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# **Anatomical study of the superior cluneal nerve and its estimation of prevalence as a cause of lower back pain in a South African population**

by

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Dissertation to be submitted in full fulfilment of the requirements for the degree

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**Leigh-Anne Loubser**

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“For nothing will be impossible with God.” Luke 1:37

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“I profess to learn and to teach anatomy not from books but from dissections, not from the tenets of Philosophers but from the fabric of Nature.” - William Harvey

Leigh

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## Abstract

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*Background* Lower back pain (LBP) remains a common ailment among adult populations and a superior cluneal nerve (SCN) entrapment accounts for 10% of reported LBP cases. The diagnostic criteria of SCN entrapment include anaesthesia of the SCN. This entrapment can be caused by bone procurement procedures but tends to happen more spontaneously and particularly to sportsmen. This study aimed to describe the location of all three branches of the SCN as well as to estimate the prevalence of entrapment which causes LBP.

*Methods* The SCN was identified as it pierced the thoracolumbar fascia and crossed over the posterior part of the iliac crest on both sides of 50 adult cadavers. A sliding dial calliper was used to measure the distance from the posterior superior iliac spine (PSIS) to the SCN and from the midline lumbar spinous processes to the nerve. A total of 400 patient files were used to estimate the prevalence of SCN entrapment in a South African population.

*Results* The branches of the SCN were found to be  $72.6 \pm 4.2$  mm,  $76.6 \pm 4.4$  mm and  $79.6 \pm 4.4$  mm from the PSIS to the medial, intermediate and lateral branches respectively. From the midline to the medial, intermediate and lateral branches – the SCN was found to be  $77.9 \pm 4.2$  mm,  $79.6 \pm 4.4$  mm and  $89.5 \pm 4.5$  mm. It was estimated that the SCN being the cause of LBP to be 28%.

*Discussion* The measurements found in this study correlate with the measurements found in previous studies. However, this study failed to show sex differences and this could be attributed to sampling as well as chance due to human variation. This study estimated the prevalence of an SCN entrapment as a cause of LBP to be 28% compared to previous studies which estimate it to be 10%. The difference seen here can be a consequence of the limitation of this study in that it was conducted in a private practice.

# 1. Introduction

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Lower back pain (LBP) is one of the most common complaints seen by general practitioners and is a leading cause of debilitating ailments seen in the general adult population <sup>(1)</sup>. This condition is one of the major causes of workdays lost in the corporate industry and has an estimated prevalence of 80-90% in the general adult population <sup>(2)</sup>.

With the prevalence of nonspecific LBP in the general adult population being as high as 85–90% <sup>(2)</sup>, many cases go misdiagnosed or even undiagnosed. One of the causes, is the entrapment of the medial branch of the superior cluneal nerve (MSCN). The course of the MSCN puts it at risk for neural entrapment and can be the cause of nonspecific LBP in 10% of reported cases <sup>(3)</sup>. The presentation of this entrapment further confuses the diagnosis as it may present the same as a facet syndrome, lower lumbar disc problems or an iliolumbar syndrome <sup>(4)</sup>.

The current literature on the entrapment of the superior cluneal nerves (SCN) has given physicians the ability to distinguish between mechanical LBP and LBP caused by the entrapment of the SCN <sup>(5)</sup>. Many of the articles have explained and investigated the condition with regards to case studies. In these case studies, patients presented with nonspecific LBP for longer than 3 months and were majority sport related injuries which correlates with the statement made by Trescot in 2003 that the entrapment of the SCN is more a spontaneous occurrence as opposed to it happening due to complications from back surgery <sup>(6)</sup>. However, few investigations actually discuss the pure anatomy of the SCN. In 1998, Lu *et al.* <sup>(7)</sup> discussed the relationship of the SCN and the posterior superior iliac spine and the midline. This article was one of the first articles that proposed these relationships and have subsequently been used in investigations done by Kuniya *et al.* <sup>(8)</sup> and Loubser and co-workers <sup>(9)</sup>.

The current study aims to investigate the SCN in its entirety. It is of clinical importance that physicians are equipped with the knowledge of the where the SCN comes from, which muscles it transverses and estimate the prevalence of an entrapment in a South African population. We aim to highlight the variations between populations as it has

been shown in previous studies <sup>(9)</sup> that there is variation due to population differences. Kuniya *et al.* (2014) investigated the potential that entrapment of the SCN also presented with referred pain down the leg and in this study we also investigate this possibility and how often the entrapment presented this way <sup>(10)</sup>.

## 1.1. Aim and Objectives

The purpose of this study was to examine and report on the detailed anatomy of all three branches of the SCN and to obtain more information on the prevalence of a SCN entrapment as a cause of LBP in patients with chronic LBP.

### 1.1.1. Research objectives

- 1.1.1.1 Investigate the position of all three branches of the SCN in relation to the PSIS and the spinous processes of the lumbar vertebrae, i.e. the midline of the body.
- 1.1.1.2 Determine the root value of the SCN to gain better insight in the possible pain distribution with injury or entrapment.
- 1.1.1.3 Report on the presence of an osteofibrous tunnel and whether any of the three branches of the SCN pass through such a tunnel.
- 1.1.1.4 Examine hospital records of patients that complained of LBP to determine the diagnosed cause of their complaint.
- 1.1.1.5 Determine the prevalence of a confirmed SCN entrapment in the patients mentioned in 1.1.1.4.

## 2. Literature Review

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Pain is a sensation that results from an extraordinarily complex and interactive series of mechanisms integrated at all levels of the neuroaxis; from the periphery to higher cerebral structures. Pain is usually elicited from the activation of two specific nociceptors connected with C- and A-delta fibres or from injury to sensory fibres or from damage to the central nervous system in the case of neuropathic pain <sup>(11)</sup>. The nature of pain is patient specific and because of this, physicians must use various tools to help differentiate and diagnose chronic pain from chronic pain syndrome (CPS). The mechanisms and pathophysiology of the pain are obscure, rendering the classic medical treatment model inappropriate; and physical findings are usually inconclusive and considered nonorganic <sup>(12)</sup>.

Chronic pain has been defined in numerous ways in an attempt to enable the physician to give a definitive diagnosis, but it will always remain subjective and patient specific. Manchikanti *et al.* (2009) defines chronic pain as, “pain that persists longer than six months after an injury and beyond the usual course of an acute disease or a reasonable time for a comparable injury to heal; that is associated with chronic pathological processes that cause continuous or intermittent pain for months or years; that may continue in the presence or absence of demonstrable pathologies; may not be amenable to routine pain control methods; and healing may never occur.” <sup>(11)</sup> By this very definition, a chronic pain diagnosis is beset with controversy. In many cases, physicians understand this diagnosis as a persistent pain not amenable to routine pain control methods.

CPS is a complex pain condition with physical, psychological, emotional, and social components <sup>(11)</sup>. Addison (2009) describes patients with CPS as one of the most common, difficult, and frustrating clinical challenges that a physician can deal with. CPS is usually referable to an organ system but seldom results in a definitive and treatable diagnosis. It has a few clinical aspects that help in the differentiation from chronic pain: the pain rarely serves a biological function; psychological and environmental factors lead to the development of “chronic pain behaviours”. These “chronic pain behaviours” are seen as common characteristics that patients with CPS

exhibit. The first and most common is excessive “pain talk” where patients complain constantly about being in pain and how much pain they are in to a point where all conversations are about this. Increased anxiety is also a symptom that comes from patients having to function in society when they’ve assumed the sick role. Inappropriate medication use by patients is definitely not uncommon with patients with CPS and they are often “taking 30 to 40 pills daily of various medications” but they are very rarely seen to have a psychological dependence. Decreased activity and movement and bed rest also reinforces the behaviour that is expected from someone who is “sick” (12).

CPS is different to chronic pain itself and must be used with caution because grouping pain problems together under a general disorder may allow important psychological differences to be masked and left untreated. Consequently, chronic pain usually exists in the absence of CPS but CPS always presumes the presence of chronic pain (11).

## 2.1. Lower Back Pain

As the studies into the complex structure of the spine continue, this area not only involves bony elements but multiple components of neurological and muscular tissue as well. With so many factors contributing to the function and homeostasis of this area, physicians dealing with LBP complaints should be aware that all these complex interconnected structures lend itself to the idea that there could be multiple causative factors for the onset of acute or chronic LBP (13).

LBP is defined as pain, muscle stiffness or tension that is localized below the inferior margin of the 12<sup>th</sup> rib and above the inferior gluteal folds with or without sciatica (pain affecting the lower back, coxa, or lateral side of the thigh); and is described as chronic when it persists for 12 weeks or more. This condition is also one of the most common musculoskeletal complaints that a general practitioner will have to deal with. Acute LBP is an episode of LBP that resolves itself within 6 weeks. Subacute LBP is pain that lasts between 6 to 12 weeks. A further classification of LBP is whether it is nonspecific or specific in its causes. Nonspecific LBP is pain not attributed to a recognizable pathology, e.g. infection, tumours, osteoporosis, rheumatoid arthritis,

fractures, or inflammation <sup>(5)</sup>. Specific causes of LBP account for approximately less than 15% and are generally seen as uncommon causes <sup>(1)</sup>. Very few cases of LBP are as a result from physical causes. Any trauma to the back, such as a motor vehicle accident or a fall in younger people or lesser traumas such as osteoporotic fractures are precursors to the known origins of chronic LBP. Even less likely causes of specific LBP are vertebral infections and tumours or their metastases <sup>(14)</sup>. The prevalence of nonspecific LBP is estimated to be 80 to 90% of the general adult population with approximately 50% of cases having no obvious cause even with the use of new imaging techniques <sup>(4)</sup>. In consultation, practitioners should establish if the pain is mechanical or inflammatory and are urged to look for the “red flags” before specific causes are ruled out, these red flags are listed below:<sup>(1)</sup>

- Pain in patients <20 years and >55 years
- Pain not relieved on rest or posture modification
- Pain unchanged despite 2-4 weeks of treatment
- History of malignancy
- Immunosuppressed status
- Fever/malaise/weight loss
- High fracture risk, e.g. osteoporosis
- Neurological impairment
- Bladder or bowel dysfunction
- Severe morning stiffness as the primary complaint
- Inability to ambulate

A few of the known and possible causes of LBP include:

*Lumbosacral strains*, which is most commonly seen in manual labourers who carry heavy loads. There isn't a preference between the left and right side, but the pain is generally located in the lumbosacral region. Modern imaging techniques often give negative results as this condition involves the injury of the soft tissue in the lumbosacral area. The high correlation of this complaint to worker's compensation has led studies to exclude these cases from LBP studies <sup>(13)</sup>.

*Posterior Facet Syndrome* refers to the early onset of degenerative arthritis in the posterior facet joints of the vertebral column <sup>(14)</sup>. Each level of the spine acts a three-joint complex. There are two facet joints in the back and an intervertebral disc in front that comprises each intervertebral segment. This tripod ensures great stability, supports all the weight above each level and gives support for the movement in all directions. The posterior facet joints are synovial and endure constant and repetitive motion causing them to become worn and susceptible to injury. They become inflamed and may cause pain <sup>(15)</sup>. Patients suffer from loss of motion that causes stiffness of the whole spine and subsequently LBP. Posterior facet syndromes are seen most commonly in elderly patients <sup>(14)</sup>.

*Sacroiliac Syndromes* refer to the pain associated with the hypermobility or hypomobility of the sacroiliac (SI) joint. The SI joint is a true diarthrodial joint that joins the ilia of the os coxa to the sacrum on both the left and right hand sides of the pelvis. Hypermobility of the joint can be that the joint has become “loose” due to spasm of the paraspinal muscles which include the iliocostalis, longissimus and spinalis muscles that eventually become weakened or sprained resulting in abnormal movements of the SI joint <sup>(16)</sup>. Hypomobility of the joint results in the SI joint becoming stiff and essentially “locking” and this is generally a consequence of degenerative diseases. The symptoms of this syndrome include general lower backache during certain movements <sup>(17)</sup>.

*Spondylolisthesis*, which is the anterior displacement of one vertebra over the vertebra beneath it and can be asymptomatic <sup>(13)</sup>. Forward slippage of the vertebra is referred to as anterolisthesis and backward slippage of the vertebra is referred to as retrolisthesis <sup>(19)</sup>. It occurs most often in the lumbar spine. A consequence of this slippage could result in the narrowing of the intervertebral foramen where the nerve roots exit the spinal column from the spinal cord. This can cause general weakness, pain and numbness over the areas supplied by the affected nerve. Overcompensation by the paraspinal muscles could also lead to lumbosacral strain as well <sup>(18)</sup>.

*Osteoporosis* affects the vertebral bodies and leads to abnormally porous bone that is compressible like a sponge. Bone density decreases after 35 years of age and occurs more rapidly in woman after menopause. Key risk factors for osteoporosis include genetics, lack of exercise, lack of calcium and vitamin D, personal history of fractures as an adult, cigarette smoking, excessive alcohol consumption, history of rheumatoid arthritis and low body weight <sup>(20)</sup>. The vertebral bodies often collapse due



to compression and the intervertebral discs can often be identified as bulging or herniating <sup>(13)</sup>.

*Neuropathy* can be caused by several different factors and can affect both the peripheral and central nervous systems. Peripheral nerve damage can result in paraesthesia, pain, numbness or general body weakness. However, neuropathy can also be idiopathic with no obvious or known cause <sup>(13, 21)</sup>.

*Sciatica* is a painful condition that can be felt from the lower back, through the gluteal region, and as far down as the toes. It is essentially caused by the compression of the sciatic nerve from either a herniated or slipped intervertebral disc or spasm of the piriformis muscle <sup>(13)</sup>. Pseudo-sciatica is the term given to pain that presents the same way as sciatica but all investigations have been negative. Entrapment of the SCN has been found to have the same clinical presentation. It has been shown that entrapment of the MSCN can account for approximately 10% of all LBP cases and this condition often goes undiagnosed or misdiagnosed because of the similarities with the abovementioned conditions <sup>(3)</sup>.

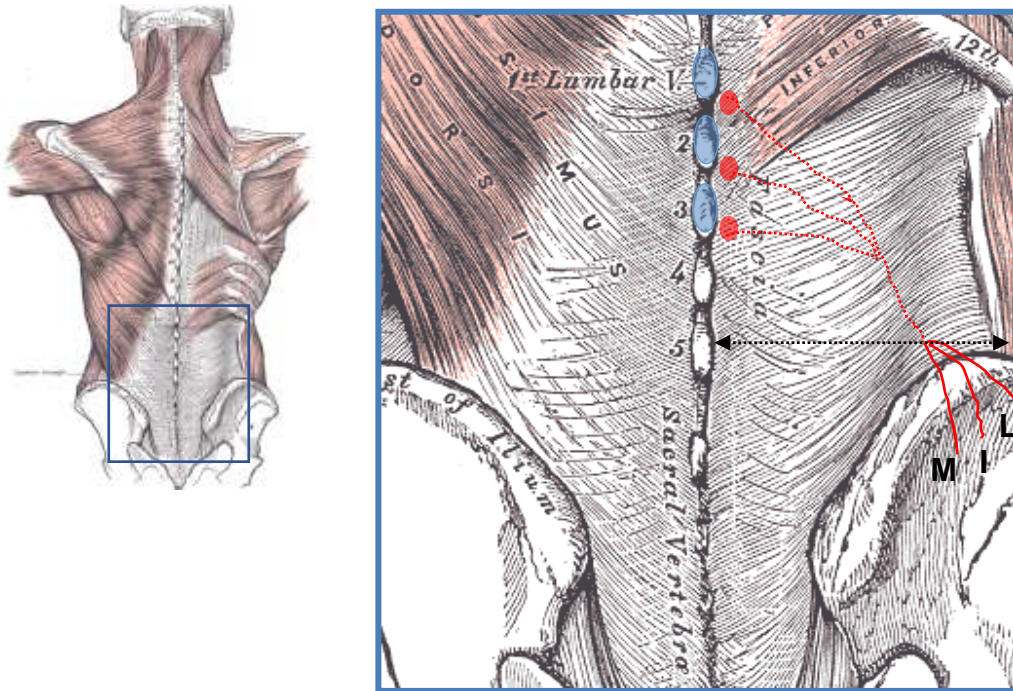
## 2.2. Anatomy of the Superior Cluneal Nerve

The SCN's primary function is to provide sensory innervation over the iliac crest and the upper middle buttock <sup>(22)</sup>. There are, however, conflicting reports of where the SCN originates from. Lu *et al.* (1998) confirmed what is commonly reported in anatomical texts and with the origin to be from the cutaneous branches of the dorsal rami of 1<sup>st</sup> to the 3<sup>rd</sup> lumbar spinal nerves (L1 – L3) <sup>(7)</sup>. On the other-hand Kuniya *et al.* (2013) reported the origin to be more variable. They reported that the root value of the SCN could range between the dorsal rami of the 11<sup>th</sup> thoracic spinal nerve to the 4<sup>th</sup> lumbar spinal nerve (T11 – L4) <sup>(8)</sup>.

At the origin, branches merge to form the SCN and pierces the psoas major, iliocostalis lumborum, longissimus thoracis and spinalis thoracis muscles on its path to supply the skin over the upper middle buttock. It then runs posterior to the quadratus lumborum muscle and pierces the thoracolumbar fascia as it crosses over the iliac crest (Figure 1). As it crosses over the iliac crest the SCN passes through an osteofibrous tunnel formed by the iliac crest posteriorly and thoracolumbar fascia anteriorly <sup>(9)</sup>. The SCN



divides into three branches, namely the MSCN, intermediate (ISCN), and lateral (LSCN) branches. In the cases where the three branches cross the iliac crest separately, they can be found approximately 70 to 80 mm, 75 to 85 mm and 82 to 90 mm lateral from the midline at the level L5 vertebra, respectively <sup>(8)</sup>.



*Figure 1: Course of the SCN and its three branches (shown in red); M = medial branch approximately 70 – 80mm from the midline; I = intermediate branch approximately 75 – 85mm from the midline; L = lateral branch approximately 82 – 90mm from the midline (Adapted from Standing et al., 2008).*

Some anatomical studies have noted that all the branches of the SCN pierced the thoracolumbar fascia above the iliac crest. In contrast, Maigne *et al.* (1989), Lu *et al.* (1998), and Xu *et al.* (1996) reported that all medial branches passed through an osteofibrous tunnel that is present between the iliac crest and the thoracolumbar fascia <sup>(7, 23, 24)</sup>. Moro *et al.* (2007) reported that 80% and Yazaki *et al.* (1997) reported that 95% of the MSCN passed through an osteofibrous tunnel <sup>(25, 26)</sup>. In a study performed by Loubser *et al.* (2015), the authors reported that only one in 54 (2%) cadavers showed an actual entrapment of the MSCN and Lu *et al.* (1998) reported that 2 in 10 (20%) cadavers showed an entrapment of the MSCN <sup>(7,9)</sup>. Entrapment of the SCN is thought to be a rare occurrence <sup>(4)</sup>. Kuniya *et al.* (2013) conducted a more in-depth

study in which they reported on the prevalence of each of the branches passing through the thoracolumbar fascia <sup>(8)</sup>, their results are presented in Table 2.

*Table 1: Prevalence of each branch passing through the osteofibrous tunnel over the iliac crest <sup>(8)</sup>*

Description of branches passing through the osteofibrous tunnel	Prevalence (n=109)
No branches	44%
MSCN only	22%
ISCN only	10%
LSCN only	3%
MSCN and ISCN	10%
MSCN and LSCN	1%
ISCN and LSCN	3%
All three branches	3%

The proposed criteria for the diagnosis of a SCN entrapment is if the pain presents itself as unilateral and localised projecting from the iliac crest to the upper buttock, a myofascial trigger point may be palpated and relief can be found by performing a regional nerve block. It has been reported that entrapment of the SCN can also be a cause of referred pain down the thigh caused by the shared nerve root value of the SCN, also referred to as “pseudo-sciatica”. Pseudo-sciatica is a condition that results when nerves, that share the same nerve root value as the sciatic nerve (L4-S3), become entrapped or injured thereby presenting the same as sciatica. All scans using lumbosacral radiography, computerised tomography (CT) and magnetic resonance imaging (MRI) should be clear of any other pathological signs that could be causative factors of LBP <sup>(27)</sup> and a SCN entrapment should be considered as a cause of LBP when all other causes have been ruled out.

### 2.3. Causes of a SCN Entrapment

The posterior iliac crest is an excellent site for autogenous bone procurement procedures for osteoinduction, osteoconduction and osteogenesis as it affords the

ability to yield a large amount of corticocancellous bone with multiple applications and this entrapment has been described because of complications from bone procurement procedures using the iliac crest <sup>(3)</sup>. Both Lu *et al.* (1998) and Loubser *et al.* (2015) reported that keeping skin incisions and procurement procedures in a safe zone of less than 60 mm from the posterior superior iliac spine (PSIS) would avoid post-operative complications and stay clear of the MSCN during these procedures (Figure 2) <sup>(7, 9)</sup>.

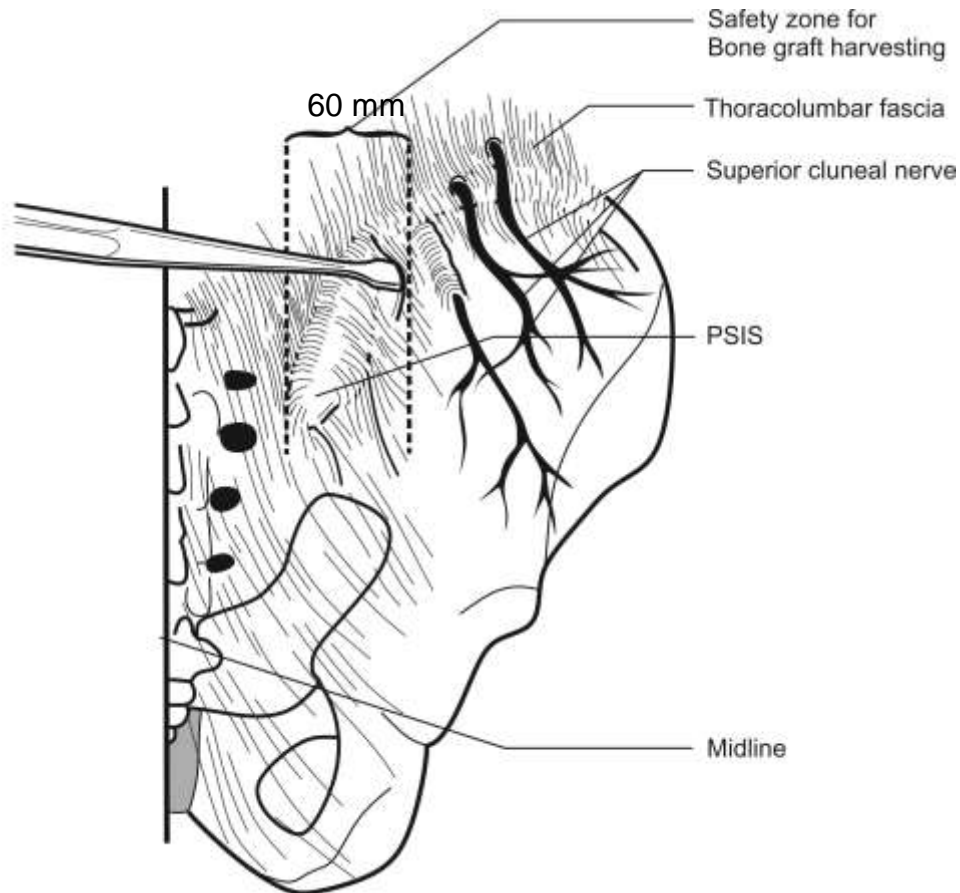


Figure 2: Depiction of the "safety zone" during bone harvesting procedures <sup>(7)</sup>

However, Trescot (2003) noted that this entrapment happened more spontaneously rather than due to complications of bone harvesting <sup>(6)</sup>. There are two recognised nerve pathologies that could be the cause of a spontaneous entrapment. The first recognised nerve pathology is the entrapment of the SCN as it passes through the osteofibrous tunnel over the iliac crest. Here, thickened fibrous tissue causes a restricted path for the SCN to pass through to reach the area of cutaneous innervation. This would normally be treated with surgical intervention to release the band formed over the

nerve by the thoracolumbar fascia and give complete relief to the patient. The second recognised nerve pathology is caused by a muscle spasm of any of the muscles (psoas major, paraspinal muscles and quadratus lumborum muscles) that the SCN passes through along its course. Usually, a nerve block performed at the point where the nerve crosses over the iliac crest, as well as treatment with antispasmodics and anti-inflammatories will allow the affected muscles to heal and the pain to subside. This should give the patient complete relief.

#### 2.4. Case Studies

There have been many articles that discuss the entrapment of the SCN with regards to case studies that have been encountered during consultations. From the literature, it has been noted that this entrapment generally affects sportsmen who engage in activities that require constant flexion or extension of the lower back such as cricket and tennis <sup>(29, 31)</sup>.

*Case Study 1:* A 17-year-old female who played tennis presented with a 3-month history of pain radiating from the left buttock to the posterior thigh. She had the inability to sit for longer than 10 minutes or run short distances. Subsequent investigations with modern imaging techniques could not detect any abnormalities. A diagnosis of facetogenic pain was made and the patient was treated with a facet block and continuous epidurals for a month with no improvement. A physical exam was done where a trigger point was found 60 mm to the left of the midline over the iliac crest, manifesting itself as a mobile tender mass that caused pain radiating from the lower back to the posterior thigh. This was consistent with the distribution of the MSCN. Local anaesthesia was given in conjunction with a corticosteroid at the sight of the trigger point. This was effective in minimizing the pain. After 3 injections of the previous combination at weekly intervals, the patient was completely relieved of pain <sup>(29)</sup>.

*Case Study 2:* A 66-year-old male presented with a 3-month history of LBP that was treated conservatively. The symptoms worsened and he had difficulty sitting down and rising from the sitting position. At the time of admission, he reported LBP in the left lateral iliac crest region with radiation to the left lateral buttock, which interfered with his daily activities. His LBP did not worsen when he sat for long periods of time

but did get worse when he walked upright with an extended lumbar position or bent over. Trigger points eliciting severe pain were located at the left lateral iliac crest of the superior rim. Tactile stimulation elicited pain radiating from the low back down to the posterior thigh. Although SCN block performed four times dramatically reduced his pain, it returned after only a few days. Surgery was opted for. After the surgical release of osteofibrous tunnel, the SCN was decompressed and the patient experienced immediate pain relief postoperatively <sup>(30)</sup>.

*Case Study 3:* A 31-year-old professional cricketer playing at an elite level presented with a 5-month history of new onset left iliac crest and buttock discomfort superimposed on the background of generalised back problems for the preceding 12 months. He presented with point tenderness over the left iliac crest 80 mm from the midline, and pain radiating in a fan shape inferior and lateral from this location. There were no symptoms distributed from the groin or thigh and his back was relatively pain free on presentation. On examination, there was point tenderness to palpation of the iliac crest 80 mm from the midline and pain in the buttock region with deep squats. Infiltration of local anaesthetic into the point of maximal tenderness to palpation (80 mm laterally from the midline and 6 mm inferiorly to the iliac crest) on two separate occasions resulted in a clear improvement in symptoms with a pain-free interval. Permission was given to do a surgical release of the fibrous band compressing the SCN. An oblique incision was made at 85 mm from the midline at the level of the iliac crest. The MSCN was seen tracking inferiorly to the crest and seen to emerge from beneath the fibro-osseous fascia before bifurcating. The thoracolumbar fascia was released and a fat graft was placed over the nerve release site. The patient recovered well and was able to return to cricket four weeks post-surgical decompression <sup>(31)</sup>.

## 2.5. Treatment of a SCN entrapment

The most widely accepted and first line treatment for SCN entrapment syndrome is injecting local anaesthetic solution over the iliac crest in the area coinciding with the area of subcutaneous innervation. Talu *et al.* (2000) described a technique using fluoroscopic guidance to localise the SCN over the iliac crest <sup>(28)</sup>. The superficial tissues and thoracolumbar fascia were infiltrated, with 20 ml of 0.5% bupivacaine and 80 mg of triamcinolone solution, approximately 70 to 80 mm lateral to the midline at

the level of the L5, this was found to give complete pain relief to the patient. Akbas *et al.* (2005) also used fluoroscopic guidance to identify the position of the SCN over the iliac crest but there are discrepancies in the level of the lumbar vertebrae and local anaesthesia that was used <sup>(27)</sup>. They described the procedure using L4 and they used 3 ml of 0.2% ropivacaine with 20 ml of triamcinolone as a local anaesthetic and reported complete pain relief.

Although entrapment of the SCN and the treatment thereof has only been sporadically reported, even fewer articles describe the anatomical location of all three branches of the SCN. Pain specialists and general physicians will be better equipped with the detailed knowledge of the anatomy of the SCN and its prevalence of entrapment. This will help to give a definitive diagnosis of not only the cause of the LBP but also to differentiate between diagnoses of chronic pain caused by the entrapment and CPS. Patients with this ailment will be able to find pain relief quicker.



### 3. Materials and Methods

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#### 3.1. Cadaveric Study

A total of 50 formalin-preserved cadaveric specimens were dissected to examine the anatomy of the SCN. The sample comprised of 33 males and 17 females older than 18 years of age. Table 3 summarises the demographic information of this cadaveric sample.

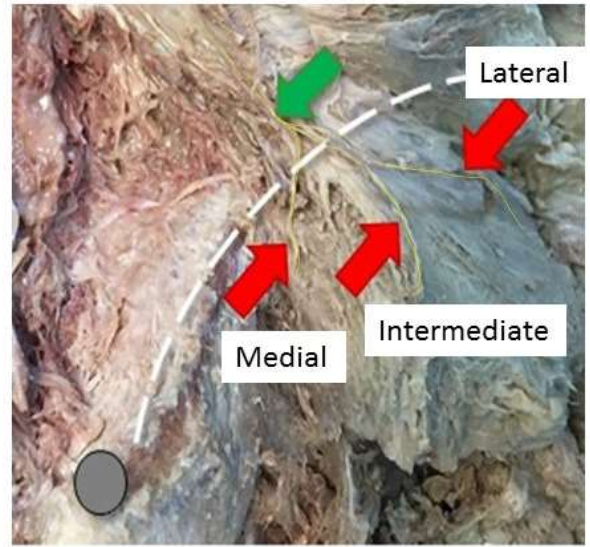
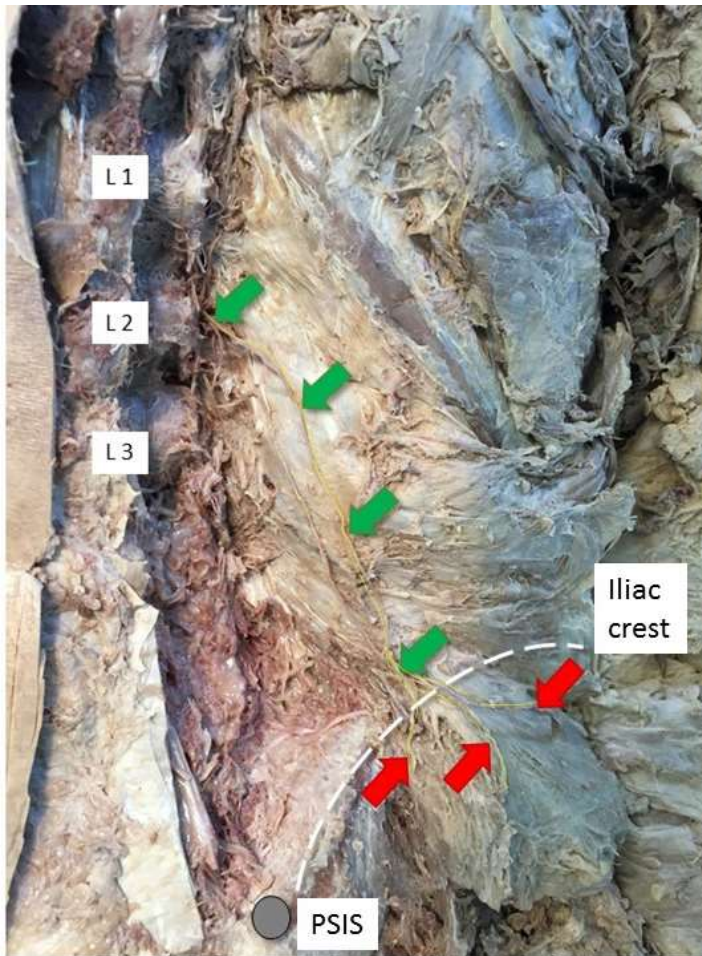
*Table 2: Cadaver demographics*

	<b>Age (years)</b>	<b>Height (m)</b>	<b>Weight (kg)</b>	<b>BMI (kg/m<sup>2</sup>)</b>
<b>n</b>	50	50	50	50
<b>Mean</b>	71	1.69	57.44	19.90
<b>SD</b>	14	0.11	18.52	5.49
<b>Min</b>	22	1.43	29.60	12.30
<b>Max</b>	91	1.90	102.40	35.00

All of the cadavers were obtained from the Department of Anatomy, Faculty of Health Sciences at the University of Pretoria. All BMI ranges were included for statistical purposes, all cadavers were weighed and the height was measured in the Department of Anatomy prior to being embalmed. Bilateral dissections were performed on the lower back from the 12<sup>th</sup> thoracic vertebra to the inferior gluteal fold.

Cadavers were placed in a prone position, the skin removed over the lower back and gluteal region from the midline laterally. Through careful dissection over the iliac crest, all three branches (MSCN, ISCN and LSCN) were identified (Figure 3). Once all branches were identified correctly, pins were placed in a horizontal plane into the spinous processes (midline) of the vertebral column, ipsilateral PSIS, as well as the MSCN, ISCN, and LSCN at the point where they cross the iliac crest. A sliding dial calliper was used to take measurements (to an accuracy of 0.01 mm) of the linear distance from the PSIS to each branch, as well as the horizontal distance from the midline to each branch. To determine the vertebral level, the spinous processes and lamina of the L4 and L5 vertebra were exposed. When the midline to the SCN

measurement was taken – the vertebral level that coincided with the horizontal plane was noted.



*Figure 3: Dissection of cadaver specimens on the left side. The red arrows show the terminal branches (MSCN, ISCN, and LSCN) and the green arrows show the path of the SCN up to where it originates from L1 spinal nerve.*

After the measurements were taken, the nerve was traced back to the nerve roots, where possible, by separating and removing the back muscles and following the nerve proximally.



The following was captured onto a data sheet:

1. All measurements of the three branches from both PSIS and midline to all three branches.
2. The vertebral level at which the branches crossed over the iliac and the measurements were taken at.
3. Root value of the SCN.
4. Cadaver demographics – height, weight, age, sex, and BMI
5. Whether or not the SCN branched before or after passing through the osteofibrous tunnel.

### 3.2. Estimation of Prevalence Study

The sample consisted of 400 patient record of which 148 were males and 252 were females. These patients were seen by Dr RP Raath at the Jacaranda Pain Clinic during the years 2014 to 2017. Patient records were randomly selected and the complaint of LBP was the only inclusion criteria. Patients were not excluded based on their age, height or weight.

*Table 3: Patient demographics*

	<b>Age (years)</b>	<b>Height (m)</b>	<b>Weight (kg)</b>	<b>BMI (kg/m<sup>2</sup>)</b>
<b>n</b>	400	400	400	400
<b>Mean</b>	57.6	170.01	81.38	28.12
<b>SD</b>	17.43	0.12	20.73	7.20
<b>Min</b>	16	1.05	42	15.81
<b>Max</b>	96	2.04	160	79.82

During the collection of the data from the patient files – patient demographics (Table 3), the diagnosis, as well as the recorded treatment was noted. For the diagnosis of each patient, it was important to first confirm if the patient had reported LBP. If the patient was diagnosed with LBP, then it was checked if the patient had the diagnosis of a SCN entrapment confirmed by means of a nerve block in the region of the SCN. When it came to the treatment of the confirmed SCN entrapment, it was noted whether

the patient had a surgical release or if the patient was treated conservatively (with analgesics and anti-inflammatories).

In the patients with a confirmed SCN entrapment, the impact of the entrapment was of interest. The impact of this entrapment from the patients perspective was available in each patient file in the form of a questionnaire. Upon their first consultation, each patient was asked to rate – on a scale from 0 (not at all) to 10 (severe) – the impact that the pain had on various social aspects of their social life. This questionnaire forms part of the initial consultation with the physician and was not administered specifically for the study. There were eight different social aspects included in the questionnaire and they were:

1. Reduced social life
2. Problem sleeping
3. Pain
4. Problems with light activity
5. Problems with strenuous activity
6. Problem doing job
7. Reduced energy and strength
8. Low spirit

Also available in the patient files were a chart (as seen in Figure 4) whereupon they had to indicate the exact location(s) where they experienced the pain. Each area was given a corresponding number to quantify the prevalence of LBP and referred leg pain for statistical purposes.

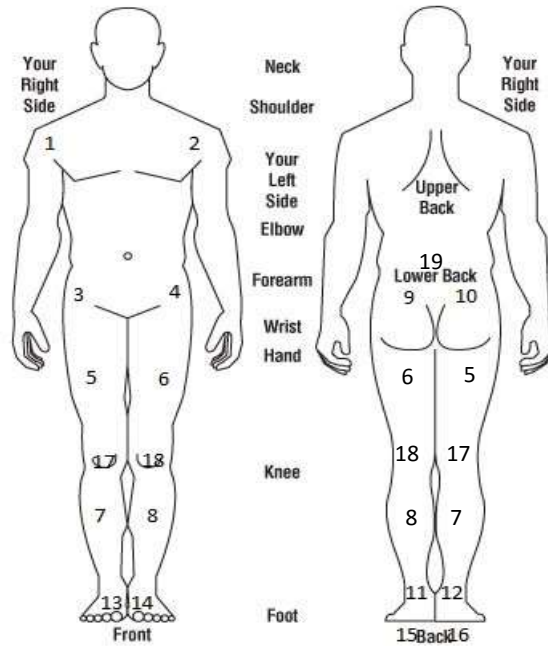


Figure 4: Chart used by patients to indicate where they experienced pain

### 3.3. Exclusion criteria

#### 3.3.1. Cadaveric Study

Cadavers with previous surgery, pathology or have been previously dissected where the thoracolumbar fascia and iliac crest was not intact or exposed were excluded. There were no exclusion criteria with regards to age, BMI or sex.

#### 3.3.2. Estimation of Prevalence Study

All patients that came to the Jacaranda Pain Clinic over the years 2014 – 2017 with a chief complaint of LBP was used in this study. To estimate the prevalence of a SCN entrapment as a cause of LBP, all patients that complained of either LBP, thigh or leg pain was included in this study. There were no exclusion criteria for age, BMI or sex.

### 3.4. Statistical Analysis

#### 3.4.1. Cadaveric Study

The Shapiro-Wilk (SWILK) test as well as the Wilcoxon signed-rank test was performed on all measurements to determine if the data was normally distributed.

The SWILK test tests the null hypothesis that a sample comes from a normally distributed population. If the p-value is less than the chosen alpha level, then the null hypothesis is rejected and there is evidence that the data tested are not from a normally distributed population<sup>(32)</sup>. The Wilcoxon signed-rank test is a non-parametric statistical hypothesis test used when comparing two related samples or repeated measurements on a single sample to assess whether their population mean differ. It can be used as an alternative to the paired Student's t-test when the population cannot be assumed to be normally distributed<sup>(33)</sup>. Both these tests were used to compare the left and right sides for normality of data as well as whether or not there was a difference in the measurements for each branch on the left and right side.

Further hypothesis testing was done on the sample to assess sex differences between each measurement. The Mann-Whitney Wilcoxon Rank-sum test was performed on the measurements to be seen as normally distributed<sup>(34)</sup>. The T-test with equal variances was performed on the data to determine whether or not they were significantly different from each other<sup>(35)</sup>. The Welch test was performed on the measurements that were significantly different from each other and is more reliable when the same has unequal variances and unequal sample sizes<sup>(36)</sup>.

The Fischer's exact test was used to compare male vs. female. The null hypothesis is that male and female are equally likely to have the same distribution and that there is no differences in measurements<sup>(33)</sup>. This statistical analysis was performed to analyse the sex differences in the root value of the SCN as well as the presence of an osteofibrous tunnel.

### 3.4.2. Estimation of Prevalence Study

Proportions were used to establish how many patients (n=400) experienced LBP. Of those confirmed LBP patients, how many had a SCN entrapment. It was then of interest how many of those confirmed SCN entrapment patients opted for conservative treatment or surgery.

When analysing the Social Impact of a SCN entrapment, scores out of 10 were collected for each aspect. It was of interest which aspect ranked the highest and affected the patients the most from their perception of living with the condition.

Referred pain experienced by each patient was calculated in proportion to the pain experienced by all the patients. Frequency of each area is important to the physicians in practice when it comes to identifying this entrapment.

### 3.5. Ethical Considerations

Permission was obtained from Dr RP Raath to use his patient files for the Estimation of Prevalence Study. This included maintaining patient confidentiality, using his notes during consultation as well as the relevant information needed for this part of the study.

Ethical clearance was obtained from the Research Ethics Committee (reference number 304/2016) at the University of Pretoria in July 2016 and permission from the MSc Committee at the University of Pretoria in June 2016.

## 4. Results

### 4.1. Cadaveric Study

#### 4.1.1. Position of all three branches of the SCN in relation to the PSIS and midline

The results for all the measurements are summarised in Tables 4 and 5.

*Table 4: Results of measurements for all three branches (mm) from the PSIS*

	PSIS					
	Left side			Right side		
	MSCN	ISCN	LSCN	MSCN	ISCN	LSCN
<b>n</b>	49	43	41	46	41	39
<b>Mean</b>	70.9	74.9	78.1	74.4	78.3	81.2
<b>SD</b>	16.3	15.9	15.5	13.7	13.6	13.2
<b>Min</b>	41.8	45.7	47.3	35.1	37.4	38.9
<b>Max</b>	114	116.2	120	106	109	129

*Table 5: Results of measurements for all three branches (mm) from the midline*

Midline						
	Left side			Right side		
<b>n</b>	MSCN	ISCN	MSCN	ISCN	MSCN	ISCN
<b>Mean</b>	48	42	48	42	48	42
<b>SD</b>	78.9	79.8	78.9	79.8	78.9	79.8
<b>Min</b>	13.5	13.0	13.5	13.0	13.5	13.0
<b>Max</b>	39.1	41.3	39.1	41.3	39.1	41.3
<b>n</b>	116	118	116	118	116	118

Both the Shapiro-Wilk (SWILK) Test and the Wilcoxon signed-rank test was used to compare the left and right sides for both the PSIS to the nerve and the midline to the nerve distances. When multiple hypotheses are tested, the chances of a rare event

increases and the likelihood of making a Type I error increases. The Bonferroni correction compensates for that increase by testing each individual hypothesis with a  $p\text{-value} = \alpha/m$ , where  $\alpha = 0.05$  and  $m = 6$  (number of hypotheses to be tested). Therefore, to compare left and right sides for both PSIS and midline to the nerve, the  $p\text{-value} = < 0.0083$  for the measurement to be statistically significant. Table 6 gives a summary of the  $p\text{-values}$  of each comparison, from this we can see that there is no difference between left and right sides except that due to chance.

*Table 6: Comparison of left and right sides of both the PSIS and midline measurements*

<b>Measurement</b>	<b>p-value</b>
PSIS-MSCM (L) vs. PSIS-MSCN (R)	0.274
PSIS-ISCM (L) vs. PSIS-ISCN (R)	0.225
PSIS-LSCM (L) vs. PSIS-LSCN (R)	0.280
Midline-MSCN (L) vs. Midline-MSCN (R)	0.414
Midline-ISCN (L) vs. Midline-ISCN (R)	0.988
Midline-LSCN (L) vs. Midline-LSCN (R)	0.301

*Key: (L) = Left; (R) = Right*

Table 7 shows the results of each measurement taken from the PSIS and midline as well as the left and right sides. The SWILK test was performed on the data to determine if the data were normally distributed. Only the measurements taken from the PSIS to the ISCN on the left, PSIS to the LSCN on the right, midline to the ISCN and LSCN was seen to be statistically significant and cannot be rejected under the null-hypothesis ( $p\text{-value} < 0.05$ ). However, the rest of the data were seen to be not normally distributed and can be rejected under the null-hypothesis.

Table 7: Shapiro-Wilk (SWILK) W test for normal distribution of data

	n	Mean	SD	Min	Max	p-value
<b>PSIS-MSCN (L)</b>	49	70.93	15.85	41.8	114	0.0619
<b>PSIS-ISCN (L)</b>	43	74.85	17.48	45.7	116.2	0.0495 *
<b>PSIS-LSCN (L)</b>	41	78.13	17.17	47.3	120	0.1599
<b>PSIS-MSCN (R)</b>	46	74.37	13.31	35.1	106.3	0.4714
<b>PSIS-ISCN (R)</b>	41	78.32	13.70	37.4	108.6	0.1091
<b>PSIS-LSCN (R)</b>	39	81.17	15.19	38.9	129	0.0109 *
<b>Midline-MSCN (L)</b>	48	78.53	15.00	39.1	116	0.8602
<b>Midline-ISCN (L)</b>	42	79.75	17.41	41.3	118	0.1019
<b>Midline-LSCN (L)</b>	40	81.59	17.61	43.2	123	0.2988
<b>Midline-MSCN (R)</b>	45	77.18	16.68	46.7	129.6	0.0930
<b>Midline-ISCN (R)</b>	40	79.45	17.56	48.8	131.7	0.0305 *
<b>Midline-LSCN (R)</b>	38	97.46	92.14	50.4	138	0.0000 *

\*statistically significant

Key: (L) = Left; (R) = Right

Further hypothesis testing was done to determine whether sex differences were seen amongst the sample. Table 8 shows a summary of the type of test done, p-value as well as the 95% confidence interval for this data. From these results, we can conclude that for this sample we failed show sex differences between males and females.



Table 8: Hypothesis Testing to test for sex differences within the sample

Measurement	n		Name of Test	p-value	95% Confidence Interval	
	Female	Male				
PSIS-MSCN (L)	17	32	T-test with equal variances	0.0561	-0.243	18.35
PSIS-ISCN (L)	16	27	Mann-Whitney Wilcoxon Rank-sum Test	0.1870		
PSIS-LSCN (L)	15	26	Welch Test	0.2351	-4.831	18.81
PSIS-MSCN (R)	16	30	T-test with equal variances	0.1793	-2.654	13.79
PSIS-ISCN (R)	15	26	Welch Test	0.3082	-4.725	14.375
PSIS-LSCN (R)	15	24	Mann-Whitney Wilcoxon Rank-sum Test	0.3191		
Midline-MSCN (L)	16	32	Welch Test	0.7141	-7.666	11.080
Midline-ISCN (L)	15	27	Welch Test	0.9090	-11.742	10.482
Midline-LSCN (L)	14	26	Welch Test	0.8818	-12.209	10.536
Midline-MSCN (R)	15	30	Welch Test	0.7613	-8.987	12.164
Midline-ISCN (R)	14	26	Mann-Whitney Wilcoxon Rank-sum Test	0.8760		
Midline-LSCN (R)	14	24	Mann-Whitney Wilcoxon Rank-sum Test	0.3002		

Key: (L) = Left; (R) = Right

The results of the vertebral level used to measure the SCN from the midline are seen in Table 10. A Fischer's exact test was used to determine the statistical significance in the difference between male and females. The p-value equalled 0.728, therefore, no statistical significant difference was found and the sample could be grouped together. This data showed that 78% of measurements taken from the midline were done on the level of L5 and 22% of the measurements were done at the level of L4.

*Table 9: Vertebral level used to measure the SCN from the midline*

Vertebral Level	Female	Male	Total
L4	8	3	11
L5	25	14	39
<b>Total</b>	<b>33</b>	<b>17</b>	<b>50</b>

#### 4.1.2. Root value of the SCN

The results of the root value of the SCN are presented in Table 11. These results showed that in most of cases it was found that the SCN originated from spinal nerves L1 to L3, with variable contributions from the dorsal rami of L4 as well as L5. A Fisher's exact test was used instead of a  $X^2$  test because more than 10% of expected cell values (under  $H_0$ ) were less than 5. No statistical significant difference was found between males and females for both the left ( $p=0.575$ ) and right ( $p=0.881$ ) sides. Therefore, males and females were grouped together in these results.

*Table 10: Root value of SCN*

Root Value	Left	Right	Total
L1	11	8	19 (20%)
L2	12	14	26 (27%)
L3	14	11	25 (26%)
L4	8	9	17 (17%)
L5	4	4	8 (8%)
<b>Total</b>	<b>49</b>	<b>46</b>	<b>95 (100%)</b>

#### 4.1.3. Presence of an osteofibrous tunnel

One of the observations of interest was the presence of an osteofibrous tunnel formed by the iliac crest and the thoracolumbar fascia as the branches of the SCN passed through on its path to supply the skin over this area. However, during the dissections of the cadavers, it became apparent the presence of an osteofibrous tunnel could only be noted if the SCN branched after passing through the osteofibrous tunnel. Therefore, the observations changed from noting whether each branch passed through the

osteofibrous tunnel to whether or not the SCN branched before or after passing through the osteofibrous tunnel. Table 12 shows the breakdown of the observations made during the dissections. A Fischer's exact test was used to determine the statistical significance in the difference between male and females. The p-value was 0.728 and therefore no statistical significant difference was found. The sample was also grouped together with an estimation of prevalence of 78%.

*Table 11: Proportion of nerves that branched before or after passing through the thoracolumbar fascia*

	<b>n</b>	<b>Before (%)</b>	<b>After (%)</b>
<b>Female</b>	17	82.35	17.65
<b>Male</b>	33	75.76	24.24
<b>Total</b>	50	78.00	22.00

#### 4.2. Estimation of Prevalence Study

The results of the estimation of prevalence of an SCN entrapment are represented below in Figure 5. The total number of patients with a confirmed LBP diagnosis was 246 of 400, which means that of the randomly selected sample of 400 patients, 62% of them complained of LBP. Alarmingly, SCN entrapment was eventually confirmed in 46% (112 of 246) of the patients who complained of LBP or 28% (112 of 400) of the entire patient sample. The patients that had a confirmed SCN entrapments (n=112), 77% opted for surgical intervention which entailed a surgical release of the nerve, whereas 24% were treated conservatively at the time that the patient files were examined.

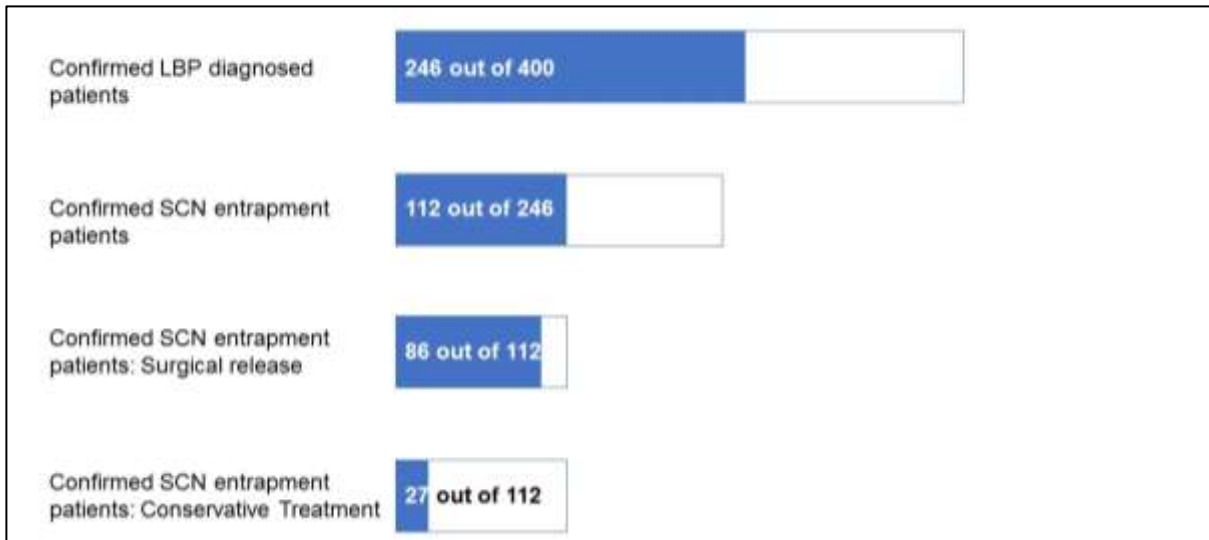


Figure 5: Estimation of Prevalence

The social impact of the nerve entrapment on all the confirmed entrapment patients was collected and averaged out of 10 (Figure 6) – this was based on the patients’ perception of the impact on their own lives. A score of 0 meant that there was no affect; while a score of 10 meant that the affect was severe. Pain received the highest score of 7.5 and low spirit received the lowest score of 4.9.

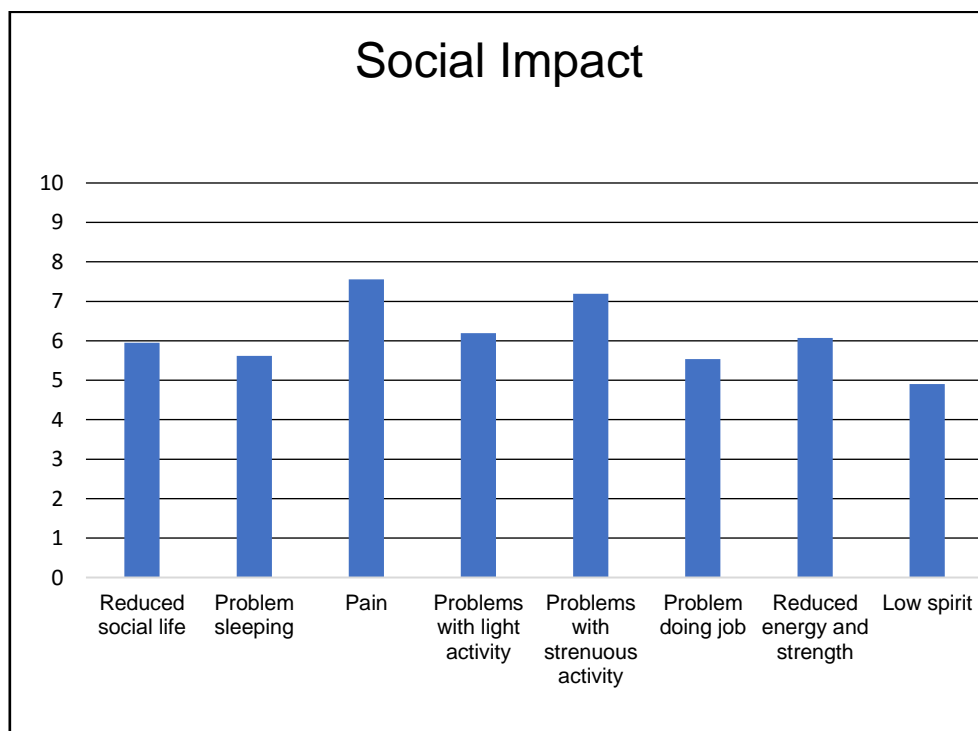


Figure 6: Social impact experienced by patients

Figure 7 shows the referred pain experienced by the patient's positive for a SCN entrapment. Area 9 (A) and area 10 (D) were experienced the most as this is the area directly over the site of entrapment. The second most common combination of areas of referred pain that was experienced was area 9 & 6 (B) and area 10 & 5 (C), these areas lie directly over the site of entrapment, as well as down the side or front of the thigh on the same side. The third most common combination of areas that patients experienced referred pain were the areas that involved the area directly over the site of entrapment, down the side or front of the thigh on the same side as well as the groin area on the same side (area 9 & 4 & 6 (E) on the left and area 10 & 3 & 5 (F) on the right).

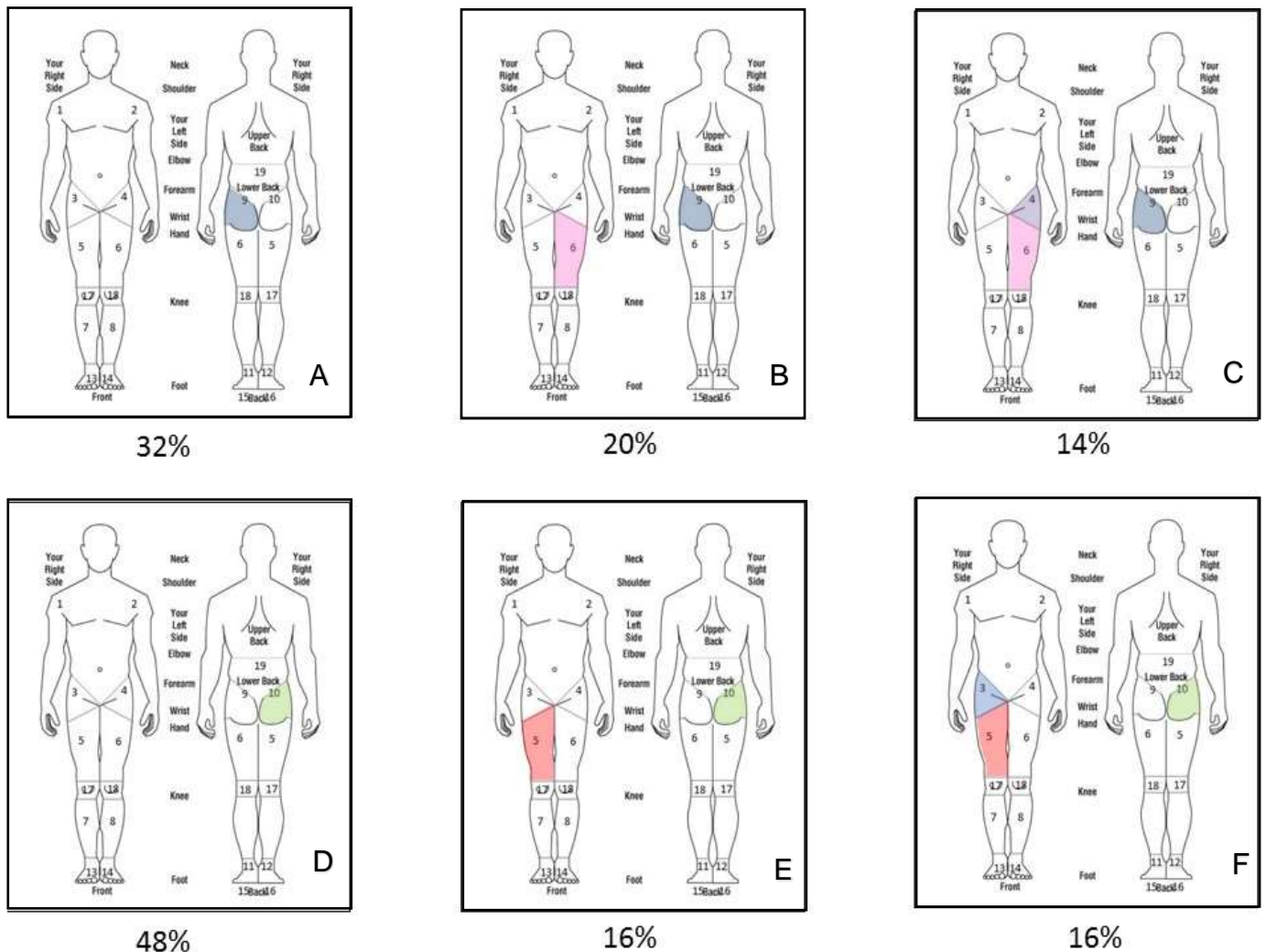


Figure 7: Referred pain charts, coloured areas represent areas – or combination of areas – where patients most commonly experienced pain

## 5. Discussion

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### 5.1. Cadaveric Study

#### 5.1.1. Position of all three branches of the SCN in relation to the PSIS and midline

LBP experienced over the posterior aspect of the iliac crest has the same representations as numerous conditions associated with the complex skeletal and regional neuromuscular system that is the lower back <sup>(11)</sup>. LBP experienced with an SCN entrapment can also present as a lumbosacral strain, posterior facet syndrome, sacroiliac syndrome, spondylolisthesis, osteoporosis, neuropathy, and sciatica <sup>(13)</sup>. Lumbosacral strain and sacroiliac syndrome is the pain associated with tension or strain involving any of the muscles and ligaments of the lower back such as the posterior and anterior longitudinal ligament and the iliocostalis lumborum, longissimus thoracis and spinalis thoracis (paraspinal) muscles. The insertion of iliocostalis lumborum ligament corresponds to the area in which LBP is experienced for both an SCN entrapment and an iliolumbar syndrome <sup>(7)</sup>. However, the insertion of this ligament is on the ventral aspect of the posterior iliac crest and is therefore protected by the iliac crest <sup>(37)</sup>. This makes the insertion point of the ligament difficult to palpate and may not correspond to the area where the trigger point is experienced for a SCN entrapment. Posterior facet syndromes have been described as originating from the cutaneous dorsal rami from the thoracolumbar junction (the junction between T12 and L1 vertebra) and radiographic abnormalities have led to the incorrect diagnosis of LBP. Facet syndromes are generally seen in the elderly and are caused by the breakdown of the vertebral column and subsequent irritation or damage of the nerves in that area. Damage to these nerves lead to chronic pain of the area supplied by these nerves, as well as referred pain down the side of the thigh and the groin – again coinciding with the referred pain experienced with an entrapment of the SCN and possibly sharing referred pain areas or sites. Spondylolisthesis is a condition in which the top vertebra slides forward over the sub adjacent vertebra. In some cases, it can be asymptomatic but it can also lead to the spinal cord and nerve roots becoming entrapped. Should this happen in the lumbar area, the symptoms would coincide with the area supplied

by the SCN and the referred pain experienced by patients would also be the same because of the shared nerve supply <sup>(19)</sup>. Neuropathy is a condition that can be caused by several different factors and can affect both the peripheral and central nervous systems. Peripheral nerve damage can result in tingling, pain, numbness, or general body weakness. These symptoms also coincide with the symptoms experienced with an SCN entrapment and the referred pain experienced down the lateral side of the thigh. However, neuropathy can also be idiopathic with no obvious or known cause. These diagnoses can quite easily become confusing and lead to a misdiagnosis of an entrapment of the SCN <sup>(21)</sup>.

The thoracolumbar fascia has three layers in the lumbar region. The posterior layer is attached to the spines of the lumbar and sacral vertebrae and to the supraspinous ligaments. The middle layer is attached medially to the tips of the lumbar transverse processes and the intertransverse ligaments, along the iliac crest, the lower border of the 12th rib and the lumbocostal ligament. The anterior layer covers quadratus lumborum muscle and is attached medially to the anterior surfaces of the lumbar transverse processes behind the lateral part of psoas major; below it is attached to the iliolumbar ligament and the adjoining part of the iliac crest; above it forms the lateral arcuate ligament. Constant contraction of the latissimus dorsi muscle <sup>(7)</sup> and flexion and extension of the hip joint <sup>(6)</sup> have shown to influence the tension of the fibres of the thoracolumbar fascia. As the SCN passes through these fibres to reach the area over the middle central buttock, to supply cutaneous sensory innervation to this area, the increased tension in these fibres may lead to a subsequent entrapment of this branch. The iliac crest is used to harvest large amounts of corticocancellous bone for multiple applications such as the repair of long bone reconstruction, fracture non-union, spinal fusion, arthrodesis in various joints and maxillofacial surgical procedures. However, it was found that many patients suffered chronic LBP at the donor site after the procurement procedure was done. Anatomical studies revealed that the technique being used placed the SCN in a vulnerable position of being damaged <sup>(7)</sup> and it was then revealed that subsequent entrapment of the SCN was a possible complication of bone procurement procedures from the posterior iliac crest <sup>(6)</sup>. The current study shows that the MSCN emerged  $72.6 \pm 4.2$  mm lateral from the midline and  $77.9 \pm 4.2$  mm lateral from the PSIS, the ISCN emerged  $76.6 \pm 4.4$  mm lateral from the midline and  $79.6 \pm 4.4$  mm lateral from the PSIS and the LSCN emerged  $79.6 \pm 4.4$  mm lateral



from the midline and  $89.5 \pm 4.5$  mm lateral from the PSIS. Table 13 shows a comparison of the study done by Kuniya *et al.*, (2013) on a Japanese cadaver population and the current study on a South African population <sup>(8)</sup>. The midline measurements agree in both studies, although the standard deviation is almost double for Kuniya *et al.*, (2013). When comparing the PSIS to SCN measurement, the current study found measurements to be almost one and a half times longer than those found by Kuniya *et al.*, (2013). This difference can be accounted for by the stature differences seen between the populations and is in agreement with the study done by Loubser *et al.*, (2015) <sup>(8, 9)</sup>. However, the clinical implications of this difference will result in a different site used to inject the local anaesthesia, as well as the surgical incisions having to be longer to find the SCN. To be the most accurate, it is suggested that both measurements are used when determining this point.

*Table 12: Comparison of the current study to previous studies  
(measurements are in mm)*

Study	PSIS			Midline		
	MSCN	ISCN	LSCN	MSCN	ISCN	LSCN
<b>Current</b>	$77.9 \pm 4.2$	$76.6 \pm 4.4$	$79.6 \pm 4.4$	$72.6 \pm 4.2$	$76.6 \pm 4.4$	$89.5 \pm 4.5$
<b>Kuniya <i>et al.</i> (2013)</b>	$45.7 \pm 9.3$	$50.9 \pm 9.2$	$56.5 \pm 9.8$	$71.0 \pm 7.9$	$76.7 \pm 7.6$	$82.6 \pm 8.2$

This study did not show any differences between males and females when it came to each measurement. In a previous study done by Loubser *et al.*, (2015), the authors showed a difference in the measurement of PSIS to the SCN between males and females and attributed it the high sexual dimorphism of the pelvis between the two sexes <sup>(9)</sup>. Although the current study did not show any differences statistically between the sexes, it is suggested that the sex of the patient is taken into consideration when it comes to surgical intervention of the SCN entrapment because the high sexual dimorphism of the pelvis between male and female is well documented and cannot be ignored <sup>(22)</sup>.



One of the main causes of entrapment of the SCN was postoperative complication of bone harvesting procedures <sup>(3, 24, 25, 26)</sup>. From these results seen in Tables 5 and 6, it is suggested that if surgeons keep skin incisions and procurement techniques within 65 mm lateral from the PSIS, they would keep any postoperative complications to a minimum. This suggested measurement agrees with the study done by Lu *et al.*, (1998) in which they give the safe zone as 60 mm lateral from the PSIS and a safe zone of 64 mm lateral from the PSIS suggested by Loubser *et al.* (2015) <sup>(7, 9)</sup>.

The current diagnostic tool used to identify and treat a SCN entrapment is to palpate the trigger point, which is thick tender tissue at the site of entrapment over the iliac crest, and inject it with local anaesthesia at 70 to 80 mm lateral to the midline <sup>(28)</sup>. If this provided complete relief to the patient, even just for a few minutes, it confirms the entrapment of the SCN <sup>(38)</sup>. Talu *et al.* (2000) described a technique using fluoroscopic guidance to localize the SCN over the iliac crest at the level of L5, whereas <sup>(28)</sup>, Akbas *et al.* (2005) also used fluoroscopic guidance to identify the position of the SCN over the iliac crest but described the procedure using the spinous process of L4 <sup>(27)</sup>. In the current study, it was found that in 78% of the cadavers the SCN was found on the level L5 and in 22% of the cadavers the SCN was found on the level of L4. Therefore, it is suggested that using L5 as a landmark to find the SCN in both male and females should provide effective nerve block give positive results when injecting the local anaesthesia into this area.

#### 5.1.2. Root value of the SCN

A nerve root is the initial segment of a nerve leaving the central nervous system. A spinal nerve root is the initial or proximal segment of one of the thirty-one pairs of spinal nerves leaving the central nervous system from the spinal cord <sup>(22)</sup>. Each spinal nerve is formed by the union of a sensory dorsal root and a motor ventral root, meaning that there are sixty-two dorsal/ventral root pairs, and therefore one hundred and twenty-four nerve roots in total, each of which stem from a bundle of nerve rootlets (Figure 8) <sup>(38)</sup>.

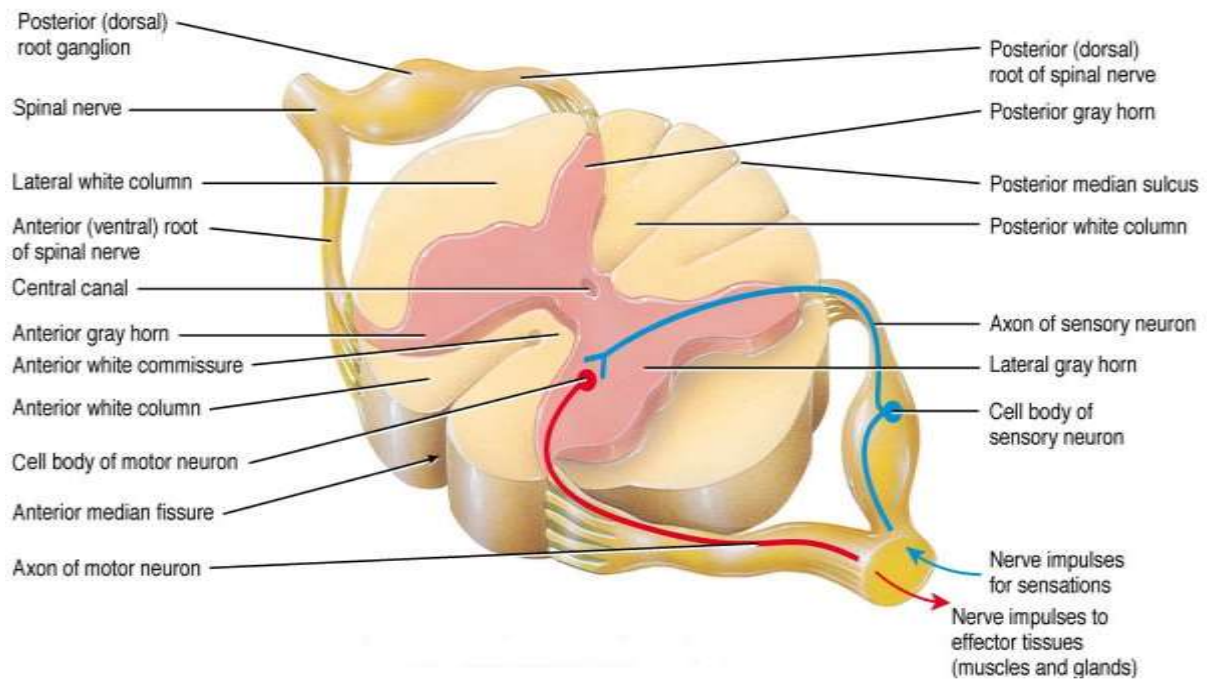


Figure 8: Transverse section of the spinal cord showing the spinal nerve root (38)

Various sources have given the nerve root values of the SCN as starting at T10 to L5 (4, 7, 8, 9, 22). The majority of the sources state the nerve root values as originating from vertebral levels between L1 to L3. With these discrepancies, it can cause confusion in the referred pain that patients may experience with an entrapped SCN and possibly lead to a misdiagnosis. When it comes to determining which spinal nerve is linked to the specific area of skin, dermatomes are particularly helpful. A dermatome is an area of skin supplied by sensory neurons that arise from a spinal nerve ganglion (22). As seen in Figure 9, T10 to T12 is shown to give sensory innervation to the skin over the lower abdomen and middle back. This does not correlate with the areas shown in Figure 7 where the patients gave feedback on the areas of referred pain most experienced when having a confirmed SCN entrapment diagnosis. During dissection, the current study in specific showed that in most of cases the SCN originated from L1 to L3 but with possible contributions from as far caudal as L5 (Table 10).

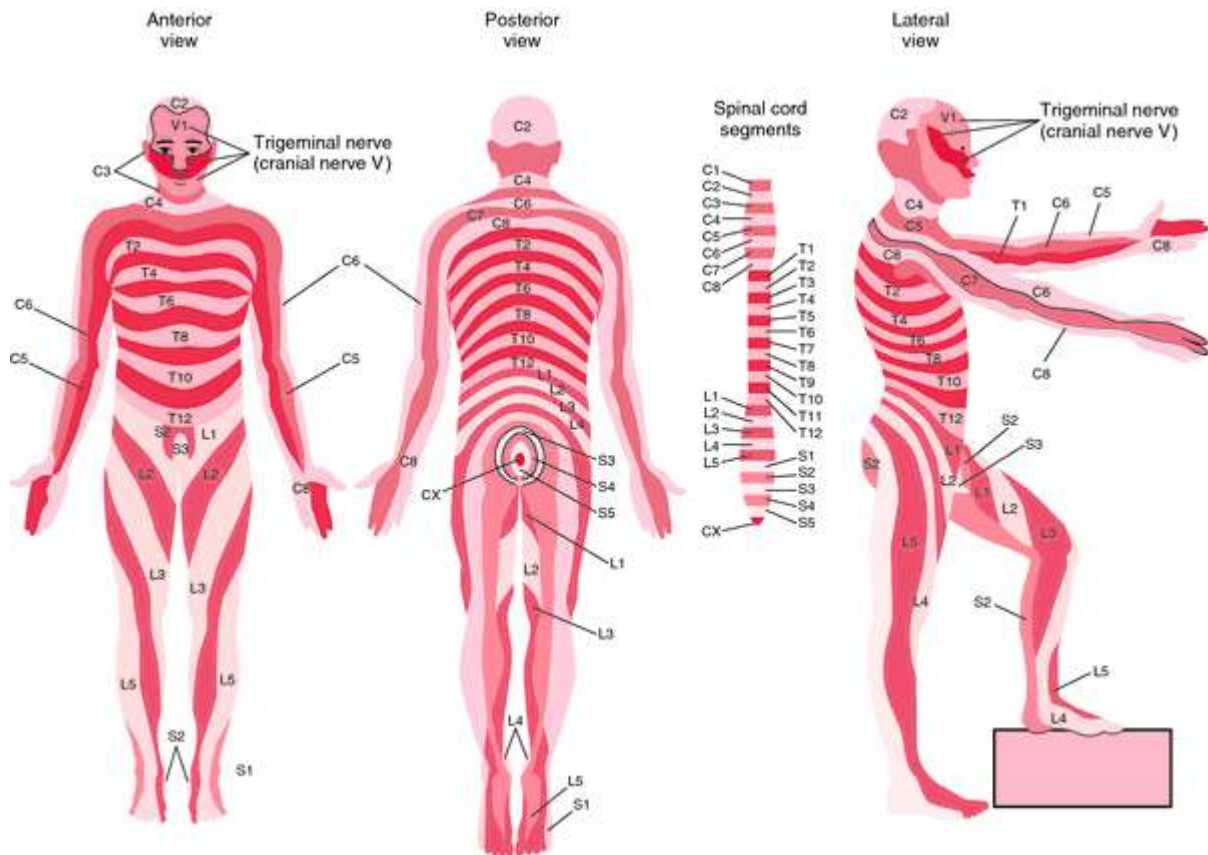


Figure 9: Dermatomes of the human body <sup>(40)</sup>

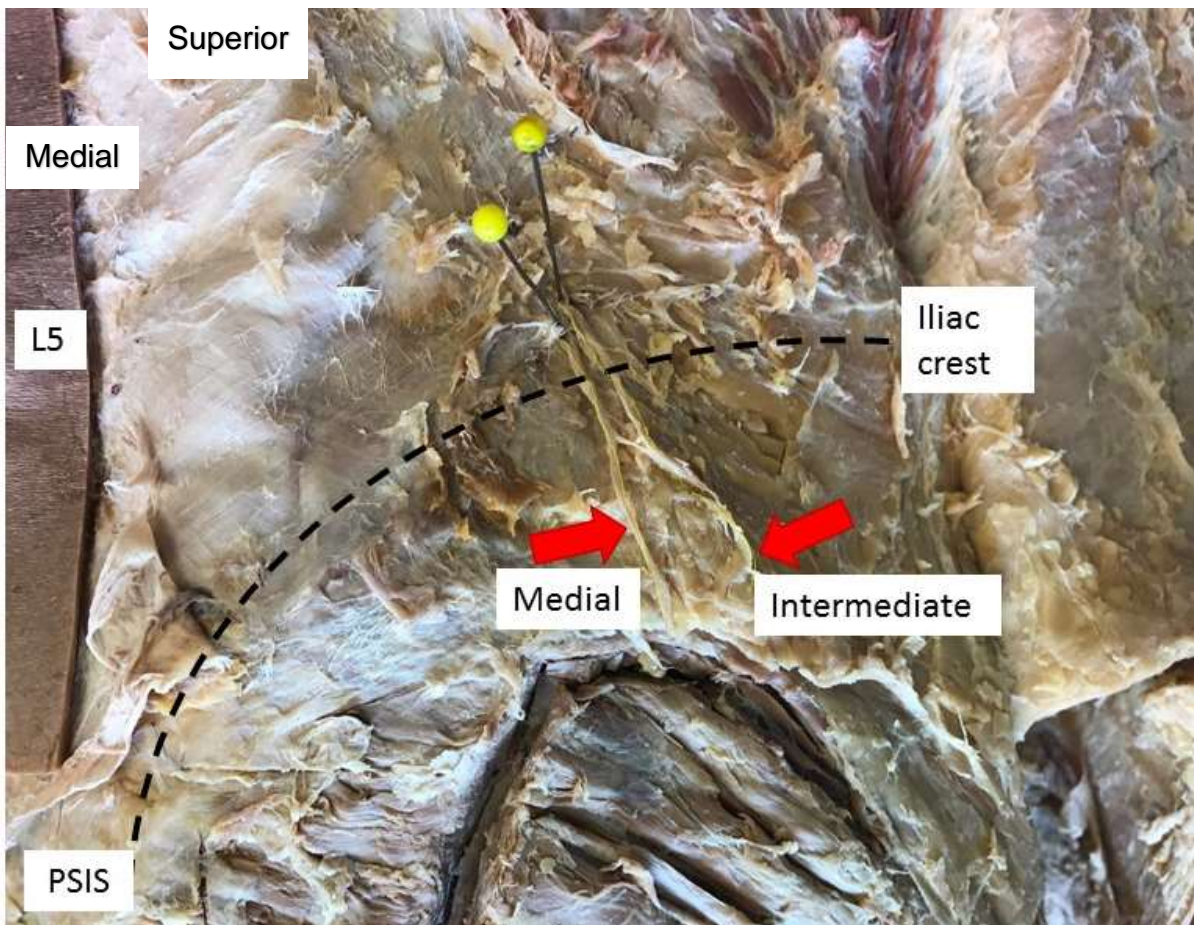
### 5.1.3. Presence of an osteofibrous tunnel

In the study done by Kuniya *et al.* (2013), the authors delved quite extensively into the presence of an osteofibrous tunnel and whether one or all three branches passed through this tunnel <sup>(7)</sup>. Their findings showed that in 38,5% of the sample none of the branches passed through the osteofibrous tunnel and that only 2% (2 out of 109) of the sample showed an actual entrapment of the SCN. In the study done by Loubser *et al.*, (2015), they reported that only 2% (1 out of 54) of cadavers showed an entrapment of the SCN <sup>(9)</sup>. In contrast, the current study revealed that 8% (4 out of 50) of cadavers showed an actual entrapment of the SCN.

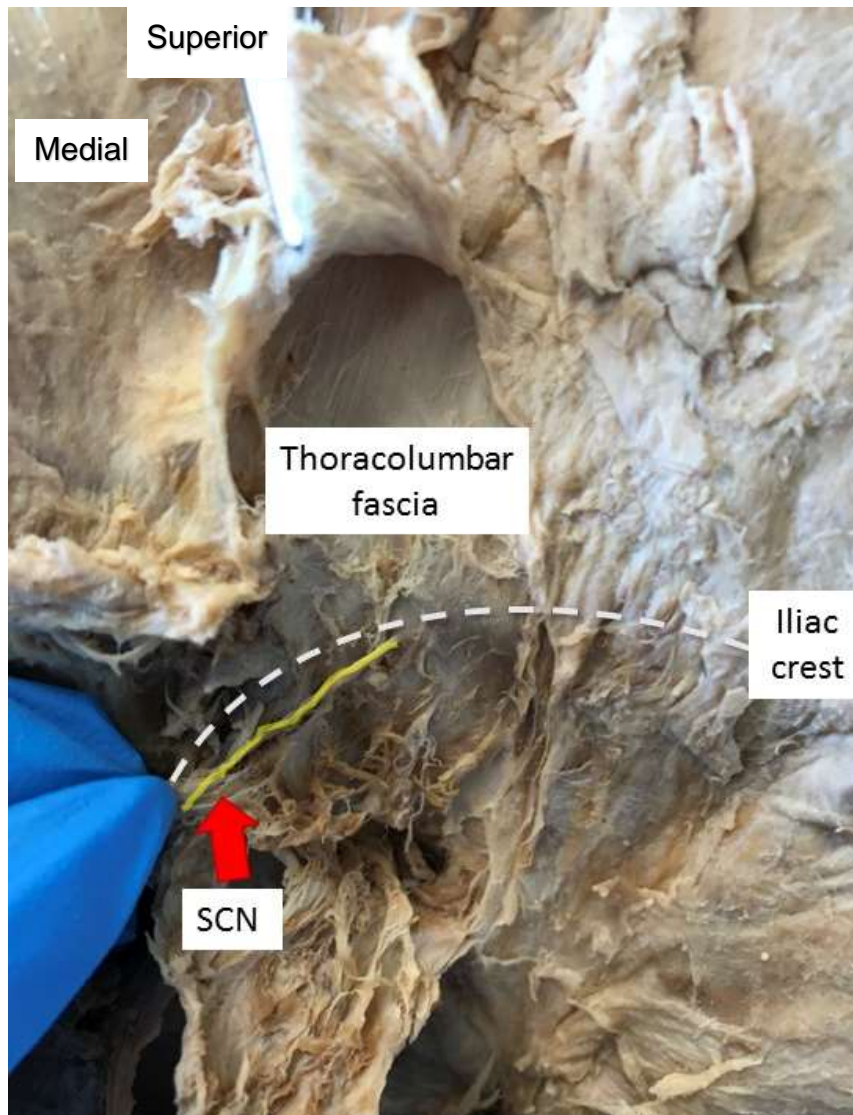
In the current study, the observations that were made changed from noting which branch passed through the osteofibrous tunnel to if the SCN branched before or after passing through the osteofibrous tunnel. In Figure 10, the yellow pin shows the MSCN and ISCN passing through the thoracolumbar fascia. It can be seen that the nerves



pass through without being constricted by the thoracolumbar fascia they pass through. However, in Figure 11 the SCN passes through the thoracolumbar fascia before branching but it can be seen that the nerve is being constricted by the osteofibrous tunnel formed by the iliac crest anteriorly and the thoracolumbar fascia posteriorly. The results of this study showed that in 78% of the sample, the SCN branched before passing through the thoracolumbar fascia and 22% of the sample branched after passing through the thoracolumbar fascia.



*Figure 10: SCN passing through the thoracolumbar fascia after branching. MSCN and ISCN passing through the osteofibrous tunnel (marked by yellow pins)*



*Figure 11: SCN passing through the osteofibrous tunnel before branching into the three branches.*

## 5.2. Estimation of Prevalence Study

Very few studies, besides a few sporadic case studies, have given a clinical assessment of the symptoms experienced and the social impact of patients that suffer from chronic LBP (29, 30, 31).

In a sample of 400 patients, 62% of these patients had a main complaint of LBP ranging from approximately 4 weeks to more than 10 years. These diagnoses included osteoporotic degradation of the spinal column to general mechanical pain experienced by manual labourers to pain experienced by patients from previous injuries. The study

performed by Ermis *et al.* (2011) gave an estimated prevalence of 80 to 90% of nonspecific LBP whereas this study estimates the prevalence of nonspecific LBP to be 62% in a South African population <sup>(4)</sup>. Although this number is a lot lower than the number given by Ermis *et al.* (2011), the patients included in these study have access to specialised medical care. This access is greatly affected by their socio-economic status <sup>(4)</sup>. This was a limiting factor to this study because it was conducted in a specialist physician's pain practice and patients that rely on care from the South African government sector health system are not represented in this study. However, it is still valuable information for physicians that deal with chronic pain on all platforms. From the 246 confirmed chronic LBP patients, 112 (47%) were given a positive SCN entrapment diagnosis. Which means that slightly less than half of the patients, who complained about LBP, needed treatment for an entrapment of the SCN. This treatment included surgical release of the SCN (77%) or the use of conservative treatment (24%) to provide immediate as well as long-term relief for these patients. Conservative treatment included patients who found complete relief with the nerve block, performed as part of the diagnostic criteria; patients who used pharmaceuticals to manage pain, as in the case of muscle spasms causing the entrapment, and patients who couldn't afford the extra cost of surgery or opted out of surgery.

### 5.2.1. Social Impact

Part of trying to explain the effect of this condition, in its entirety, is to look at not only the physical aspects but also the social aspects that are affected. Out of the eight different aspects, pain was ranked the highest, which was expected. In general, the entrapment only affected patients when they were required to perform a fair amount of movement or strenuous activities. They could function as normal as possible in their daily lives while managing the pain with analgesics or nonsteroidal anti-inflammatory drugs (NSAIDs). It is interesting to note that the lowest score was Low Spirit and this can be linked to the symptoms of CPS. A CPS diagnosis relies on a medical report of a psychiatrist linking the pain experienced by the patient and various mental health issues such as depression, anxiety, or suicidal ideations. The longer the patients are disabled because of the pain, the less likely the patients will return to a normal level of activity specific to each patients lifestyle <sup>(40)</sup>. In recognising the psychological factors,



“suffering” becomes an important characteristic of these patients and this leads to them exhibiting pain behaviours. The cause of the chronic pain has overwhelmed the patient and caused them to retreat and play the role of a “sick” person. They see themselves as being out of control and therefore fill the role further. They lose interest in short-term and long-term planning, family involvement as well as eventual loss in interest of their social and financial responsibilities <sup>(12)</sup>. The result of these social scores suggests that patients with a confirmed and treated SCN entrapment do not qualify for a CPS diagnosis.

### 5.2.2. Referred Pain

Referred pain, also known as reflective pain, is pain perceived at a location other than the site of the painful stimulus <sup>(41)</sup>. The referred pain charts (Figure 7) provided significant insight as to where and why patients experienced the pain they did.

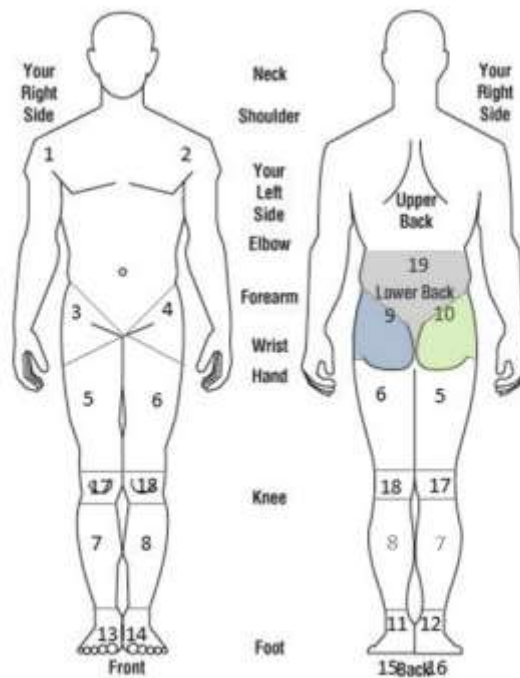


Figure 12: Referred pain chart - areas 9, 10 and 19.

As seen in Figure 12, most patients experienced the pain in areas 9, 10 and 19. This was expected with this entrapment as these areas lie directly over the course and area of supply of the SCN. If the cause of the entrapment were due a muscle spasm in any

of the paraspinal muscles then patients would experience the pain in area 19. If the thoracolumbar fascia caused the entrapment, as the nerve passes over the iliac crest, then patients would experience the pain in area 9 on the left-hand side and area 10 on the right-hand side. Pain in these areas were experienced by 48% of patients – exclusive back pain – this agrees with the study done by Kuniya *et al.*, (2014) with exclusive LBP presenting 52% of the cases that they examined <sup>(10)</sup>.

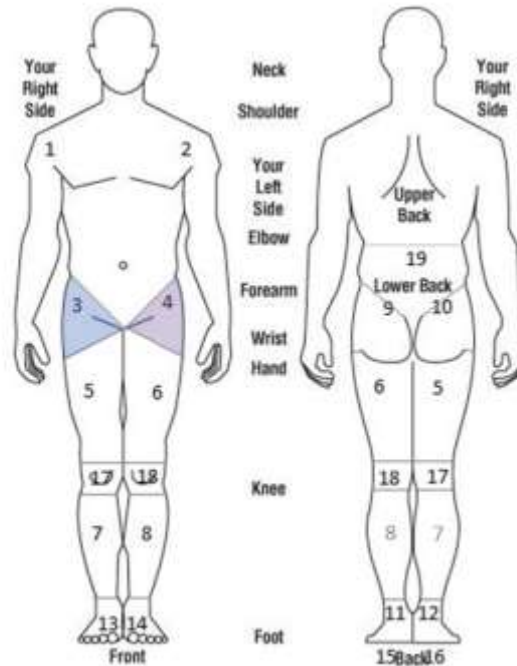


Figure 13: Referred pain chart - areas 3 and 4.

Since this study showed that the SCN originated from L1 to L3, with contributions from spinal nerves L4 and L5, the pain can be experienced along many dermatomes which translates to different areas of referred pain. In areas 3 and 4 (Figure 13), the pain may present because of the involvement of the genitofemoral nerve from L1 to L2 and ilioinguinal nerve from L1. Since the shared nerve root values, it is common that a SCN entrapment may present with referred pain in the groin area on both the left and right sides respectively.

Areas 5 and 6 (Figure 14) can present with pain because of the shared nerve root value of the lateral femoral cutaneous nerve and the anterior femoral cutaneous nerve – both from L2 to L3. It should also be noted here that the posterior aspects of the thigh are not affected as these areas are supplied from spinal nerves S1 to S3.



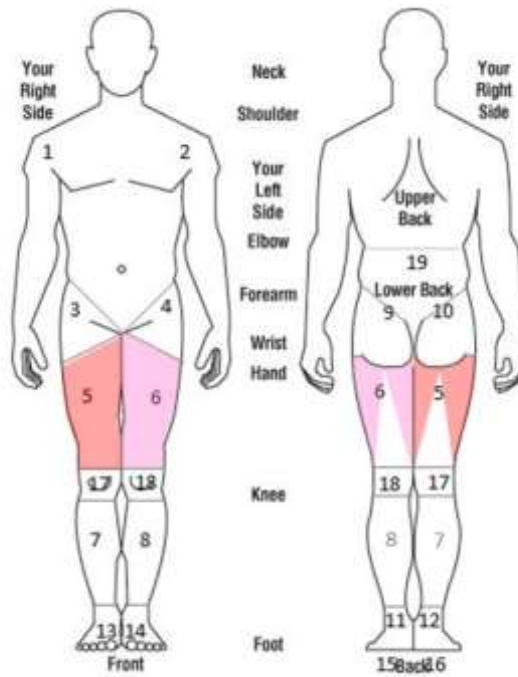


Figure 14: Referred pain chart – areas 5 and 6.

## 6. Conclusion

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Entrapment of the SCN should be considered when attempting to diagnose the cause of persistent nonspecific LBP. There is an agreement between the current study and the study done by Loubser *et al.* (2015) with regards to the suggested measurements of the SCN to the PSIS and midline<sup>(9)</sup>. Although this study did not show a difference between sexes, surgeons should always consider the possibility that there might be sex-related differences in the position of the SCN during the surgical release of the SCN. The safety zone of less than 60 mm from the PSIS during bone harvesting procedures is highly recommended to surgeons – the current study, the study done by Loubser *et al.* (2015) and Kuniya *et al.* (2013) all agree that this would lessen the likelihood of damaging the SCN during these procedures<sup>(7, 9)</sup>.

With this condition being one that is often misdiagnosed, the root value of the SCN does play an important role in noticing the symptoms of an entrapment. This study found that majority of the time, the SCN had a root value of L1 – L3 but due to human variation it is possible to have variable contribution from T11 – L5. It needs to be kept in mind when faced with a patient who presents with referred pain as opposed to the localised pain over the upper middle buttock because it could lead to a misdiagnosis and prolonged suffering by the patient.

LBP was experienced by 62% of the patients with just less than half of them having a confirmed SCN entrapment. Although this estimation of prevalence is almost 20% lower than what was expected, the amount of confirmed SCN entrapment cases is almost four times the amount expected. This points out the biggest limitation of this study. The patient records used in this study were seen by a specialist physician at a private hospital so patients that rely on the South African Government for healthcare are not represented in this study. However, this doesn't lessen the importance of this data as it definitely gives physicians the information that hasn't been readily available for a South African population with regards to this condition.

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