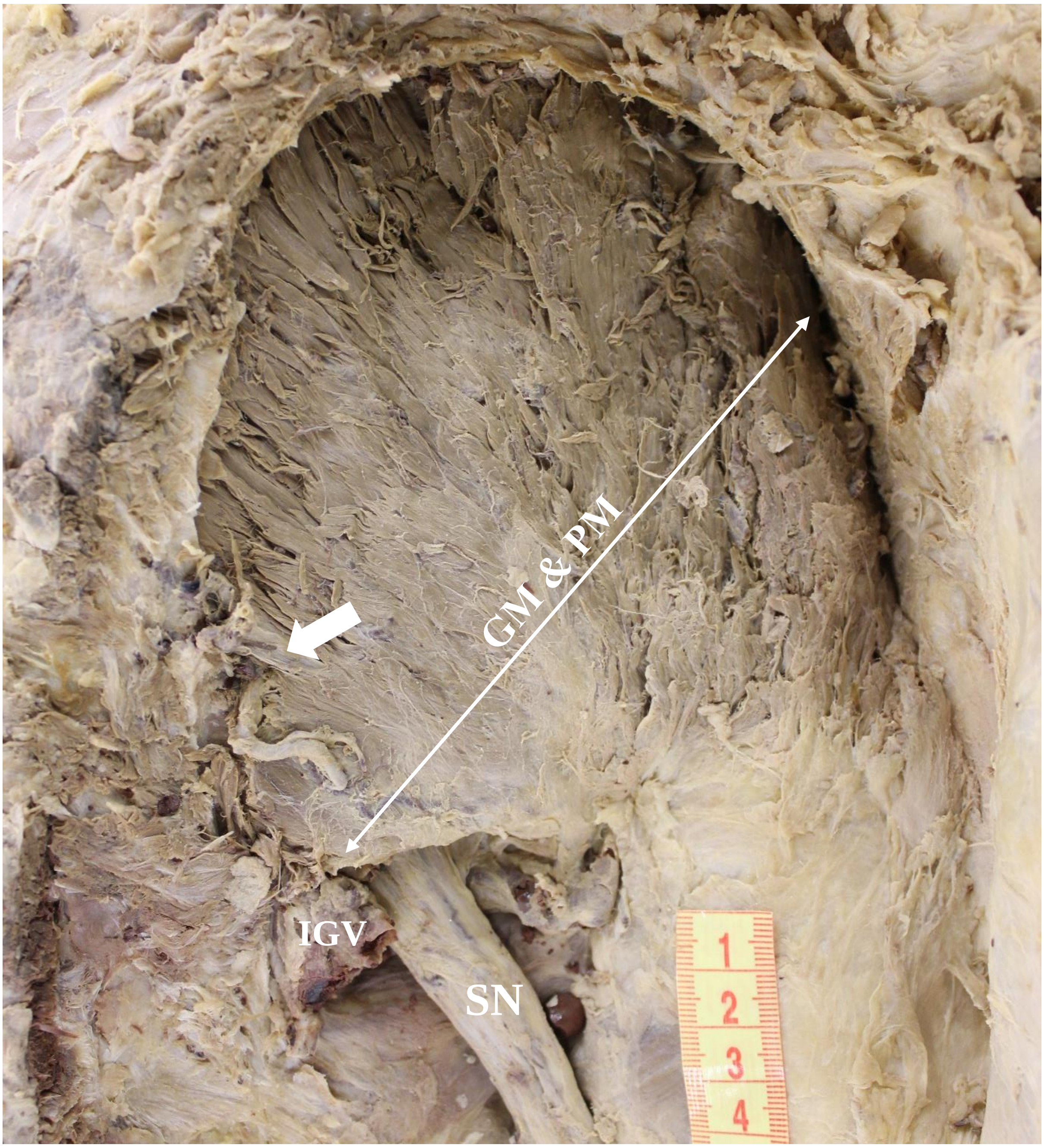

Figure 5.11: Fusion of piriformis and gluteus medius in the right gluteal region. The white arrowhead represents the superior gluteal vessels, running between the fibres of the fused muscle mass. GM & PM – fused muscle, IGV – inferior gluteal vessels, SN – sciatic nerve.

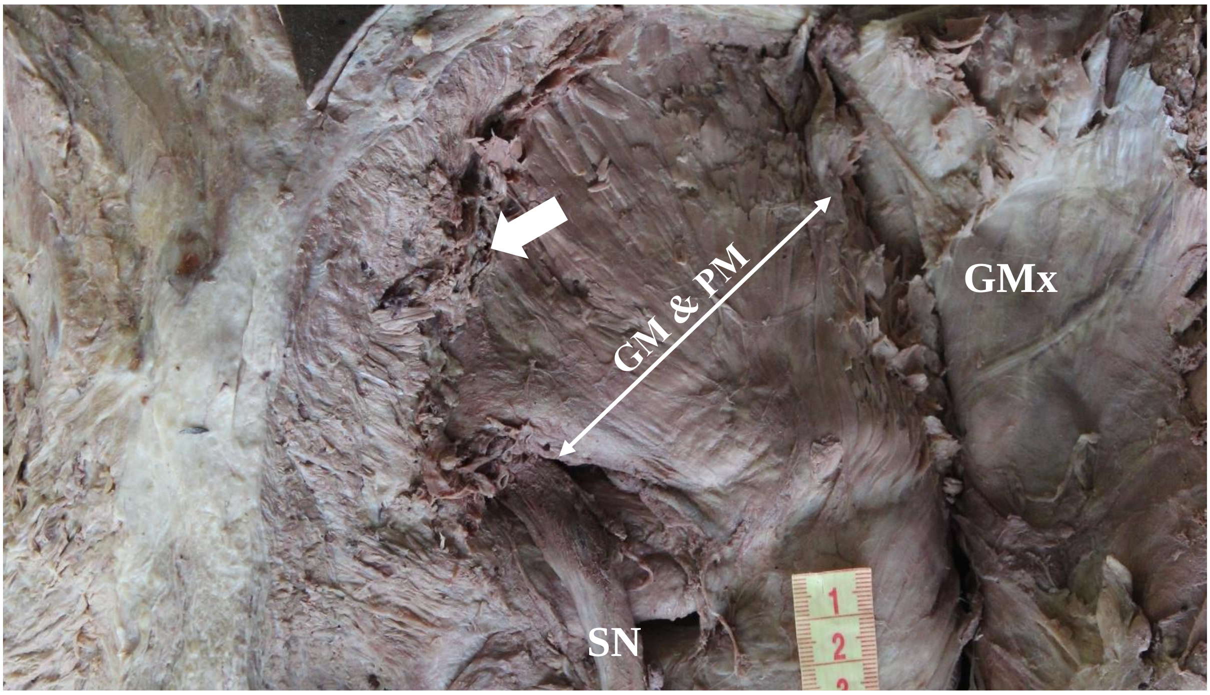

Figure 5.12: Fusion of piriformis and gluteus medius in the right gluteal region. The white arrowhead represents the superior gluteal vessels, running between the fibres of the fused muscle mass. GMx – gluteus maximus, GM & PM – fused muscle, SN – sciatic nerve.

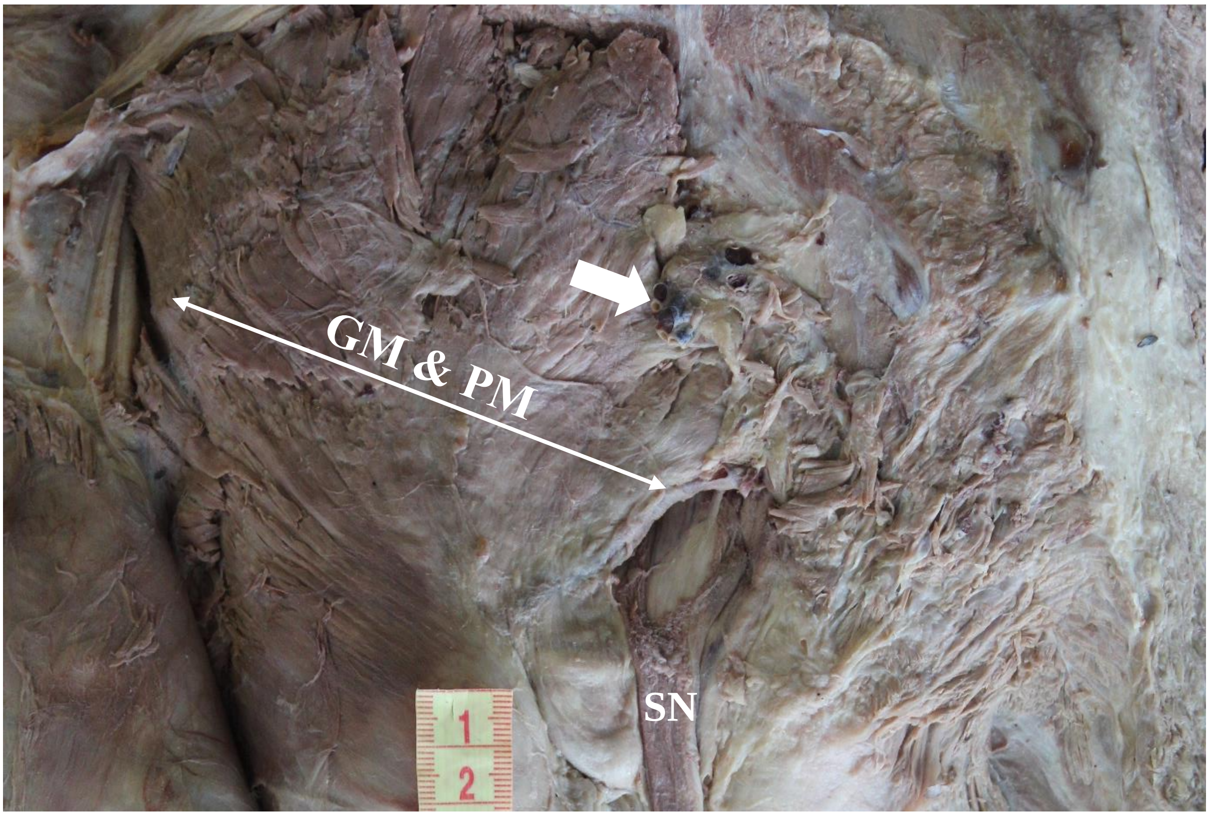

Figure 5.13: Fusion of piriformis and gluteus medius in the left gluteal region. The white arrowhead represents the superior gluteal vessels, running between the fibres of the fused muscle mass. GM & PM – fused muscle, SN – sciatic nerve.

5.3 VARIATIONS IN THE SCIATIC NERVE BIFURCATION

5.3.1 Overview

In the present study, 338 lower limbs were examined to classify the level at which the sciatic nerve bifurcated into the common fibular and tibial nerves. This group consisted of 189 male specimens, and 149 female specimens. Additional specimen characteristics are summarised in table 5.2, below. There were two specimens, from the same cadaver, that were excluded from the classification process because this cadaver had undergone a bilateral amputation above the knee joint. This meant that there was insufficient evidence of where the bifurcation of the nerve was. Table 5.2 consists of accurate classification, descriptions, and a summary concerning the variations in the bifurcation of the sciatic nerve for the 338 specimens available, because of the new SNBL index.

Table 5.2: Summary of the sciatic nerve bifurcation level classified in the study, along with additional sample characteristics.

Type	Description	Specimens (N)	Percentages (≅)	Side		Sex		Population group		
				Right	Left	Male	Female	White/ Caucasian	Mixed race	South Africa Black
A	Sciatic nerve bifurcates in the pelvic region.	24	7.1	12	12	12	12	23	-	1
B	Sciatic nerve bifurcates in the gluteal region.	-	-	-	-	-	-	-	-	-
C	Sciatic nerve bifurcates in the proximal third of the posterior compartment of the thigh.	-	-	-	-	-	-	-	-	-
D	Sciatic nerve bifurcates in the middle third of the posterior compartment of the thigh.	2	0.6	1	1	2	-	2	-	-
E	Sciatic nerve bifurcates in the distal third of the posterior compartment of the thigh.	43	12.7	17	26	27	16	32	7	4
F	Sciatic nerve bifurcates within the popliteal fossa proper.	269	79.6	139	130	148	121	173	71	25
Total	Total sample size for study	338	-	169	169	189	149	230	78	30

5.3.2 Type A

In this type of variation, the sciatic nerve bifurcates within the pelvic region, and the result is that two very distinct terminal branches, the common fibular and tibial nerves, course separately throughout the lower limb. In the present study, 24 (7.7%) specimens present this type of variation (Table 5.2). The index accounted for these specimens, where there was no measured length for the sciatic nerve, as there was no sciatic nerve present in the gluteal region (Table 4.3). Figure 5.14 depicts a type A variation. This specimen shows both the common fibular nerve and tibial nerve coursing separately through the gluteal region and posterior compartment of the thigh. In addition, bifurcation of the sciatic nerve proximal to the gluteal region, will have an effect on the piriformis morphology.

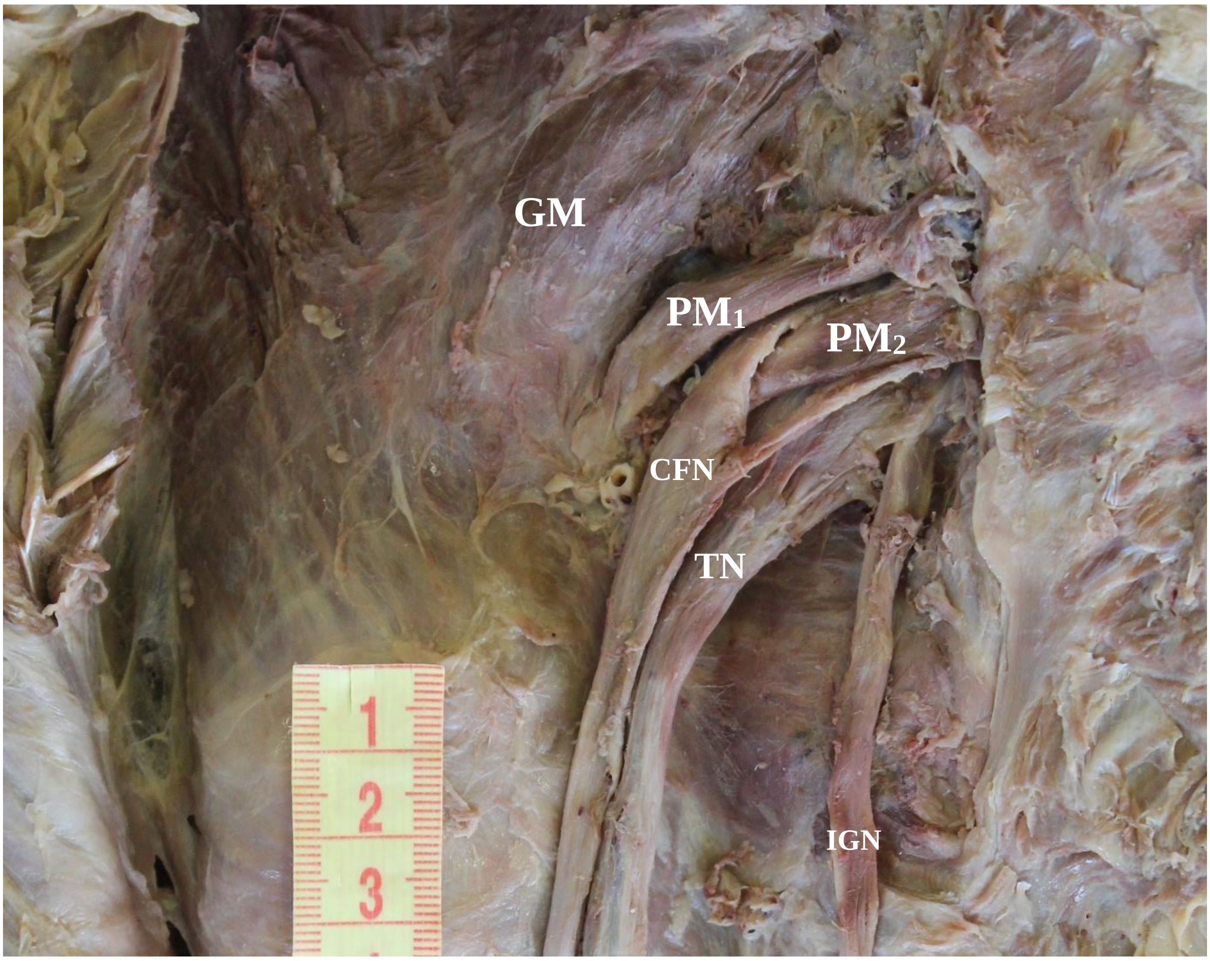

Figure 5.14: Sciatic nerve bifurcating superiorly, within the pelvic region. As a result, the common fibular nerve and tibial nerve run separately in the gluteal region. The nerves pierce and divide piriformis. CFN – common fibular nerve, GM – gluteus medius muscle, IGN – inferior gluteal nerve, PM_1 – superior piriformis belly, PM_2 – inferior piriformis belly, TN – tibial nerve.

In 15 specimens, the sciatic nerve bifurcated prior to entering the gluteal region, and resulted in similar variations seen in figure 5.14, with subsequent variations to piriformis. However, these specimens were not added to the total in this bifurcation category, because the branches converged into a single nerve inferior to piriformis (Figure 5.15). These nerves went on to follow the more traditional patterns of bifurcation, where terminal bifurcation took place in the distal third of the posterior compartment of the thigh, for one of the specimens, and 14 specimens where the sciatic nerve branched further down, bifurcating into the common fibular and tibial nerves within the popliteal fossa proper. The discussion, below, concerns the last two types of bifurcation variations.

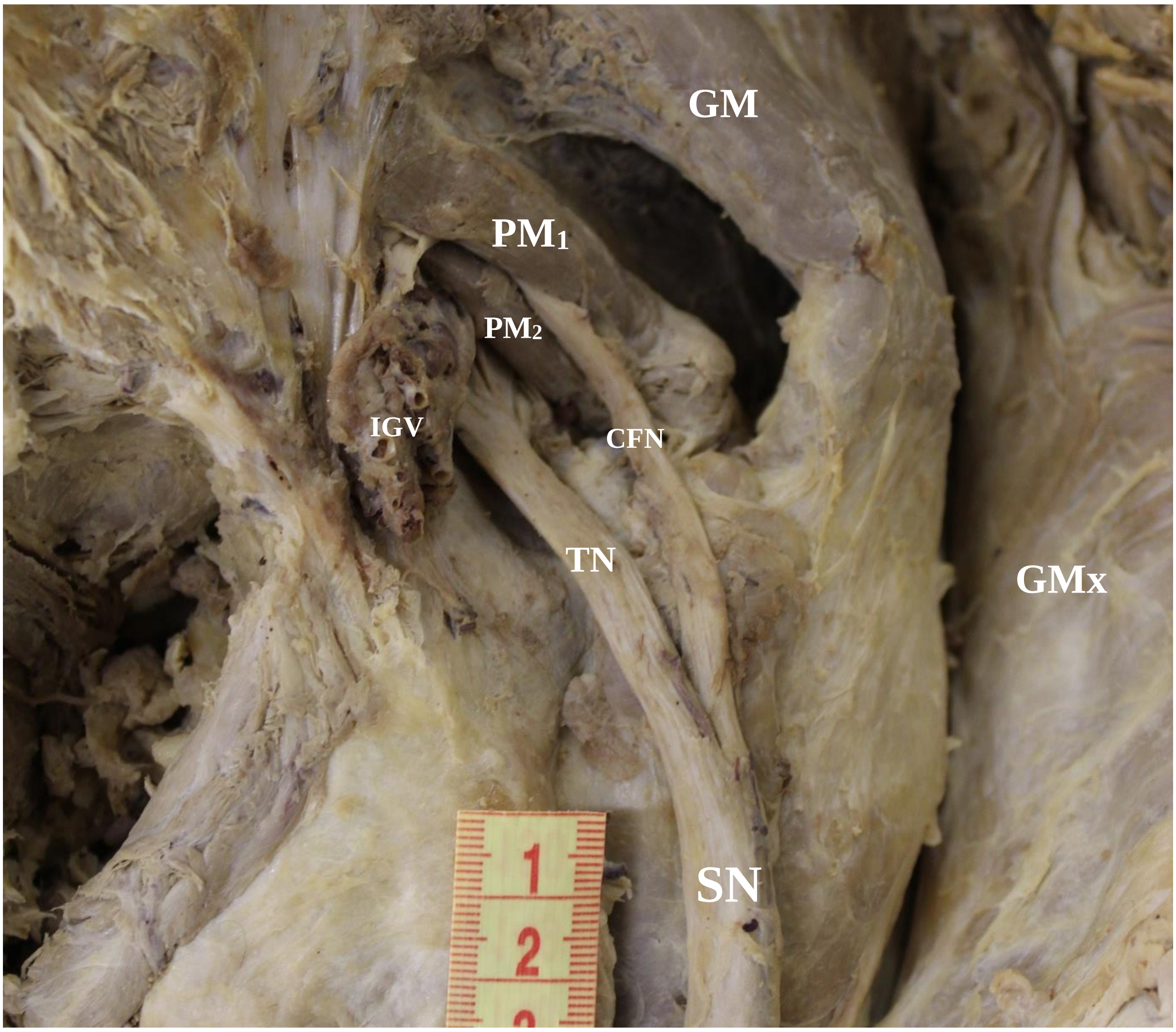

Figure 5.15: The common fibular and tibial nerve converge, within the gluteal region, forming the sciatic nerve. Piriformis divided into two bellies, pierced by the common fibular nerve. CFN – common fibular nerve, GMx – gluteus maximus, GM – gluteus maximus, PM_1 – superior piriformis belly, PM_1 – inferior piriformis belly, SN – sciatic nerve, TN – tibial nerve. IGV – inferior gluteal vessels.

5.3.3 Type D

Type D represents the fourth classification in the possible bifurcation level of the sciatic nerve. This type is characterised by a sciatic nerve that bifurcates in the middle third of the posterior compartment of the thigh. In this study, this type of variation was rare, with only two (0.6%) specimens presenting with a sciatic nerve that bifurcated at this level (Table 5.2). According to table 4.3, this category was quantified by using the ratio of the sciatic nerve length to the length of the thigh, and accepting all the values that fall within a range greater than but not equal to 45%, and lesser than and equal to 65%.

5.3.4 Type E

In this study, 43 (12.7%) specimens conform to the requirements for this category (Table 5.2). For this category, type E, specimens were only selected where the calculated index ratio was greater than but not equal to 65%, and lesser than or equal to 85% (Table 4.3). The researcher added one specimen, similar to the one depicted in figure 5.15, to the total, where the sciatic nerve bifurcated prior to the gluteal region. In this specimen, the branches rejoin to form a single sciatic nerve inferior to piriformis. The sciatic nerve then bifurcated lower down into its terminal branches within the distal third of the posterior compartment of the thigh. Generally, the sciatic nerve bifurcation occurs within this region, namely proximal to the superior border of the popliteal fossa. The common fibular and tibial nerves will then course to their respective compartments in the leg.

5.3.5 Type F

In the final classification, the sciatic nerve bifurcates most distally, within the popliteal fossa proper. This type of variation made up the majority of the variations seen in the present study. In the present study, the researcher classified 269 (79.6%) specimens as type F (Table 5.2). The researcher quantified this classification by including all the specimens with an index value that was greater than but not equal to 85% (Table 4.3). The 14 specimens, which had sciatic nerves that bifurcated within the gluteal region, only to fuse and reform the sciatic nerve inferior to piriformis (Figure 5.15), were added to the total specimens in this category. This was done because the sciatic nerve in these 14 specimens bifurcated within the popliteal fossa proper, after unification higher up.

5.4 MORPHOMETRIC MEASUREMENTS

In the present study, the researcher assessed 297 lower limbs to analyse the anatomy of piriformis and the sciatic nerve using morphometric measurements. This group included 168 male specimens, and 129 female specimens. Furthermore, the researcher grouped specimens according to side: with 150 right lower limbs, and 147 left lower limbs, and population group: 192 White/Caucasian, 76 Mixed race, and 29 South African Black specimens. Only 297 specimens were included, and not all 340 specimens, as the 297 specimens conformed to the most normal representation of anatomy, and have no variations to render any measurements invalid, thus qualifying for morphometric analysis. The researcher excluded an additional two specimens because this cadaver had a bilateral amputation above the knee, which meant that accurately recording of some of the measurements required for this study, were not possible.

The researcher obtained and assessed seven different measurements for each specimen. Thereafter, dividing the measurements into two broader subgroups, according to the structures measured, namely, the measurements of piriformis, and measurements of the sciatic nerve. Piriformis measurements included the medial width of piriformis (MWP), lateral width of piriformis (LWP), length of the superior border of piriformis (PSBL), and length of the inferior border of piriformis (PIBL). The sciatic nerve measurements included the width of the sciatic nerve (SNW) and length of the sciatic nerve (SNL). Also grouped with the sciatic nerve measurements, is the thigh length (TL) measurement, because this measurement was used in conjunction with the sciatic nerve measurements. The researcher used the TL, previously in the SNLBI, to quantify and categorise the level of bifurcation of the sciatic nerve in each specimen (Table 4.3). Table 5.3, below, summarises the measurements, characteristics, and means. Subsequently, the researcher will discuss the various measurements in detail. Using a two-way ANOVA test, statistical significance is determined at a p-value that is less than 0.05.

Table 5.3: Summary of the morphometric measurements conducted in present study (measured in mm).

Measurement	Abv.	Mean	Standard deviation	Side		Sex		Population group		
				Right	Left	Male	Female	White /Caucasian	Mixed race	South African Black
Medial width of piriformis	MWP	34.1	7.48	34.20	33.99	34.91	32.63	33.46	34.58	36.19
Lateral width of piriformis	LWP	17.0	4.81	17.02	17.50	17.82	15.81	15.78	18.85	20.02
Length of superior piriformis border	PSBL	55.77	9.47	55.62	55.60	55.86	55.85	56.43	54.70	55.11
Length of inferior piriformis border	PIBL	59.85	9.74	59.85	60.45	59.77	60.26	59.74	60.46	60.27
Width of the sciatic nerve	SNW	15.19	3.44	14.85	15.16	15.22	15.23	15.99	14.05	13.02
Length of the sciatic nerve	SNL	390.57	32.20	390.54	390.76	396.09	383.03	391.00	386.99	395.60
Length of the thigh	LT	430.63	27.30	429.86	430.62	437.39	421.09	433.78	420.95	433.11

5.4.1 Measurements of piriformis

The widths and lengths of the piriformis muscle were measure for each specimen. The mean and standard deviation is summarised, and tabulated, in table 5.3. Additionally, comparisons between the left and right sides, sex, and the three population groups are available.

5.4.1.1 Medial width of piriformis

The MWP is determined by measuring the width of piriformis at the point where the muscle enters the gluteal region, coursing through the greater sciatic foramen, where piriformis runs deep to the sacrotuberous ligament. The researcher used the superior and inferior landmarks of the muscle, at this point, when measuring this parameter in a straight line. Overall, the MWP for the study sample ($n = 297$) was 34.1 mm, and a standard deviation of ± 7.48 mm (Figure 5.16). Furthermore, the distribution of the data is normal. The variability for the dataset is high, with a minimum of 9.88 mm, and a high of 58.81 mm.

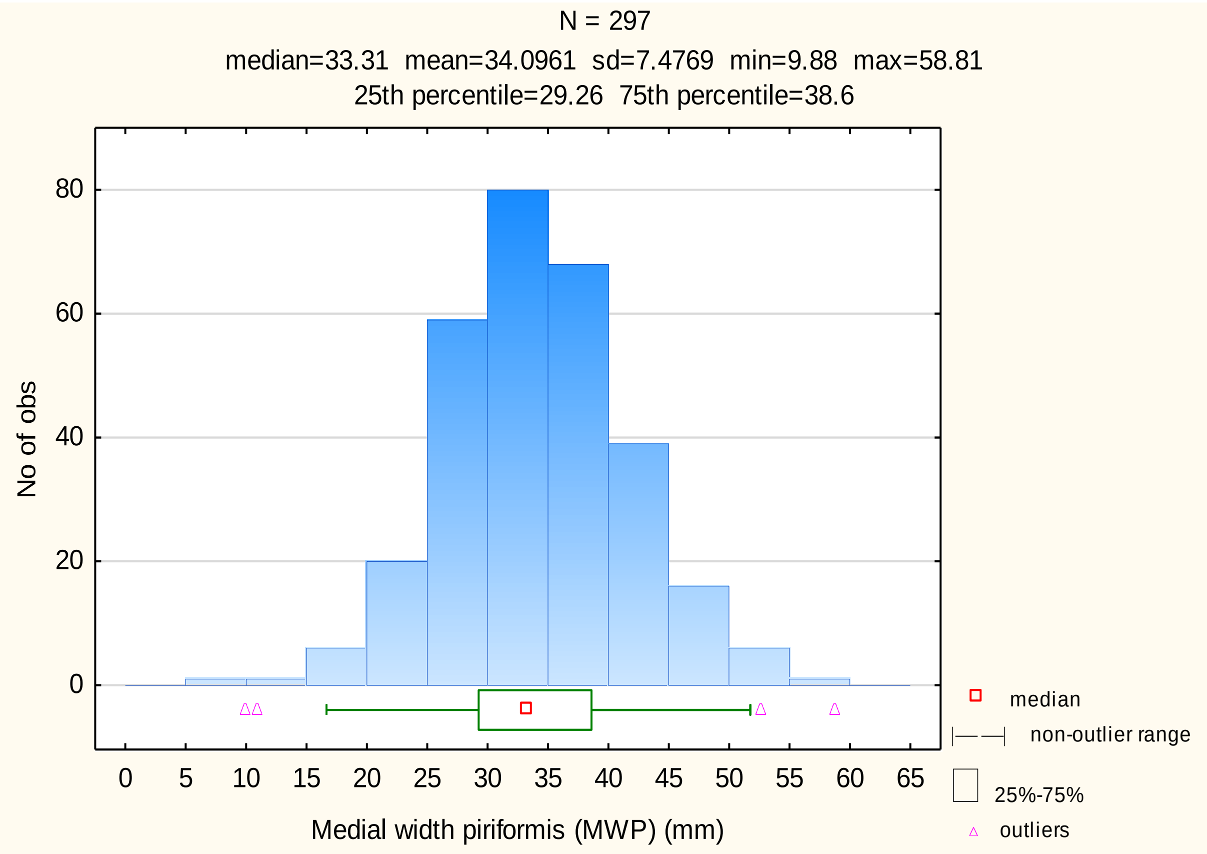

Figure 5.16: A histogram summarising the measurements for the medial width of piriformis.

5.4.1.2 Lateral width of piriformis

The researcher obtained the LWP by measuring the vertical width of piriformis mid-section of the muscle belly. Again, the researcher measured this vertical width in a straight line. The LWP was narrow compared to the MWP, with a mean of 17.01 mm for all specimens ($n = 297$) (Table 5.3). In accordance with a smaller measurement, the calculated standard deviation for this mean is $\pm$4.81 mm (Figure 5.17). The LWP mean is consistent with the expected size of the muscle at this point, becoming tendinous and increasingly narrow, ahead of its distal attachment to the piriformis fossa at the medial aspect of the greater trochanter of the femur.

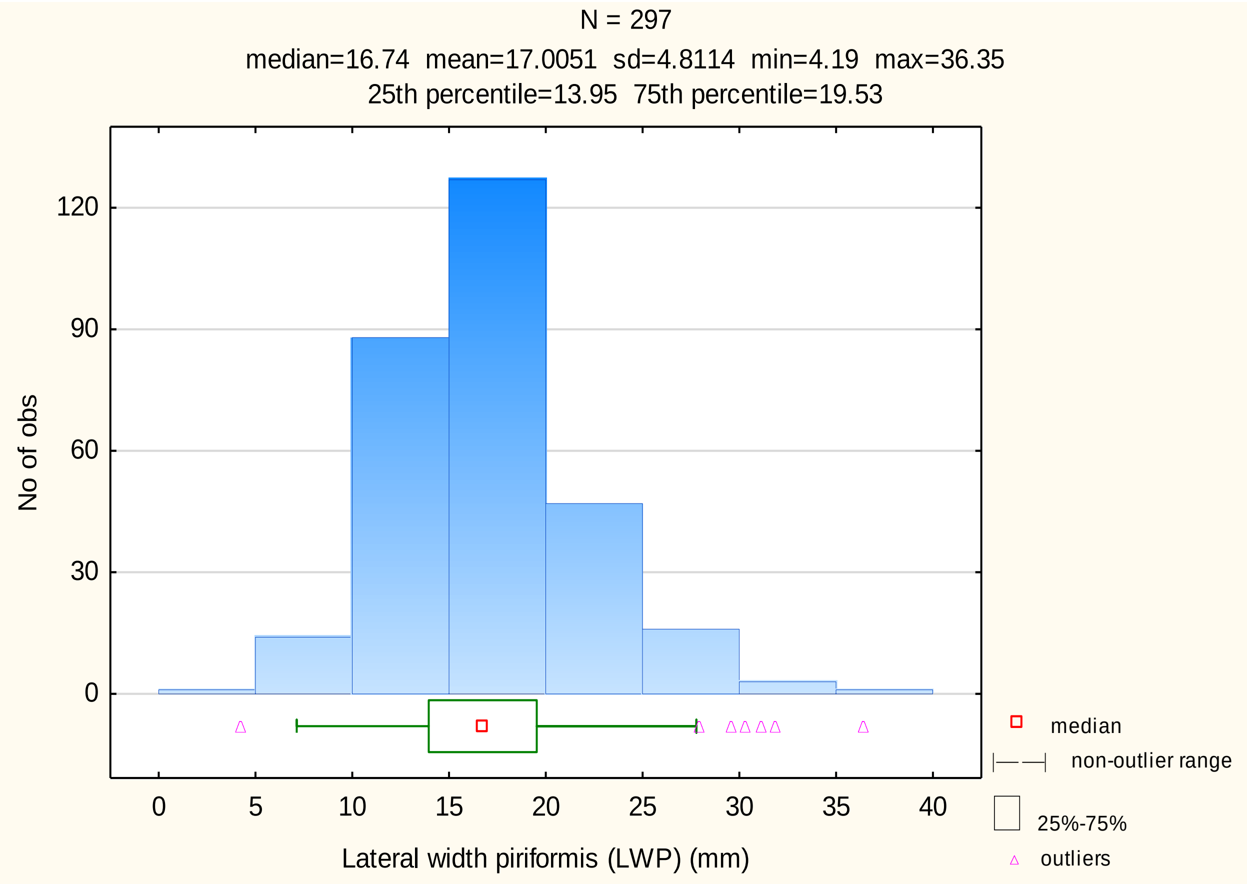

Figure 5.17: A histogram summarising the measurements for the lateral width of piriformis.

As illustrated in figure 5.18, the two different box plots represent the different comparisons made regarding the LWP. In this test, the effect of both side and sex are used to understand the LWP. As depicted, a high significant difference is observed between the right lower limbs of male and female specimens ($p < 0.01$), and similarly, a high significant difference is observed when comparing left lower limbs that belonged to male and female specimens ($p = 0.01$). Therefore, a highly significant difference exists between male (blue) and female (red) LWP, represented by the p-values and box plots in figure 5.18. Males (17.82 mm) have a larger LWP mean, compared with female (15.81 mm) specimens used in the present study (Table 5.3).

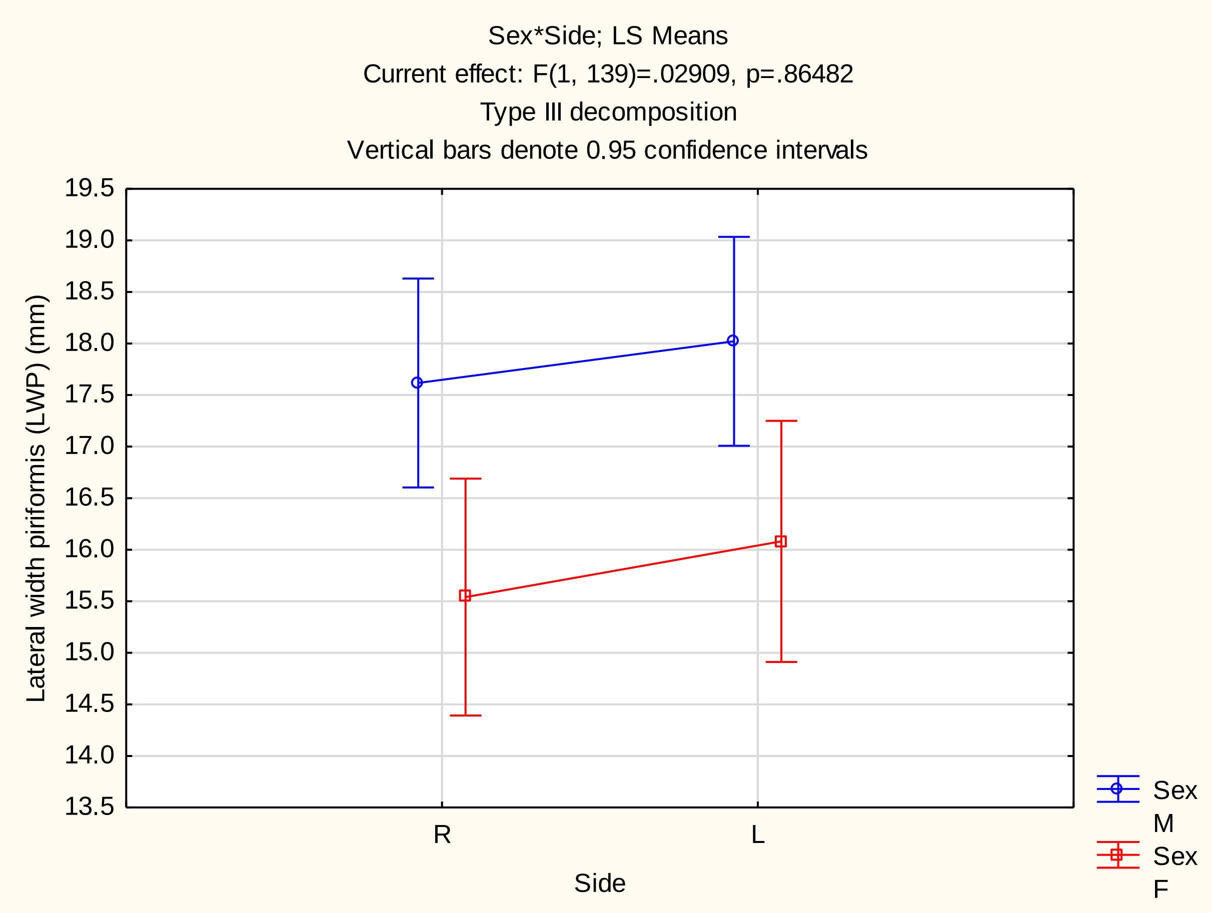

Figure 5.18: The effect that sex and side has on the lateral width of piriformis.

In figure 5.19, below, a two-way ANOVA analyses variance by examining the influence of the two independent variables on the LWP. The independent variables tested are population group and side variability. According to the test, the comparison of the right lower limb between Mixed race and White/Caucasian specimens yield a highly statistically significant difference ($p < 0.001$), and a similar outcome is reported for the comparisons of the left lower limb between Mixed race and White/Caucasian specimens, confirmed by a highly significant p-value, where $p < 0.001$. Additionally, the mean LWP comparison of the right lower limb between White/Caucasian and South African Black specimens is statistically significantly different ($p < 0.01$), and the comparison made for the left lower limb between White/Caucasian and South African Black specimens present a highly statistically significant difference ($p < 0.001$).

The LWP is significantly smaller in White/Caucasian specimens, with a mean of 15.78 mm, while the means for Mixed race and South African Black specimens are larger and more similar in size compared to one another, at 18.85 mm and 20.02 mm, respectively (Table 5.3). Figure 5.19 depicts this comparison visually, represented by use of the “a” and “b”, where different letters between different groups indicate that a statistically significant difference is present between the two different groups. However, the repetition of the same letter for two different groups denotes that there is no statistically significant difference present between the two different groups. Therefore, a statistically significant difference exists between the smaller LWP for White/Caucasian (b) specimens, compared to either Mixed race (a) or South African Black (a) specimens (Figure 5.19).

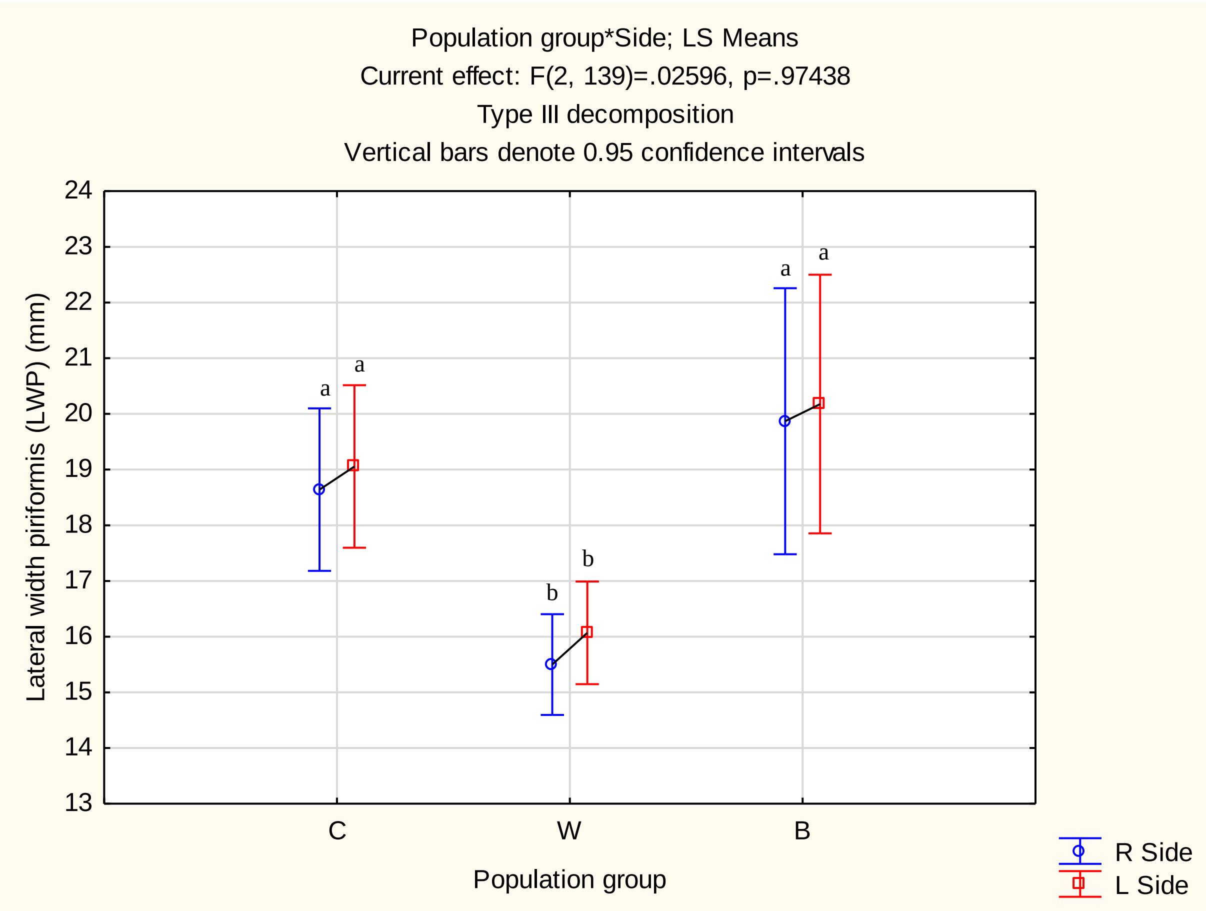

Figure 5.19: The effect of population group and side on the lateral width of piriformis.

5.4.1.3 Length of the superior border of piriformis

The PSBL was determined by measuring the superior border length of piriformis, from the superior point at which the muscle emerges beneath the sacrotuberous ligament, along the superior aspect of the muscle, to its distal attachment to the piriformis fossa at the medial aspect of the greater trochanter of the femur. The PSBL has a mean of 55.77 mm, with a standard deviation of ±9.47 mm (Table 5.3). There are many outliers present in the data, predominantly occurring above the 75th percentile, in relation to the box plot (Figure 5.20). However, the data distribution appears normal. The maximum value is 87.68 mm, and minimum value is 26.04 mm. Figure 5.20, below, visually presents these summarising characteristics.

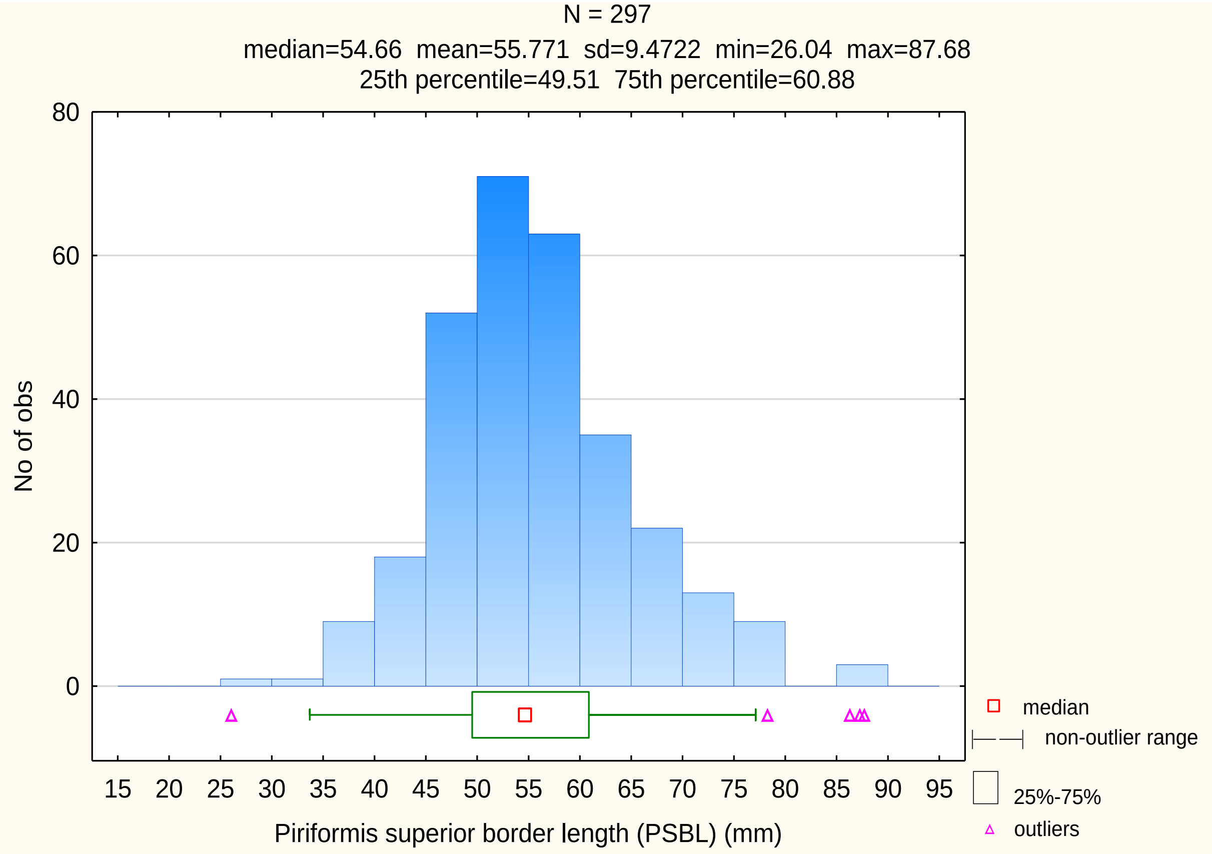

Figure 5.20: A histogram summarising the measurements for the superior border length of the piriformis.

In this dataset, there are no significant comparisons made between the groups. The mean PSBL between the different population groups were similar and almost equal in the right and left lower limb comparisons. In the comparison between sexes, the mean for the male group was 55.86 mm, and the female group had a similar mean of 55.85 mm (Table 5.3).

5.4.1.4 Length of the inferior border of piriformis

The researcher obtained the LIBP measurement by measuring the length of the inferior border of piriformis, from the inferior point at which the muscle emerged beneath the sacrotuberous ligament, along the inferior aspect of the muscle, to its distal attachment to the piriformis fossa at the medial aspect of the greater trochanter of the femur.

Figure 5.21 visually summarises the LIBP measurement results for the total study sample ($N = 297$). This length has a mean value of 59.85 mm, and an even distribution amongst the entire sample group. Furthermore, the LIBP comparisons present no statistical values of interest when represented graphically. Therefore, the researcher observed no statistically significant differences for comparisons between sexes and side.

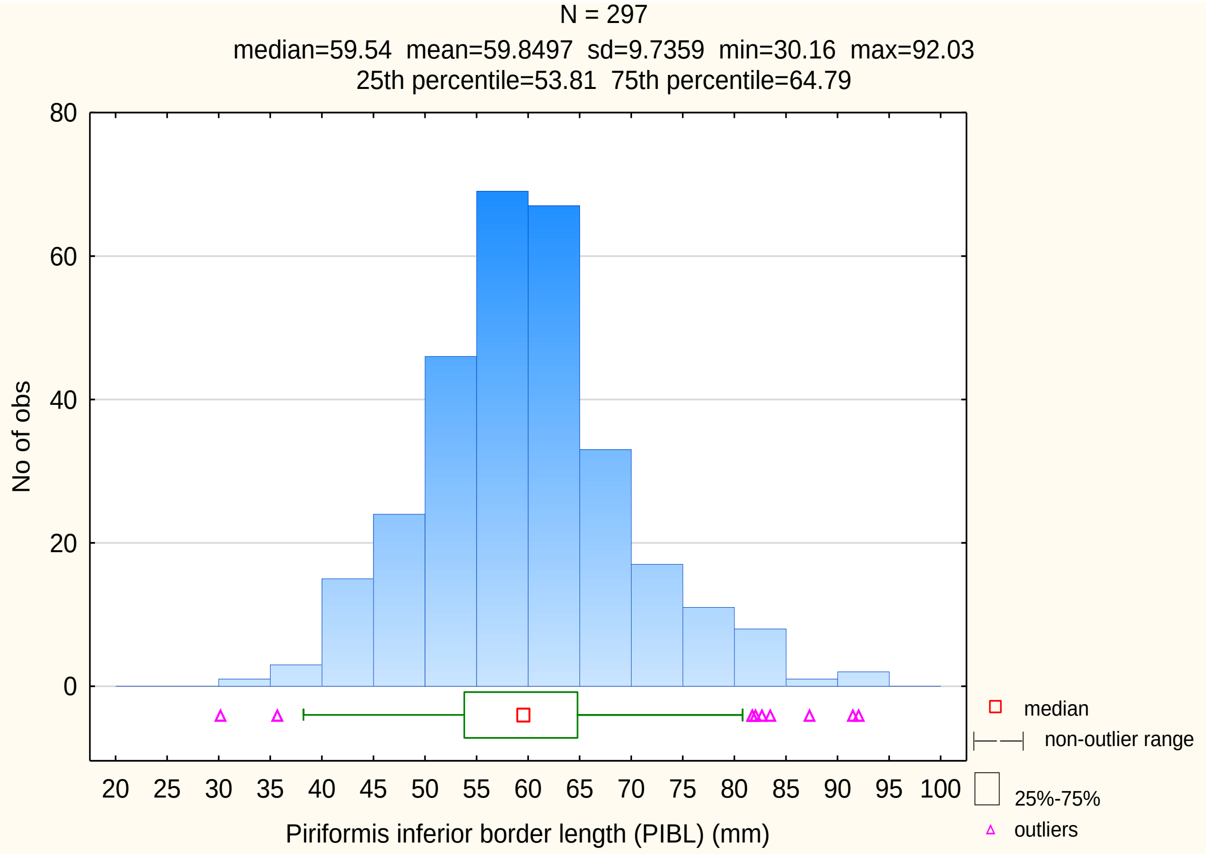

Figure 5.21: A histogram summarising the inferior border length of piriformis measurements.

Very similar means seen in the comparison between the White/Caucasian, Mixed race, and South African Black population groups. Table 5.3 depicts the similarities between the three mean values, where the mean values for the White/Caucasian, Mixed race, and South African Black specimens are 59.74 mm, 60.46 mm, and 60.27 mm, respectively.

5.4.2 Measurements related to the sciatic nerve

5.4.2.1 Width of the sciatic nerve

The SNW measurement was obtained for the sciatic nerve. This measurement is determined by measuring the width of the sciatic nerve, immediately as it became visible in the gluteal region, inferior to the inferior border of piriformis. The width of the sciatic nerve has a mean value of 15.19 mm, and a standard deviation of ± 3.44 mm. There is a large variability between the minimum and maximum values, being 2.91 mm and 26.03 mm, respectively (Figure 5.22).

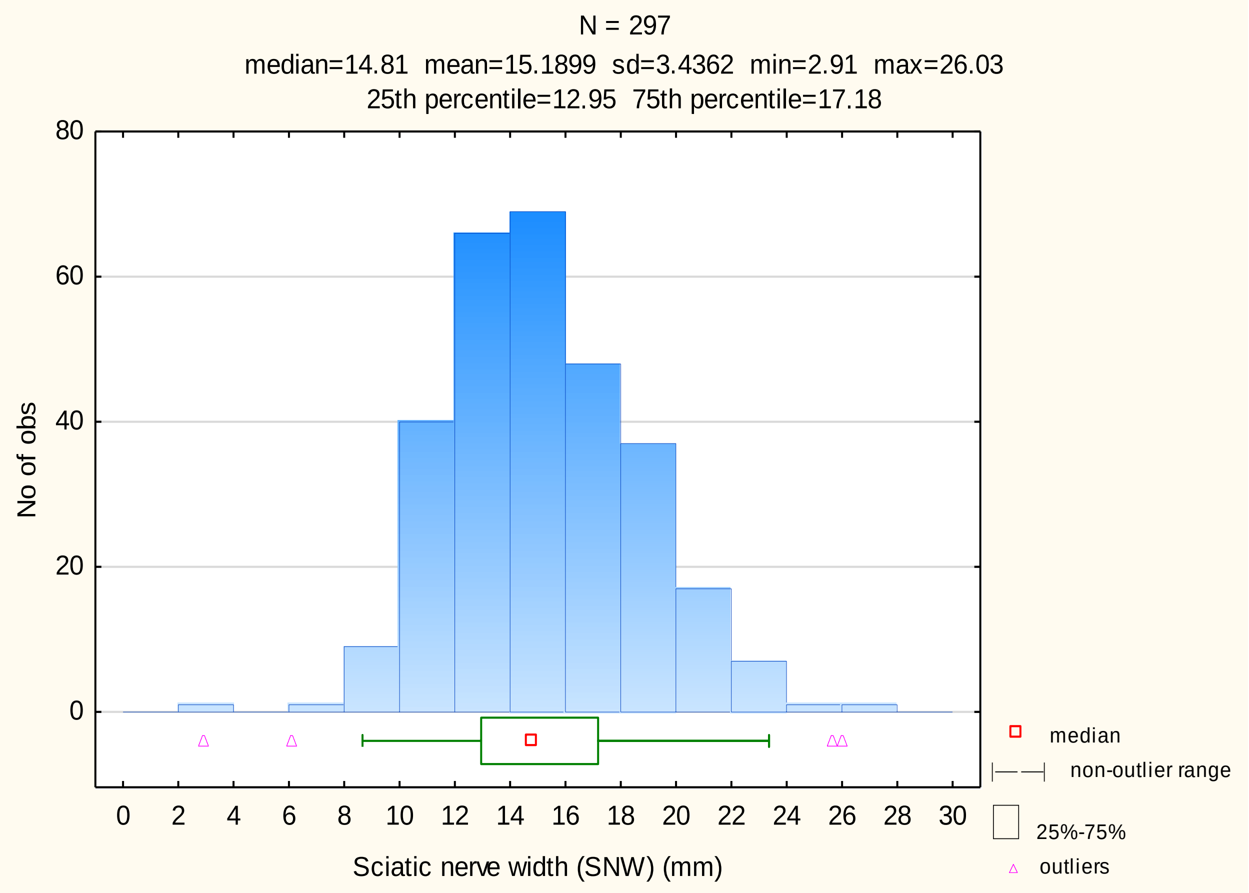

Figure 5.22: A histogram summarising the measurements for the width of the sciatic nerve.

In the two-way ANOVA completed for the SNW (Figure 5.23), it can be seen that the mean SNW presents a statistically significant difference when a comparison is made between the right lower limb for Mixed race and White/Caucasian specimens, as is the case for the comparison of the left lower limb between Mixed race and White/Caucasian specimens ($p <$ 0.05 and $p < 0.001$, respectively). Therefore, the mean SNW for Mixed race specimens is statistically significant different to the mean SNW for White/Caucasian specimens, where the mean for Mixed race specimens (14.05 mm) is statistically smaller than the mean for White/Caucasian specimens (15.99 mm). Additionally, the comparison of the right lower limb between White/Caucasian and South African Black specimens yields a statistically significant difference ($p < 0.05$), while a highly statistically significant difference is present in the comparison of the left lower limb between White/Caucasian and South African Black specimens ($p < 0.001$). Therefore, the mean SNW for White/Caucasian specimens is statistically significantly different to the mean SNW for South African Black specimens, where the mean for White/Caucasian specimens (15.99 mm) is significantly larger than the mean for South African Black specimens (13.02 mm).

Figure 5.23 depicts this comparison visually, represented by use of the "a", "b" and "c", where different letters between different groups indicate that a statistically significant difference is present between the two different groups. However, the repetition of the same letter for two different groups denotes that there is no statistically significant difference present between the two different groups. In summary, a statistically significant difference is observed in the comparisons between White/Caucasian (a/b) and Mixed race (c) specimens, and White/Caucasian (a/b) and South African Black (c) specimens, but not for the Mixed race (c) and South African Black (c) specimens.

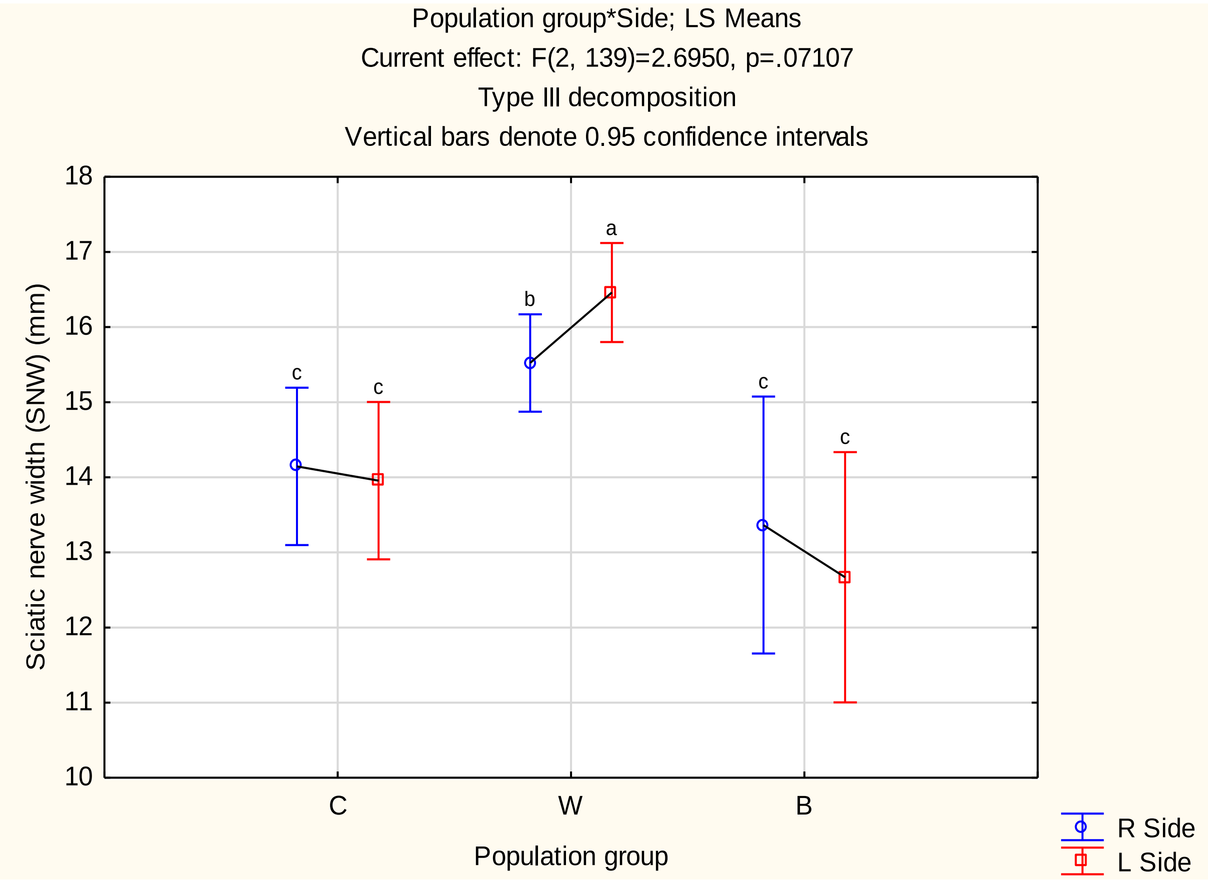

Figure 5.23: The effect of population group and side to evaluate the width of the sciatic nerve.

5.4.2.2 Length of the sciatic nerve

The researcher obtained the measurement for the SNL by measuring the entire length of the sciatic nerves course within the lower limb of each specimen. This measurement starts at the level of piriformis in the gluteal region, where the sciatic nerve becomes visible at the inferior border of the muscle, and terminates as the sciatic nerve bifurcates. The various findings for the SNL in the study sample ($n = 295$), are represented graphically, in figure 5.24. The sample size decreased by two specimens compared to previous measurements, which accounts for the one cadaver with bilateral amputations above the knee joint. The SNL has a mean of 390.57 mm, with a standard deviation of ± 32.20 mm.

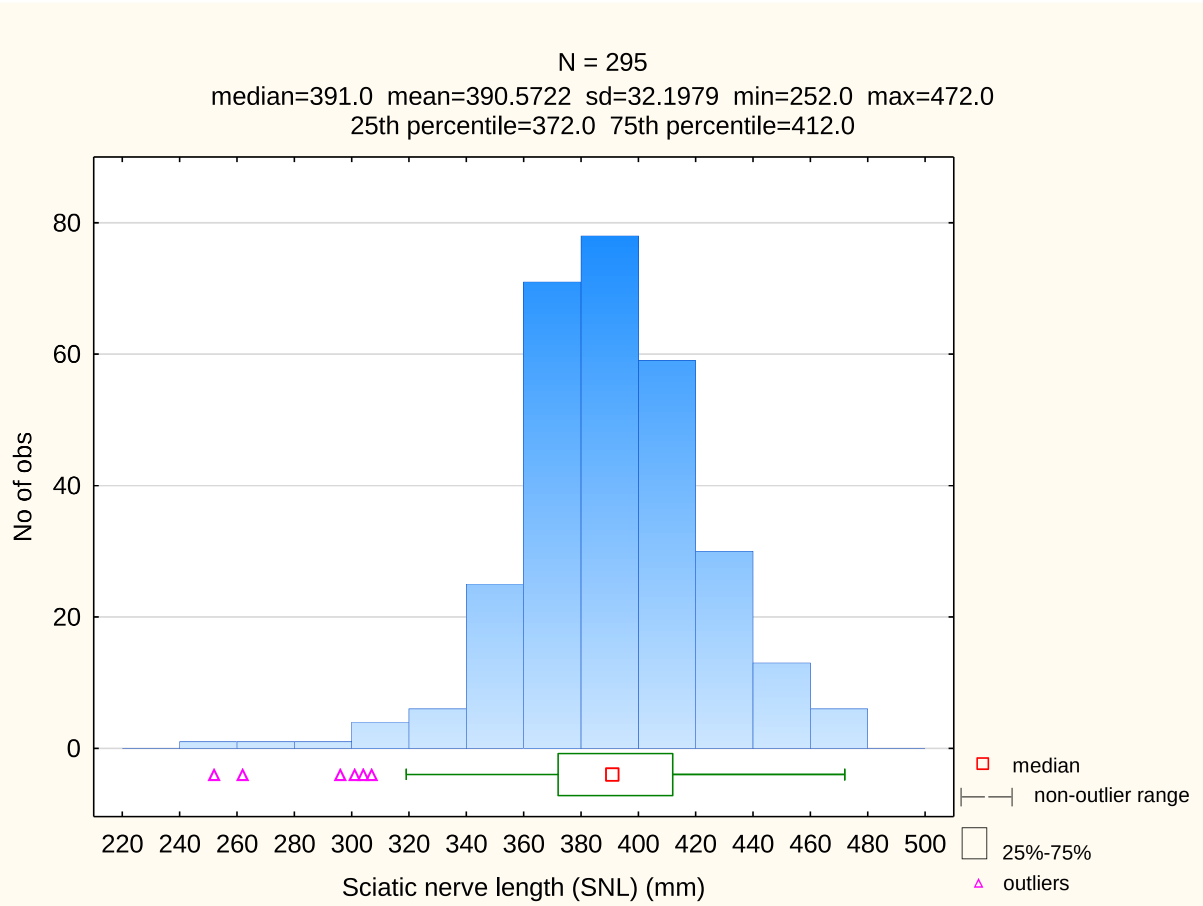

Figure 5.24: A histogram summarising the measurements for the length of the sciatic nerve

In the two-way ANOVA, depicted in figure 5.25, the researcher compares the interaction that sex and side have on the SNL. In this test, there is a statistically significant difference in the comparison of the right lower limb between male and female specimens ($p < 0.05$), and a highly statistically significant difference when comparing the left lower limb between male and female specimens ($p < 0.01$).

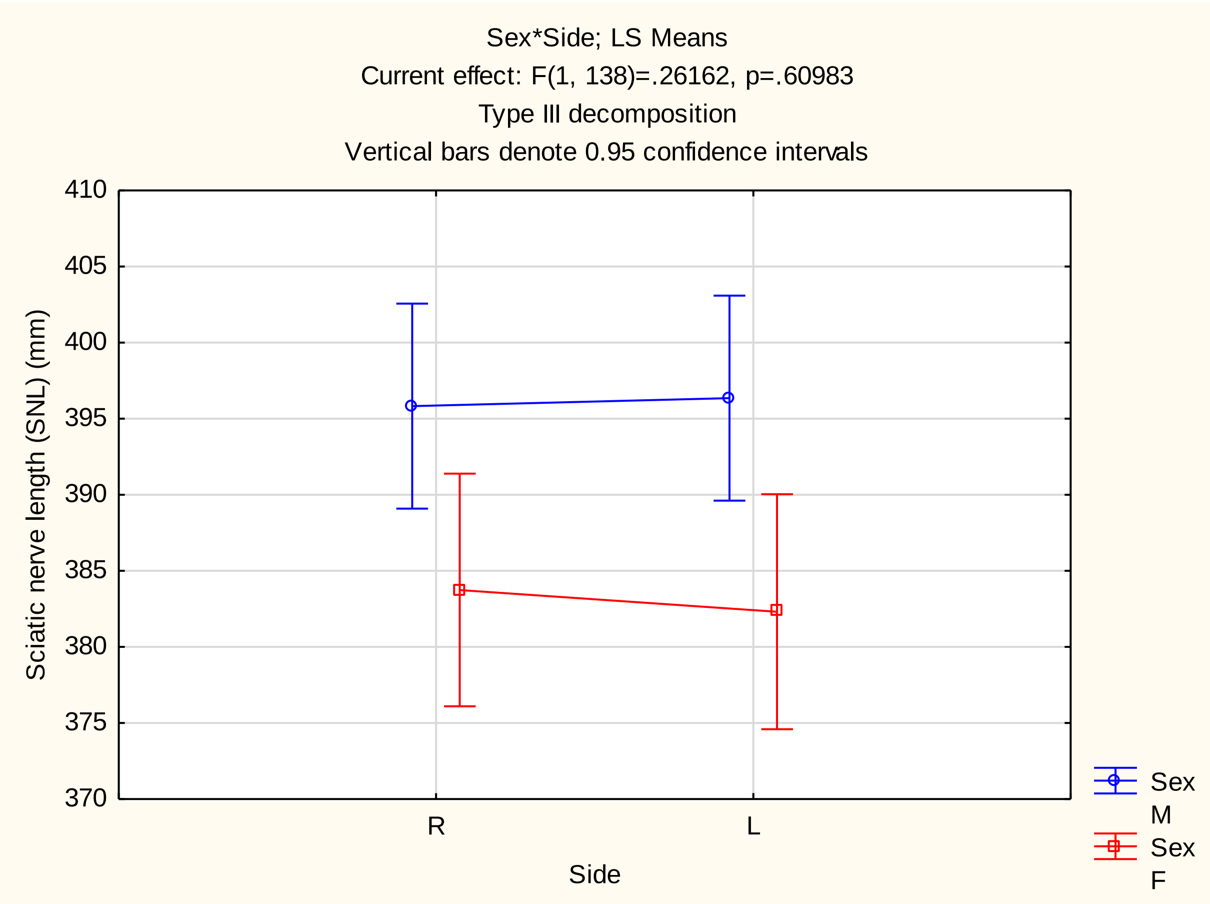

Figure 5.25: The effect that sex and side has on the length of the sciatic nerve.

Therefore, a statistically significant difference in the mean SNL exists between male and female specimens. The mean length of the nerve for men is 396.09 mm, and 383.03 mm for females (Table 5.3).

5.4.2.3 Length of the thigh

The researcher measured the LT by using two very distinct landmarks to denote the beginning and termination of this region within the lower limb. The most proximal point on the greater trochanter of the femur is the proximal landmark, while the distal landmark is the popliteal fossa, on the line connecting the medial and lateral femoral epicondyles. The researcher measured the TL in a straight line. While this measurement does not relate directly to the sciatic nerve, it was used to improve understanding of the SNL. The mean LT is 430.63 mm, with a standard deviation of ± 27.30 mm, for all specimens. A graphical representation depicted below, in figure 5.26, summarises the rest of the data obtained for this measurement.

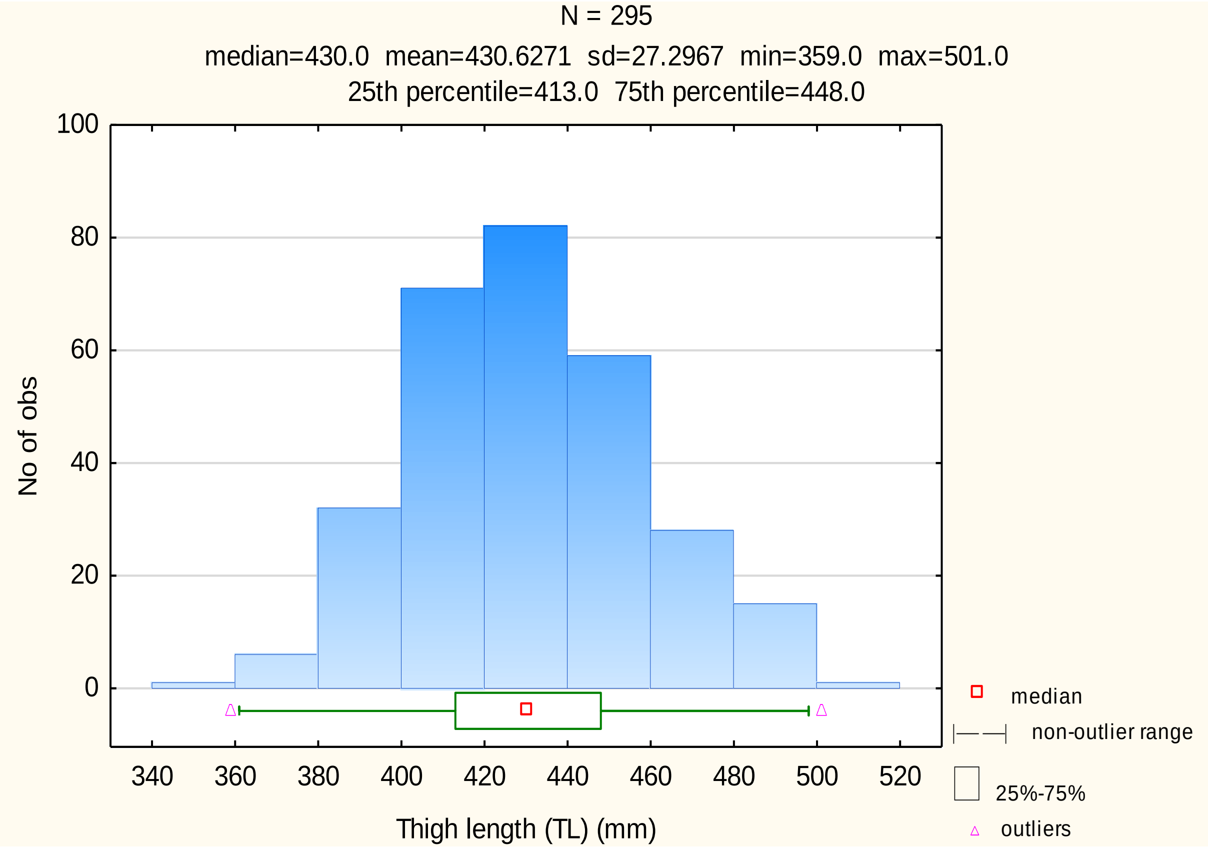

Figure 5.26: A histogram summarising the measurements for the length of the thigh.

When reviewing the mean length of the thigh, the interaction between side and sex present statistically significant differences between the comparable groups. Figure 5.27, below, graphically depicts these interactions. The right lower limb in male specimens had a larger length compared to the right lower limb in female specimens. This is statistically significantly different, yielding a significant p-value, where $p < 0.05$. Additionally, the left limb between male and female specimens presented a highly statistically significant difference, as $p < 0.01$.

Therefore, male and female specimens have statistically significant differences in thigh length, where male specimen present significantly larger thigh lengths (437.39 mm) compared to the thigh lengths (421.09 mm) recorded for female specimens.

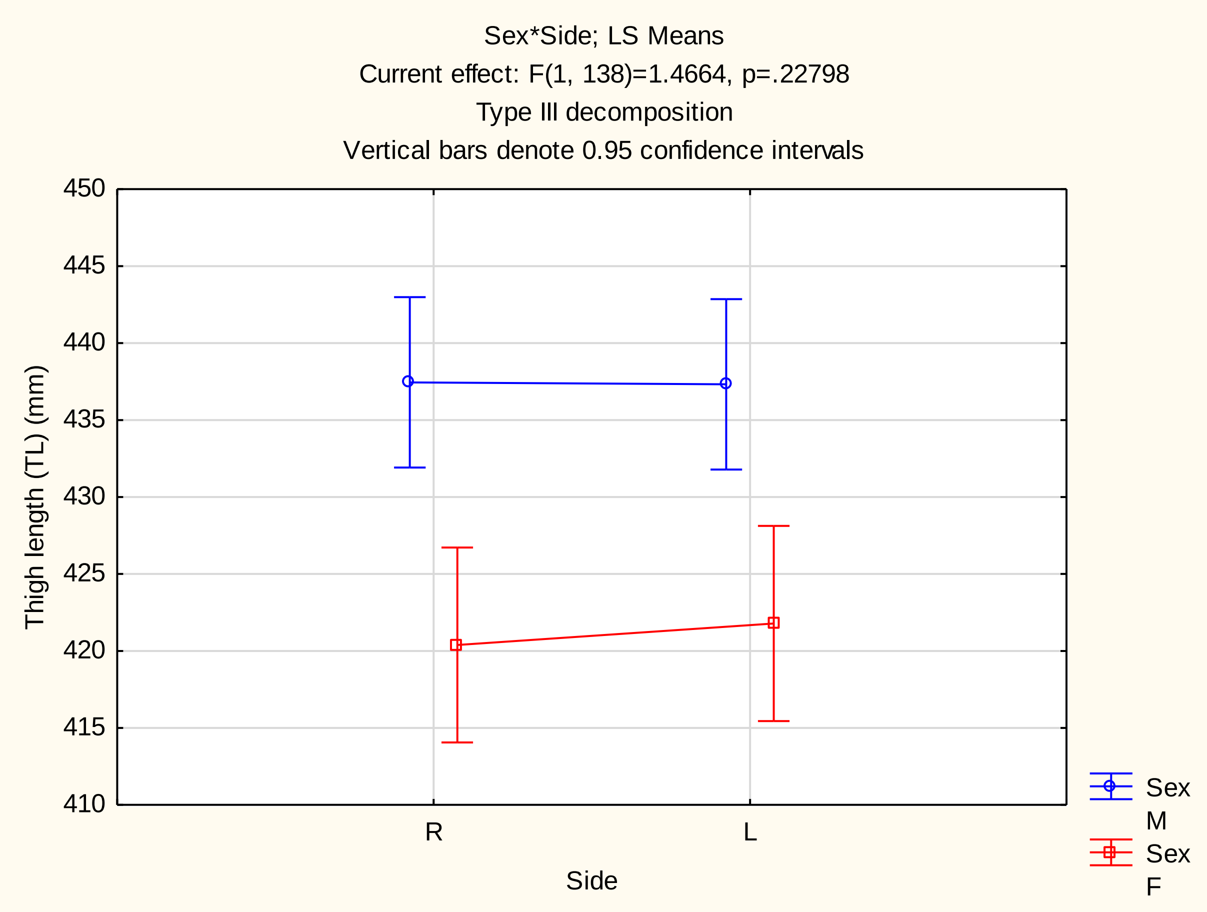

Figure 5.27: The effect of sex and side on the length of the thigh.

In the next two-way ANOVA, seen below, in figure 5.28, the interaction of population group and side is tested against thigh length. In this test, both the right and left lower limbs of Mixed race and White/Caucasian specimens were statistically significantly different, with calculated p-values of $p < 0.01$ and $p < 0.05$, respectively. Therefore, Mixed race specimens had statistically significant differences in thigh length compared to White/Caucasian specimens. The mean thigh length for Mixed race specimens is 420.95 mm, and is significantly shorter than the thigh length of White/Caucasian specimens, with a mean measurement of 433.78 mm. However, this is not the case when comparing Mixed race and South African Black specimens, or White/Caucasian and South African Black specimens. These two latter comparisons did not yield statistically significant results, as the mean thigh lengths did not differ significantly.

Figure 5.28 depicts this comparison visually, represented by the use of “a” and “b”, where different letters between different groups indicate that a statistically significant difference is present between the two different groups. However, the repetition of the same letter for two different groups denotes that there is no statistically significant difference present between the two different groups. In summary, a statistically significant difference is observed in the comparisons between White/Caucasian (a) and Mixed race (b) specimens, but not for Mixed race (b) and South African Black (b) specimens, or White/Caucasian (a) and South African Black specimens (a).

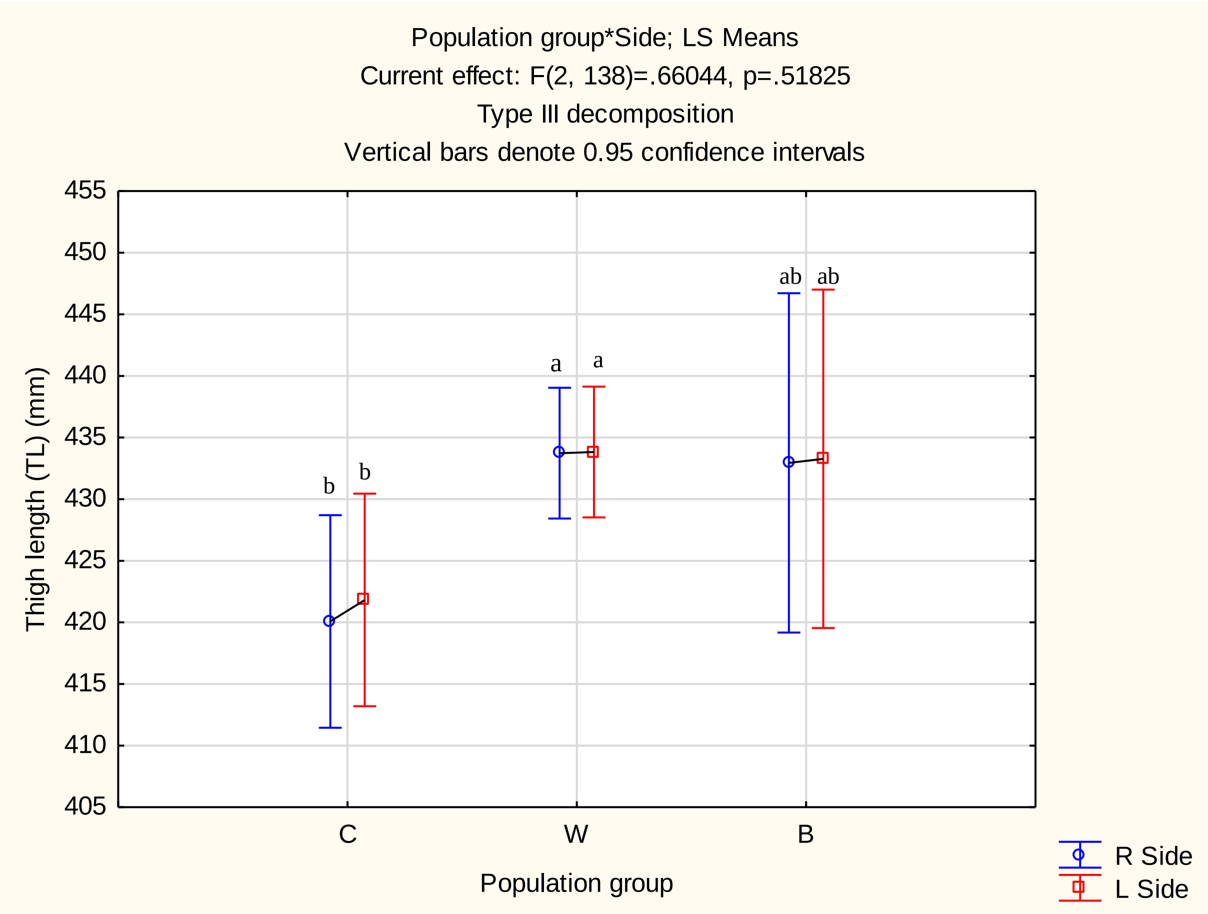

Figure 5.28: The effect of population group and side on the length of the thigh.

CHAPTER SIX: DISCUSSION

Damage resulting from injections into the sciatic nerve or structures closely related to the nerve is the most frequent cause of nerve injuries in children (Senes *et al*., 2009). Although the intramuscular injection is considered a basic skill, it must be treated with due diligence. To avoid complications, medical staff need to understand regional anatomy properly. Additionally, clinicians need to understand the different injection sites, along with advantages and disadvantages for each site (Small, 2004). Too often, local anatomical variations predispose injury to nerves. These variations include abnormal subdivision of the piriformis due to proximal bifurcation of the sciatic nerve into its terminal branches. Regardless of what procedure the clinician intends to follow, good clinical judgement using the best evidence available on case-specific assessment will result in the best outcome (Small, 2004). Therefore, maintaining the best possible clinical practices requires up to date relevant anatomical knowledge. It is for this reason that studies, such as the present one, ensures that vital "new" information is available.

6.1 ANATOMICAL VARIATIONS OF PIRIFORMIS

In the present study, the researcher examined 340 specimens to study and describe the variation in the relationship between the sciatic nerve and piriformis. By comparison, this study had a much larger sample size than many other studies published previously.

Similar to previous studies published, type A in the classification, was the most prevalent type of morphology. In a similar study conducted by Natsis *et al*. (2014), type A was present in 93.6% of the specimens studied. However, 76% of the specimens presented type A morphology in the study conducted by Guvencer *et al*. (2009), which helps to understand the prevalence range of this type. In a meta-analysis conducted by Tomaszewski *et al*. (2016), the population prevalence for the normal pattern was 85.2%. According to Pokorny *et al*. (2006), 79.1% of the cases had an undivided sciatic nerve that passed distally below a complete piriformis, resembling type A. Furthermore, in two studies conducted in Brazil, where 40 specimens were used in both studies, type A was seen in 85% (Vicente *et al*., 2007), and 90% of the specimens (Brooks *et al*., 2011), respectively. In the present study, the researcher observed this morphology in 297 (87.35%) specimens. The prevalence in the present study is therefore similar to the prevalence documented elsewhere in the world.

The current study had 43 (12.65%) specimens, in 28 (16.47%) cadavers, which presented variations in the course of the sciatic nerve in relation to piriformis. Again, these numbers are consistent with literature published previously. A more detailed description of each type of variation, observed in the present study, will follow.

Numerous studies (Chiba *et al*., 1992; Pecina, 1979; Pokorny *et al*., 2006; Haladaj *et al*., 2015) have published the prevalence of each category described by Beaton & Anson *et al*. (1937) in detail. Overwhelmingly, previous literature points to type B as the most prevalent deviation from the normal morphology. The results in the present study confirm this assumption, as type B made up the majority of all variations seen. Piriformis was pierced by the common fibular nerve in 36 (10.59%) of specimens in the present study. In a study conducted on 514 lower limbs, Chiba *et al*. (1992) found that this variation occurred in as many as 38% of the cases, which is the highest prevalence reported in literature. Subsequent literature has reported a prevalence of between 10-20%. Guvencer *et al*. (2009), Haladaj *et al*. (2015), Pokorny *et al*. (2006) and Moore *et al.* (2017) have confirmed this, with a reported prevalence of 16%, 20%, 14.3%, and 12%, respectively. However, the prevalence was lower in literature published in Africa. In the study conducted by Ogeng'o *et al.* (2011), the prevalence for the common fibular nerve division of the sciatic nerve piercing piriformis was 7.9%, and only occurred in 13 of the 164 specimens examined. Berihu and Debeb (2015) saw similar numbers, where 9% of the specimens observed belonged to the type B variation. Furthermore, Chukwuanukwu *et al*. (2007) reported no variations that resembled type B. The present study confirms the lower prevalence of this variation in the African population.

The third variation in the classification, type C, is rarer than the previous type, and occurs when the common fibular nerve runs through the supra-piriform space, superficially across piriformis, while the tibial nerve courses through the infra-piriform space, as normal. In the meta-analysis conducted by Tomaszewski *et al*. (2016), this variation had a prevalence of 1.9%, with no major sex or geographical variations amongst populations (Tomaszewski *et al*., 2016). Pokorny *et al*. (2006) largely reinforces this, where 4.4% of the specimens presented this variation. Other prevalence amongst different authors include: 6% of the cases published by Okraszewska *et al*. (2002), 1.5% of the specimens studied by Ugrenovic *et al*. (2005), and 2.4% in the Black Kenyan population (Ogeng'o *et al*., 2011). Additionally, only one specimen presented this variation type in a study conducted by Chukwuanukwu *et al*. (2007), resulting in a 3.8% prevalence of this variation in this Nigerian population group. Only three (0.88%) specimens presented this variation, in the present study (Table 5.1).

The fusion of piriformis with gluteus medius muscle is rare, with only a few reports in literature. According to Haladaj *et al*. (2015), fusion occurred between the bellies of these two muscles in 10% of the Polish population group studied. However, in the present study, this anomaly is only present in four (1.18%) specimens, and occurred bilaterally in two male cadavers.

6.2 VARIATIONS IN THE SCIATIC NERVE BIFURCATION LEVEL

According to previous literature, no researcher has created and published an index similar to the one established in the present study. In previous literature, the classification of the sciatic nerve bifurcation was largely subjective, and predominantly relied only on the researcher conducting the study. There has been no classification record to prevent bias information. Therefore, this is the first time such a measurement will be used to quantify the bifurcation classification. The index will strive to decrease the amount of variability that is possible within the study's classification system, and therefore, solidify the classification in its objectivity, and increased reliability.

For the present study, 340 lower limbs were dissected in order to observe the sciatic nerve and the level at which this nerve bifurcates. The study included 189 male specimens, and 149 female specimens, from 169 embalmed cadavers. Data from two specimens, were not included because the cadaver had undergone a double amputation superior to the knee joint. With 338 specimens, this study sample size is the largest known of its kind. Only three known studies have been published in Africa, and so this study will help to provide insight on the variations within an African population. This is the first known study of its kind in South Africa.

Traditionally, literature reports that the sciatic nerve bifurcates in the distal region of the thigh, just proximal to the superior angle of the popliteal fossa proper (Moore *et al*., 2007). However, this bifurcation can take place as proximal as the pelvic region, and as distal as the popliteal fossa proper, in line with the crease of the popliteal fossa (Prakash *et al*., 2010).

Numerous sources attest to the rarity of the sciatic nerve bifurcating proximal to piriformis, within the pelvic region. According to Ogeng'O *et al*. (2011), who undertook the largest study of its kind in Africa, bifurcation in the pelvic region is seen in 33 (20.1%) of the 164 Kenyan specimens. Similarly, Kukiriza *et al*. (2010) reproduced this study in Uganda, where 18 (22.5%) specimens showed sciatic nerve bifurcation taking place in the pelvic region. According to Guvencer *et al*. (2009), the prevalence of this variation was 24% in a Turkish sample group. However, there are fewer occurrences of this type of variation in areas such as Poland and Malaysia, where the prevalence of the bifurcation in the pelvic region were 13.8% and 12.5%, respectively (Haladaj *et al*., 2015; Khan, Asari & Pasha, 2015). Numerous studies published in India reiterate this variations prevalence in the subcontinent. According to Sangram *et al*. (2015), Kotian *et al*. (2015), and Saritha *et al*. (2012), the prevalence of the sciatic nerve bifurcation in the pelvic region was 14%, 5%, and 6%, respectively. On the other hand, Prakash *et al*. (2010), Kumar *et al*. (2011), Ansari *et al*. (2016), and Shewale *et al*. (2013), report no such variations in the specimens used for their studies.

In the present study, the researcher observed the bifurcation proximal to piriformis in 24 (7.1%) specimens. The prevalence in the present study contradicts the results observed by other researchers in Africa. The prevalence is more similar to the population prevalence documented in the Indian subcontinent. However, while only seen in White/Caucasian specimens, there was an underrepresentation of Mixed race and South African Black specimens, which means that this prevalence cannot be accurately representative of the South African population as a whole.

Contrary to the previous variation, the type B variation is rarer in a number of populations groups across the world. Ogeng'o *et al*. (2011) and Kumar *et al*. (2011) both found four specimens with the sciatic nerve bifurcation taking place in the gluteal region, which correlated to 2.4% and 8% prevalence, respectively. Furthermore, Kiros & Woldeyes (2010), Khan *et al*. (2015), Sangram *et al*. (2015), and Prakash *et al*. (2010) all saw two specimens with this variation in their respective studies. However, Ansari *et al*. (2016) observed this variation in 13 of the 30 specimens studied, with a prevalence of 43% for the study.

While the majority of authors detailed the level at which bifurcation takes place within the posterior compartment of the thigh, this is not always the case. Kiros & Woldeyes (2015) and Kotian *et al*. (2015) note that the bifurcation of the sciatic nerve takes place in the posterior compartment of the thigh for 24% and 18.33% of the specimens in their studies, respectively. There is no further detail provided on the level of bifurcation within the posterior compartment of the thigh.

Prakash *et al*. (2010) and Shewale *et al*. (2013) noted that the bifurcation of the sciatic nerve took place in the proximal third of the posterior compartment of the thigh in 3 (3.5%) and 6 (6.7%) specimens, respectively. On the other hand, Ogeng'o *et al*. (2011), Kumar *et al.* (2011), and Ansari *et al*. (2016) all observed a higher prevalence in the bifurcation of the sciatic nerve in the proximal third of the posterior compartment of the thigh, with 17 (10.4%), 7 (14%) and 11 (36%) specimens, respectively. No reports of this variation were present this study.

According to Prakash *et al*. (2010), Shewale *et al*. (2013), and Okaszewska *et al*. (2002) the prevalence of sciatic nerve bifurcation taking place in the middle third of the posterior compartment of the thigh was 2.3%, 4.4%, and 14%, respectively, while this prevalence was 38%, according to a study published by Kumar *et al*., in 2011. The present study revealed a prevalence of only 0.6%, with only two specimens that had the bifurcation occurring in the middle third of the posterior compartment of the thigh. This prevalence is low when compared to the prevalence of 10.4% in a Kenyan Black population study (Ogeng'o *et al*., 2011). The prevalence obtained in the present study is more in line with the reports from Prakash *et al*. (2010) and Shewale *et al*. (2013), however, the total sample sizes for these studies are much smaller than in the present study.

The variation where the bifurcation of the sciatic nerve takes place in the distal third of the posterior compartment of the thigh tends to have a higher prevalence than other variations. According to Prakash *et al*. (2010), this variation had a prevalence of 40.6% in the Indian population group. However, the prevalence of this variation was far greater in other studies conducted in India. Shewale *et al*. (2013) observed a prevalence of 70%, while Sangram *et al*. (2015) and Saritha *et al*. (2012) observed a prevalence of 82%, and 88%, respectively. Additionally, in a Malaysian population group, this variation were seen in 18 (75%) of the 24 cases (Khan *et al*., 2015). The present study revealed a much lower prevalence, at 12.7% for this variation. There were no studies on a South African population group to compare with. However, this study provides a foundation for further investigations.

The variation where the sciatic nerve bifurcated at its lowermost level, namely the popliteal fossa proper, occurred at a higher prevalence than the previous types. While the prevalence is lower in studies published by Saritha *et al*. (2012), Khan *et al*. (2015), and Shewale *et al*. (2013), with 4%, 4.2%, and 7.78%, respectively, this is not the case with other publications. Kotian *et al*. (2015), Kumar *et al*. (2011), and Prakash *et al*. (2010) observed a prevalence of 31.7%, 32%, and 34.9%, in their respective studies. The prevalence was substantially higher in studies published by Kiros & Waldeyes (2015), Ogeng'o *et al*. (2011), and Okraszewska *et al*. (2002), where the bifurcation of the sciatic nerve in the popliteal fossa proper had a prevalence of 64%, 67.1%, and 72%, respectively. In the present study, the prevalence correlates well with reports from Ogeng'o et al. (2011) and Okraszewska et al. (2002), at 79.6% for the South African population sample. Population specific prevalence is similar when looking at the South African White/Caucasian specimens, with a prevalence of 75.2%. However, the Mixed race and South African Black specimens have a prevalence of 91% and 83.3%, respectively. The prevalence for these groups are much higher; however, larger sample sizes and data is needed for these individual subgroups before assumptions can be made. The prevalence of this variation in the present study is similar to the prevalence observed in the Kenyan and Polish populations

(Ogeng'o *et al*., 2011; Oraszewska *et al*., 2002), but not as low as the prevalence reported by Kotian *et al*. (2015), Kumar *et al*. (2011), and Prakash *et al*. (2010).

6.3 MORPHOMETRIC ANALYSIS

Comprehensive anatomical data concerning the morphology of piriformis itself is lacking in the literature (Windisch *et al*., 2007). Variations of the piriformis is lacking in anatomical and radiological literature This is important for the interpretation of ultrasound and magnetic images, especially if ultrasound is being used to aid in injection administration (Windisch *et al*., 2007). Therefore, it is important that researchers undertake morphometric analysis on the sciatic nerve, piriformis, and other structures, within the gluteal region. To our knowledge, this study is the first of its kind to morphometrically quantify the differences seen in gluteal region between sides, sex, and subpopulation groups, in a South Africa context. To our knowledge, this is the only study to morphometrically quantify the many parameters of the sciatic nerve and piriformis in specimens.

In the present study, the researcher had the opportunity to investigate numerous morphometric measurements of the structures in the gluteal region. This assists in understanding the variability of structures in the gluteal region, and when compared between population groups, right and left limbs, and between sex groups. The present study was done under the premise that these measurements have not been recorded for a South African population group before. While the essence of this study remains descriptive in nature, the morphometric measurements are used to aid in understanding the morphology of the gluteal region. To understand if changes are seen when there are no variations in major structures present, and to present this morphology statistically.

Very few studies reported morphometric measurements as an aid to describe the morphology of the gluteal region. Vicente *et al*. (2007) and Brooks *et al*. (2011) used 40 Brazilian specimens in their respective studies and made use of two measurements which are used in the present study. The width of the sciatic nerve at the inferior border of piriformis, extra-pelvic width of piriformis at the midpoint and the length of piriformis were measured in 40 Brazilian specimens for each study.

According to Vicente *et al*. (2007), the width of the sciatic nerve had a mean value of 18.85 mm for the 17 non-variant right lower limbs, while the left lower limbs had a mean width of 22.34 mm. Furthermore, the authors proceed to conclude that the sciatic nerve width had a statistically significant difference, when comparing the right and left groups (Vicente *et al*., 2007). In addition, Brooks *et al*. (2011) observed similar values in their specimens, where the mean sciatic nerve width in the 18 non-variant right lower limbs was 19.45 mm, while the sciatic nerve width in the 18 left lower limbs was 19.46 mm. However, since these numbers were almost equal in value, no statistical significance was calculated when comparing the two groups. Additionally, Brooks *et al*. (2011) goes on to state that the study sample did not allow for statistical comparisons and conclusions because the sample sizes were so small. This begs the question as to whether Vicente *et al*. (2007) were able to accurately draw significant conclusions from their sample, as the sample sizes in both Brazilian studies were identical at 40 specimens. In a meta-analysis completed by Tomaszewski *et al*. (2016), morphometric data from three studies ($n = 252$), which included the study by Brooks *et al*. (2011), resulted in a pooled mean width of 15.55 mm for the sciatic nerve. Haladaj *et al*. (2015) included the width of the sciatic nerve within their study. In the 20 Turkish specimens included in the study by Guvencer *et al*. (2008), he calculated the mean width of the sciatic nerve at 17.00 ± 3.70 mm in the infra-piriform space.

In the present study, the sciatic nerve has a mean width of 15.19 mm, with a standard deviation of $\pm$3.44 mm, for all 297 specimens included in the calculation. This width is similar to that calculated by Tomaszewski *et al*. (2016), and it is possible that these values are similar due to comparable sample sizes in both their study and the present study. Vicente *et al*. (2007) and Brooks *et a*l. (2011) have widths that are slightly larger, but this could be due to the much smaller sample sizes used in their studies.

In addition, there were significant statistical differences when comparing means of the sciatic nerve width between the population groups. There were significant statistical differences seen between White/Caucasian and South African Black sample specimens, and White/Caucasian and Mixed Race specimens, with the width in the White/Caucasian specimens being the largest (15.99 mm). However, there are less Mixed race and South African Black specimens, compared to White/Caucasian specimens, in the current study. Therefore, it is uncertain whether the significant statistical differences observed are due to differences in population group morphology, or due to the lack of Mixed race and South African Black specimens, which increases sample bias, and variability in the data.

Very few studies make use of the extra-pelvic length of piriformis (Vicente *et al*., 2007; Brooks *et al*., 2011; Haladaj *et al*., 2015) as a component of comparison. According to Vicente *et al*. (2007), the mean extra-pelvic length of piriformis in right lower limbs was 76.38 mm, while the left mean was 79.51 mm. Similar measurements were observed in the 40 specimens included in the study by Brooks *et al*. (2011), with 74.52 mm, and 78.45 mm observed for the same groups, respectively. In addition, a mean measurement of 81 mm was calculated for the superior border length of piriformis, and 82 mm for the inferior border length of piriformis (Haladaj *et al*., 2015). In the present study, this was very different, at a mean of 55.77 mm for the superior border length, and 59.85 mm for the inferior border length. This is significantly shorter compared to measurements published elsewhere, even though comparable reference points were used.

The last comparable measurement between the present study and previously studies is the extra-pelvic width of piriformis at the midline of the muscle belly. Haladaj *et al*. (2015) found a mean width of 32 mm, while Brooks *et al*. (2011) recorded right and left lower limb widths of 23.19 mm and 22.37 mm, respectively. Additionally, another publication recorded widths of 22.98 mm and 21.84 mm for the right and left limbs, respectively (Vicente *et al*., 2007). The widths recorded in the present study have a mean value of 17.0 mm, where the mean width measurement for the different population groups, namely; White/Caucasian, Mixed Race and South African Black, were 15.78 mm, 18.85 mm, and 20.02 mm, respectively. When comparing the widths of piriformis in the present study to literature published previously, the extra-pelvic width of piriformis is smaller in the present study reports. There are notable difference between subpopulation groups in the South African sample, with the mean width of piriformis for White/Caucasian specimens being statistically smaller than Mixed race or South African Black specimens. This comparison between population groups was statistically significant in the present study; however, a larger Mixed race and South African Black sample size is needed to further validate these findings.

Overall, there are no studies published in South Africa, or Africa that make use of these morphometric measurements, and thus, the researcher has no existing data to compare the results with. However, this study attempts to provide a foundation of literature for a South African population sample.

CHAPTER SEVEN:

CONCLUSION

In conclusion, the sciatic nerve plays an important role in the clinical intervention that takes place within the gluteal region. While researchers have described this nerve and its branches extensively in literature, the same is not true for the variations of the sciatic nerve, and especially the variation in the relations between the sciatic nerve and piriformis muscle. This is especially true for the continent of Africa, and its different population groups.

The present study attempts to change this, and provides a foundation of literature for the description of the morphology of the gluteal region in a South African population. Therefore, this study has set the stage for research into the variations to described morphology, and the prevalence of these variations in the South African population.

The present study has described the possible types of variations in the relationship between the sciatic nerve and piriformis. While this is the first known study based on the South African population, preliminary conclusions can be drawn. In the present study, a large study sample was used. This study sample has proven that the prevalence of piriformis variations, and related sciatic nerve variations, are comparable with the prevalence obtained in other regions of the world. The prevalence of variations is 12.5%, and is important for clinicians, as this translates to about one in every 10 South African patients that might present a variation in the gluteal region. Furthermore, when looking at specimens that belong to the South African White/Caucasian population group, the prevalence of variations is 17%. This translates to almost one in every five patients that might present with a variation in the gluteal region. However, further studies are needed in order to confidently reveal trends about the variation prevalence in the Mixed race and South African Black population groups, which makes up the majority of the population in South Africa.

The present study provides a foundation of literature for the South African population. However, further studies are needed for comparison and to solidify the results found in the present study. While there are significantly more variations present in a South African White/Caucasian population, the underrepresentation of South African Mixed race and South African Black specimens in this study, means that this assumption remains largely inconclusive.

Thus, speaking to the aim of the research, the prevalence has been reported for the variations in the relationship between the piriformis and sciatic nerve. This is also true for the prevalence of the variation in the sciatic nerve bifurcation levels. The morphometric analysis of piriformis and the sciatic nerve has not been documented intensively, thus detailed descriptions were given on these structures in the gluteal region. Additionally, comparisons were made between the sides, sexes, and different subpopulation groups.

LIMITATIONS AND FUTURE STUDIES

The study sample comprised of all the cadavers that were dissected by the undergraduate medical students, during the dissection for the respective undergraduate anatomy programmes. Therefore, the study sample is not an accurate and true reflection of the South African population. A limitation of the study is that results obtained by the researcher does not directly reflect the anatomy of the South African population, but only the sample that was incorporated in the present study.

The study could have benefited from a longer experimental period, as this would have allowed for the use of a larger sample size. Thus, the study was limited by the number of cadavers used at the three South African universities. A larger sample size could ensure that additional rare variations and anomalies are identified and analysed. The 340 lower limbs used is a considerably larger sample than previously reported studies.

The medical students dissected the cadavers that constituted the majority of the sample for this study. This meant that further dissection by the researcher was not always possible, in order to reveal additional anatomical landmarks in the gluteal region. These landmarks would have allowed for the measurement of additional morphometric points of importance, such as the placement of the sciatic nerve in relation to the medial and lateral osteological structures of the gluteal region, or the variability in the motility of the sciatic nerve during extension and flexion of the lower limb. Future studies should include the use of additional landmarks for detailed morphometric and anthropometric analysis, where possible.

In the present study, there was an unequal distribution of specimens in the different population and sex groups, which could have resulted in bias results reported. This is especially true for the population groups where the researcher obtained a larger number of White/Caucasian specimens, compared to fewer Mixed race and South African Black specimens. While the results might tend to the conclusion that there is a higher prevalence of variations in the relationship between piriformis and the sciatic nerve in the South African White/Caucasian population group, the lack of Mixed race and South African Black specimens could have meant that fewer specimens with variations were incorporated into the present study. Therefore, future studies should include larger numbers of Mixed race and South African Black specimens, as these subpopulation groups make up a significant majority in South Africa.

Lastly, to the researcher’s knowledge, this is the first study of its kind in South Africa. Therefore, no literature is available that can be compared to the results obtained in the present study. Additionally, very few studies make use of the many morphometric measurements used in the present study. Future studies on the South African population are needed for comparison, in order to reiterate the results found in the present study.

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