The Slump Test; A screening tool for neuropathic pain

By

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Abstract

This study investigated the utility of using a neurodynamic test, the Slump test by itself and with qualifiers to identify neuropathic pain (NeP).

The study utilized a control group and a low back pain group. The low back pain group was pre-diagnosed as NeP or non neuropathic pain (NNP) by an experienced clinician using an accepted diagnostic examination. A slump test was performed recording knee ROM, pain location and verbal pain descriptors followed by Quantitative Sensory Testing (QST).

Various versions of the slump test were compared to the pre test diagnosis. Sensitivity, specificity and likelihood ratios were calculated. The conventional slump test was shown to be a sensitive and moderately specific screening test for NeP. Including whether pain extended below the knee dramatically increased specificity.

QST revealed localized cold sensation hyposensitivity, widespread cold pain hyposensitivity and suggestions of increased thresholds of pressure pain levels.

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Lastly I have to thank my family, my three children, Michael, Matthew and Stuart and especially my wife Ti for their ongoing support, encouragement and patience. The time that was invested into this journey belonged to them. I hope that I can somehow pay them back.

Dedication

I would like to dedicate this thesis to my father, Lawrence A. Urban who passed away in the middle of this project in January of 2008. He convinced me that I could do anything or be anything that I wanted to be. My father encouraged me to set my sights high and has provided me with inspiration on a daily basis.

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Introduction

Clinicians have been treating various presentations of radicular pain including sciatica for a long time. Although mistakenly considered synonymous with all forms of referred pain, radicular pain is now considered to be a form of neuropathic pain (Costigan et al. 2009). What is unchanged is the difficulty in diagnosing neuropathic pain although attempts to develop neuropathic pain screening tools have recently alerted clinicians that neuropathic pain may occur more frequently than previously suspected. Indeed, it is recognized that the prevalence of neuropathic pain is surprisingly high.

A significant proportion of all chronic pain patients report neuropathic pain characteristics (Bouhassira et al. 2008) especially those with diabetes (Boulton et al. 1985) and a full third of low back pain and cancer patients report neuropathic pain symptoms (Freynhagen et al. 2006b) (Chong and Bajwa 2003). Importantly, the presence of neuropathic pain has been linked with poor short-term and long-term recovery (Sterling et al. 2002;Kasch et al. 2005;Scott et al. 2005;Jull et al. 2007;Sterling and Pedler 2009a). It follows that early recognition of neuropathic pain and appropriately focused treatment such as appropriate medications may reduce the potential for progression to chronic pain conditions (Sterling and Pedler 2009a).

The diagnosis of neuropathic pain classically has consisted of a thorough history together with an exhaustive neurosensory examination looking for both positive and negative signs. This examination is usually performed by a specialist, takes a lot of time to perform and in many regions involves a relatively long waiting period for the consultation. Recently, abbreviated screening tools have combined the identification of

certain pain descriptors and some key physical bedside examination findings to identify individuals with predominantly neuropathic pain. These tools have evolved to include verbal descriptors only (LANSS) (Bennett 2001)(S-LANSS) (Bennett et al. 2005)(DN4 (Bouhassira et al. 2005)(painDetect (Freynhagen et al. 2006a). The screening tools may take between five and ten minutes to administer depending upon whether or not they contain a physical bedside examination component. Generally, these tools demonstrated sensitivity and specificity of around 80%.The most recent clinical tool, The Standardized Evaluation of Pain (StEP) developed by Scholz et al. (Scholz et al. 2009)has attempted to identify the key verbal descriptors and physical components of the bedside examination and combine them into a tool for the differentiation of neuropathic pain from non neuropathic pain. This tool has proved to be very sensitive (92%) and specific (97%). However, it takes too long to administer (10 – 15 minutes) to be considered a true screening tool. Of interest however is the fact that this tool utilizes and subsequently identifies a neurodynamic test, namely the Straight-Leg-Raising Test, as being the key indicator of neuropathic pain. Coincidently Sterling and Pedler (Sterling and Pedler 2009a) have recently identified another neurodynamic test, the Brachial Plexus Provocation Test (BPPT) which is highly suggestive of the presence of a neuropathic pain component in post whiplash injured patients (p-value 0.003).

Historically, neurodynamic tests have been successfully utilized in the clinical setting to differentiate pain arising from neural vs non-neural tissue. The Straight-Leg-Raising test is also used in the diagnosis of lumbar disc herniations. In surgical populations the straight-leg-raising test has demonstrated high sensitivity and widely varying results for

specificity (van der Windt et al. 2010). The same review found that there was still insufficient evidence to support the clinical usefulness of the straight-leg-raising test or the crossed straight-leg-raising test in the diagnosis of disc herniation in primary care populations. The Straight-Leg- Raising Test has recently been shown to be a very sensitive indicator of neuropathic pain. The Slump Test is another neurodynamic test commonly used in the clinical setting to identify sensitized neural tissue. It is a more sophisticated test than the Straight Leg-Raising Test in that it can generate more overall neural tension, incorporates a sensitizing maneuver as part of the test and facilitates easy quantification through knee extension measurement. Neurodynamic tests have always been sensitive to changes in sensitivity but not very specific to the mechanism or pathology. Further augmentation of the Slump Test to include analysis of the verbal descriptors of the symptoms experienced during the Slump Test may provide even more specificity for the test. If the Slump Test is shown to be a highly sensitive and specific indicator of neuropathic pain it could serve as a quick and simple clinical screening tool.

Review of the Literature

Pain

Acute pain is the direct result of strong noxious stimulation applied to the skin or deep tissues which activates specialized transducer ion channel receptors. Noxious stimuli can be mechanical, thermal, chemical or artificial. Nociception is mediated by high threshold unmyelinated C fibres and thinly myelinated Aδ fibres. The activation of these receptors produces nerve impulses which are conveyed to the brain where they are ultimately interpreted as pain (Basbaum 2005). To do what it has been designed to do, which is

guard against tissue injury, nociceptive pain has to be unpleasant. Ideally, nociceptive stimulation produces a withdrawal from the stimulus before tissue injury occurs.

Tissue damage occurs when the noxious stimulus exceeds a certain threshold and is immediately accompanied by the production of numerous inflammatory mediators including bradykinin, prostaglandins, leukotrienes, serotonin, substance P, thromboxones, histamine, platelet-activating factor, adenosine, ATP, protons and free radicals. In addition, cytokines and neurotrophins play an important role during the inflammatory process (Meyer 2006). Many of these mediators directly activate nociceptors, producing pain, and also alter the function of the nociceptors such that the threshold required for activation is lowered, a process referred to as peripheral sensitization (LaMotte et al. 1982). Central sensitization within the spinal cord also occurs due to the ongoing nociceptive input from the injury site. Both peripheral and central sensitization contributes to the amplification of pain responses. Specifically, hyperalgesia is defined as a leftward shift of the stimulus response function that relates magnitude of pain to stimulus; stimuli that were previously painful are now more painful. An additional outcome of changes in central pain processing is allodynia, which is defined as pain that arises from stimuli that were previously non painful.

The heightened pain state that accompanies injury is a result of inherent plasticity in the nociceptors and the central nociceptive pathways and is considered a normal physiological response. In contrast, when the injury includes neural tissue distinct pain processes can arise, collectively referred to as neuropathic pain. Neuropathic pain is a

consequence of a malfunction of the somatosensory apparatus itself. Neuropathic pain occurs secondary to activity within the nociceptive system in the absence of adequate stimulation of the peripheral sensory endings (Treede et al. 2008b). According to the location of the injury, the terms peripheral neuropathic pain or central neuropathic pain are applied. The focus here will be entirely on peripheral neuropathic pain.

Many individuals with neuropathic pain have stimulus induced pain or evoked pain together with some sensory abnormalities. More often than not most individuals report mechanical hypersensitivity together with cold and heat hyposensitivity or hypersensitivity. The mechanical sensitivity may present as allodynia or as hyperalgesia. The underlying process that gives rise to neuropathic pain mainly involves changes in ion channels and growth factors in the damaged nerve (Cook et al. 1987;Sheen and Chung 1993;Yoon et al. 1996;Chen and Devor 1998;Gold 2000;Boucher and McMahon 2001;Ji and Woolf 2001;Gardell et al. 2003;Ringkamp and Meyer 2005;Griffin 2006;Devor 2006b;Bennett et al. 2007). Nerve injury sees increased expression of messenger RNA for voltage gated sodium channels in primary afferent neurons (Baron 2009). At the same time localized demyelination has also been associated with nerve injury (Bennett and Xie 1988). Myelin normally inhibits ion channel insertion. Subsequently there is an accumulation of sodium channels at the injury site which permits ectopic impulse generation (Omana-Zapata et al. 1997a;Omana-Zapata et al. 1997b;Lai et al. 2003). The increase in density of these ion channels produces a reduction in activation threshold and increased excitability of these cells. Ectopic discharge originating in the peripheral nervous system acts as a primary pain signal as well as triggering and maintaining central

sensitization (Devor 2006b). It is these changes in membrane function that are believed to give rise to the distinct shooting pain that can result from seemingly normal movements when neuropathic pain is present. A classic example is the shooting leg pain associated with sciatic radiculitis/radiculopathy, an injury to the dorsal spinal root/spinal nerve that frequently accompanies intervertebral disc herniation or lateral stenosis.

Although inflammatory and neuropathic pain are distinct, they do share some common mechanisms (Costigan et al. 2009). Immune mediators such as interleukin 1β, tumor necrosis factor, bradykinin and nerve growth factor act directly on nociceptors following inflammation which produces peripheral sensitization. In addition these same substances are released by peripheral immune cells and microglia following nerve injury and promote increased production, transport and insertion of transducer and voltage gated ion channels at the site of nerve injury. Similarly, central sensitization is common to inflammatory and neuropathic pain (Costigan et al. 2009). Common central mechanisms include increased excitability of spinal sensory neurons due to alterations in neurotransmitter release and synaptic plasticity (Dougherty et al. 1993;Ali et al. 1999;Gold 2000;Liu et al. 2000;Wu et al. 2001;Gold et al. 2003;Yoshimura and Yonehara 2006), changes in descending inhibition which produce a shift to enhanced facilitation of sensory transmission (Dickenson 2008), and marked activation of glia cells (microglia, astrocytes) which contributes to the development of dorsal horn sensitization (Marchand et al. 2005;Wieseler-Frank et al. 2005a;Wieseler-Frank et al. 2005b;Banks and Watkins 2006;Scholz and Woolf 2007).

Given that some of the mechanisms are common between inflammatory and neuropathic pain, it is not surprising that some of the clinical manifestations of these different pain states are also the same including allodynia and hyperalgesia. Common mechanisms affecting different tissues in the same patient may indeed produce a mix of signs and symptoms representing different types of pain simultaneously in the same patient.

The Definition of Neuropathic Pain

The definition of neuropathic pain has evolved and continues to evolve over the past several years. The International Association for the Study of Pain (IASP) initially defined neuropathic pain as "pain initiated or caused by a primary lesion or dysfunction of the nervous system" (Merskey 1994)(see Table 1). This definition, as was probably intended, is very broad in scope and includes all pain involving the nervous system irrespective of mechanism. Another definition of neuropathic pain has been offered by Bennett who stated that it is "pain occurring in an area of abnormal or absent sensation" and "when the distribution of pain and associated sensory abnormalities jointly, and in a clinical context, point to a neurological condition"(Bennett 2006b). Treede et al. (Treede et al. 2008b) have argued that the initial IASP definition does not distinguish neuropathic pain sufficiently from pain due to secondary neuroplastic changes such as central sensitization. This group has proposed that the definition of neuropathic pain be limited to "pain arising as a direct consequence of a lesion or disease affecting the somatosensory system"(Treede et al. 2008a). The term dysfunction was replaced with the words lesion or disease to avoid the misinterpretation of the word dysfunction which they felt includes the normal plasticity of the nervous system. It was also felt that the term "nervous

system" did not reflect the requirement that the presence of neuropathic pain requires a change in the somatosensory system (Loeser and Treede 2008). Yet another definition is put forward by Costigan et al.; "maladaptive plasticity caused by a lesion or disease affecting the somatosensory system which alters the nociceptor signalling system so that pain is felt in the absence of a stimulus, and responses to innocuous and noxious stimuli are enhanced"(Costigan et al. 2009).

Table 1: Summary of Definitions of Neuropathic pain

International Association for the Study of Pain (Merskey 1994) • "pain initiated or caused by a primary lesion or dysfunction of the nervous system"
Treede et al.(Treede et al. 2008b) Loeser and Treede (Loeser and Treede 2008) • "pain arising as a direct consequence of a lesion or disease affecting the somatosensory system"
Bennett et 2006 (Bennett 2006b) • "pain occurring in an area of abnormal or absent sensation" and "when the distribution of pain and associated sensory abnormalities jointly, and in a clinical context, point to a neurological condition"
Costigan et al. (Costigan et al. 2009) • "maladaptive plasticity caused by a lesion or disease affecting the somatosensory system which alters the nociceptor signalling system so that pain is felt in the absence of a stimulus, and responses to innocuous and noxious stimuli are enhanced"

While the debate may be ongoing, the definition currently endorsed by the Neuropathic pain Special Interest Group of the IASP and included in the IASP basic pain terminology is that of "pain arising as a direct consequence of a lesion or disease affecting the somatosensory system" (Loeser and Treede 2008).

The Current Method of Diagnosing Neuropathic Pain

The difficulties around defining neuropathic pain likely arise from incomplete knowledge of mechanisms specific to neuropathic pain and the overlap of several pain processes between inflammatory and neuropathic pain. As such, the task of diagnosing neuropathic pain as a separate entity from inflammatory pain is challenging. The current "gold standard" for the diagnosis of neuropathic pain utilizes the classical neurological diagnostic approach which includes a meticulous history taking followed by a comprehensive neurosensory clinical examination (Hansson 2008). The pertinent subjective and objective areas of interest are depicted in Figure 1.

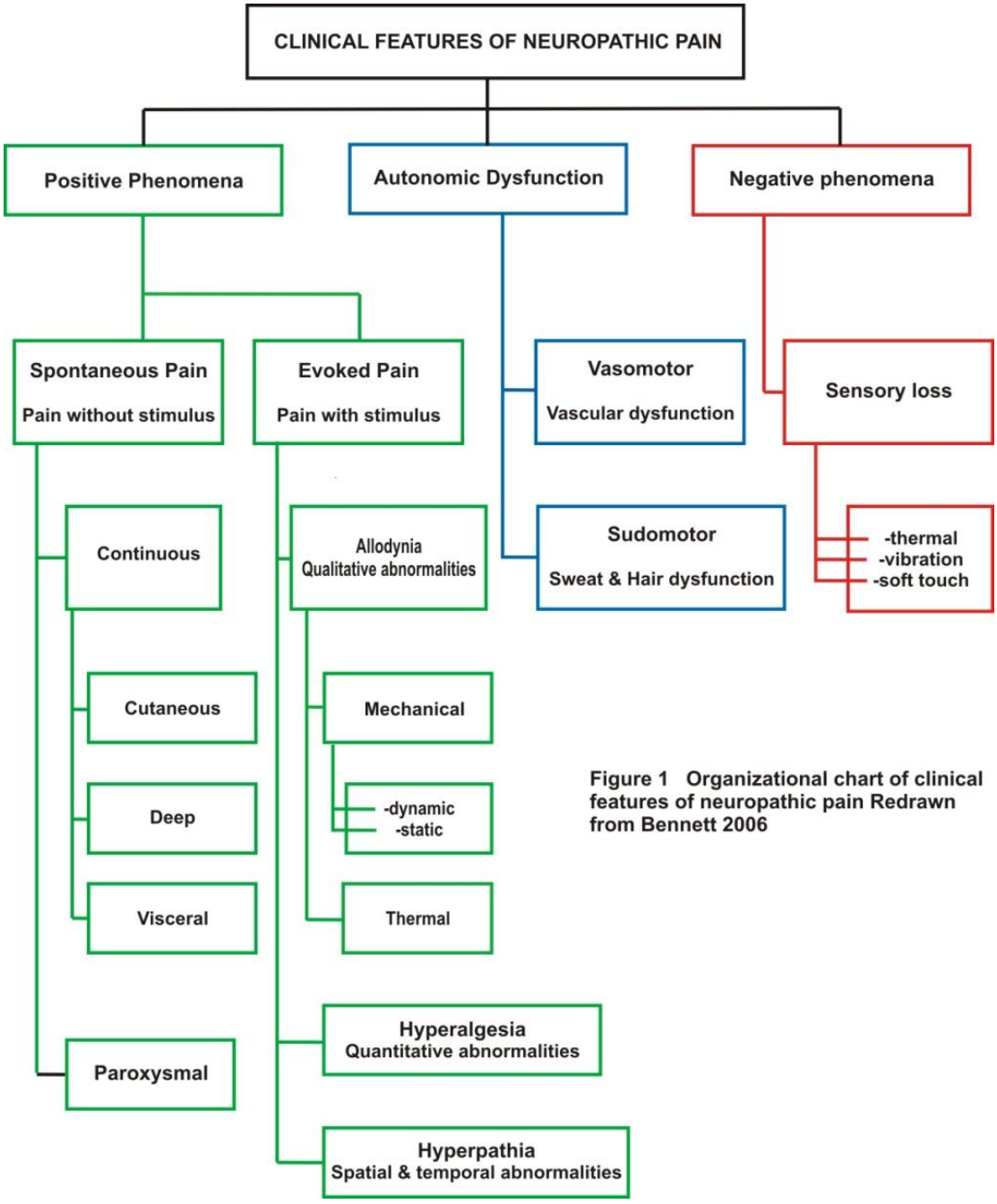


Figure 1 Organizational chart of clinical features of neuropathic pain Redrawn from Bennett 2006

Following the examination the investigator then needs to consider the results of the history and clinical examination and come up with a diagnosis. A task force consisting of neurologists, neuroscientists, clinical neurophysiologists and neurosurgeons working with

an IASP Special Interest Group on Neuropathic pain have put forward a grading system for clinical and research purposes for the interpretation of the signs and symptoms collected during the examination (Treede et al. 2008b)(Figure 2). The grading system to ascertain the presence of neuropathic pain considers four criteria:

1. Pain with a distinct neuroanatomically plausible distribution

2. A history suggestive of a relevant lesion or disease affecting the peripheral or central somatosensory system

3. Demonstration of the distinct neuroanatomically plausible distribution by at least one confirmatory test (confirmation of the presence of negative and or positive signs consistent with the distribution of pain)(eg. decreased pin prick sensation, changes in cold sensation)

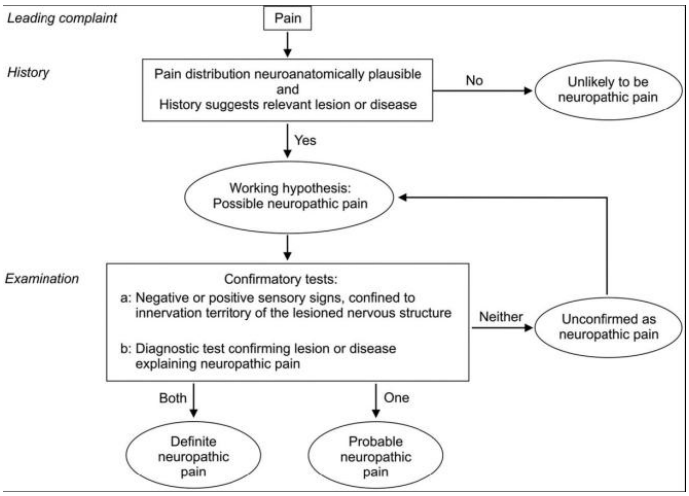


Figure 2 Algorithm for diagnosing NeP From (Treede et al. 2008b) Reproduced with permission

4. Demonstration of the relevant lesion or disease by at least one confirmatory test (these tests would confirm the diagnosis of the suspected disease or lesion which is responsible for the pain)(eg MRI or nerve conduction studies)(see below).

As illustrated in Figure 2, the lowest level

of certainty, ***possible*** **neuropathic pain**, would be assigned to patients if only criteria 1 and 2 were present. If criteria 3 or 4 were also present the patient would be assigned to the category of ***probable*** **neuropathic pain**. Lastly, ***definite*** **neuropathic pain** would be assigned if all four criteria are met. For the purpose of the current study, the diagnosis of neuropathic pain will follow the criteria outlined above.

It is acknowledged that MRI is the choice for evaluating disc morphology and possesses good sensitivity (60-100%) and specificity (43-97%) (Roudsari and Jarvik 2010). At the same time it is recognized that a significant proportion of asymptomatic people have herniated discs and for this reason imaging may not always be relevant in predicting back problems (van der Windt et al. 2010).

The Potential for Neurodynamic Tests in Diagnosing Neuropathic Pain

Within the context of a busy clinical practice the achievement of a definite or even probable diagnosis of neuropathic pain would be difficult simply due to the length of time required to complete the suggested neurosensory examination. Facing this practical dilemma the question arises, are there some key items contained in the comprehensive examination that are unique to neuropathic pain? If there are, would it possible to extract these key items to construct a shorter neuropathic pain diagnostic examination?

Four studies have addressed these questions and are summarized in Table 2; (Bennett 2001;Bouhassira et al. 2005;Scholz et al. 2009;Sterling and Pedler 2009a). It is apparent

from these studies that the most important bedside physical tests to perform in an examination seeking a diagnosis of neuropathic pain are as follows:

1. Pin prick pain thresholds, especially lowered thresholds
2. Cold pain threshold detection, especially lowered thresholds
3. Positive neurodynamic tests indicating lowered mechanical thresholds

Table 2: Summary of physical findings comparing neuropathic to non neuropathic pain

	Increased responses		Decreased responses					Positive neuro-dynamic test
Study	Touch	Pin prick	Pin prick	Touch	Heat	Cold	Pressure	
Bennett 2001	Yes	Yes	Yes	Not tested	Not tested	Not tested	Not tested	Not tested
Bouhassira et al. 2005	Yes	Yes	No	Yes	Yes	Yes	No	Not tested
Sterling and Pedler 2009	Not tested	Not tested	Not tested	No	Not tested	Yes	Yes	Yes
Scholz et al. 2009	No	No	Yes	No	No	Yes	No	Yes

The neurodynamic tests in the above studies included the Straight Leg-Raising-Test and the Brachial Plexus Provocation Test. In fact, the Straight-Leg-Raising Test was found to be the most discriminatory indicator for radicular pain (neuropathic pain) of 27 physical examination components (Scholz et al. 2009). The Straight-Leg-Raising Test, together with the Brachial Plexus Provocation Test, Slump Test, the Neck Flexion Test, and the Femoral Nerve Stretch Test are all neurodynamic tests. A neurodynamic test is defined as a series of multijoint movements of the limbs and/or trunk that produces mechanical and physiological events together with any subsequent interactions in the nervous system, accomplished by altering the length and dimensions of the nerve bed surrounding the corresponding neural structures (Butler 2000;Shacklock 2005;Nee 2006). These tests are also referred to as neural provocation tests (Coppieters et al. 2005) and in the past were commonly referred to as neural tension tests.

All of these tests are designed to mechanically stimulate neural tissues via applied tension and to move these neural tissues in relation to their containers. An explicit purpose of these tests has been to assess the sensitivity of neural tissues to mechanical tension and to gain insight into their mobility in relation to their containers. The continuum of the nervous system from the brain to peripheral tissues is the key concept in neurodynamics (Butler 2000). Peripheral nerves are enclosed in connective tissue layers: the perineurium, the epineurium, the endoneurium and the mesoneurium or paraneurium (Smith 1966;Sunderland 1990;Millesi et al. 1995;Topp and Boyd 2006). These tissues strengthen and protect the neural tissue. The spinal neural tissue are also enclosed in connective tissue coverings as well. The dura mater and the leptomeninges, consisting of

the arachnoid and pia, protect and at the same time allow movement of the spinal neural tissues. The neural and connective tissues lie within a flexible nerve bed or interface. Within this nerve bed these tissues are attached at various points allowing relative movement between the neural tissue and the container. The nervous system must be able to adapt to changes in the container surrounding it. These changes include alterations in the length, diameter and shape of the neural tissues which occur with all movements of the container or interface surrounding them.

This study will look at a slight modification of a commonly used clinical neurodynamic test, the Slump Test, and its ability to differentiate neuropathic pain from non neuropathic pain. The Slump Test is more sophisticated than the Straight-Leg-Raising Test in that it easily applies the maximum available tension to the central and peripheral nervous systems. At the same time it allows simple alteration of that tension via the manipulation of various peripheral components to aid in verifying the outcome of the test.

Variations of the Slump Test have been around for a long time. The first mention of an assessment procedure which resembles the Slump Test (Kernig's sign) was in 1884 by a Russian physician, Vladimir Kernig (Kernig 1969;Brody 1969). Originally promoted as a test for infectious meningitis, subsequent variations have popped up (Petren 1909;Woodhall 1950;Brody 1969;Brudzinski 1969) including Cyriax's (Cyriax 1942) description of the "Head-and-Knee Test" for the diagnosis of sciatic perineuritis. Dr. Cyriax defined perineuritis as inflammation of the connective tissue of the "nerve sheath" at the same time sparing the conducting elements of the nerve. The test was described as

the patient sitting with the legs over the edge of the bed. The trunk and thigh are motionless. The leg is then passively extended at the knee until pain is reproduced. The knee is then flexed until the pain disappears. The patient then flexes his chin on to his chest. The pain is again reproduced. The knee is flexed further. Disappearance of the pain indicates the sciatic nerve to be at fault. Cyriax states that this test is much more diagnostic than the Straight-Leg-Raising Test because neck flexion and the tension that it produces in the spinal cord and its continuation the sciatic nerve, has no effect on the posterior structures of the hip and thigh. Cyriax felt therefore that the "Head-and-Knee Test" could differentiate pain originating from the sciatic nerve and its sheath from non neural tissues located in the buttock and posterior thigh.

Figure 3 The Slump test. Note cervical, thoracic and lumbar spinal flexion together with hip flexion, knee extension and ankle dorsi flexion From (Butler 2000) Reproduced with permission

In 1979 Maitland formally introduced the "Slump Test"(Maitland 1979). The test, with some refinements resembled both the combined tests of Kernig and Brudzinski and Cyriax's Head- and-Knee Test. The test continued to be performed in a seated position; however, Maitland added flexion of the thoracic and lumbar spine, thus the name, the Slump Test. Head and neck flexion with overpressure, were then added followed by knee extension. The final modification was, while maintaining the spinal, hip and knee positions, adding ankle dorsiflexion (see Figure 3). Maitland asserted that the test endeavors to determine the relationship between the patient's symptoms and any restriction of movement of the pain sensitive structures located within the spinal canal or the intervertebral foramen(Maitland 1979;Maitland 1985). Butler and Gifford

suggested that the Slump Test was “perhaps the most important tension test linking neural and connective tissue components of the nervous system from the pons to the terminations of the sciatic nerve in the foot”(Butler 1989).

Building the Slump Test – Movement of Neural Tissue within their Nerve Beds

The Basis of the Slump Test

The spinal canal is a rigid skeletal tube. The axis of rotation for anterior (flexion) and posterior (extension) sagittal rotation is located in the posterior ½ of the intervertebral disc (Gertzbein et al. 1985). Since the spinal canal is located behind the axis of rotation flexion will result in lengthening of the canal and extension will shorten the canal. Flexion of the entire spine from an extended position will elongate the spinal canal by up to 9 cm.(Louis 1981). The spinal cord has to adapt to the changes in length of the spinal canal. The spinal cord and its connective tissue coverings react to changes in the spinal canal by stretching and by movement relative to the container. Significantly, cervical flexion by itself has been observed to produce cranial movement of the lumbosacral nerve roots as well as increasing tension in the dura and root sleeves of the sacral cone (SMITH 1956;Breig 1962;Breig 1978;Breig 2007). The fact that cervical flexion, by itself, produces movement and tension changes in the lumbosacral roots has lead to the use of cervical flexion at specific stages of the Slump Test as a means of increasing or decreasing tension from a distant site. This is known as a sensitizing maneuver (Butler 2000).

The starting position of the Slump Test is flexion of the thoracic and lumbar spine. This is achieved in a sitting position by having the subject assume a slumped posture. The seated position prepositions the hips in 90^0 of flexion. Note that the cervical spine is maintained in a neutral position at this point. The remainder of the Slump Test involves knee extension and ankle dorsi flexion (see figure 3). The extraforaminal spinal nerves, the sciatic nerve, the tibial nerve and its branches in the foot are all located posterior to the axis of rotation of the joints which they transverse. Knee extension and ankle dorsi flexion, in combination with the pre-existing hip flexion will therefore lengthen the nerve bed. Beith et al. (Beith 1995) measured the change in length of the combined nerve beds of the sciatic and tibial nerves in 5 human cadavers during the straight leg raise/dorsiflexion maneuver. Following 90^0 of hip flexion, 90^0 of knee extension and 20^0 of ankle dorsi flexion the peripheral nerve bed was observed to lengthen by 89 – 124 mm. The amount of intraspinal and intraforaminal movement of the nerve roots and the spinal nerve is relatively small (.55 – 5.0 mm)(Inman 1942;Falconer MA 1948;GODDARD and REID 1965;Breig and Troup 1979;de et al. 1989;Smith et al. 1993;Breig 2007;Gilbert et al. 2007). The amount of strain sustained by the lumbosacral nerve roots that was reported was more substantial but varied considerably ranging from .12% to 3.4%(Smith et al. 1993;Gilbert et al. 2007).

Straight- leg-raising with the ankle in neutral does produce movement of the sciatic and tibial nerves as far distally as the foot(Goddard and Reid 1965;Breig and Troup 1979;Coppieters et al. 2006;Breig 2007). The movement is greatest adjacent to and in the

direction of the moving joint. Ankle dorsiflexion produces distal movement of the tibial nerve as far proximally as the knee. Strain produced within the nerve is proportional to the amount of excursion which occurs in that part of the nerve(Boyd et al. 2005;Coppieters et al. 2006).

The position of maximum neural tension is thoracic and lumbar spinal flexion, bilateral hip flexion, bilateral knee extension, bilateral ankle dorsiflexion and cervical spinal flexion. Conversely, the position of minimal neural tension is thoracic and lumbar spinal extension, bilateral hip extension, bilateral knee flexion and bilateral ankle plantar flexion and cervical extension. This same posture has been observed in patients with meningitis as a means of minimizing pain.

Interpretation of the Typical Application of the Slump Test

Asymptomatic Subjects

Most subjects will experience some sort of sensory response if they undertake the Slump Test. Indeed, the intensity of the sensations may be as great as 6/10 on a Visual Analogue Pain Scale. The locations of these sensations are usually felt in the posterior thigh, knee and only occasionally in the calf but may also include the back and neck. The sensations are usually described as “stretching, tight and pulling” and generally are interpreted as arising from the stretching of local tissues such as muscle, fascia, tendons and neural connective tissue in these areas. Extending the neck reduced the sensations in 40% to 79.2% of the subjects. At the same time, flexing the neck reduced knee extension range

of motion from 6^0 to 30^0. Along the same line the addition of ankle dorsi flexion also reduced knee extension range of motion by 7^0 to 10.2^0. The fact that cervical extension and ankle dorsiflexion affected the experience of sensations and the range of motion at the knee is most often interpreted as implicating neural tissue as the source of the sensations. Of note was that cervical flexion and ankle dorsiflexion had equal effects on both lower limbs and therefore a normal response to the Slump Test would be symmetrical restriction of range of motion(Maitland 1979;Gajdosik et al. 1985;Johnson and Chiarello 1997;Lew and Briggs 1997;Walsh 2007;Herrington et al. 2008;Davis et al. 2008).

Current Interpretation of a "Positive Test"

The Slump Test is routinely used to differentiate pain arising from *neurogenic* tissue versus *non-neurogenic* tissue. Specifically, neurogenic tissue includes axons and all associated connective tissue but excludes all other structures such as muscles, tendons, and ligaments. The test is interpreted subjectively utilizing deductive reasoning. Butler provides a scheme which illustrates the accumulation of findings which support the declaration of a "positive test" indicating involvement of the nervous system (Butler 2000) (Fig 4).

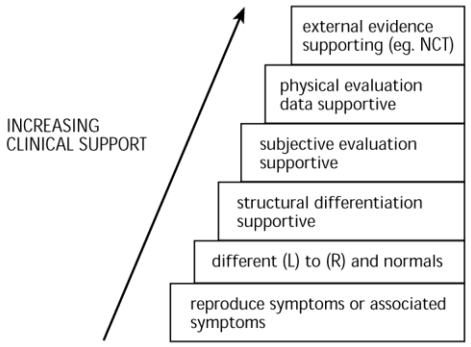


Figure 4 The accumulation of data to help infer a neurodynamic test is positive for the nervous system. NCT = nerve conduction test. From Butler (Butler 2000) Reproduced with permission

Reproduction of Symptoms

The first level of support is whether the Slump Test

reproduces the patient's symptoms (Shacklock 1996;Butler 2000;Hall 2004;Shacklock 2005;Coppieters et al. 2005). However, caution is advised in accepting this component at face value. One must first ask, what are the sensations that the test reproduces? Walsh et al(Walsh 2007) clearly demonstrated that 97.6% of asymptomatic subjects reported a sensory response during the Slump Test. It is therefore important to confirm that the sensations reported during the test are indeed the same symptoms that the patient is suffering with and not a new sensation that is specific to the test. Intensity of symptoms should also be considered with caution. Intensities as great as 6/10 on the VAS have been reported in asymptomatic subjects during the Slump Test(Walsh 2007).

Differences from Left to Right

Differences between the affected and the unaffected limb is another factor in determining whether a test is positive or negative (Butler 2000;Coppieters et al. 2003a;Coppieters et al. 2003b;Shacklock 2005). In fact, in the lower limb, reproduction of unilateral radicular pain projecting into a dermatome during the Straight-Leg-Raising Test was found to be the most discriminatory indicator for radicular pain (Scholz et al. 2009). Accepting this, one should always bear in mind the possibility of an overall increase in sensitivity associated with a state of central sensitization which may affect the outcome of any neurodynamic test. For this reason, neurodynamic tests are always, first, a test of sensitivity(Butler 2000). Acknowledging this, numerous studies demonstrate differences in responses to the upper limb neurodynamic tests between the affected and unaffected limbs in patients with brachial or cervicobrachial neurogenic pain(Quintner 1989;van der et al. 2001;Coppieters et al. 2003a). Thus, differences between affected and

unaffected limbs remain a powerful diagnostic facet despite the presence of central sensitivity.

It should be noted that there is an enormous variability in the absolute range of motion observed during these tests (Hall 2004) and bilateral restriction of knee extension occurs in many asymptomatic subjects (Johnson and Chiarello 1997;Coppieters et al. 2005;Herrington et al. 2007). Therefore, the essential feature is whether any difference in knee extension is observed rather than how much restriction is present.

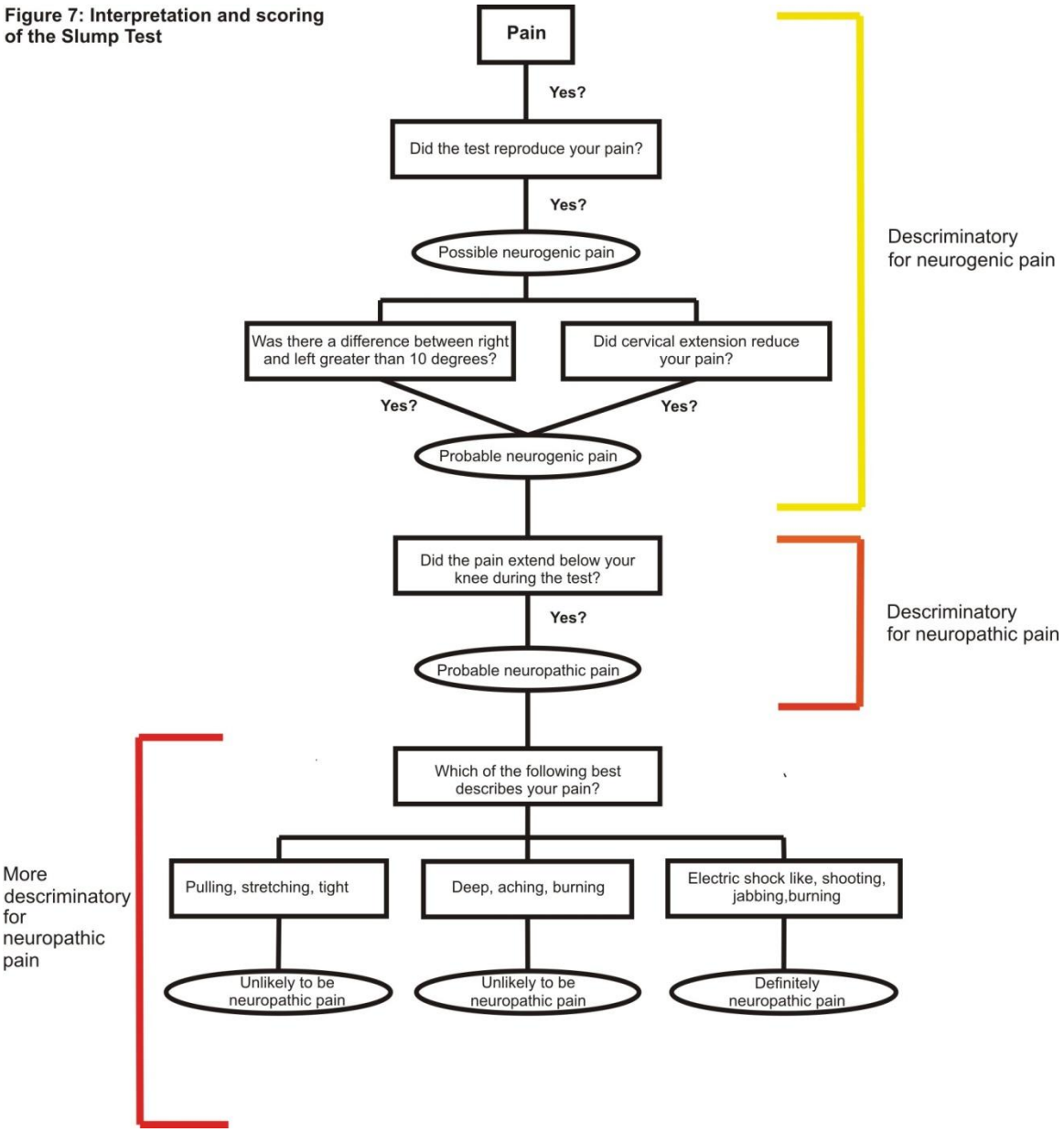
Structural Differentiation (cervical flexion/extension)

The basis for structural differentiation stems from the idea that the nervous system is continuous and that certain movements load the peripheral nervous system more than the overlying muscles or fascia. Structural differentiation is achieved through the use of a sensitizing maneuver. A sensitizing maneuver should utilize the movement of a structure or body part that is located some distance from the region that is being tested and has no physical link with the region except by means of the nervous system. The subsequent addition of a sensitizing maneuver introduces more tension into the neural tissue continuum. If the addition of a sensitizing maneuver increases symptoms it is said to implicate *neurogenic tissue*. Conversely, the subtraction of a sensitizing maneuver that reduces symptoms is also said to implicate *neurogenic tissue*. Numerous sensitizing maneuvers exist including: the addition of cervical flexion during the SLR and Slump Tests, lateral neck flexion with the upper limb neurodynamic tests and medial hip rotation during the SLR test, to name a few.

In summary, following completion of the Slump Test three questions are asked: 1) did the test reproduce your pain? 2) was there a difference between right and left? and 3) did cervical extension reduce or eliminate your pain? If the responses to the questions are yes then there is strong probability that the source of the patient's symptoms is *neurogenic tissue* (figure 7). Indeed, for those already diagnosed with neuropathic pain, a positive neurodynamic test was also observed in all patients (100% sensitivity)(Scholz et al. 2009). However, a "positive" neurodynamic test, unqualified and considered in isolation is a blunt instrument. These tests have been predominantly used to discriminate between neural and non neural tissue. However, when used to discriminate the source or mechanism the test is sensitive but not very specific. The issue is that not all *neurogenic* tissue is neural tissue. In keeping with the previously stated focus on peripheral neuropathic pain, the *neurogenic* tissues that will be reviewed here are those associated with the peripheral nervous system including all tissues distal to the dorsal horn including nerve trunks, nerve roots and dorsal and ventral rami.

Nerves are made up of conducting axons, connective tissues, vascular tissue and an intrinsic innervating plexus, the nervi nervorum. The nervi nervorum give rise to free nerve endings that are located within the nerve connective tissue (Hromada1963;Vilensky et al. 2005;Bove 2008). The

Figure 7: Interpretation and scoring of the Slump Test



nervi nervorum are unmyelinated peptidergic fibres (Bove and Light 1995a;Bove and Light 1995b) that are sensitive to stretch and will signal pain with excessive elongation (Bove and Light 1995b). Stretching of a normal nerve during neurodynamic testing will often produce sensations like

stretching, tight, pulling and strain. The source, of these sensations is most likely the nervi nervorum since, in a normal state, axonal tissues are incapable of generating impulses in response to this stimulus (Devor 2006a). Sensitized nervi nervorum will

respond to mechanical stimulation in an exaggerated fashion. This pain is typically described as aching, occasionally knifelike, tender, familiar and deep(Asbury and Fields 1984). This is in contrast to the common descriptors used when describing neuropathic pain which include electric shock like, burning, tingling, pins and needles like and numb. Thus, the nervi nervorum fulfill a nociceptive function in the neural connective tissues at the extremes of range in asymptomatic
individuals and also signals decreased pain
thresholds arising from damaged or inflamed neural connective tissue.

Additional Differentiation

Accepting that the Slump Test is able to *identify* neurogenic tissue as a source of pain sets the stage for a very significant question. Can the Slump Test *differentiate* which of the neurogenic tissues produces the pain? In other words, can the Slump Test indicate whether the pain originates from the neural connective tissue or from axons? If the Slump Test could identify pain that originates from axons, it would also indicate that neuropathic pain was present.

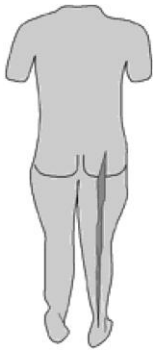


Figure 6 An illustration of the pattern of radicular referred pain illustrating its narrow distribution extending below the knee (Bogduk 2009) Reproduced with permission

The Slump Test selectively applies tension to various parts of the nervous system. If mechanically sensitized by whatever mechanism, the connective tissue, or the axonal tissue, or both, will produce pain when it is stretched. Because of this the patient may experience somatic referred pain, neuropathic pain or both simultaneously. Key to differentiating neuropathic pain from neurogenic pain is the location of the symptoms produced during

the Slump Test. As previously mentioned investigators have reported sensations produced predominantly in the posterior thigh and knee in asymptomatic subjects (Lew and Briggs 1997;Walsh 2007). In symptomatic patients, somatic referred pain from the lumbar spine, including the connective tissue of the lumbar spinal nerve roots is usually felt in the low back, buttock and posterior thigh (figure 5). On the other hand, radicular referred pain originating from a lumbar spinal root travels down the posterior leg, usually in a narrow band extending below the knee (Figure 6) (Bogduk 2009). Thus it is proposed that a conventional positive finding on a Slump Test can be further refined to indicate that neuropathic pain is present if pain elicited by the Slump Test extends below the knee (Figure 6).

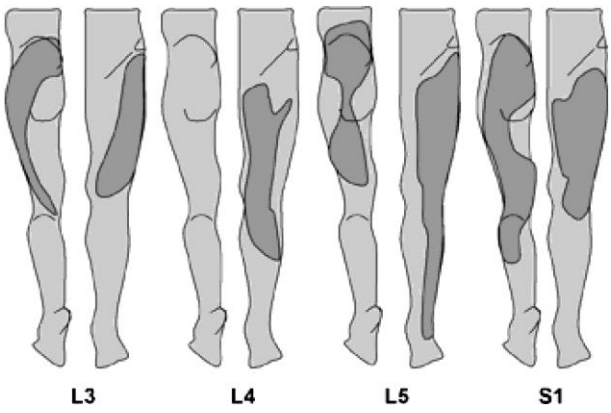


Figure 5 Patterns of somatic referred pain evoked by noxious stimulation of the interspinous ligament at the segments indicated (Bogduk 2009) Reproduced with permission

The Role of Verbal Descriptors of Pain

It is expected that adding the criterion of pain that extends below the knee will enhance the usefulness of the Slump Test in diagnosing neuropathic pain. However, it is recognized that in some cases somatic referred pain may extend to the posterior knee and into the calf. In addition it is possible that some patients may interpret pain near the knee as pain below the knee. Both of these would result in false positives and reduce the specificity of the test. To address this, an additional aspect can be added to the Slump Test; the quality of the pain that is produced during the Slump Test.

Typically, the classical neurological examination has omitted any pursuit of verbal descriptors of pain. It has been felt that there are no pathognomonic pain descriptors that are specific for neuropathic pain and they, therefore, serve no use in the diagnosis (Hansson and Haanpaa 2007). Further, the subjective nature of pain would be expected to result in a wide variety of personal experiences and an equally variable use of verbal descriptors. At the same time, it is known that neuropathic pain is generated by unique processes affecting the nervous system. It seems reasonable to deduce that this could result in unique sensations. Clinical experience has suggested that patients with neuropathic pain use certain descriptors more often than those who have inflammatory pain. A number of studies have confirmed that this is indeed the case (Boureau et al. 1990;Galer and Jensen 1997;Bennett 2001;Krause and Backonja 2003;Bouhassira et al. 2005;Bennett et al. 2005;Jensen et al. 2006;Dworkin et al. 2007). For example, the behaviour of pain arising from sensitized nociceptors is usually described as continuous with waxing and waning whereas neuropathic pain is variable, intermittent, lancinating and paroxysmal(Asbury and Fields 1984;Bouhassira et al. 2005;Jensen et al. 2006;Freynhagen et al. 2006a;Bennett et al. 2007). It is also becoming apparent that different subgroups of neuropathic pain may present different sub groupings of sensory descriptors and physical findings (Baron et al. 2009;Cruccu and Truini 2009a).

Several screening tools based primarily on verbal descriptors have been developed and validated to detect neuropathic pain (Galer and Jensen 1997;Bennett 2001;Krause and Backonja 2003;Bouhassira et al. 2004;Bennett et al. 2005;Freynhagen et al. 2006a).

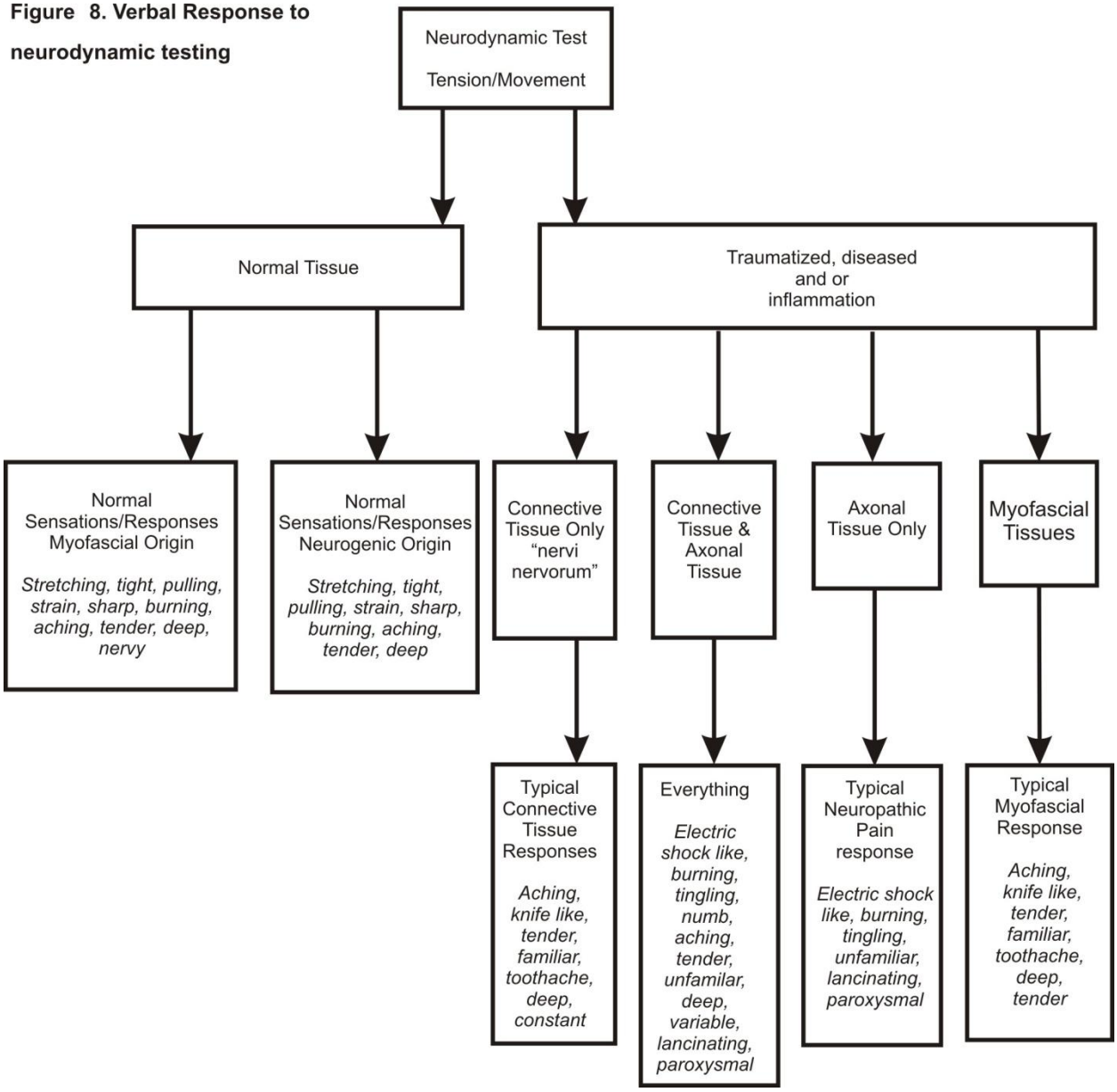
While some neuropathic screening tools incorporate limited sensory testing, others rely solely on verbal descriptors and these have shown relatively high sensitivity and specificity for neuropathic pain. For example, the painDetect questionnaire has a sensitivity of 85% and a specificity of 80% (Freynhagen et al. 2006a). The common descriptors that have been identified across a number of studies include: electric shock like, burning, Tingling, pins and needles, variable, lancinating, paroxysmal.

Incorporation of Verbal Descriptors in the Slump Test

The fact that different symptoms appear to originate from two different sources within *neurogenic tissue* may offer an opportunity to gain further insight into the source of those symptoms. If the pain that is experienced during the Slump Test originates from non-neuropathic mechanisms (nervi nervorum) it will present with certain qualities. On the other hand if the pain that arises originates from neuropathic mechanisms (axons) then it will present with different qualities. Figure 8 summarizes the expected responses to tension applied to various tissues during a neurodynamic test in two states of sensitivity. The left side of the figure represents expected sensations described when normal neurogenic and non neurogenic tissues are stretched. The right side of the figure represents the expected responses when: neural connective tissue, neural connective tissues and axonal tissues,

axonal tissue only and surrounding myofascial tissue is stretched following sensitization secondary to trauma, disease and or inflammation.

Figure 8. Verbal Response to neurodynamic testing



Acknowledging that no one word is pathognomonic for neuropathic pain, the neuropathic pain screening tools have shown us that subjective verbal descriptors used to describe somatic

nociceptive pain is different than the verbal descriptors used when experiencing neuropathic pain. Utilizing this knowledge the Slump Test may be further focused by noting which verbal descriptors best describe the pain produced by the test. Somatic pain arising from stretched neurogenic tissue during the Slump Test is different in quality and

in distribution than pain arising from stretched mechanically sensitive axonal tissue (figure 5). Stretching neurogenic connective tissue will produce diffuse pain in a non neuroanatomical distribution usually not extending below the knee. Stretching neurogenic axonal tissue will produce pain often described as electric shock like, burning, tingling and like pins and needles. This pain will usually be better defined and will usually extend below the knee.

Figure 7 illustrates that the only part of the Slump Test that is truly discriminatory for neuropathic pain is "does the test produce pain below the level of your knee?" All other components serve only to aid in confirming *neurogenic* tissue as a source of symptoms. Further to this, the identification of the verbal descriptors electric shock like, shooting, jabbing and burning as those words which best describe the pain reproduced by the Slump Test then further strengthens the diagnosis of *neuropathic pain*. The expectation is that further improvement in specificity will result from the inclusion of verbal pain descriptors in the criterion for a positive Slump Test.

Summary

It is now recognized that a significant proportion of the population suffering with chronic pain have some degree of neuropathic pain characteristics. It has also been demonstrated that the presence of neuropathic pain has been linked to poor short term and long term recovery. At present the diagnosis of neuropathic pain is difficult. The examination and subsequent diagnosis is usually done by a specialist which may involve a long waiting period. In addition the diagnostic procedure is lengthy and requires advanced skill. It

follows that this creates delays in diagnosis which will then also delay appropriate treatment which may promote the progression to chronic pain conditions.

The signs and symptoms associated with neuropathic pain may include mechanical and thermal allodynia, hyperalgesia and tactile and thermal sensory loss. Recent investigations have shown that the most discriminatory clinical tests for neuropathic pain are decreased pin prick sensation, decreased cold pain detection thresholds and a positive Straight-Leg-Raising Test. The Straight-Leg-Raising Test is a neurodynamic test routinely used by clinicians in the evaluation of low back and radiating leg pain. Another neurodynamic test which incorporates the Straight-Leg-Raising Test, the Slump Test, is considered by some to be a superior test to the Straight-Leg-Raising Test.

The Slump Test, like the Straight-Leg-Raising Test appraises neural tissue mechanical sensitivity. Both of these tests have been shown to be highly effective in detecting the presence of increased sensitivity of neurogenic tissues to tension. Currently, the routine use of these neurodynamic tests is to differentiate symptoms arising from neurogenic versus non neurogenic tissues.

It is proposed that incorporating the location and quality of pain experienced during the Slump Test can be used to differentiate neuropathic pain from non-neuropathic pain. Non neuropathic pain demonstrates a pattern of referred pain that is distinctly different than that observed with neuropathic pain. At the same time, neuropathic pain quality is different than non neuropathic pain quality. If the pattern and quality of pain reproduced

during the Slump Test is characteristic of neuropathic pain then a diagnosis of neuropathic pain should be possible with both high sensitivity and specificity.

Purpose

To determine the effectiveness of combining the conventional Slump Test with additional criteria regarding pain location and pain quality to detect the presence of neuropathic pain.

Primary Objectives

- to assess the sensitivity and specificity of the conventional Slump Test in identifying individuals with and without neuropathic pain compared to a standard neurosensory examination and a neuropathic pain screening tool.
- to assess the sensitivity and specificity of the conventional Slump Test combined with a pain location criterion in identifying individuals with and without neuropathic pain compared to a standard neurosensory examination and a neuropathic pain screening tool.
- to assess the sensitivity and specificity of the conventional Slump Test combined with pain location and pain quality criteria in identifying individuals with and without neuropathic pain compared to a standard neurosensory examination and a neuropathic pain screening tool.

Secondary Objectives

- To determine whether **cold detection thresholds** differ between the control groups, the neuropathic pain group and the non-neuropathic pain group as diagnosed by the Slump Test, standard neurosensory examination, or a neuropathic pain screening tool.
- To determine whether **cold pain thresholds** differ between the control group, the neuropathic pain group and the non-neuropathic pain group as diagnosed by the Slump Test, standard neurosensory examination, or a neuropathic pain screening tool.
- To determine whether **pressure pain thresholds** differ between the control group, the neuropathic pain group and the non-neuropathic pain group as diagnosed by the Slump Test, standard neurosensory examination, or a neuropathic pain screening tool.

Hypotheses

It is hypothesized that this investigation will demonstrate that a commonly used clinical neurodynamic test, The Slump Test will show good sensitivity and low to moderate specificity when compared to a standardized neurosensory examination in the identification of neuropathic pain. It is further hypothesized that the same Slump Test combined with a novel criteria for pain location and pain descriptors will demonstrate improved specificity.

Methods

Subjects

The study consisted of 2 primary groups; a control group and a low back pain/sciatica group. The control group was recruited from the general public and from the Faculty and student body of the School of Medical Rehabilitation, University of Manitoba as well as from the staff of the Sports Physiotherapy Centre and the Pan Am Clinic. The low back pain/sciatica group was recruited from a busy, musculoskeletal medical practice and a large musculoskeletal private physiotherapy practice.

Sample Size

Data reported in Sterling and Pedlar (Sterling and Pedler 2009a) was used to estimate the required sample size. In this study pressure pain thresholds and cold pain thresholds were compared between two groups, one with predominantly neuropathic pain (NeP) and one with non neuropathic pain (NNP). In the pressure pain component the NeP group produced a mean of 146.8 kPa $\pm$ 83.7 (n=29) while the NNP group produced a mean of 242.6 kPa $\pm$ 110 (n=56). The following formula was used to calculate the sample size required to demonstrate a significant difference between the NeP group and the NNP group.

$$n = 2(PI\ (\sigma/\mu_1 - \mu_2))^2$$

PI is the Power Index and represents a combination of type I and type II error factors. In this example it is set at an α or type 1 error of .05 which equals a PI of 1.64. The β or type 2 error is set at 0.20 which equals a PI of 0.84. This when added would then equal a PI of 2.48. σ is determined by averaging the standard deviations (83.7 + 110/2 = 96.9) while μ_1

- μ_2 is 242.6 – 146.8 = 95.8. From these values the following sample size for each group required to demonstrate a significant difference is:

$$n= 2(2.48\ (96.9/95.8))^2$$

$$n = 12.6$$

In the cold pain threshold component of the same study the NeP group produced a mean of 16.38 ^{0}C $\pm$ 6.2 while the NNP group produced a mean of 12.3 ^{0}C $\pm$ 6.0. The sample size generated from these values is:

$$n = 2(2.48\ (6.1/4.1))^2$$

$$n = 27.2$$

In this example from Sterling et al. the minimum number of subjects that were required to show a significant difference between groups was 13 for one variable and 27 for another. In that the Slump Test investigation is measuring similar variables, a sample size of 25 will be targeted for each group to ensure adequate statistical power.

Inclusion and Exclusion Criteria

All subjects were required to be over 18 years of age and able to understand and speak English. Control subjects (n=25) were to be excluded if they had any complaints of spinal or limb pain or history of trauma or medical treatment to the spine or limbs. In addition any subjects with diagnoses listed in Appendix 2 were to be excluded from consideration for the study. Recruitment was by poster (see Appendix 1) and by word of mouth.

In the end, twenty four (10 males and 14 females) asymptomatic subjects were examined in the Control group (aged 25-70 mean age 44.2 standard deviation 12.8). No subjects were excluded due to complaints of spinal or limb pain or history of trauma or major medical treatment to the spine or limbs. In addition none of the subjects presented with any of the diagnoses listed in Appendix 2 and therefore none were excluded from consideration in the study. All control subjects were provided with a fact sheet (see Appendix 3) at the time of initial contact. It is recognized that the highest rates of non specific low back pain are found in the adult population from the third to sixth decades. It is documented that those individuals in their third decade are most likely to experience a new onset of low back pain. In addition there seems to be little difference between genders in respect to incidence of non specific low back pain (Rubin 2007). In the case of lumbar disc syndrome or "typical sciatica" the prevalence was significantly higher ($p<0.005$) in men (5.1%) than in women (3.7%). In both genders the prevalence was highest in those aged 45-64 (Heliovaara et al. 1987;Stafford et al. 2007). Taking all this into account the control group was recruited in such a way as to reflect an equal mix of male and females predominantly between the ages of 30 and 60.

Unfortunately only twenty one subjects (10 male and 11female were recruited into the low back/sciatica group (aged 25-74 mean age 44 median age 41 standard deviation 14.9). All testing was carried out in a blinded fashion. At the same time an effort was be made to recruit sufficient and balanced numbers of subjects into the study who were likely to have neuropathic versus non-neuropathic pain. To this end, a neuropathic

screening tool, painDetect, was used to track recruitment. The screening tool utilized in this investigation, the painDetect questionnaire (Freynhagen et al. 2006a) has been shown to have a sensitivity and specificity of 85% and 83%, respectively, when applied to those pre-diagnosed with neuropathic pain (Freynhagen et al. 2006a).The intent was to recruit approximately ½ of the subjects who had some elements of neuropathic pain (painDetect score >12) and approximately ½ of the subjects who were unlikely to have any elements neuropathic pain (painDetect score <=12). If a subgroup had reached the target of 25, no further enrollment into this subgroup would occur. The monitoring of intake was performed by a non investigative administrative assistant. Similar to the control group, any subjects with diagnoses listed in Appendix 2 were excluded from the study. In addition, any subjects having a physical limitation to undergoing a complete neurosensory examination and or a Slump Test were also excluded from the study.

Subjects expected to be categorized as experiencing neuropathic pain and scoring >12 on the painDetect screening tool would probably include but not be limited to pain caused by physical injury to the lumbosacral nerve roots by entrapment or compression. On the other hand, subjects expected to be categorized as experiencing non neuropathic pain and scoring <=12 on the painDetect screening tool would probably include but not be limited to pain caused by osteoarthritis of the zygapophysial joints, inflammatory arthropathies of the zygapophysial joints or any injury to the spine or its surrounding soft tissues and including the connective tissue coverings of the nerve roots and spinal nerves.

Procedure

Initial contact with all potential study participants was usually made in person at the Sports Physiotherapy Centre reception desk. An overview of the study was provided and those willing to participate were scheduled for testing. A study fact sheet was provided for the subjects at that time and any concerns or questions were addressed. If the subject agreed to proceed with the study he/she were given an Informed Consent Form to review and sign (Appendix 3). Data base information was then collected. A subject number was then provided for the subject. An appointment was then scheduled for the subject. All investigators, including any research assistants had undergone Personal Health Information Act Orientation and pledge signing prior to participating in this study. All subjects filled out a painDetect neuropathic pain screening questionnaire at initial contact. Upon arrival on their scheduled study date the control subjects were allowed to change their clothes if required. The subjects then proceeded to the testing area where they were administered the Slump Test, cold threshold detection test, cold pain threshold test and a pressure pain threshold test.

Patients attending the Pan Am Clinic either in the Primary Care Medical practice or the Physiotherapy practice who had been assessed and diagnosed as “mechanical low back pain” or low back pain together with radiculitis, “sciatica” and or radiculopathy were approached by their examining physician/therapist to determine if they were interested in participating in the study. Posters (see Appendix 10) inviting patients to participate in the study were also on display in the Pan Am Clinic waiting areas and examination rooms.

Following recruitment each Low Back Pain subject was provided with a fact sheet (see Appendix 4) which provided a brief description of the study. The subjects were then required to report to the Physiotherapy reception desk within the Pan Am Clinic for registration. If the subject did not have time to read and sign the Informed Consent form and was willing, their name and phone number was obtained and they were provided with a card containing the study administrators name and contact number and e-mail address. These subjects were contacted by the study administrator. A rough grouping was made by the administrator by asking the subject if they had pain extending into their leg. If the quota for a specific group was already filled the subject may be have been rejected. Those subjects who could take the time were be required to read and sign an Informed Consent document constructed following the University of Manitoba Bannatyne Campus Ethics Board consent-form for non- clinical trials (see Appendix 5 Informed Consent Form). Data base information was then collected. This information is stored in the Pan Am Clinic electronic patient data system which is a secure system. The subject was then required to complete a painDetect questionnaire (see Appendix 6) to determine if they had any elements of neuropathic pain. This was done to balance recruitment of those with and without neuropathic pain. This stage of subject recruitment did not involve any of the clinical assessors nor were the results of the painDetect questionnaire revealed to the clinical assessors until after the study. Once sufficient subjects had been recruited that fit the neuropathic or non-neuropathic categories (n=25 for each), no further enrollment occurred for that group. Those not selected to continue were informed and thanked for their interest. For those continuing in the study, a study appointment time was scheduled and a subject number assigned. From this point onwards only the subject number

appeared on all data forms. Appointments were booked as soon as possible to minimize changes in the participant's signs and symptoms which might occur between recruitment and testing.

The Low Back Pain participants, upon arrival at the testing location, were greeted by the study assistant and any questions or concerns addressed. If the subject had not already done so they read and sign the Informed Consent Form. In addition, any missing database information was collected. These subjects then again filled out the painDetect questionnaire to ensure that the screening tool data accurately reflected the subjects' status on the same day of clinical assessment. The clinical assessors were blinded to the outcome of the painDetect questionnaire. The subject changed into appropriate clothing.

The Low Back Pain participants were initially examined by an experienced orthopaedic manual therapist(s) to determine if neuropathic pain was present. This was evaluated using a standardized assessment form which included a detailed neurological-sensory examination (see Appendix 8). The neurological examination closely follows the reference examination commonly used for the identification of Neuropathic pain (Bennett 2001;Bouhassira et al. 2004;Freynhagen et al. 2006a;Treede et al. 2008b;Scholz et al. 2009;Cruccu and Truini 2009b). Following the examination the therapist was required to decide if the participant had *possible*, *probable* or *definite neuropathic pain*. These classifications are based on the grading system of neuropathic pain suggested by Treede et al. (Treede et al. 2008b).The information from the examination was then recorded on the Examination Summary Sheet (see Appendix 9). Since it was not expected that

confirmatory diagnostic tests would be available for many subjects, a result of *probable neuropathic pain* or *definite neuropathic pain* was considered as positive for the presence of neuropathic pain. If a subject was placed in the category of *possible neuropathic pain,* they were considered to be negative for neuropathic pain.

The participants then proceeded to the Slump Test component of the investigation. The participant was again greeted and asked if they had any questions. A brief explanation of the procedure was given. The participant was seated on the edge of a treatment plinth. The participant was instructed to sit back on the plinth so that the posterior aspect of their knees was just touching the plinth. They were then instructed to place their hands behind their back. A Saunders Digital Inclinometer was attached by tape to the anterior aspect of the right shin of the subject. The Slump Test was then administered as described by Butler(Butler 2005b) with some minor modification. The subject started with their knees together and thighs well supported. The subject was then asked to move into the spinal slump position. The subject was encouraged not to roll their pelvis forward. The subject was instructed to report any reproduction of any pain or sensation during this part or during any subsequent part of the test. The subject was then instructed to flex their neck. The examiner was seated beside the participant and guided and then maintained the cervical flexion with gentle pressure from the forearm and hand. Again the subject was asked if this part of the test reproduced any sensation or pain. The subject was then asked to dorsiflex their right ankle. The subject then extended their right knee. The angle of the right knee was then recorded by the investigator. The participant was again asked if the addition of this component reproduced any sensations or pain. The participant was then

asked to extend their neck. The participant was then asked if this had any effect on their pain, either worsening or relieving it. Cervical flexion was then be reapplied and the subject was asked to flex their right knee and relax their right ankle. The inclinometer was then moved to the left leg and the same procedure was then repeated for the left knee. Following the completion of the test the subject was asked an additional two questions. The questions were:

1. During the test did any part of the test cause your pain to extend past your knee?
2. Which of the following groups of words **best** describes the sensation/pain produced by the test?
    a. Pulling, stretching, tight
    b. Deep, aching burning
    c. Electric shock like, burning, shooting, jabbing

All results including maximum knee extension were recorded on the Slump Test and QST results form (Appendix 7). Following the Slump Test the subjects moved to a third station for the last part of the investigation. The third station was where the subjects were tested for cold detection thresholds, cold pain thresholds and pressure pain thresholds. The thermal testing was done utilizing a TSA-II NeuroSensory Analyzer (Medoc, Durham, NC).The TSA-II is a precise computer-controlled device capable of generating and documenting response to highly repeatable thermal stimuli, such as warmth, cold, heat-induced pain, and cold-induced pain. During the thermal testing a 30x30mm thermode was held against the participant's skin. The thermode is capable of heating or

cooling the participant's skin. This device is based on Peltier elements which consist of semiconductor elements which produce a temperature gradient between the upper and lower stimulator surfaces produced by the passage of an electric current. As the temperature rises or lowers the participant indicates when he/she first feels cold sensation and cold induced pain. The temperature for these sensations was recorded when the participant triggered the device. The participant was tested for cold sensitivity and cold pain thresholds in six areas; the lumbar region bilaterally at the level of the iliac crests over the paravertebral muscles, the anterolateral lower legs over the tibialis anterior bilaterally and the medial forearms bilaterally (regions PLF5, PRG5, ARB2, ALC2, ARA5 and ALD5 on the Neurosensory Examination Template [Appendix 8]). The minimum temperature to which the thermode would cool was 0^0 .The measurement sites for CS and CP were chosen not to reflect specific dermatomes but rather to assess responses throughout the body on the chance that central processes might be at play in some subjects. In addition, local sensory changes may be detected in the right and or left legs. Lastly pain pressure thresholds were then measured using a pressure algometer with a probe size of 1 cm^2 (Wagner Pressure Algometer Model FPK20 [100 x .01 N]). The readings were made at remote upper limb sites (regions ARA6 and ALD6) specifically over the lateral deltoid muscles bilaterally. Again, these sites were chosen to assess the potential presence of systemic mechanical hypersensitivity. This information was recorded on the Slump Test and QST results Form (see Appendix 7).

As described previously, the QST measuring device and the pressure algometer had minimum and maximum values. Some of the subjects reached those limits and this produced a floor and ceiling effect with some degree of clustering.

The investigator administering the Slump Test, the cold detection threshold test, the cold pain threshold test and the pain pressure threshold test was blinded to the results of the neurosensory examination.

Data Analysis

All QST data were analyzed on the statistical computer package Statisica by StatSoft. In the low back pain/sciatica group the presence of neuropathic pain was established utilizing the previously described "Gold Standard" examination. The low back pain/sciatica group subjects were subsequently designated non neuropathic pain (NNP) or neuropathic pain (NeP).

Slump Test Analysis

The following tests and screening tools were then compared to the "Gold Standard" examination to establish the sensitivity, specificity, positive predictive values, negative predictive values, positive likelihood ratios and negative likelihood ratios. To calculate sensitivity and specificity for each test group, 2 x 2 contingency tables were used. When a zero cell value was encountered, a 0.5 value was added to all cell values to permit calculation of the LRs (Wainner et al. 2003).

1. The Conventional Slump Test,
2. The Slump Test combined with a pain location criterion,
3. The Slump Test combined with pain location and verbal pain descriptor criteria
4. The Slump Test combined with verbal pain descriptor criteria only
5. The painDetect screening tool

Sensitivity is the test's ability to obtain a positive outcome when the condition is actually present (true positive). When sensitivity is very high one can be sure that a negative test will rule the disorder out (SnOUT) (Davidson 2002). This is true because there can be very few false negatives (see Table 4 cell c) Specificity is the test's ability to obtain a negative outcome when the condition is actually absent (true negative). If the specificity is very high chances are that a positive test will rule the disorder in. Here this is so because there can be very few false positives (see Table 4 cell b) (SpIN)(Davidson 2002).

Table 3 illustrates how the experimental findings are converted to a positive or negative designation in preparation for analysis. Listed below are the five test results and the possible outcomes that would designate them as either negative or positive.

(1) If the "Gold Standard" assessment classified the subject as "unlikely" or "possible" to have neuropathic pain it is designated as a **negative.** If however the "Gold Standard" assessment classified the subject as a "probable" or "definite" to have neuropathic pain it is designated as a **positive**".

(2) If the Conventional Slump Test alone reproduces pain but it does not reduce with neck extension nor is there a difference between left or right knee extension and there is no difference in right or left pain distribution it would be designated as **negative**. If however, the pain does reduce with neck extension **and** there is a difference from right to left knee extension **or** there is a right to left difference in pain distribution it would be designated as a **positive**. This is because these components of the Slump Test are able to discriminate neural tissue sources of pain from non neural sources of pain (Butler 2000).

(3) If the Slump Test combined with a pain location criterion reproduces pain but it does not extend below the knee it would be designated as **negative**. If however, the pain does extend below the knee it would be designated as a **positive**. This is because only pain below the knee is discriminatory for *neuropathic pain*.

(4) If the Slump Test combined with pain location plus pain quality verbal descriptors demonstrated pain that did not extend below the knee and where the pain was not best described by burning and or electric like it would be designated as **negative**. If however, the pain did extend below the knee **and** the verbal descriptors that best described the pain were burning and or electric like the designation would be **positive**.

(5) If the Slump Test combined with verbal descriptors that was not best described by burning and electric like it would be described as **negative.** If however, the Slump test was positive by side to side difference in pain location or difference in knee extension **and** the verbal descriptors that best described the pain were burning and or electric like, the designation would then be **positive**

(6) Lastly, if the painDetect score was<= 12 it was designated as **negative.** If however, the painDetect score was > 12 then it was designated as **positive.**

Table 3: Summary of designation of test results in analysis for sensitivity and specificity		
Test	**Negative Response**	**Positive Response**
1. Neurosensory Examination "Gold Standard Diagnosis"	Unlikely/Possible	Probable/Definite
2. Conventional Slump Test alone	Non Neurogenic	Neurogenic
3. Conventional Slump test plus pain location	Pain above the knee only	Pain extending below the knee
4.Conventional Slump test plus pain location plus pain quality	Aching, deep, burning	Pain extending below the knee plus burning electric like quality
5. Conventional Slump Test plus pain quality only	Aching, deep, burning	Pain in one leg, knee extension restriction plus burning electric like quality
6. painDetect only	<=12	>12

Table 4: 2 x 2 Contingency table

Summary of sensitivity and specificity analyses

		Reference Diagnosis		Total
		Positive	Negative	
Alternate Diagnosis	Positive	a (true positive)	b (false positive)	a + b
	Negative	c (false negative)	d (true negative)	c + d
Total		a + c	b +d	

Sensitivity = a/(a+c)

Specificity = d/(b+d)

Positive predictive value (PV+) = a/(a+b)

Negative predictive value (PV-) = d/(c+d)

Each of the individual findings listed in Table 3 (2-6) were then analyzed for sensitivity and specificity as described above. To test for concurrent validity, the presence or

absence of neuropathic pain as determined by the neurosensory examination according to the diagnostic criteria established by Treede et al.(Treede et al. 2008a) (#1 Table 3) was used as the reference group. Each of the individual findings from the variations of the Slump Test and the painDetect questionnaire (#2-6 Table 3) were compared to this reference outcome (see table 5).

The various screening components (2-6) were also analyzed for **predictive values**. Predictive values help establish the usefulness of a test. A positive predictive value (PV+) estimates the possibility that a subject who tests positive on the test actually has the condition or test being screened for. As shown in **Table 4 a Positive Predictive value (PV+)** = a/(a + b) represents the proportion of those who tested positive who were indeed true positives. A test may have a high level of sensitivity but a low predictive value if it generates a large number of false positives. Indeed, the test may be so sensitive that it finds everyone positive and would then have a very poor positive predictive value. **A Negative Predictive value (PV-)** = d/(c + d) on the other hand represents the proportion of those who tested negative that were truly disease or condition free. A test with a high negative predictive value provides a robust estimate of the actual number of subjects who do not have the disease or condition under consideration. A test with a high negative predictive value will be very specific. In other words the test will identify negative tests more readily. A test with a very high predictive value may do so at the expense of its sensitivity and failure to identify some actual positive subjects. A problem with predictive values is that the values only apply when the clinical prevalence is the same as that reported in the study(Davidson 2002).

Likelihood ratios are a powerful measure of the accuracy of a diagnostic test. The Likelihood ratio for a test result indicates how much that test result will raise or lower the pretest probability of the disease or condition (Hayden and Brown 1999). The calculation of Likelihood ratios is straight forward; Likelihood ratio (test +ve) = sensitivity/(1-specificity) or (a/[a=b])/(9b/[b+d]) and Likelihood ratio (test-ve) = (1-sensitivity)/specificity or (c/[a+c])/(d/b+d]). The pretest odds of having a disease or condition multiplied by the Likelihood ratio will give the post test odds of the subject having that disease or condition. Nomograms are commonly used for the determination of the post test probability(Hayden and Brown 1999;Davidson 2002;Grimes and Schulz 2005;Hegedus and Stern 2009)(figure 16). Davidson (Davidson 2002) summarizes the interpretation nicely:

- A +ve LR of 10 or more is an indicator that a positive test will be very good at ruling the disorder **IN** and generate often conclusive changes from pretest to post-test probability
- A +LR of 2 to 5 and 0.5 to 0.2 will generate small but sometimes important changes in probability (Jaeschke et al. 1994)
- A –ve LR of 0.1 or less is an indicator that a negative test will be very good at ruling a disorder **OUT**
- A LR close to 1.0 will provide little change in probability that a person has or does not have a disorder

Table 5: Definition & calculation of test characteristics (modified from Davidson(Davidson 2002)		
Test characteristic	Definition	Calculation
Sensitivity	The proportion of people who have the disorder who test positive	a/(a+c)
Specificity	The proportion of people who do not have the disorder who test negative	d/(b+d)
PPV	The proportion of people who test positive who have the disorder (the probability that someone who tests positive has the disorder)	a/(a+b)
NPV	The proportion of people who test negative who do not have the disorder (the probability that someone who tests negative does not have the disorder)	d/(c+d)
Prevalence	The proportion of people in the same sample who had the disorder	(a+c)/(a+b+c+d)
Likelihood ratios	The likelihood of a given test result in a person with a condition or disease compared with the likelihood of this result in a person	+LR = (a/[a+c])/(b/[b+d]) -LR = (c/[a+c])/(d/b+d])

	without the disease	

Quantitative Sensory Data Analysis

To determine whether sensory function (cold sensation (CS), cold pain perception (CP) and pressure pain (PP)sensation) differs between those within the control group and those identified as having NNP or NeP, the Shapiro-Wilk test was utilized at the onset to determine if the sample came from a normally distributed population. It was determined that the data was not normally distributed and analysis utilizing non parametric techniques would be employed. The Mann-Whitney U test was used for between group analyses. The Control Group CS, CP and PP were compared to the equivalent low back pain/sciatica groups. The Wilcoxon Matched Pairs Test was used to determine if any significant differences existed between right and left within each group for CS, CP and PP. The Kruskal-Wallis ANOVA test was then used to look at differences in CS, CP and PP for each testing area (eg left leg) between the Control, NNP and NeP groups within each diagnostic category (eg conventional slump test). Following the identification of locations where differences were demonstrated the Mann-Whitney U test was used to confirm which pair (eg control vs NNP) demonstrated the differences.

Within the low back pain/sciatica group those subjects with NeP will usually exhibit signs and symptoms in either the left or the right leg. The fact that this occurs makes analysis of the NeP group a little more complex. Acknowledging this, the NeP group was then subdivided into a NeP right side affected group and a NeP left side affected group.

The Mann-Whitney U test was then used to compare the Control group and those NeP subjects with right sided symptoms. Comparisons were made by the various diagnostic categories (eg conventional slump) for CS, CP, and PP for all of the testing locations. The same procedure was then repeated for those NeP subjects with left sided symptoms.

Results

The Control group consisted of 24 subjects and the low back pain/sciatica (LBP) group consisted of 21 subjects. The descriptive statistics for both groups are summarized in Table 6. The two groups were very similar in terms of gender proportions and age. The control group demonstrated no evidence of NeP as per the painDetect scores whereas the LBP group had significantly higher scores ($p < 0.001$). Further, the control group demonstrated minimal differences in knee extension during the slump test while the LBP group had a significantly greater side-to-side difference ($p = 0.003$).

Table 6. Descriptive statistics for control and LBP subjects.

Group	n (male/female)	age[a]	PainDetect[a]	Knee Diff[a,b]
Control	24 (10/14)	44.2 ± 12.8	0.4 ± 1.5	4.1 ± 2.7
LBP	21 (10/11)	44.0 ± 14.9	10.9 ± 5.6[#]	13.4 ± 12.1[#]

[a] values are means ±standard deviation

[b] difference in knee range of motion during slump test

[#] significantly different from Control group, $p<0.05$

The PainDetect scores and the differences in knee extension during the slump test are listed according to diagnostic definitions in Table 7. When the LPB subjects were categorized as having NNP or NeP according to the clinical examination, the conventional slump test or the anatomical slump test, no differences were seen in PainDetect scores. As expected, a significant difference in PainDetect scores was present between NNP and NeP groups when the LBP subjects are categorized by their PainDetect scores. Significant differences in knee extension during the slump test were only seen when LBP subjects were categorized by the conventional slump test whereas no other diagnostic definition resulted in significant differences.

Table 7. PainDetect scores and differences in knee extension during the slump test for NNP and NeP subjects according to different diagnostic definitions.

	n		PainDetect[a]		Knee Extension[a]		Symptom Duration[a]	
	NNP	NeP	NNP	NeP	NNP	NeP		
Clin. Exam	10	11	9.3±6.5	12.3±4.6	10.3±11.7	16.2±12.2	37±39	14±16
Slump	8	13	9.1±6.5	11.9±5.0	5.0±2.8	18.5±12.7[#]	36±40	18±23
Slump Anat	15	6	10.5±6.2	11.8±4.1	11.3±10.1	18.5±16.0	32±34	7±9
Pain-Detect	14	7	7.6±3.5	17.3±2.6[#]	12.2±12.4	15.7±12.0	26±32	22±30

[a] values are means ±standard deviation
[#] significantly different from NNP, $p<0.01$

CLin Dx: p=0.088

Slump: p=0.216

Anat: p=0.088

Pdet: p=0.776

At the time of initial contact, 12 of 21 LBP subjects had painDetect scores greater than 12 indicating the presence of some components of neuropathic pain. On the date of assessment the number had dropped to 7. The mean number of days between administration of the painDetect test at initial contact and on the study date was only 13.8 days. Thus, even short delays may permit significant changes in PainDetect scores.

Sensitivity and Specificity

The sensitivity and specificity for the diagnostic outcomes as determined by the slump test and its variations as well as the painDetect screening test (Table 3) are listed in Table 8. All analyses use the clinical examination outcomes as the reference diagnosis. The number of cases in the NNP and NeP groups are listed for each diagnostic definition in Table 7.

Table 8: Sensitivity, specificity, PPV, NPV, +ve LR, -ve LR of the variations of the slump test and the painDetect diagnoses vs the clinical examination diagnosis					
	Conventional Slump Test	**Conventional Slump test plus anatomical location**	**Conventional Slump test plus verbal descriptor only**	**Conventional Slump Test plus anatomical location plus verbal descriptor**	**painDetect screening tool**
Sensitivity	**.91**	**.59**	**.64**	**.46**	**.46**
Specificity	**.70**	**.95**	**.60**	**.95**	**.80**
PPV	**.77**	**.93**	**.64**	**.92**	**.71**
NPV	**.86**	**.66**	**.60**	**.62**	**.57**
+ve LR	**3.03**	**11.8**	**1.6**	**9.2**	**2.3**
-ve LR	**.13**	**.43**	**.61**	**.57**	**.68**

The conventional slump test demonstrated high sensitivity (91%) and moderate to good specificity (70%) relative to the reference diagnosis from the clinical examination. Adding an anatomical criterion to the slump test produced a dramatic decrease in sensitivity while greatly increasing specificity. The verbal descriptor was not able to enhance either aspect of the slump test with both sensitivity and specificity decreasing

compared to the conventional slump test. Combining the anatomical and verbal criteria produced an outcome very similar to that already achieved with just the anatomical criterion, albeit with lower sensitivity. Lastly, the PainDetect questionnaire displayed poor sensitivity but was able to match the specificity of the conventional slump test.

Quantitative Sensory Testing (QST)

Cold Detection

The cold detection temperatures for the control and LBP groups are plotted in the order in which they were collected in Figure 9. The pattern of responses across all sites suggested an order effect in that the first sites tested, the legs, displayed responses different from those seen at other sites. In particular, control subjects demonstrated an increasing response from left leg to right leg and from right leg to right arm ($p < 0.05$) with no further significant differences in responses between the remaining sites. The possibility exists that there were regional differences between legs and arms and the back which may have accounted for this pattern. However if this was the case, it would be expected that the two legs would be similar, the two arms to be similar and so forth. This was not the case. The LBP group displayed a slightly different pattern in that both legs had similarly low responses relative to the other sites but responses did plateau across the arms and back, similar to that in controls. Owing to this apparent order effect, further analyses were limited to 1) left-right differences within the legs, arms or back and 2) differences between patient groups at the same site. Further comparisons across legs, arms or back were excluded.

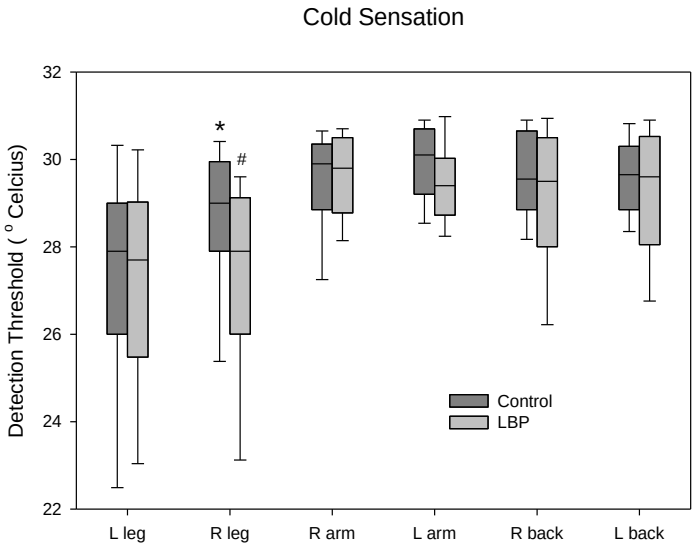


Figure 9. Box and whisker plot of cold detection temperatures in legs, arms and back in Control and LBP subjects. The rectangular boxes represent the 25th to 75th percentile range (central quartiles) with the horizontal bar indicating the median value. Whiskers are 10th and 90th percentiles.

*: significantly different from left leg response in Control group; $p < 0.05$

#: significantly different from right leg response in Control group; $p < 0.05$

Consistent with an order effect, a significant difference was noted within the control group between the left and right legs ($p = .014$, Fig. 9) but no differences were present between the arms or either side of the back. No significant differences were present between the legs in the low back pain/sciatica group. Between group comparisons at each site revealed only one significant difference between control and LBP subjects. The right leg responses in the LBP group were lower than those in the control group ($p = 0.035$).

To further explore potential differences in cold detection thresholds, the LBP group was separated into NNP and NeP groups according to the various diagnostic definitions; clinical examination, the variations of the slump test, and PainDetect questionnaire. The single significant outcome of this analysis was present for the slump-anatomy definition (Kruskal-Wallis ANOVA, $p = 0.053$). Pair wise comparisons revealed significantly lower cold detection temperatures in those in the NeP category compared to controls ($p = 0.038$, Fig. 10). Similar trends were seen within other diagnostic definitions but these did not reach statistical significance ($p < 0.11$). No significant differences were present within the arms or the back testing sites (Figs. 11 & 12).

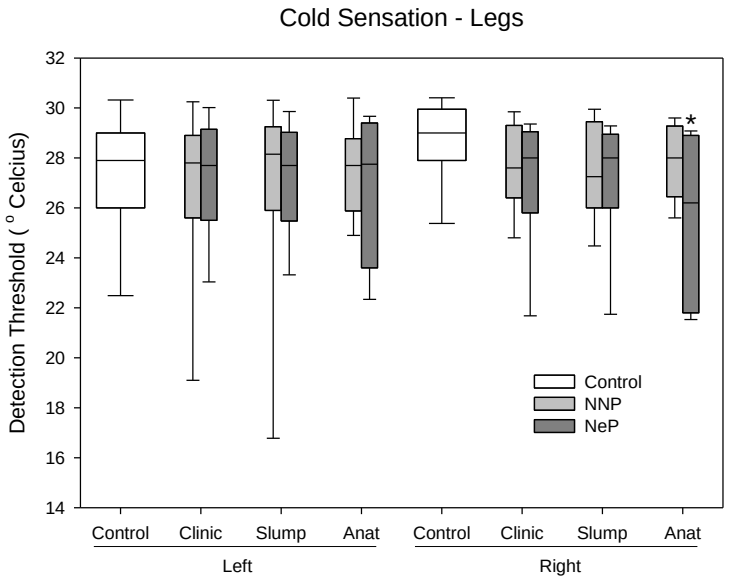


Figure 10. Box and whisker plot of cold detection temperatures in left and right legs in Control and NNP and NeP subgroups according to three different diagnostic definitions. The rectangular boxes represent the 25th to 75th percentile

range (central quartiles) with the horizontal bar indicating the median value. Whiskers are 10th and 90th percentiles.

*: significantly different from Control right leg responses; $p < 0.05$

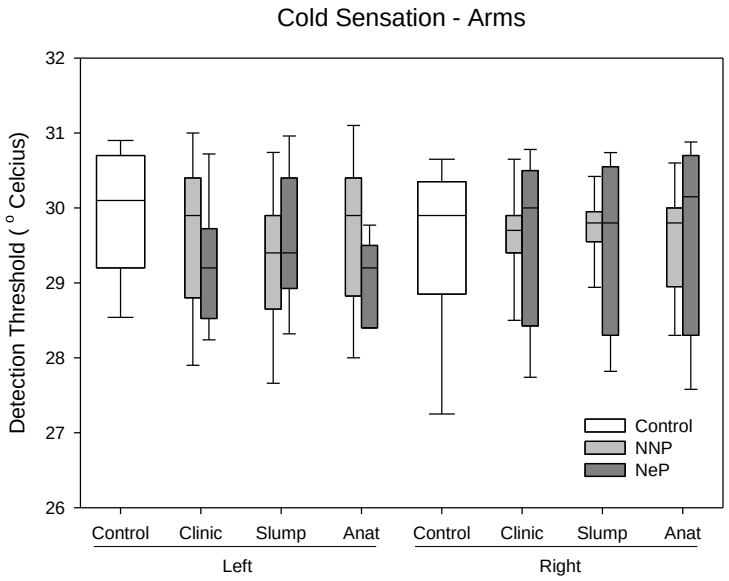


Figure 11. Box and whisker plot of cold detection temperatures in left and right arms in Control and NNP and NeP subgroups according to three different diagnostic definitions. The rectangular boxes represent the 25th to 75th percentile range (central quartiles) with the horizontal bar indicating the median value. Whiskers are 10th and 90th percentiles.

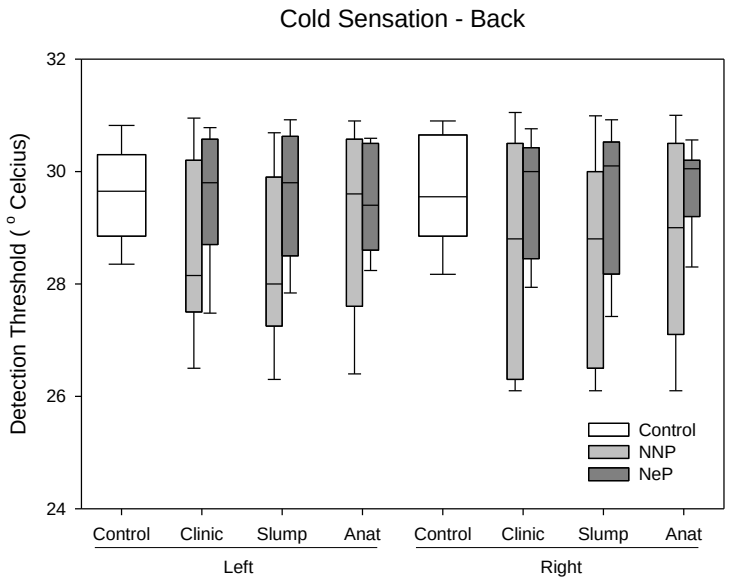


Figure 12. Box and whisker plot of cold detection temperatures in left and right backs in Control and NNP and NeP subgroups according to three different diagnostic definitions. The rectangular boxes represent the 25th to 75th percentile range (central quartiles) with the horizontal bar indicating the median value. Whiskers are 10th and 90th percentiles.

The nature of lumbar radicular pain is that it is essentially a unilateral disorder affecting either the left or the right leg. Consequently, the NeP subgroup was subdivided into left-side and right-side conditions. This allowed comparison of affected legs only to the Control group without contamination of the data by the unaffected legs. The results of the Mann-Whitney U test analysis of right side affected NeP subjects are summarized in Table 9. A significant reduction in CS detection temperatures in the right leg were found for the clinical examination ($p = 0.038$) and conventional slump ($p = 0.052$) criteria with

a trend in the slump-anatomy definition (p = 0.113). That no differences were seen in the left within those with right-sided conditions may be due to it being the unaffected leg. However, it is also possible that the increased variability due to being the first site tested precludes significant outcomes.

An isolated finding was that of increased sensitivity to cold detection in the right arm. This was only present when comparing right-side NeP patients as per the anatomical slump definition to controls (p = 0.028). No other diagnostic definition produced this outcome. Given the isolated nature of the finding and that it was opposite to that for cold sensation in the right leg, it may reflect a type I error.

	Table 9: **Mann-Whitney U test analysis of right-side affected subjects of CS** **Control vs NeP by Diagnostic group**					
Test/Area	Gold Stan Dx	Conv Slump	Slump Anat	Slump Verb	Slump AnaVer	painDetect
CS R Leg	p = .038	p = .052	p = .113			
CS R Arm			p = .030			

Analysis of left-side affected NeP subjects did not reveal any significant differences between NeP subjects and Controls. The most likely site to detect these differences in left-sided patients would be the left leg but, as stated above, any potential effects in the left leg are likely masked by the order effect.

Cold Pain

The cold pain temperatures for the control and LBP groups are plotted in the order in which they were collected in Figure 13. Similar to those for cold sensation, the overall pattern suggested an order effect. Presumably, as the subjects became more familiar with the testing procedure the response temperatures increased. Control subjects demonstrated an increasing response from left leg to right leg and from right leg to right arm ($p < 0.05$) with no further significant differences in responses between the remaining sites. The LBP group displayed a similar pattern although no adjacent test sites were significantly different.

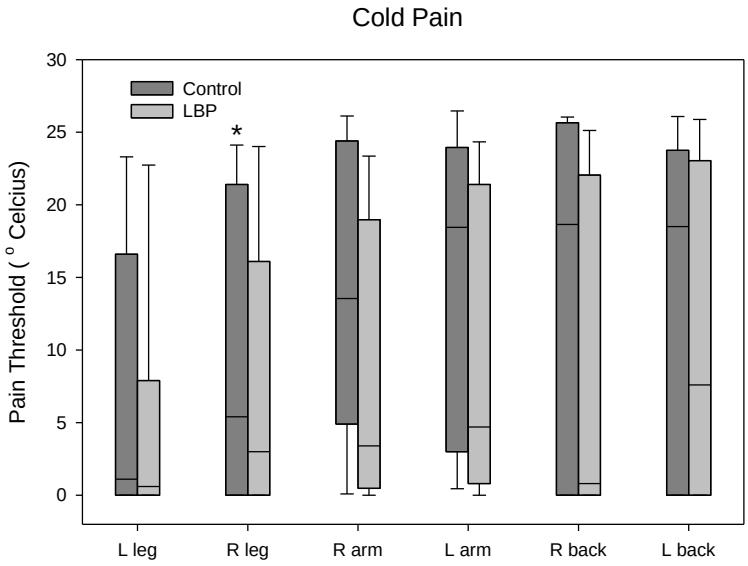


Figure 13. Box and whisker plot of cold pain temperatures in legs, arms and back in Control and LBP subjects. The rectangular boxes represent the 25th to 75th percentile range (central quartiles) with the horizontal bar indicating the median value. Whiskers are 10th and 90th percentiles.

*: significantly different from left leg response in Control group; $p < 0.05$

The LBP group was further separated into NNP and NeP groups according to the various diagnostic definitions to determine whether any differences in cold pain thresholds were present. Despite significant findings in the legs for cold detection thresholds, no differences were present for cold pain threshold temperatures (Fig. 14). In the right arms, a significant reduction in cold pain temperatures was present in the NeP group when defined by the clinical examination ($p=0.030$)(Fig. 15). The same effect was present in the left arm but this did not reach statistical significance ($p = 0.087$). No significant differences were found for either side of the back (Fig.16).

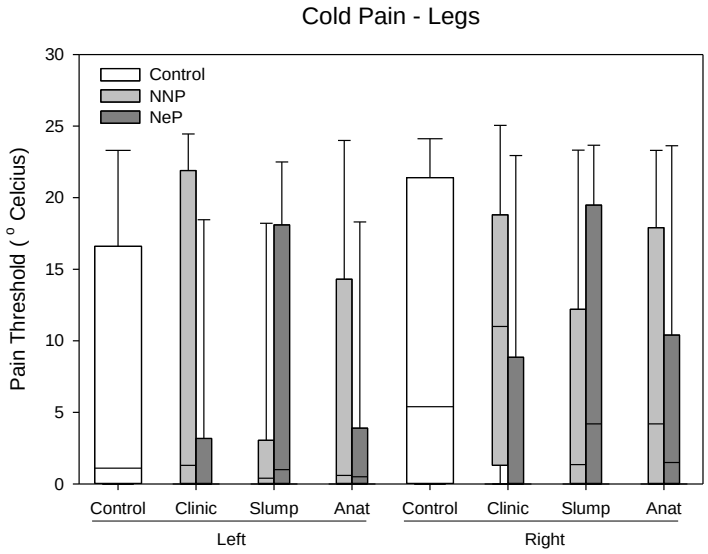


Figure 14. Box and whisker plot of cold pain detection temperatures in left and right legs in Control and NNP and NeP subgroups according to three different diagnostic definitions. The rectangular boxes represent the 25th to 75th percentile range (central quartiles) with the horizontal bar indicating the median value. Whiskers are 10th and 90th percentiles.

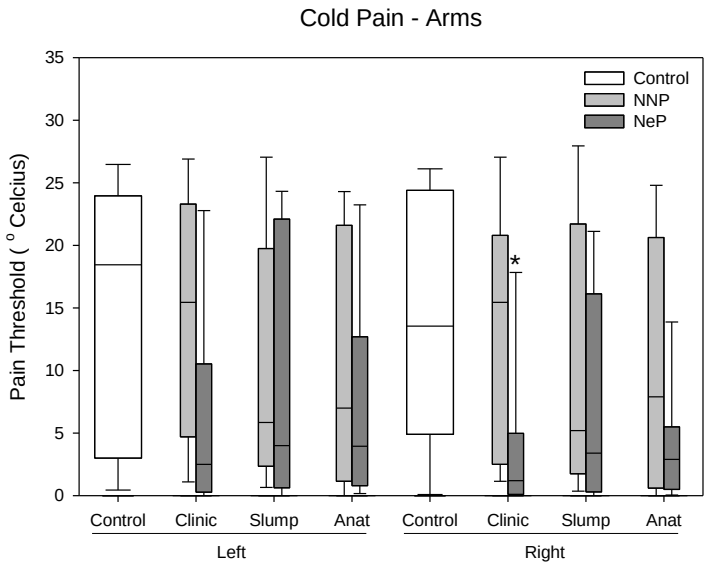


Figure 15. Box and whisker plot of cold detection temperatures in left and right arms in Control and NNP and NeP subgroups according to three different diagnostic definitions. The rectangular boxes represent the 25th to 75th percentile range (central quartiles) with the horizontal bar indicating the median value. Whiskers are 10th and 90th percentiles.

*: significantly different from Control right leg responses; $p < 0.05$

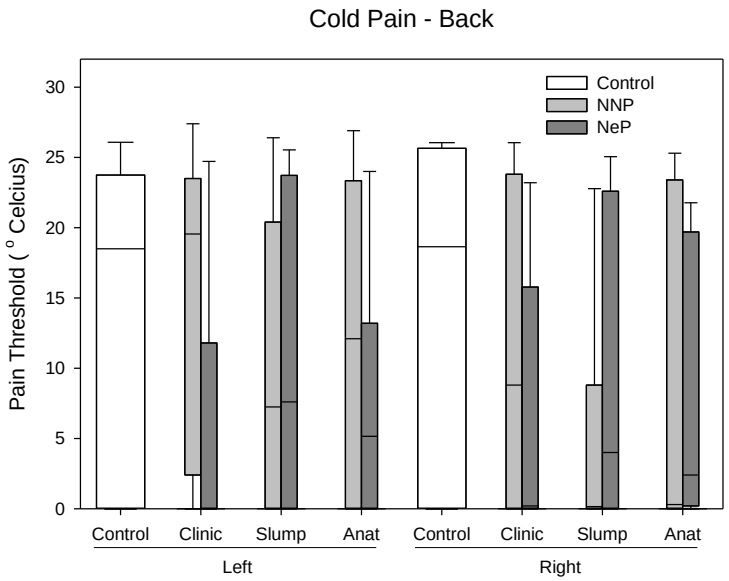


Figure 16. Box and whisker plot of cold detection temperatures in back in Control and NNP and NeP subgroups according to three different diagnostic definitions. The rectangular boxes represent the 25th to 75th percentile range (central quartiles) with the horizontal bar indicating the median value. Whiskers are 10th and 90th percentiles.

As was the case for cold sensation, separate analyses were completed by dividing the NeP subjects into left-side and right-side affected subgroups. No significant differences were found for any comparisons within those with right-side NeP, presumably due to very low group sizes (n = 3-4). The results for left-side affected NeP subjects are summarized in Table 10. In general, NeP patients displayed an overall hyposensitivity to cold pain with significant changes present for the left and right arms and the right side of the back. The right leg and the right back showed the same pattern but did not reach

statistical significance. The lack of difference in cold pain temperatures in the left leg are likely masked by the order effect described above.

	Table 10: Mann-Whitney U test analysis of left side affected subjects of CS, CP and PP Control vs NeP by Diagnostic group				
Test/Area	Gold Stan Dx	Conv Slump	Slump Anat	Slump Verb	Slump AnaVer
CP R Leg	p = .079	p = .083	p = .073		
CP L Arm	**p = .032**	**p = .020**	p = .139	**p= .018**	p = .184
CP R Arm	**p = .024**	**p = .012**	p= .084	**p = .011**	p = .123
CP L Back	**p= .041**	p = .101	p = .119		
CP R Back	p = .060				

Pressure Pain

Figure 17 illustrates the pressure pain thresholds in control, NNP and NeP subjects. No significant outcomes were detected although pressure pain thresholds tended to be higher in NeP subjects when defined by the anatomical slump test (p = 0.063). The same was

true in the slump verbal and painDetect definitions (not shown). The bilateral presentation of these changes may suggest central mechanisms.

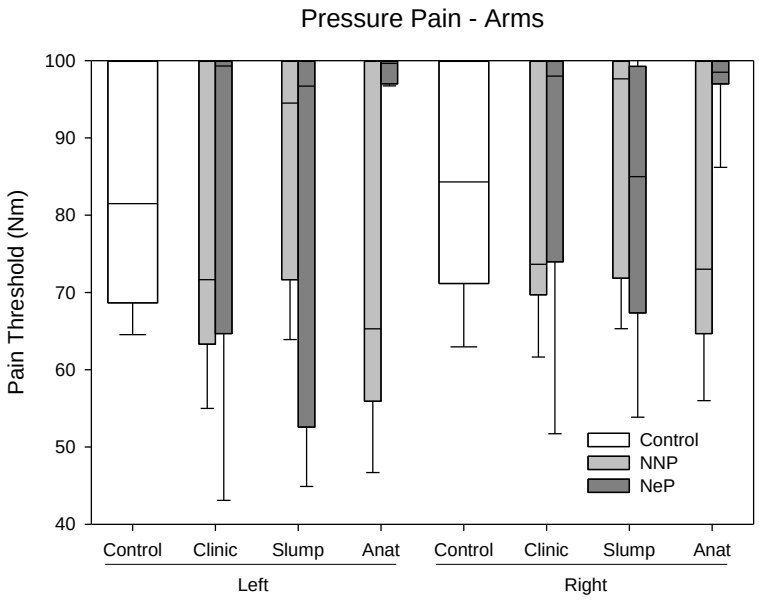


Figure 17. Box and whisker plot of pressure pain thresholds in left and right arms in Control and NNP and NeP subgroups according to three different diagnostic definitions. The rectangular boxes represent the 25th to 75th percentile range (central quartiles) with the horizontal bar indicating the median value. Whiskers are 10th and 90th percentiles.

Discussion

Sensitivity, specificity, PPV, NPV, +ve LR and –ve LR

It was hypothesized that this investigation would demonstrate that a commonly used clinical neurodynamic test, the slump test, would show good sensitivity and low to moderate specificity when compared to a standardized neurosensory examination in the identification of neuropathic pain. It was further hypothesized that the same slump test combined with novel criteria of pain location and verbal pain descriptors would demonstrate improved specificity.

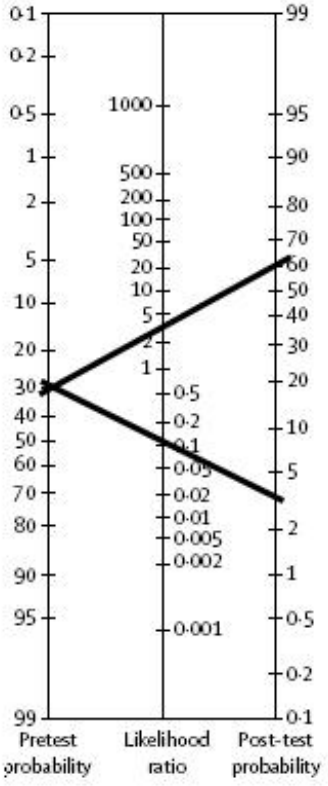


Figure 18 LR nomogram (adapted from Davidson (Davidson 2002) for the conventional slump test. The pretest probability of NeP in a population of LBP patients is placed at 30%.

The conventional slump test when compared to the "Gold Standard" diagnostic criteria demonstrated high sensitivity (91%) and moderate to good specificity (70%). The same test when modified through the addition of anatomical location of the pain during the test, specifically pain described below the knee during the test, increased the specificity of the test to 95%. The conventional slump test with the addition of certain pain descriptors decreased the sensitivity (64%) and specificity (60%) of the test but when combined with the anatomical location criterion further lowered the sensitivity (46%) while maintaining the specificity very high at 95%.

The conventional slump test by itself identified 91% of those subjects presenting with NeP. However it falsely identified 9% of subjects as having NeP. This lowered the

specificity and adversely affected the +ve LR. The conventional slump test is very sensitive at the cost of moderate to good specificity. These results indicate that a negative conventional slump test would rule out NeP while a positive conventional slump test would be inconclusive. In a group of low back pain patients with a pre test probability of having components of NeP of 30% a +ve LR of 3.3 would change the post test probability to about 57% (figure 18). On the other hand the –ve LR of .13 is helpful in that a negative slump test will be very good at ruling out NeP. In this example, a negative test would decrease the pre test probability of 30% to about 4% (figure 18). This can be easily calculated using the nomogram in figure 18. A straight edge is placed on the pre test probability on the left hand column, in this case 30%. The straight edge is then aligned with the positive Likelihood ratio of 3.3 on the middle column. The straight edge will then indicate on the right hand column the post-test probability of 57%. The same procedure is then followed for the negative Likelihood ratio.

The slump test is a neurodynamic test. The straight leg raising test is a more commonly used neurodynamic test to identify mechanically sensitized neural tissue. Scholz (Scholz et al. 2009) has recently demonstrated that the straight leg raising test was the most discriminatory clinical indicator for neuropathic pain followed by abnormal responses to cold and to pin prick. The straight leg raising test was used as part of the "Gold Standard" diagnostic assessment in the Clinical Assessment part of this study. In this study, when compared to the final designation of NNP or NeP the straight leg raising test demonstrated sensitivity of 82%, specificity of 90%, PPV of 90%, NNP of 81%, +ve LR of 8.2 and a –ve LR of .2. Considering the small sample, these numbers are very similar

to the conventional slump test. In both the Scholz study and the "Gold Standard" assessment used within this study the criteria for a positive straight leg raising test was less rigorous than that used for a positive slump test within this study. In the Schulz study the method involved lifting the affected leg with the knee extended to a 90^0 angle unless elevation was limited by pain; followed by elevation of the leg with the knee fully extended. The test was considered positive "when pain projecting into a dermatome was reproduced by raising the affected leg a second time with the knee extended". In the "Gold Standard" assessment utilized within this study the test was considered positive if, when the affected leg was lifted with the knee maintained in full extension, there was a difference in hip flexion range of motion due to reproduction of the subject's pain (Butler 2000;Butler 2005a). These small differences in method of application and interpretation are likely responsible for the minor differences in outcomes. Caution should be applied when considering the sensitivity and specificity outcomes of the straight leg raising test. Since the straight leg raising test was used as part of the Gold Standard" diagnostic assessment, comparing the results of the test to the final diagnosis does create a circular argument and tends to reaffirm itself.

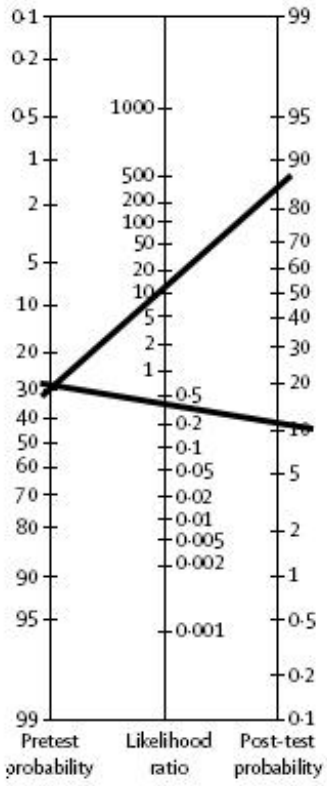


Figure 19 LR nomogram (adapted from Davidson (Davidson 2002) for the conventional slump test plus pain reproduced below the knee. The pretest probability of NeP in a population of LBP patients is placed at 30%.

When **pain below the knee** is added to the conventional slump test as a criterion for a positive test the sensitivity drops from 91% to 59%. The reason for the plunge in sensitivity is due to the large number of

false negatives. This variation of the slump test missed 5 of 11 (45%) subjects identified as having NeP by the "Gold Standard" assessment. At the same time the specificity jumped to 95% while the PPV changed to 93% meaning that a positive test strongly supports the presence of NeP. The associated +ve LR of 11.8 would transform a pre-test NeP probability of 30% to greater than 80% (figure 19). The –ve LR of .43 is weak with the potential of changing a pre test probability of 30% to about 14% with a negative result. The relatively large number of false negatives could be due to a number of factors. There may be a subgroup of subjects with pathology involving the connective tissue of nerves only. When this tissue becomes sensitized and subsequently stimulated by tension it may give rise to NNP felt more proximally. The "Gold Standard" assessment, by its nature, may identify these subjects as having neuropathic pain when in reality they have NNP and radiculopathy masquerading as NeP. These subjects would be excluded from the NeP category by the anatomical slump test.

When one add **verbal pain descriptors** to the conventional slump test the test becomes at best, mediocre in identifying subjects diagnosed as having NeP by the "Gold Standard". This is due to a high number of both false positives and false negatives. Specifically, painDetect only identifies 46% of the subjects identified by the "Gold Standard" diagnostic criterion. This may be due to subgroups within the NeP group. For example the slump anatomical verbal diagnostic criterion may capture subjects who have been similarly identified by painDetect while the conventional slump test may identify more classical radiculopathy type subjects. The conventional slump test appears to be more aligned with the Treede et al. algorithm whereas the addition of anatomical pain location

and verbal pain descriptors aligns more with the painDetect subgroup. In addition, in that no one word is pathognomic or even specific for NeP it has been suggested (Bouhassira and Attal 2011) that only a combination of descriptors may be of discriminate diagnostic value. With this in mind, the small grouping of verbal descriptors used in the study that each subject had to pick from may have been inadequate. However, if the outcome measures for the conventional slump combined with verbal descriptors are compared to those from the painDetect comparison, they are similar (Table 8).

Adding the **anatomical location and verbal pain descriptor** criterion to the conventional slump creates a very insensitive but very specific test. A positive outcome with this test would strongly indicate the presence of NeP but a negative test does not exclude NeP. The +ve LR of 9.2 suggests that a positive outcome on this test would increase the pre test probability to almost 80% (figure 20). The poor sensitivity is due to a large number of false negatives. The test simply failed to recognize a number of subjects diagnosed as NeP. At the same time the extremely high specificity and +ve LR are due to the absence of false positives. The reasons for the large number of false negatives may be similar to those previously discussed for the slump test variations.

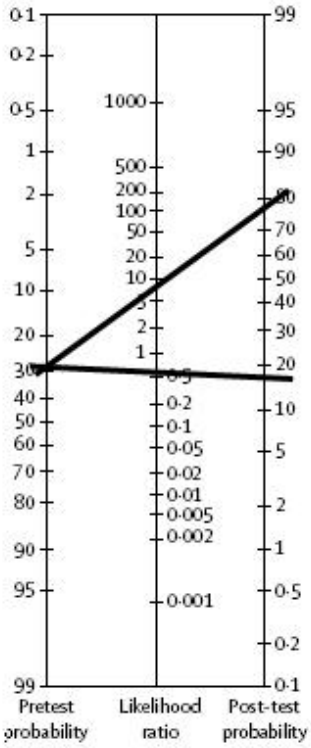


Figure 20 LR nomogram (adapted from Davidson (Davidson 2002) for the conventional slump test plus pain reproduced below the knee plus verbal pain descriptors. The pretest probability of NeP in a population of LBP patients is placed at 30%.

When the **painDetect screening tool** was compared to the "Gold Standard" diagnosis the sensitivity was poor at 46% but the

specificity was good at 80%. The PPV was also fair to good at 71%. The remaining outcome measures were also poor. A similar discrepancy was noted in the study by Scholz et al. (Scholz et al. 2009). They compared the StEP (Standardized Evaluation of Pain) with the DN4(Bouhassira et al. 2005) . In this study the 10-item version of the DN4 exhibited 61% sensitivity and 73% specificity when compared to the StEP. The painDetect screening tool is a validated instrument which has demonstrated sensitivity of 85%, specificity of 80% and a PPV of 83% (Freynhagen et al. 2006a). Accepting that the painDetect tool is a valid means to identify NeP why did this test fail to identify 6 of 11 subjects which were diagnosed by the "Gold Standard"?

The painDetect, conventional slump combined with anatomical location, conventional slump combined with verbal pain descriptors and conventional slump combined with anatomical location and verbal pain descriptors all exhibited poor sensitivity and excellent (except with the combination of verbal descriptors only) specificity. This may suggest that the NeP subgroup within the low back pain/sciatica group is not a homogeneous group.

The various definitions of neuropathic pain have already been reviewed earlier in this document. The debate over the definitions has divided those interested in NeP into two groups (Max 2002;Backonja 2003;Bennett 2003;Bouhassira and Attal 2011). One group aligns itself around the still "official" International Association for the Pain (IASP) definition of NeP, "pain initiated or caused by a primary lesion or dysfunction of the nervous system" (Merskey 1994). The second group aligns itself around the recently

proposed definition (Treede et al. 2008a) which states “pain arising as a direct consequence of a lesion or disease affecting the somatosensory system”.

The first definition has been criticized as being too vague and therefore overly inclusive. It allows for problematic diagnoses which exhibit some NeP qualities such as complex regional pain syndrome-1 (CRPS-1) and fibromyalgia and whiplash. Some of these conditions when assessed using NeP screening tools demonstrate that varying degrees of neuropathic pain may contribute to their pain experience. Sterling and Pedler (Sterling and Pedler 2009b) using the S-LANSS screening tool looked at acute whiplash patients and found that 34% demonstrated a predominantly NeP component. It is worth noting that if the Treede et al. definition were applied to the Sterling and Pedler study none of these patients would have met the definition for NeP.

The proposed definition implies that the diagnosis of a disease or the identification of a lesion should precede the diagnosis of the type of pain(Bouhassira and Attal 2011). This is not typical in the clinical setting. In fact, the majority of patients present with pain as their primary complaint and only following the detection of components of NeP might the assessment be directed towards the discovery of a neurological lesion. The absence of neurosensory signs might then preclude appropriate treatment for NeP.

On the other hand, a patient in any kind of pain with a confirmed lesion or neurological disease may be labeled as having NeP. For example, radiculitis by this definition is neuropathic pain. Injury to a nerve root results in increased mechanical sensitivity of the

nerve root and varying degrees of pain radiating into the back, buttock and leg. When the nerve root is stretched it generates pain which may extend to varying degrees down the leg. This does not confirm the mechanism of pain, only the source. The mechanism could be amongst other things, inflammation or ischaemia of the connective tissue components of the nerve root which could mimic NeP. A detailed neurosensory examination might or might not then confirm the presence of either positive or negative signs consistent with the distribution of pain.

Quantitative Sensory Testing

The QST utilized in the study assessed nociceptive and non nociceptive processes. Cold sensation detection thresholds measured non nociceptive processes while cold pain and pain pressure thresholds assessed nociceptive processes. In addition, it is possible that the somatosensory changes observed in NeP subjects involve both central and peripheral mechanisms.

The secondary objectives of the study were to determine if there were any differences in CS detection temperature, CP detection temperatures and PP detection levels between the Control group, the NNP group and the NeP group. In general few differences were found between the control and LBP groups aside from that for cold sensation in the right leg. This was not surprising given that the low back pain/sciatica group is not a homogenous group. Within the LBP group there exists two subgroups; those with predominantly non neuropathic pain (NNP) and those with predominantly neuropathic pain (NeP). For this reason, further analysis split the LBP group into NNP and NeP categories according to several diagnostic schemes. However, this approach provided very little further insight

into sensory function in these subjects. A significant difference in CP detection temperatures were found in the right arm between the Control group and the NeP group in the "Gold Standard" diagnostic group. Similar trends were found in the left arm (figure 15). In this case the CP detection temperatures were lower representing higher thresholds or hyposensitivity to CP. Patterns suggesting similar trends are apparent in the legs and backs of NeP subjects (figures 14 & 16).

A further complication to data analysis was the fact that radicular or NeP usually results in unilateral signs and symptoms. Therefore, further subdivision of NeP subjects into those with right-side or left-side conditions was necessary. This was especially important when analyzing CS and CP thresholds in the legs.

It is worth noting that following the partition of the NeP subjects into right and left side affected conditions considerably more significant outcomes emerged, right side excepted, despite the reduced sample size.

The NeP subjects who were right side affected demonstrated significantly lower cold sensation detection temperatures in their affected leg than the control group and the NNP group. This was not unexpected in that localized changes in temperature sensation responses, especially lowered, have been previously reported in NeP subjects (Bennett 2001;Bouhassira et al. 2005;Scholz et al. 2009). In addition this is common in lumbar radiculopathy. What was not expected was the absence of similar findings in the left leg in left side affected subjects. The inability to demonstrate a change in CS detection temperatures in the left leg in left side affected NeP subjects was most likely due to the

previously described order effect which produced increased variance in the initial data collected in the left leg.

Regarding cold pain, those with left sided conditions had a significant reduction in cold pain threshold temperatures in both arms and the left back with and nonsignificant reductions elsewhere. No significant findings were present in those with right-sided conditions but this may have resulted from the very small number of subjects with NeP on the right side. It is notable that, despite the severe limitations imposed by an even smaller sample size, a greater number of statistically significant comparisons were revealed after segregating NeP subjects into right and left conditions. Presumably, without this further measure of refinement, any comparisons of NeP subjects would include some with a left side condition and some without. For example, comparing right leg responses between NeP and control subjects would include some NeP subjects with an effected right leg and some with an unaffected right leg resulting in increased variability and reduced statistical power.

The literature has described cold pain detection temperature changes with NeP. Sterling and Pedler (Sterling and Pedler 2009a) measured CP thresholds over the mid and lower cervical spine in post whiplash subjects and found lowered CP thresholds (cold pain hyperalgesia). Scholz et al. (Scholz et al. 2009) found decreased responses to cold stimulation to be more important in diagnosing radicular low back pain than "cold allodynia". It is uncertain as to where the Scholz group took their measurements. It is suspected that the changes were noted in the neuroanatomical distribution of the subject's pain and reflected neural conduction changes.

The decreased CP detection temperatures observed in the arms of NeP subjects together with trends in the legs and back might suggest a systemic change in this group of subjects. The effect is bilateral and usually demonstrated in regions some distance from the areas of complaint. Chien and Sterling (Chien and Sterling 2010) have demonstrated sensory hypoaesthesia together with sensory hypersensitivity in individuals with chronic whiplash who have demonstrated components of NeP. Whereas sensory hypersensitivity is likely secondary to augmented central processing, hyposensitivity on the other hand may be due to central inhibitory processes related to prolonged or chronic nociceptive input. It is suggested that prolonged nociceptive input into the central nervous system may bring about an inhibitory effect which in turn reduces the ability of the central nervous system to process afferent input (Chien et al. 2008).

PP detection levels were included in this study because previous investigations have demonstrated widespread mechanical hyperalgesia as common features of NeP (Bennett 2006a) and more recently sensory hypoaesthesia in individuals with chronic whiplash (Chien et al. 2009;Chien and Sterling 2010). In this study, NeP subjects were hyposensitive to PP as indicated by higher pressure responses in the left arm in those with NeP when defined by the slump anatomical and the slump anatomical verbal diagnostic criteria. Similar, but nonsignificant trends were present in the right arm. Like the thermal testing, no training or practice was provided prior to the PP detection threshold testing. The right arm was always tested first and this may have been a source of higher variability on the right side.

Limitations

The small sample size of the low back pain/sciatica group limited the statistical power of some of the analysis. When this group was subdivided into NNP and NeP subgroups and then subsequently further subdivided into right and left affected sides the numbers available for analysis were small.

A familiarization training session should have been included as part of the QSA testing regime. The obvious order effect demonstrated between left and right legs for cold sensation thresholds and to a lessor degree, for cold pain sensation thresholds, rendered the left leg data highly variable.

Conclusion

The conventional slump test has been shown to possess high sensitivity and good specificity in identifying NeP which has been previously identified by an accepted "Gold Standard" diagnostic algorithm. The conventional slump test was shown to have a positive Likelihood ratio of 3.3 and a negative likelihood ratio of 0.13. Adding reproduction of pain distal to the knee as a component of the conventional slump test decreases the sensitivity of the slump test but considerably improves the specificity. The positive likelihood ratio climbs to 11.8. A positive slump test combined with pain below the knee would increase the pretest probability of having NeP from 30% to 85%. The negative likelihood ratio of .43 is not that useful. The addition of verbal pain descriptors did not improve the sensitivity, specificity or likelihood ratios of the slump test. When the painDetect NeP screening tool was compared to the "Gold Standard" diagnosis it compared closely to the conventional slump test combined with verbal pain descriptors

and with the conventional slump test combined with pain distal to the knee and verbal pain descriptors.

Cold sensation detection temperatures, cold pain detection temperatures and pressure pain detection values were measured over various anatomical locations in the control group and the low back pain/ sciatica groups. The data was analyzed utilizing non parametric statistical techniques. An order effect was identified in the cold sensation detection temperatures of the left leg and to a lessor extent the cold pain detection temperatures of the same leg. Reduced cold pain detection temperatures (hyposensitivity to cold pain) suggesting a central effect, were identified in the arms of the NeP subgroup. Reduced cold sensation detection temperatures (hyposensitivity to cold sensation) were identified in the right leg of right side affected subjects in the NeP subgroup. There was also a suggestion of reduced pressure pain sensitivity (hyposensitivity) in the arms of the NeP subgroup.

The conventional slump test has been shown to be a sensitive and moderately specific screening test for NeP. Clinically a negative response to the conventional slump test will strongly rule out the chances of having NeP. However, if the slump test is positive and reproduces pain below the knee then the test very strongly supports the presence of NeP.

Appendix 1

WANTED

CONTROL SUBJECTS

FOR A STUDY INVESTIGATING A SIMPLE CLINICAL TEST COMMONLY USED IN LOW BACK AND "SCIATICA" PATIENTS

THIS STUDY IS PART OF A MSc. REHAB PROJECT

REQUIREMENTS:	18 YEARS OF AGE
	ABLE TO SPEAK AND UNDERSTAND ENGLISH
	NO COMPLAINTS OF SPINE OR LIMB PAIN
	NO HISTORY OF TRAUMA OR MEDICAL TREATMENT TO THE SPINE OR LIMBS
TIME COMMITMENT:	ONE HOUR
WHEN:	March/April 2010
LOCATION:	ROOM 355, 3rd FLOOR, REHAB HOSPITAL
	800 SHERBROOK, WINNIPEG
TO PARTICIPATE:	CONTACT HELEN AT 925-1554

A SMALL HONOURARIUM WILL BE PROVIDED TO THOSE SUBJECTS WHO COMPLETE THE STUDY

Appendix 2

Exclusionary Diagnoses

1. Physical Injury
    a. Neuropathy secondary to tumour infiltration
    b. Complex regional pain syndrome II
2. Metabolic
    a. Diabetes mellitus
    b. Renal or hepatic dysfunction
3. Infectious/parainfectious
    a. Trigeminal neuralgia
    b. Post-herpetic neuralgia
    c. HIV
4. Toxic
    a. Chemotherapy-induced neuropathy
    b. Alcoholism
5. Nutritional deficiencies
    a. Vitamin B_{12} deficiency (also B_1 and B_6)
6. Vasculitis
    a. Rheumatoid arthritis
7. Immune related
    a. Paraneoplastic
    b. Paraproteinaemia
8. Central Nervous System
    a. Spinal cord compression/injury pain
    b. Multiple sclerosis
    c. Post stroke

Modified from Nash T. Neuropathic Pain. New York: Oxford University Press, 2007. pp. 37-48.

Appendix 3

Neuropathic Pain Study

Control Subject Fact Sheet

Thank you for agreeing to participate in this study.

This study is part of a Master's degree at the University of Manitoba, School of Medical Rehabilitation, and Faculty of Medicine.

The purpose of the study is to try and validate a simple clinical test which is used to identify pain that originates from injured or inflamed nerves. Pain originating from nerves as opposed to other tissues like muscle or ligaments requires different treatment than do muscles or ligaments. If a simple test to identify pain arising from nerves were available then nerve pain could be diagnosed earlier and subsequently treated earlier. Studies have suggested that nerve pain left untreated can lead to chronic pain.

Your participation will provide important normal values for various parts of the study

This study will involve about one hour of your time. Your involvement in the study will consist of:

- **Reading and signing an Informed Consent Form (10 minutes)**
- **The "Slump Test"**
    - **A clinical test done in sitting**
- **Cold sensation testing (15 minutes)**
    - **Testing your ability to feel cold applied to your arms, legs and back**
- **Pressure sensation Testing (15 minutes)**
    - **Testing your ability to feel pressure applied to your arms, legs and back**

The study will be conducted on the 3rd Floor of the Rehab Hospital. The study will be conducted in Room 355 Rehab Hospital. The address is 800 Sherbrook. Please try to arrive 15 minutes before your scheduled time. When you attend for the study be sure to bring your Subject Number. In addition please bring a T-shirt or some other loose fitting top and a pair of loose shorts. If you cannot attend or are sick on the day of your appointment please call us at 204-925-1554 and ask for Helen or Laurie to reschedule your appointment.

None of the components of the study are dangerous or harmful. All parts of the study are parts of routine examination procedures.

Appendix 4

Neuropathic Pain Study

Low back pain/"sciatica" Fact Sheet

Thank you for agreeing to participate in this study.

This study is part of a Master's degree at the University of Manitoba, School of Medical Rehabilitation, and Faculty of Medicine.

The purpose of the study is to try and validate a simple clinical test which is used to identify pain that originates from injured or inflamed nerves. Pain originating from nerves as opposed to other tissues like muscle or ligaments requires different treatment than do muscles or ligaments. If a simple test to identify pain arising from nerves were available then nerve pain could be diagnosed earlier and subsequently treated earlier. Studies have suggested that nerve pain left untreated can lead to chronic pain.

This study will involve two hours of your time. Your involvement in the study will consist of:

- **Reading and signing an Informed Consent Form (10 minutes)**
- **Filling out two short questionnaires (10 minutes)**
    - **Two questionnaires about your pain**
- **An assessment of your spine and hips (45 minutes)**
    - **Very similar to the examination that your therapist or doctor has already done**
- **The "Slump Test"**
    - **A clinical test done in sitting which involves moving your spine and your legs.**
- **Cold sensation testing (15 minutes)**
    - **Testing your ability to feel cold applied to your arms, legs and back**
- **Pressure sensation Testing (15 minutes)**
    - **Testing your ability to feel pressure applied to your arms, legs and back**

The study will be conducted on the 3rd Floor of the David and Ruth Asper research Centre, Pan Am Clinic, 75 Poseidon Bay, Winnipeg, Manitoba. When you attend for the study be sure to bring your Subject Number. In addition please bring a T-shirt or some other loose fitting top and a pair of loose shorts. If you cannot attend or are sick on the day of your appointment please call us at 204-925-1554 and ask for Helen or Laurie to reschedule your appointment.

None of the components of the study are dangerous or harmful. All parts of the study are parts of routine examination procedures. However if your find yourself suffering from a flare up of your low back pain or leg pain please let us know and we may reschedule for a later date when you are feeling better.

Upon completion of the study you will receive a token gift certificate valued at $50.00 to partially compensate you for your time.

If you have any questions regarding the preceding information or anything else about our study please call Helen Lock or Laurie Urban at 925-1554.

Again, thank you for participating in this important medical research.

Laurie Urban, B.A., B.P.T.

Appendix 5

RESEARCH PARTICIPANT INFORMATION AND CONSENT FORM

Title of Study: "The Slump Test; A screening test for neuropathic pain

Principal Investigator: "Lawrence M. Urban, Sports Physiotherapy Centre, Pan Am Clinic, 75 Poseidon bay, Winnipeg, Manitoba, R3M 3E4

You are being asked to participate in a research study. Please take your time to review this consent form and discuss any questions you may have with the study staff. You may take your time to make your decision about participating in this study and you may discuss it with your friends, family or (if applicable) your doctor before you make your decision. This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand.

Purpose of Study

This research study is being conducted to determine the effectiveness of combining the Slump Test with a new scoring system to help in identifying a type of nerve pain referred to as Neuropathic Pain. The study will compare the effectiveness of the Slump Test to a more time consuming assessment procedure that is currently used in the identification of Neuropathic Pain. In addition the study will compare the effectiveness of some other tests currently used in the study of Neuropathic Pain such as cold perception and pressure sensitivity to the Slump Test.

A total of 75 subjects will participate in this study.

Study procedures

Following recruitment all potential participants will receive a fact sheet which will include a brief description of the experiment, contact information, a description of appropriate clothing for the experiment and the location.

Potential control group participants will contact the principle investigator or Helen at the Physiotherapy Department at the Pan Am Clinic.

If you are a potential member of the control group you will read and then sign the Informed Consent document. After giving consent, you will be required to provide some basic contact information. A study date and time will be scheduled and you will be assigned a subject number. Upon arrival at the testing location will change into shorts and a loose top. You will then be administered: the Slump Test which first involves sitting on the edge of a bed with your trunk slouched forward. In this position you will be asked to straighten one knee then the other. During the test you will have to lift your head twice. Measurements of how far you can straighten your knee will be made. You will then be tested on how sensitive your perception of cold is and how sensitive you are to pain produced by cold. The last test is the Upper Limb Neurodynamic Test which involves the examiner lifting your arm and then measuring how far your elbow will extend. The entire test should take about 30 minutes.

Following recruitment each low back pain participant and each low back pain/leg pain participant will be provided with a fact sheet which will explain the purpose of the study. You will then be required to report to the Physiotherapy Department within the Pan Am Clinic to register for the study. After giving consent, some contact information will be recorded. You will then be required to fill out a short questionnaire (painDetect).There are certain conditions and diseases which would preclude you from participating in this study. If any of these are identified at this time you will be informed of such and you will not be able to continue any further with the study. If you meet the requirements of the study and do not have any of the conditions or diseases which would exclude you then you will be assigned a study date, a subject number and a time for your test.

Upon arrival on your test date you will be required to repeat the painDetect questionnaire. In addition you will be required to fill out a second questionnaire (Roland Morris). Once completed, you will proceed to the first test station. At the first test station you will undergo the Slump Test which is done in sitting and involves gently moving your spine and legs while some measurements of your knees are made. In addition, measurements of your ability to perceive cold and pressure will be made. Lastly a test of flexibility of your arm and shoulder will be made (Upper Limb Neurodynamic test).

Once station 1 is complete you will proceed to station 2 where you will receive a thorough physical examination which will be very similar to assessment of your spine that you would have received prior to this study. Once station 2 is finished you will be finished and free to go.

The study will consist of three groups. One group will have no pain (control group), the second group will have low back pain only and the third group will have low back pain and leg pain. To be placed in the Control Group you must have no history in the past year of low back pain or low back pain associated with leg pain. You must be physically

able to tolerate the movements and positions associated with the Slump Test, the cold threshold detection test, the cold pain detection test and the Upper Limb Neurodynamic test. To be placed in the Low Back Pain group you must be presently experiencing low back pain which is restricted to your low back and buttock regions and have achieved a certain score on the painDetect screening test. To be placed in the Low Back pain/leg pain group you must be experiencing low back pain associated with pain in your leg below the level of your buttocks and have scored a certain score on the painDetect screening test.

If you take part in this study, you will have the following procedures:

Visit schedule:

Control Group:

1. Registration
2. Slump Test, cold threshold detection, cold pain threshold, pressure sensitivity, Upper Limb Neurodynamic Test appointment

Low Back Pain and Low Back Pain/Leg Pain Groups:

1. Registration
2. Slump Test, cold threshold detection, cold pain threshold, pressure sensitivity, Upper Limb Neurodynamic Test, neurosensory assessment appointment

Required procedures:

Control Group:

1. The Slump Test, which involves sitting on the edge of a bed with your trunk slouched forward. In this position you will be asked to straighten one knee then the other. During the test you will have to lift your head twice. Measurements of how far you can straighten your knee will be made.
2. Cold threshold detection will be measured on different parts of your back and legs. This test involves you indicating when you first feel cold applied to a part of your body by a metal surface probe.
3. Cold pain threshold detection will be measured on the same areas of your back and legs. This test involves you indicating when you first feel pain or an unpleasant sensation as a surface metal probe gets colder.
4. Pressure pain threshold detection will be measured on both shoulders over your deltoid muscles. An instrument will measure the minimal amount of pressure which feels painful to you.

Low Back Pain and Low Back Pain/Leg Pain Group:

1. The Slump Test which involves sitting on the edge of a bed with your trunk slouched forward. In this position you will be asked to straighten one knee then the other. During the test you will have to lift your head twice. Measurements of how far you can straighten your knee will be made.

2. Cold threshold detection will be measured on different parts of your back and legs. This test involves you indicating when you first feel cold applied to a part of your body by a metal surface probe.

3. Cold pain threshold detection will be measured on the same areas of your back and legs. This test involves you indicating when you first feel pain or an unpleasant sensation as a surface metal probe gets colder.

4. Pressure pain threshold detection will be measured on one side of your low back. An instrument will measure the minimal amount of pressure which feels painful.

5. A thorough neuromuscular and neurosensory examination. This examination will be very similar to the examination that your therapist and or doctor would have already done on you in the course of diagnosing your condition.

Questionnaires:

Control group:

1. NPS (numeric pain scale) a verbal test which asks you to rate your pain numerically. On a scale of 1 to 10 how would you rate your pain today?" You will be required to rate any pain you experience during the Upper Limb Neurodynamic test.

Low Back Pain and Low Back Pain/Leg Pain Group:

1. NPS (numeric pain scale). A verbal test which asks you to rate your pain numerically."On a scale of 1 to 10 how would you rate your pain today?" You will be required to rate your pain intensity twice.

2. The painDetect questionnaire is a questionnaire designed to detect the presence of "nerve pain". An example of a question from the painDetect questionnaire is "Do you suffer from a burning sensation (e.g. stinging nettles) in the marked areas?" You will have to complete this questionnaire twice.

If you have had any recent x-rays, CAT scans or MRI scans of your spine these will be reviewed.

Participation in the study will be for one visit only. The Control Group participants experiment will take about thirty minutes. The Low Back Pain Group and the Low Back Pain/Leg Pain Group's experiments will take about ninety minutes.

You can stop participating at any time. However, if you decide to stop participating in the study, we encourage you to talk to the study staff first. If you are interested in the results of the study you may contact the Principle Investigator at the end of the study.

Discomforts

Control Group: During the Slump Test you may experience some mild discomfort in your spine or in the back of your legs. During the Cold Pain Detection Threshold Test you will

experience some momentary minimal pain. During the Upper Limb Neurodynamic Test you may feel momentary discomfort.

Low Back Pain and Low Back Pain/Leg Pain Groups: During the Slump Test you may experience some reproduction of your back and or leg pain. During the Cold Pain Detection Threshold Test you will experience some momentary minimal pain. During the Upper Limb Neurodynamic Test you may feel momentary discomfort. During the assessment part of the experiment you may experience some reproduction of your low back pain and or leg pain.

Benefits

There may or may not be any direct benefit to you participating in this study. We hope that the information learned from this study will aid in the understanding of pain originating from nerves.

Costs

All the procedures, which will be performed as part of this study, are provided at no cost to you.

Payment for participation

If you are in the Control Group and fully complete your part in the study you will receive a $25.00 gift certificate to partially compensate you for your time. If you are in the Low back Pain/Leg Pain Group and fully complete your part in the study you will receive a $50.00 gift certificate to partially compensate you for your part in this study.

Confidentiality

Information gathered in this research study may be published or presented in public forums; however your name and other identifying information will not be used or revealed. Despite efforts to keep your personal information confidential, absolute confidentiality cannot be guaranteed. Your personal information may be disclosed if required by law. Medical records that contain your identity will be treated as confidential in accordance with the Personal Health Information Act of Manitoba.

The University of Manitoba Health Ethics Research Board may review records related to the study for quality assurance purposes.

All records will be kept in a locked secured area and only those persons identified will have access to these records. If any of your medical/research records need to be copied to the above, your name and all identifying information will be removed. No information revealing any personal information such as your name, address, or telephone number will leave the University of Manitoba.

Voluntary Participation/Withdrawal from the Study

Your decision to take part in this study is voluntary. You may refuse to participate or you may withdraw from the study at any time.

Participants who are students or employees of the University of Manitoba or individuals associated professionally with the any of the investigators can be assured that a decision not to participate will in no way affect any performance evaluation of potential participants.

Medical Care for Injury Related to the Study

You are not waiving any of your legal rights by signing this consent form or releasing the investigator from their legal and professional responsibilities.

Questions

You are free to ask any questions that you may have about your treatment and your rights as a research participant. If any questions come up during or after the study or if you have a research-related injury, contact the Principle Investigator: Laurie Urban at 204-925-1554.

For questions about your rights as a research participant, you may contact The University of Manitoba, Bannatyne Campus Research Ethics Board Office at (204) 789-3389

Do not sign this consent form unless you have had a chance to ask questions and have received satisfactory answers to all of your questions.

Statement of Consent

I have read this consent form. I have had the opportunity to discuss this research study with Laurie Urban and or his study staff. I have had my questions answered by them in language I understand. The risks and benefits have been explained to me. I believe that I have not been unduly influenced by any study team member to participate in the research study by any statements or implied statements. Any relationship (such as employer, supervisor or family member) I may have with the study team has not affected my decision to participate. I understand that I will be given a copy of this consent form after signing it. I understand that my participation in this study is voluntary and that I may choose to withdraw at any time. I freely agree to participate in this research study.

I understand that information regarding my personal identity will be kept confidential, but that confidentiality is not guaranteed. I authorize the inspection of any of my records that relate to this study by The University of Manitoba Research Ethics Board, for quality assurance purposes.

By signing this consent form, I have not waived any of the legal rights that I have as a participant in a research study.

I agree to be contacted for future follow-up in relation to this study, **Yes _ No _.**

Participant signature_____ **Date**_____

(day/month/year)

Participant printed name: _____

I, the undersigned, attest that the information in the Participant Information and Consent Form was accurately explained to and apparently understood by the participant or the participant's legally acceptable representative and that consent to participate in this study was freely given by the participant or the participant's legally acceptable representative.

Witness signature_____ **Date** _____

(day/month/year)

Witness printed name: _____

I, the undersigned, have fully explained the relevant details of this research study to the participant named above and believe that the participant has understood and has knowingly given their consent.

Printed Name: _____**Date** _____

(day/month/year)

Signature: _____

Role in the study: _____

Relationship (if any) to study team members: _____

Appendix 6

Appendix 6 painDetect Questionnaire		
Item	**Score**	
Graduation of pain*		
• **Do you suffer from a burning sensation (e.g. stinging nettles) in the marked areas?**	**0-5**	
• **Do you have tingling or prickling sensation in the area of your pain (like crawling ants or electrical tingling)?**	**0-5**	
• **Is light touching (clothing, a blanket) in this area painful?**	**0-5**	
• **Do you have sudden pain attacks in the area of your pain, like electric shocks?**	**0-5**	
• **Is cold or heat (bath water) in this area occasionally painful?**	**0-5**	
• **Do you suffer from a sensation of numbness in the areas that you marked?**	**0-5**	
• **Does slight pressure in this area, e.g. with a finger, trigger pain?**	**0-5**	
Pain course pattern		
Please select the picture that best describes the course of your pain:		
 **Persistent pain with slight fluctuations**	**0**	
 **Persistent pain with pain attacks**	**-1**	
 **Pain attacks without pain between them**	**+1**	
 **Pain attacks with pain between them**	**+1**	
Radiating Pain		

• **Does your pain radiate to other regions of your body? Yes/No**	**+2/0**	
Total		
***For Each question: never, 0; hardly noticed, 1; slightly, 2; moderately, 3; strongly, 4; very strongly, 5** ***Maximum possible score = 38, Minimum possible score = -1**		
Scoring **≤ 12, a neuropathic component is unlikely** **≥ 19, a neuropathic component is likely** **Between these, the result is uncertain, but a neuropathic component may be present**		

Appendix 7

Slump Test and Quantitative Sensory Testing results form

Subject number _____

Date _____

Time _____

Slump Test Results

1. Spinal slump painful? Yes ☐ No ☐
2. Neck flexion painful? Yes ☐ No ☐
3. Right ankle dorsi-flexion painful? Yes ☐ No ☐
4. Right knee resting angle

   _____
5. Right knee maximum extension angle

   _____

5.1 Right knee extension painful? Yes ☐ No ☐
6. Neck extension, pain less? Yes ☐ No ☐

6.1 Neck extension, no change in pain? Yes ☐ No ☐
6.2 Neck extension, more pain? Yes ☐ No ☐
7. Neck flexion, painful? Yes ☐ No ☐
8. Right knee flexion, pain better? Yes ☐ No ☐

8.1 Right knee flexion, no change in pain? Yes ☐ No ☐
8.1 Right knee flexion, pain worse? Yes ☐ No ☐
9. Left ankle dorsi-flexion painful? Yes ☐ No ☐
10. Left knee resting angle

    _____

10 Left knee maximum extension angle

   _____

10.1 Left knee extension painful? Yes ☐ No ☐
11. Greater than 10 degrees difference between left & right knee extension? Yes ☐ No ☐
12. Neck extension, pain less? Yes ☐ No ☐

12.1 Neck extension, no change in pain? Yes ☐ No ☐
12.2 Neck extension, pain worse? Yes ☐ No ☐
13. Neck flexion, painful? Yes ☐ No ☐
14. Left knee flexion, pain better? Yes ☐ No ☐

14.1 Left knee flexion, no change in pain? Yes ☐ No ☐

14.2Left knee flexion, pain worse? Yes ☐ No ☐
15. During the test did your pain extend beyond your knee? Yes ☐ No ☐
16. Which of the following best describes your pain/sensation during the test?
16.1Pulling, stretching, tight? Yes ☐ No ☐
16.2Deep, aching, burning? Yes ☐ No ☐
16.3Electric shock like, shooting, jabbing, burning? Yes ☐ No ☐

Scoring Rubric for the Slump test

Responses and findings	**Yes**	**No**
1a. Do you have low back pain?		
1b. Did the test reproduce your pain?		
1c. Was there a difference between right and left knee extension greater than 10 degrees?		
1d. Did cervical extension reduce the sensation/pain?		
Subtotal		
2a. Did the pain extend below your knee during the test?		
Subtotal		
Verbal: Which of the following best describes the pain/sensation produced by the test?		
• 3a. pulling, stretching, tight		
• 3b.deep, aching, burning		
• 3c. electric shock like, shooting, jabbing, burning		
Subtotal		
Total score		

Cold Detection Thresholds

17.0 PLF5 _____^{0}c _____^{0}c _____^{0}c average _____^{0}c
17.1 PRG5 _____^{0}c _____^{0}c _____^{0}c average _____^{0}c
17.2 ARB2 _____^{0}c _____^{0}c _____^{0}c average _____^{0}c
17.3 ALC2 _____^{0}c _____^{0}c _____^{0}c average _____^{0}c
17.4 ARA5 _____^{0}c _____^{0}c _____^{0}c average _____^{0}c
17.5 ALD5 _____^{0}c _____^{0}c _____^{0}c average _____^{0}c

Cold Pain Thresholds

18.0 PLF5 _____^{0}c _____^{0}c _____^{0}c average _____^{0}c
18.1 PRG5 _____^{0}c _____^{0}c _____^{0}c average _____^{0}c
18.2 ARB2 _____^{0}c _____^{0}c _____^{0}c average _____^{0}c

18.3 ALC2	_____^{0}c	_____^{0}c	_____^{0}c	average _____^{0}c
18.4 ARA5	_____^{0}c	_____^{0}c	_____^{0}c	average _____^{0}c
18.5 ALD5	_____^{0}c	_____^{0}c	_____^{0}c	average _____^{0}c

Pain Pressure Thresholds

19.0 ARA6	_____ kPa	_____ kPa	_____kPa	average _____kPa
19.1 ALD6	_____ kPa	_____ kPa	_____kPa	average _____kPa

painDetect Score

20.0 __ $\leq$ 12 __ $\geq$ 19

Appendix 8

Slump Test Study

Neurosensory Examination Template

Study number_____

Date

_____

History (General)(Including past history) **Examiner**

_____

a. Sudden vs. insidious?
   i. Date? Time course.
   ii. Past history?
   iii. Severity of pain matches severity of injury?
b. Has the condition been diagnosed already?
   i. What is the diagnosis?
   ii. Is the diagnosis on the list?
c. Treatment up to now?

History of serious illness?
(Such as diabetes, cancer, osteoporosis)
Pain
Is your pain connected with any of the following conditions or diagnoses?

Peripheral nervous System		Yes
Physical Injury	Nerve entrapment eg Carpal tunnel	
	Root compression eg Lateral stenosis, disc protrusion	
	Post surgical eg mastectomy, thoracotomy, discectomy	
	Neuropathy secondary to tumour infiltration	
	Complex regional pain syndrome II	
Metabolic	Diabetes mellitus	
	Renal or hepatic dysfunction	
Infectious/par-infectious	Trigeminal neuralgia	
	Post-herpetic neuralgia	
	HIV	
Toxic	Chemotherapy-induced neuropathy	
	Alcoholism	
Nutritional deficiencies	Vitamin $B_{12,}$ B_1, and B_6	
Vasculitis	Rheumatoid arthritis	
Immune mediated	Paraneoplastic	
	Paraproteinaemia	
Central Nervous System		
Spinal Cord compression/injury pain		
Multiple Sclerosis		
Post Stroke		

(Indicate any of these with a check mark)

Are you experiencing any pain at present? Yes? ☐ **No?** ☐

Pain Intensity ____/10 (VAS or NPS)

Pain out of proportion to injury? **Yes?** ☐ **No ?** ☐ (like a scrape or scratch pin prick etc)

Pain Stimulus dependent? Yes? ☐ **No?** ☐ **Yes?** Elicited by what?

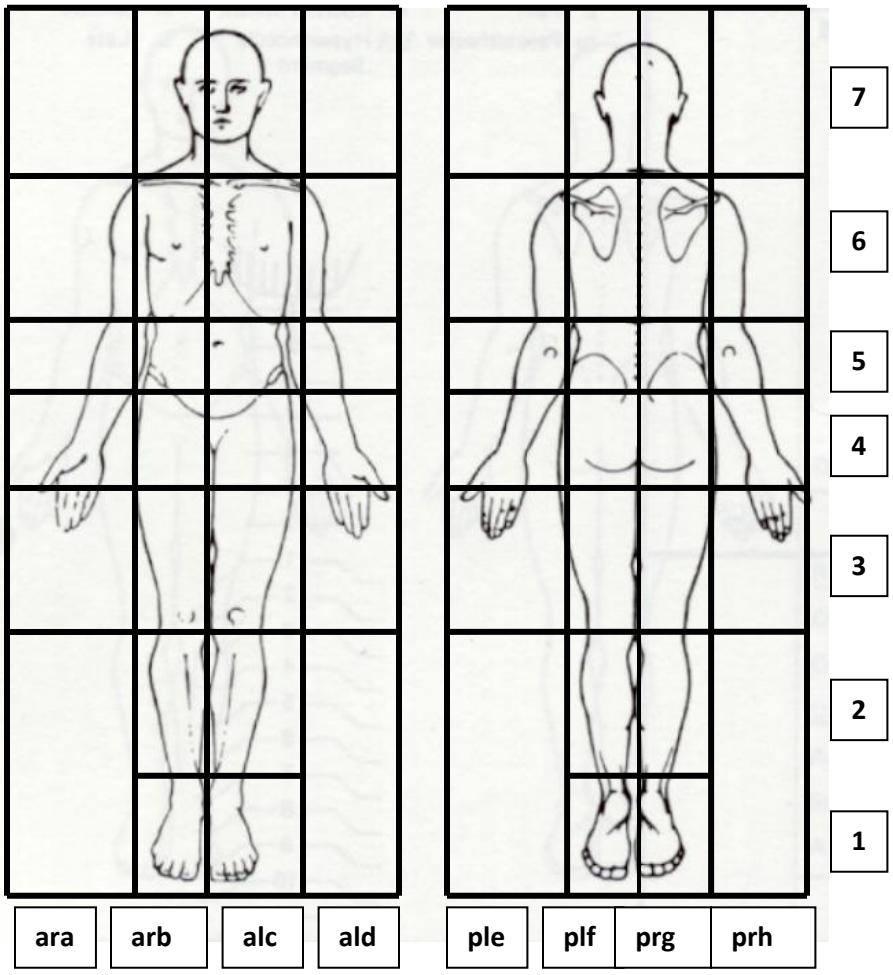
Mechanical? ☐ Thermal? ☐ Chemical? ☐

Stimulus Independent (spontaneous)? Yes? ☐ **No?** ☐ (Does the pain appear without any stimulus?

Indicate the following on the body diagram:

When assessing the posterior thigh and calf assess the posterolateral region (1/2 distance from midline to lateral edge)

Pain (xxx) **Hypoalgesia** (nn) **Hypoalgesia to cold** (cn) **Allodynia** (Al) **Paraesthesia** (oo) **Hyperalgesia** (HH) **Cold Hyperalgesia** (CH) **Autonomic abnormalities** (AA) **Heat Hypoalgesia** (HO) **Heat Hyperalgesia** (HYP)



What is the quality of the pain? Do any of the examples on this form match the patient's pain?

Do any of the following words describe your pain? Continuous? ☐ Paroxysmal? ☐

Stabbing? ☐ Burst like? ☐ Shooting? ☐ Electric shock like? ☐

Hyperalgesia Does your pain feel exaggerated? **Yes?** ☐ **No?** ☐
Establish if the patient has exaggerated pain. Do painful stimuli hurt more than usual?

Allodynia Does light touch or brushing hurt your skin? **Yes?** ☐ **No?** ☐
Establish if the patient experiences painful sensations from stimuli that normally would not hurt.

Spread Has your pain spread to a larger area? **Yes?** ☐ **No?** ☐
Establish if the patient's pain has spread to a larger area than was originally experienced.

Has your pain spread to the opposite side of your body? **Yes?** ☐ **No?** ☐
Establish if the patient's pain has moved to the opposite side of their body (mirror pain).

Other Does your pain wake you up at night? **Yes?** ☐ **No?** ☐
You want to establish if the patient's pain wakes them at night (not movement). This is a sign of sinister pathology.

Inflammation How is your pain in the morning? **Better?** ☐ **Worse?** ☐ **Same?** ☐
Pain in the a.m. is suggestive of active inflammation.

Irritability Does it hurt when you cough or sneeze? **Yes?** ☐ **No?** ☐
Pain with a cough or sneeze may suggest a high degree of irritability.

Negative Symptoms Have you noticed any numbness? **Yes?** ☐ **No?** ☐
Establish if the patient has noticed any numbness. Indicate on the body diagram.

Positive Symptoms Have you noticed any other unpleasant sensations? **Yes?** ☐ **No?** ☐
Establish if the patient has noticed any other unpleasant sensations such as pins and needles, tingling or itching.

Pins and needles? ☐ Tingling? ☐ Itching? ☐

Autonomic Sensations Have you noticed any of the following? Unusual sweating? ☐
Establish if the patient has noticed any sensations that might be attributed to dysfunction of the autonomic nervous system such as unusual sweating, orthostatic hypotension or G.I. symptoms.

Orthostatic hypotension? ☐ G.I symptoms? ☐

Imaging Tests X-ray ☐ CAT Scan ☐ MRI ☐ Other ☐

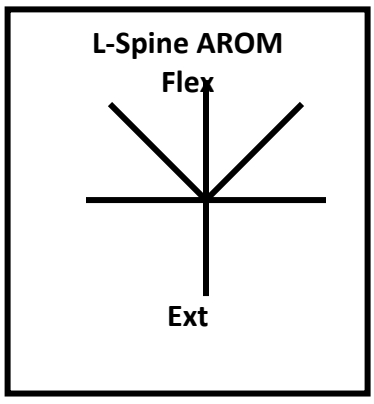
Results

Record any pertinent imaging results

Bowel and bladder dysfunction suggestive of neurological injury or dysfunction?
Yes? ☐ **No?** ☐
Looking for cord and or cauda equina signs.

Medications? (List)
Pertinent medication

Physical Examination



Indicate ROM, local and referred

Negative Signs

Myotomes

L_3 (L) ☐ (R) ☐
L_4 (L) ☐ (R) ☐
L_5 (L) ☐ (R) ☐
S_1 (L) ☐ (R) ☐

Reflexes: (L)L_3 ☐ (R)L_3 ☐
(L)S_1 ☐ (R)S_1 ☐

Hypoalgesia to pin prick present?
Yes? ☐ No? ☐

Hypoalgesia to 1 gm mono-filament
Yes? ☐ No? ☐
(indicate on diagram nnn)

Hypoalgesia to 10 gm mono- filament
Yes? ☐ No? ☐

Hypoalgesia to cold? (cn)
Yes? ☐ No? ☐

Hypoalgesia to heat?
Yes? ☐ No?
(indicate on diagram HO)

Neurodynamic Tests
SLR +ve Yes? ☐ No? ☐
ROM (L) ☐ (R) ☐

Do only SLR. Record ROM
And where the pain is felt.

Positive Signs
(Indicate on body diagram as stated)

Allodynia present? (cotton ball) Yes? ☐ No? ☐
Hyperalgesia to pin prick Yes? ☐ No? ☐
Hyperalgesia present? (monofil) Yes? ☐ No? ☐
Cold hyperalgesia present? Yes? ☐ No? ☐
Heat hyperalgesia present? Yes? ☐ No? ☐
Focal autonomic abnormalities present? Yes? ☐ No? ☐

Negative Symptoms

Myotomes should be tested with a 5 second isometric contraction of key muscles and graded from 0 – 5.

Reflexes should be graded 0 – 5 with 2+ being a normal response.

Hyperalgesia and hypoalgesia are assessed by examining pinprick thresholds (PPT). A raised PPT (patient cannot feel sharpness at site of pain) suggests Hypoalgesia, a lowered PPT (patient feels exaggerated pain compared to the control site) indicates Hyperalgesia. Initially starting with the control side, a pin roller will be used to scan both sides in order to assess any sensation differences from side to side. If differences are detected then a more detailed examination will follow. PPT will be assessed using a safety pin. (need to flesh out best method). Response to punctuate tactile stimulation will then be assessed using 1 gram and 10 gram standardized monofilaments. Testing will begin with the 1 gram filament. If the 1 gram filament is detected there is no need to progress to heavier filaments. The patient will close their eyes and the filament is applied perpendicular to the body surface, and pressure is applied until the filament bends. The filament can be applied up to 3 times to an unresponsive site. This is done to ensure delivery of the desired threshold force, as the filaments can sometimes be applied at an angle and result in too light a force. One response out of three is considered a correct response. Testing begins by examining the non painful, control site, to allow the patient to become familiar with the procedure, and the examiner to establish a normal sensibility area for reference. The patient is thus shown a normal response. The patient is instructed to respond with a "yes" when the pressure is detected. If the sensation is stronger or painful compared to the control site, the response should be "stronger". For accuracy, each filament should be applied in a smooth application of a about 1.5 seconds, held for 1.5 seconds, and removed in about 1.5 seconds. The filament should not be "bounced" against the skin. The filament should not be jerked or lifted away quickly, because this can produce a burst of stimulus to the end organs in the skin.

Hypoalgesia to cold is measured using a metal spoon. Again, the testing begins with the non painful, control side, to allow the patient to become familiar with what is expected. The patient should have their eyes closed while the spoon is applied. The spoon can be applied up to three times to an unresponsive site. Again the patient is instructed to respond "yes" if they feel the cold spoon.

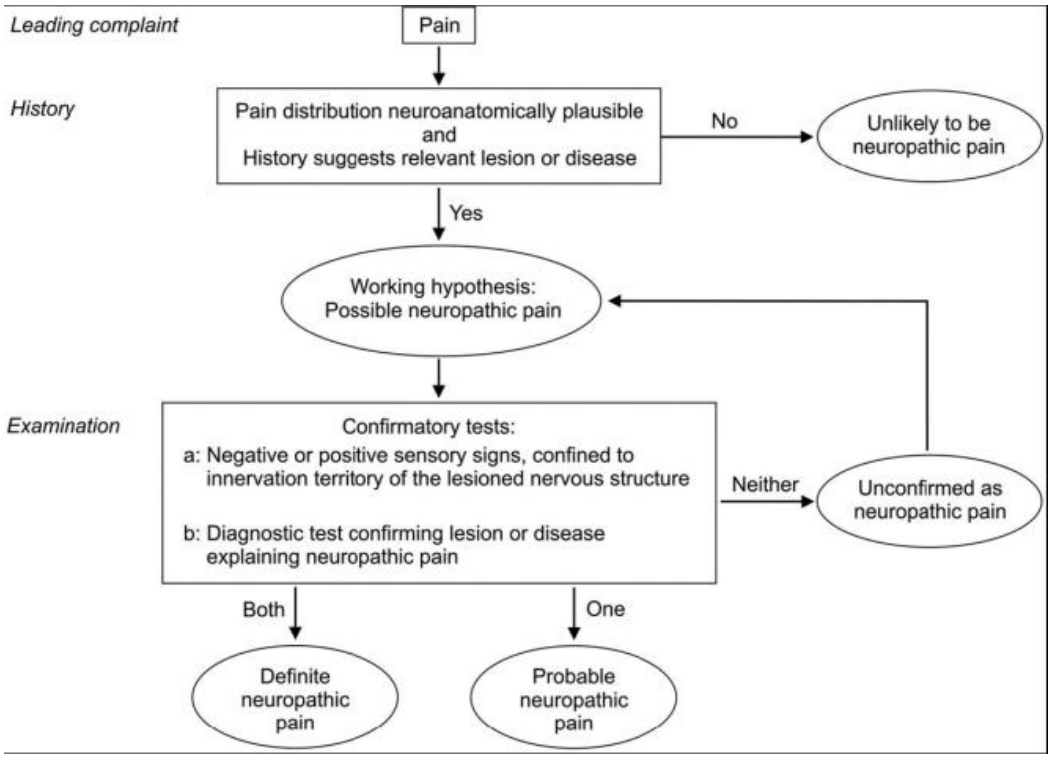
Hypoalgesia to heat is tested using a test tube with hot water. The procedure is the same as for testing cold. Start on the non affected control side then test the affected side. Instruct the patient to respond "yes" if they can feel the heat.

Positive Signs

Allodynia is tested using a cotton ball. First test the unaffected control side. Brush the skin lightly with the cotton ball. If pain is elicited or some other unpleasant sensation is elicited compared to the control site, then allodynia is present. Testing for cold and heat hyperalgesia follows the same procedure as for the testing for hypoalgesia. If cold or heat produces a more intense sensation than experienced on the control side then temperature hyperalgesia is present. If cold or heat produces pain then temperature allodynia is present.

Assessing the Proportion of Pain Type

After completing the assessment you now have to make a decision as to the type of pain present. First of all you have to decide if Neuropathic Pain is present in the patient. To assist you in this process please use the grading system by Treede et al. (Treede et al. 2008b) outlined below.



1. To be considered as Neuropathic Pain the pain has to present with a distinct neuroanatomically plausible distribution. The pain has to conform to the innervation territory of a peripheral nerve, branch of the lumbar plexus or a spinal segment. If it does not it cannot be considered as a candidate for a diagnosis of neuropathic pain.

2. There has to be a link between the history and the pain distribution. The lesion or disease should be capable of affecting the somatosensory system.

3. Having met the first 2 criteria from the history you can then assume a working hypothesis that the subject has neuropathic pain. If the first 2 criteria are met and nothing else, you may assign a diagnosis of "*Possible Neuropathic Pain*" If negative or positive sensory signs are found within the innervation territory of the lesioned nervous structure or the subject has undergone a diagnostic test (eg MRI) that confirms a lesion or disease which explains the neuropathic pain you may assign a diagnosis of "*Probable Neuropathic Pain*". To arrive at a "*definite diagnosi"s of Neuropathic Pain* 2 criteria from the clinical examination have to be met. The first is the finding of negative or positive sensory signs confined to the innervation territory of the lesioned nervous structure. The second criteria is confirmation by a diagnostic test such as MRI or CAT scan of a lesion or disease explaining the neuropathic pain. If neither criteria are met the diagnosis is unconfirmed but remains *possible*. If one

criteria is met the diagnosis is *Probable Neuropathic Pain.* If both criteria are met the diagnosis is *Definite Neuropathic Pain.*

Diagnosis

Non Neuropathic Pain	☐
Possible Neuropathic pain	☐
Probable Neuropathic Pain	☐
Definite Neuropathic Pain	☐

Reference List

Costigan M, Scholz J, Woolf CJ. Neuropathic pain: a maladaptive response of the nervous system to damage. Annu Rev Neurosci 2009;32:1-32.

Loeser JD, Treede RD. The Kyoto protocol of IASP Basic Pain Terminology. Pain 2008;137:473-477.

Treede RD, Jensen TS, Campbell JN, Cruccu G, Dostrovsky JO, Griffin JW, Hansson P, Hughes R, Nurmikko T, Serra J. Neuropathic pain: redefinition and a grading system for clinical and research purposes. Neurology 2008;70:1630-1635.

Appendix 9

Slump Test Study
Examination Summary

Physical examination

Negative Signs

1.Myotome weakness

1.1 (L) L_3	Yes ☐ No ☐
1.2 (R) L_3	Yes ☐ No ☐
1.3 (L) L_4	Yes ☐ No ☐
1.4 (R) L_4	Yes ☐ No ☐
1.5 (L) L_5	Yes ☐ No ☐
1.6 (R) L_5	Yes ☐ No ☐
1.7 (L) S_1	Yes ☐ No ☐
1.8 (R) S_1	Yes ☐ No ☐

2.Reflex reduction

2.1 (L) L_3	Yes ☐ No ☐
2.2 (R) L_3	Yes ☐ No ☐
2.3 (L) S_1	Yes ☐ No ☐
2.4 (R) S_1	Yes ☐ No ☐

3. Hypoalgesia

3.1 To pin prick	Yes ☐ No ☐
3.2 Location	☐ ☐ ☐ ☐
3.2 To 1 gm monofilament	Yes ☐ No ☐
3.3 Location	☐ ☐ ☐ ☐
3.3 To 10 gm monofilament	Yes ☐ No ☐
3.4 Location	☐ ☐ ☐ ☐
3.5 To cold	Yes ☐ No ☐
3.6 Location	☐ ☐ ☐ ☐
3.7 To heat	Yes ☐ No ☐
3.8 Location	☐ ☐ ☐ ☐

Positive Signs

4. Allodynia

4.1 Present Yes ☐ No ☐

4.2 Location ☐☐☐☐

5. Hyperalgesia to pin prick

5.1 Present Yes ☐ No ☐

5.1 Location ☐☐☐☐

6. Hyperalgesia to 1 gm monofilament

6.1 Present Yes ☐ No ☐

6.2 Location ☐☐☐☐

7. Hyperalgesia to cold

7.1 Present Yes ☐ No ☐

7.2 Location ☐☐☐☐

8. Hyperalgesia to heat

8.1 Present Yes ☐ No ☐

8.2 Location ☐☐☐☐

9. Focal autonomic abnormality

9.1 Present Yes ☐ No ☐

9.2 Location ☐☐☐☐

10. Neurodynamic Tests

10.1 (R) SLR Positive Yes ☐ No ☐

10.2 (R) ROM ☐☐

10.3 (L) SLR Positive Yes ☐ No ☐

10.4 (L) ROM ☐☐

10.5 (R) FNT Positive Yes ☐ No ☐

10.6 (L) FNT Positive Yes ☐ No ☐

11. Tenderness to palpation

11.1 (R) Lumbar paravertebrals Yes ☐ No ☐

11.2 (L) Lumbar paravertebrals Yes ☐ No ☐

11.3 (R) Thoracic paravertebrals Yes ☐ No ☐

11.4 (L) Thoracic paravertebrals Yes ☐ No ☐

Diagnosis

Non Neuropathic Pain ☐

Possible Neuropathic pain ☐

Probable Neuropathic Pain ☐

Definite Neuropathic Pain ☐

Appendix 10

DO YOU HAVE LOW BACK PAIN OR SCIATICA?

SUBJECTS ARE REQUIRED FOR A SHORT STUDY INVESTIGATING A SIMPLE CLINICAL TEST COMMOMLY USED IN THE ASSESSMENT OF LOW BACK PAIN AND SCIATICA

THIS STUDY IS PART OF A MSc. REHABILITATION PROJECT

UNIVERSITY OF MANITOBA

REQUIREMENTS: 25 YEARS OF AGE

ABLE TO SPEAK AND UNDERSTAND ENGLISH

OTHERWISE HEALTHY

NO HISTORY OF SPINAL SURGERY

TIME COMMITMENT: TWO HOURS

WHEN: SPRING, SUMMER, FALL, 2010

LOCATION: 3RD FLOOR DAVID & RUTH ASPER RESEARCH CENTRE, PAM AM CLINIC

75 POSEIDON BAY

WINNIPEG, MANITOBA

TO PARTICIPATE: SPEAK TO YOUR DOCTOR OR PHYSIOTHERAPIST

OR CONTACT HELEN LOCK AT 925-1554

A SMALL HONOURARIUM WILL BE PROVIDED TO THOSE SUBJECTS WHO COMPLETE THE STUDY

References

Ali Z, Ringkamp M, Hartke TV, Chien HF, Flavahan NA, Campbell JN, Meyer RA. Uninjured C-fiber nociceptors develop spontaneous activity and alpha-adrenergic sensitivity following L6 spinal nerve ligation in monkey. J Neurophysiol 1999;81:455-466.

Asbury AK, Fields HL. Pain due to peripheral nerve damage: an hypothesis. Neurology 1984;34:1587-1590.

Backonja MM. Defining neuropathic pain. Anesth Analg 2003;97:785-790.

Banks WA, Watkins LR. Mediation of chronic pain: not by neurons alone. Pain 2006;124:1-2.

Baron R. Neuropathic pain: a clinical perspective. Handb Exp Pharmacol 2009;3-30.

Baron R, Tolle TR, Gockel U, Brosz M, Freynhagen R. A cross-sectional cohort survey in 2100 patients with painful diabetic neuropathy and postherpetic neuralgia: Differences in demographic data and sensory symptoms. Pain 2009;146:34-40.

Basbaum ABMCaDM. Pain: Basic mechanisms. In: Jusutins DM, editor. Pain 2005-An Updated Review: Refresher Course Syllabus. Seattle: IASP Press, 2005. pp. 3-9.

Beith IRE&RP. An assessment of the adaptive mechanisms within and surrounding the peripheral nervous system, during changes in nerve bed length resulting from underlying joint movement. In: Shacklock M, editor. Moving in on pain. Sydney: Butterworth Heinemann, 1995. pp. 194-203.

Bennett GJ. Can we distinguish between inflammatory and neuropathic pain? Pain Res Manage 2006a;11:11a-15a.

Bennett GJ. Neuropathic pain: a crisis of definition? Anesth Analg 2003;97:619-620.

Bennett GJ, Xie YK. A peripheral mononeuropathy in rat that produces disorders of pain sensation like those seen in man. Pain 1988;33:87-107.

Bennett M. The LANSS Pain Scale: the Leeds assessment of neuropathic symptoms and signs. Pain 2001;92:147-157.

Bennett MI. Diagnosing neuropathic pain in clinical practice. In: Bennett MI, editor. Neuropathic Pain. New York: Oxford University Press, 2006b. pp. 25-35.

Bennett MI, Attal N, Backonja MM, Baron R, Bouhassira D, Freynhagen R, Scholz J, Tolle TR, Wittchen HU, Jensen TS. Using screening tools to identify neuropathic pain. Pain 2007;127:199-203.

Bennett MI, Smith BH, Torrance N, Potter J. The S-LANSS score for identifying pain of predominantly neuropathic origin: validation for use in clinical and postal research. J Pain 2005;6:149-158.

Bogduk N. On the definitions and physiology of back pain, referred pain, and radicular pain. Pain 2009;147:17-19.

Boucher TJ, McMahon SB. Neurotrophic factors and neuropathic pain. Curr Opin Pharmacol 2001;1:66-72.

Bouhassira D, Attal N. Diagnosis and assessment of neuropathic pain: the saga of clinical tools. Pain 2011;152:S74-S83.

Bouhassira D, Attal N, Alchaar H, Boureau F, Brochet B, Bruxelle J, Cunin G, Fermanian J, Ginies P, Grun-Overdyking A, Jafari-Schluep H, Lanteri-Minet M, Laurent B, Mick G, Serrie A, Valade D, Vicaut E. Comparison of pain syndromes associated with nervous or somatic lesions and development of a new neuropathic pain diagnostic questionnaire (DN4). Pain 2005;114:29-36.

Bouhassira D, Attal N, Fermanian J, Alchaar H, Gautron M, Masquelier E, Rostaing S, Lanteri-Minet M, Collin E, Grisart J, Boureau F. Development and validation of the Neuropathic Pain Symptom Inventory. Pain 2004;108:248-257.

Bouhassira D, Lanteri-Minet M, Attal N, Laurent B, Touboul C. Prevalence of chronic pain with neuropathic characteristics in the general population. Pain 2008;136:380-387.

Boulton AJ, Knight G, Drury J, Ward JD. The prevalence of symptomatic, diabetic neuropathy in an insulin-treated population. Diabetes Care 1985;8:125-128.

Boureau F, Doubrere JF, Luu M. Study of verbal description in neuropathic pain. Pain 1990;42:145-152.

Bove GM. Epi-perineurial anatomy, innervation, and axonal nociceptive mechanisms. J Bodyw Mov Ther 2008;12:185-190.

Bove GM, Light AR. Calcitonin gene-related peptide and peripherin immunoreactivity in nerve sheaths. Somatosens Mot Res 1995a;12:49-57.

Bove GM, Light AR. Unmyelinated nociceptors of rat paraspinal tissues. J Neurophysiol 1995b;73:1752-1762.

Boyd BS, Puttlitz C, Gan J, Topp KS. Strain and excursion in the rat sciatic nerve during a modified straight leg raise are altered after traumatic nerve injury. J Orthop Res 2005;23:764-770.

Breig A. Biomechanics of the Nervous System: Breig revisited. Adelaide: Neurodynamic Solutions, 2007.

Breig A. Adverse mechanical tension in the central nervous system: an analysis of cause and effect. Stockholm: Almqvist and Wiskell International, 1978.

Breig A, Troup JD. Biomechanical considerations in the straight-leg-raising test. Cadaveric and clinical studies of the effects of medial hip rotation. Spine 1979;4:242-250.

Breig AMO. Biomechanics of the lumbosacral nerve roots. Acta Radiol 1962;72:1141-1160.

Brody IAaWRH. The Signs of Kernig and Brudzinski. Arch Neurol 1969;21:215-216.

Brudzinski J. A New Sign of the Lower Extremities in Meningitis of Children (Neck Sign). Arch Neurol 1969;21:217-218.

Butler D. The sensitive nervous system. Unley: Noigroup Publications, 2000.

Butler D. The Neurodynamic Techniques. Adelaide: Noigroup Publications, 2005a.

Butler D. The Neurodynamic Techniques A DEFINITIVE GUIDE FROM THE NOIGROUP TEAM. Adelaide: Noigroup Publications, 2005b.

Butler D&GL. The concept of adverse mechanical tension in the nervous system. Part 1: Testing for "dural tension". Physiotherapy 1989;75:622-629.

Chen Y, Devor M. Ectopic mechanosensitivity in injured sensory axons arises from the site of spontaneous electrogenesis. Eur J Pain 1998;2:165-178.

Chien A, Eliav E, Sterling M. Whiplash (grade II) and cervical radiculopathy share a similar sensory presentation: an investigation using quantitative sensory testing. Clin J Pain 2008;24:595-603.

Chien A, Eliav E, Sterling M. Hypoaesthesia occurs with sensory hypersensitivity in chronic whiplash--further evidence of a neuropathic condition. Man Ther 2009;14:138-146.

Chien A, Sterling M. Sensory hypoaesthesia is a feature of chronic whiplash but not chronic idiopathic neck pain. Man Ther 2010;15:48-53.

Chong MS, Bajwa ZH. Diagnosis and treatment of neuropathic pain. J Pain Symptom Manage 2003;25:S4-S11.

Cook AJ, Woolf CJ, Wall PD, McMahon SB. Dynamic receptive field plasticity in rat spinal cord dorsal horn following C-primary afferent input. Nature 1987;325:151-153.

Coppieters MW, Alshami AM, Babri AS, Souvlis T, Kippers V, Hodges PW. Strain and excursion of the sciatic, tibial, and plantar nerves during a modified straight leg raising test. J Orthop Res 2006;24:1883-1889.

Coppieters MW, Kurz K, Mortensen TE, Richards NL, Skaret IA, McLaughlin LM, Hodges PW. The impact of neurodynamic testing on the perception of experimentally induced muscle pain. Man Ther 2005;10:52-60.

Coppieters MW, Stappaerts KH, Wouters LL, Janssens K. Aberrant protective force generation during neural provocation testing and the effect of treatment in patients with neurogenic cervicobrachial pain. J Manipulative Physiol Ther 2003a;26:99-106.

Coppieters MW, Stappaerts KH, Wouters LL, Janssens K. The immediate effects of a cervical lateral glide treatment technique in patients with neurogenic cervicobrachial pain. J Orthop Sports Phys Ther 2003b;33:369-378.

Costigan M, Scholz J, Woolf CJ. Neuropathic pain: a maladaptive response of the nervous system to damage. Annu Rev Neurosci 2009;32:1-32.

Cruccu G, Truini A. Sensory profiles: A new strategy for selecting patients in treatment trials for neuropathic pain. Pain 2009a;146:5-6.

Cruccu G, Truini A. Tools for assessing neuropathic pain. PLoS Med 2009b;6:e1000045.

Cyriax J. Perineuritis. British Medical Journal 1942;1:578-580.

Davidson M. The interpretation of diagnostic test: a primer for physiotherapists. Aust J Physiother 2002;48:227-232.

Davis DS, Anderson IB, Carson MG, Elkins CL, Stuckey LB. Upper Limb Neural Tension and Seated Slump Tests: The False Positive Rate among Healthy Young Adults without Cervical or Lumbar Symptoms. J Man Manip Ther 2008;16:136-141.

de PF, Micalef JP, Bourgeon A, Argenson C, Rabischong P. Biomechanics of the lumbar spinal nerve roots and the first sacral root within the intervertebral foramina. Surg Radiol Anat 1989;11:221-225.

Devor M. Peripheral Nerve Generators of Neuropathic Pain. In: Campbell JN, Basbaum ADADRDRHaSCN, editors. Emerging Strategies for the Treatment of Neuropathic Pain. Seattle: IASP Press, 2006a. pp. 37-68.

Devor M. Sodium channels and mechanisms of neuropathic pain. J Pain 2006b;7:S3-S12.

Dickenson ABA. Neurobiological Mechanisms of Neuropathic Pain and Its Treatment. In: Castro-Lopes JRSSM, editor. Pain 2008. Seattle: IASP Press, 2008. pp. 277-286.

Dougherty PM, Palecek J, Zorn S, Willis WD. Combined application of excitatory amino acids and substance P produces long-lasting changes in responses of primate spinothalamic tract neurons. Brain Res Brain Res Rev 1993;18:227-246.

Dworkin RH, Jensen MP, Gammaitoni AR, Olaleye DO, Galer BS. Symptom profiles differ in patients with neuropathic versus non-neuropathic pain. J Pain 2007;8:118-126.

Falconer MA MMBA. Observations on the cause and mechanism of symptom-reproduction in sciatica and low-back pain. J Neurol Neurosurg Psychiatry 1948;11:13-26.

Freynhagen R, Baron R, Gockel U, Tolle TR. painDETECT: a new screening questionnaire to identify neuropathic components in patients with back pain. Curr Med Res Opin 2006a;22:1911-1920.

Freynhagen R, Baron R, Tolle T, Stemmler E, Gockel U, Stevens M, Maier C. Screening of neuropathic pain components in patients with chronic back pain associated with nerve root compression: a prospective observational pilot study (MIPORT). Curr Med Res Opin 2006b;22:529-537.

Gajdosik RL, LeVeau BF, Bohannon RW. Effects of ankle dorsiflexion on active and passive unilateral straight leg raising. Phys Ther 1985;65:1478-1482.

Galer BS, Jensen MP. Development and preliminary validation of a pain measure specific to neuropathic pain: the Neuropathic Pain Scale. Neurology 1997;48:332-338.

Gardell LR, Wang R, Ehrenfels C, Ossipov MH, Rossomando AJ, Miller S, Buckley C, Cai AK, Tse A, Foley SF, Gong B, Walus L, Carmillo P, Worley D, Huang C, Engber T, Pepinsky B, Cate RL, Vanderah TW, Lai J, Sah DW, Porreca F. Multiple actions of systemic artemin in experimental neuropathy. Nat Med 2003;9:1383-1389.

Gertzbein SD, Seligman J, Holtby R, Chan KH, Kapasouri A, Tile M, Cruickshank B. Centrode patterns and segmental instability in degenerative disc disease. Spine 1985;10:257-261.

Gilbert KK, Brismee JM, Collins DL, James CR, Shah RV, Sawyer SF, Sizer PS, Jr. 2006 Young Investigator Award Winner: lumbosacral nerve root displacement and strain: part 1. A novel measurement technique during straight leg raise in unembalmed cadavers. Spine 2007;32:1513-1520.

Goddard MD, Reid JD. Movements induced by straight leg raising in the lumbo-sacral roots, nerves and plexus, and in the intrapelvic section of the sciatic nerve. J Neurol Neurosurg Psychiatry 1965;28:12-18.

Gold MS. Spinal nerve ligation: what to blame for the pain and why. Pain 2000;84:117-120.

Gold MS, Weinreich D, Kim CS, Wang R, Treanor J, Porreca F, Lai J. Redistribution of Na(V)1.8 in uninjured axons enables neuropathic pain. J Neurosci 2003;23:158-166.

Griffin JW. The Roles of Growth Factors in Painful Length-dependent Axonal Neuropathies. In: Basbaum ADADRDRHaSCN, editor. Emerging Strategies for the Treatment of Neuropathic Pain. Seattle: IASP Press, 2006. pp. 271-290.

Grimes DA, Schulz KF. Refining clinical diagnosis with likelihood ratios. Lancet 2005;365:1500-1505.

Hall T&ER. Management of mechanosensitivity of the nervous system in spinal pain syndromes. In: Boyling J&JG, editor. Grieve's modern manual therapy: The vertebral column. Edinburgh: Churchill Livingstone, 2004. pp. 413-431.

Hansson PT. Neuropathic Pain: Definition, Diagnostic Criteria, Clinical Phenomenology, and Differential Diagnosic Issues. In: Castro-Lopes JRSSM, editor. Pain 2008 An Updated review Refresher Course Syllabus. Seattle: IASP Press, 2008. pp. 271-275.

Hansson P, Haanpaa M. Diagnostic work-up of neuropathic pain: computing, using questionnaires or examining the patient? Eur J Pain 2007;11:367-369.

Hayden SR, Brown MD. Likelihood ratio: A powerful tool for incorporating the results of a diagnostic test into clinical decisionmaking. Ann Emerg Med 1999;33:575-580.

Hegedus EJ, Stern B. Beyond SpPIN and SnNOUT: Considerations with Dichotomous Tests During Assessment of Diagnostic Accuracy. J Man Manip Ther 2009;17:E1-E5.

Heliovaara M, Impivaara O, Sievers K, Melkas T, Knekt P, Korpi J, Aromaa A. Lumbar disc syndrome in Finland. J Epidemiol Community Health 1987;41:251-258.

Herrington L, Bendix K, Cornwell C, Fielden N, Hankey K. What is the normal response to structural differentiation within the slump and straight leg raise tests? Man Ther 2007.

Herrington L, Bendix K, Cornwell C, Fielden N, Hankey K. What is the normal response to structural differentiation within the slump and straight leg raise tests? Man Ther 2008;13:289-294.

Hromada J. ON THE NERVE SUPPLY OF THE CONNECTIVE TISSUE OF SOME PERIPHERAL NERVOUS SYSTEM COMPONENTS. Acta Anat (Basel) 1963;55:343-351.

Inman VTaSJB. The clinico-anatomical aspects of the lumbosacral region. Radiology 1942;38:669-678.

Jaeschke R, Guyatt GH, Sackett DL. Users' guides to the medical literature. III. How to use an article about a diagnostic test. B. What are the results and will they help me in caring for my patients? The Evidence-Based Medicine Working Group. JAMA 1994;271:703-707.

Jensen MP, Gammaitoni AR, Olaleye DO, Oleka N, Nalamachu SR, Galer BS. The pain quality assessment scale: assessment of pain quality in carpal tunnel syndrome. J Pain 2006;7:823-832.

Ji RR, Woolf CJ. Neuronal plasticity and signal transduction in nociceptive neurons: implications for the initiation and maintenance of pathological pain. Neurobiol Dis 2001;8:1-10.

Johnson EK, Chiarello CM. The slump test: the effects of head and lower extremity position on knee extension. J Orthop Sports Phys Ther 1997;26:310-317.

Jull G, Sterling M, Kenardy J, Beller E. Does the presence of sensory hypersensitivity influence outcomes of physical rehabilitation for chronic whiplash?--A preliminary RCT. Pain 2007;129:28-34.

Kasch H, Qerama E, Bach FW, Jensen TS. Reduced cold pressor pain tolerance in non-recovered whiplash patients: a 1-year prospective study. Eur J Pain 2005;9:561-569.

Kernig W. Concerning a Little Noted Sign of Meningitis. Arch Neurol 1969;21:216-217.

Krause SJ, Backonja MM. Development of a neuropathic pain questionnaire. Clin J Pain 2003;19:306-314.

Lai J, Hunter JC, Porreca F. The role of voltage-gated sodium channels in neuropathic pain. Curr Opin Neurobiol 2003;13:291-297.

LaMotte RH, Thalhammer JG, Torebjork HE, Robinson CJ. Peripheral neural mechanisms of cutaneous hyperalgesia following mild injury by heat. J Neurosci 1982;2:765-781.

Lew PC, Briggs CA. Relationship between the cervical component of the slump test and change in hamstring muscle tension. Man Ther 1997;2:98-105.

Liu CN, Wall PD, Ben-Dor E, Michaelis M, Amir R, Devor M. Tactile allodynia in the absence of C-fiber activation: altered firing properties of DRG neurons following spinal nerve injury. Pain 2000;85:503-521.

Loeser JD, Treede RD. The Kyoto protocol of IASP Basic Pain Terminology. Pain 2008;137:473-477.

Louis R. Vertebroradicular and Vertebromedullar Dynamics. Anatomia Clinica 1981;1-11.

Maitland G. Negative disc exploration: positive canal signs. Australian Journal of physiotherapy 1979;25:129-134.

Maitland G. The slump test: examination and treatment. Australian Journal of physiotherapy 1985;31:215-219.

Marchand F, Perretti M, McMahon SB. Role of the immune system in chronic pain. Nat Rev Neurosci 2005;6:521-532.

Max MB. Clarifying the definition of neuropathic pain. Pain 2002;96:406-407.

Merskey HBN. Classification of Chronic Pain: Descriptions of Chronic Pain Syndromes and definitions of Pain Terms. Seattle: IASP Press, 1994.

Meyer RARMCJN&RSN. Peripheral mechanisms of cutaneous nociception. In: McMahon SBaKM, editor. Wall and Melzack's Textbook of Pain. London: Elsevier, 2006. pp. 3-33.

Millesi H, Zoch G, Reihsner R. Mechanical properties of peripheral nerves. Clin Orthop Relat Res 1995;76-83.

Nee RJaBD. Management of peripheral neuropathic pain: Integrating neurobiology, neurodynamics, and clinical evidence. Physical Therapy in Sport 2006;7:36-49.

Omana-Zapata I, Khabbaz MA, Hunter JC, Bley KR. QX-314 inhibits ectopic nerve activity associated with neuropathic pain. Brain Res 1997a;771:228-237.

Omana-Zapata I, Khabbaz MA, Hunter JC, Clarke DE, Bley KR. Tetrodotoxin inhibits neuropathic ectopic activity in neuromas, dorsal root ganglia and dorsal horn neurons. Pain 1997b;72:41-49.

Petren K. Remarks on Sciatica and Morbus Coxae Senilis, Especially with regard to Their Treatment. Rev Neurol and Psychiat 1909;7:305-315.

Quintner JL. A study of upper limb pain and paraesthesiae following neck injury in motor vehicle accidents: assessment of the brachial plexus tension test of Elvey. Br J Rheumatol 1989;28:528-533.

Ringkamp M, Meyer RA. Injured versus uninjured afferents: Who is to blame for neuropathic pain? Anesthesiology 2005;103:221-223.

Roudsari B, Jarvik JG. Lumbar spine MRI for low back pain: indications and yield. AJR Am J Roentgenol 2010;195:550-559.

Rubin DI. Epidemiology and risk factors for spine pain. Neurol Clin 2007;25:353-371.

Scholz J, Mannion RJ, Hord DE, Griffin RS, Rawal B, Zheng H, Scoffings D, Phillips A, Guo J, Laing RJ, Abdi S, Decosterd I, Woolf CJ. A novel tool for the assessment of pain: validation in low back pain. PLoS Med 2009;6:e1000047.

Scholz J, Woolf CJ. The neuropathic pain triad: neurons, immune cells and glia. Nat Neurosci 2007;10:1361-1368.

Scott D, Jull G, Sterling M. Widespread sensory hypersensitivity is a feature of chronic whiplash-associated disorder but not chronic idiopathic neck pain. Clin J Pain 2005;21:175-181.

Shacklock M. Clinical neurodynamics: A new system of musculoskeletal treatment. Edinburgh: Elsevier/Butterworth Heinemann, 2005.

Shacklock MO. Positive Upper Limb Tension Test in a Case of Surgically Proven Neuropathy: Analysis and Validity. Man Ther 1996;1:154-161.

Sheen K, Chung JM. Signs of neuropathic pain depend on signals from injured nerve fibers in a rat model. Brain Res 1993;610:62-68.

SMITH CG. Changes in length and position of the segments of the spinal cord with changes in posture in the monkey. Radiology 1956;66:259-266.

Smith JW. Factors Influencing Nerve Repair. Arch Surg 1966;93:335-341.

Smith SA, Massie JB, Chesnut R, Garfin SR. Straight leg raising. Anatomical effects on the spinal nerve root without and with fusion. Spine 1993;18:992-999.

Stafford MA, Peng P, Hill DA. Sciatica: a review of history, epidemiology, pathogenesis, and the role of epidural steroid injection in management. Br J Anaesth 2007;99:461-473.

Sterling M, Pedler A. A neuropathic pain component is common in acute whiplash and associated with a more complex clinical presentation. Man Ther 2009b;14:173-179.

Sterling M, Pedler A. A neuropathic pain component is common in acute whiplash and associated with a more complex clinical presentation. Man Ther 2009a;14:173-179.

Sterling M, Treleaven J, Jull G. Responses to a clinical test of mechanical provocation of nerve tissue in whiplash associated disorder. Man Ther 2002;7:89-94.

Sunderland S. The anatomy and physiology of nerve injury. Muscle Nerve 1990;13:771-784.

Topp KS, Boyd BS. Structure and biomechanics of peripheral nerves: nerve responses to physical stresses and implications for physical therapist practice. Phys Ther 2006;86:92-109.

Treede RD, Jensen TS, Campbell JN, Cruccu G, Dostrovsky JO, Griffin JW, Hansson P, Hughes R, Nurmikko T, Serra J. Neuropathic pain: redefinition and a grading system for clinical and research purposes. Neurology 2008b;70:1630-1635.

Treede RD, Jensen TS, Campbell JN, Cruccu G, Dostrovsky JO, Griffin JW, Hansson P, Hughes R, Nurmikko T, Serra J. Neuropathic pain: redefinition and a grading system for clinical and research purposes. Neurology 2008a;70:1630-1635.

van der Windt DA, Simons E, Riphagen II, Ammendolia C, Verhagen AP, Laslett M, Deville W, Deyo RA, Bouter LM, de Vet HC, Aertgeerts B. Physical examination for lumbar radiculopathy due to disc herniation in patients with low-back pain. Cochrane Database Syst Rev 2010;CD007431.

van der HB, Allison GT, Zusman M. Pain and muscular responses to a neural tissue provocation test in the upper limb. Man Ther 2001;6:154-162.

Vilensky JA, Gilman S, Casey K. Sir Victor Horsley, Mr John Marshall, the nervi nervorum, and pain: more than a century ahead of their time. Arch Neurol 2005;62:499-501.

Wainner RS, Fritz JM, Irrgang JJ, Boninger ML, Delitto A, Allison S. Reliability and diagnostic accuracy of the clinical examination and patient self-report measures for cervical radiculopathy. Spine (Phila Pa 1976) 2003;28:52-62.

Walsh JFMJhNBK. Slump Test: Sensory Responses in Asymptomatic Subjects. J Man Manip Ther 2007;15:231-238.

Wieseler-Frank J, Maier SF, Watkins LR. Central proinflammatory cytokines and pain enhancement. Neurosignals 2005a;14:166-174.

Wieseler-Frank J, Maier SF, Watkins LR. Immune-to-brain communication dynamically modulates pain: physiological and pathological consequences. Brain Behav Immun 2005b;19:104-111.

Woodhall BaHJ. The Well Leg Raising Test of Fajersztajn in the Diagnosis of Ruptured Lumbar Intervertebral Disc. Journal of Bone and Joint Surgery 1950;32-A:786-792.

Wu G, Ringkamp M, Hartke TV, Murinson BB, Campbell JN, Griffin JW, Meyer RA. Early onset of spontaneous activity in uninjured C-fiber nociceptors after injury to neighboring nerve fibers. J Neurosci 2001;21:RC140.

Yoon YW, Na HS, Chung JM. Contributions of injured and intact afferents to neuropathic pain in an experimental rat model. Pain 1996;64:27-36.

Yoshimura M, Yonehara N. Alteration in sensitivity of ionotropic glutamate receptors and tachykinin receptors in spinal cord contribute to development and maintenance of nerve injury-evoked neuropathic pain. Neurosci Res 2006;56:21-28.