

The effectiveness of spinal manipulation at L3 on lumbar paraspinal extensor muscle endurance in asymptomatic males

By

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This dissertation is submitted in partial compliance with the requirements for the
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I, Gregory Justin Thiel, do hereby declare that this dissertation is representative of my own work, both in conception and execution.

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DEDICATION

This research is dedicated to my Mom and Dad, Pam and Justin Thiel, and my beautiful girlfriend Leigh Meyer. Thank you for your unconditional and unwavering love and support.

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ABSTRACT

BACKGROUND

Spinal manipulative therapy (SMT) is a commonly used therapeutic modality. It has been shown that neuromuscular reflexes are elicited during spinal manipulation resulting in changes in the surrounding muscle tonicity and seen as changes in surface electromyography. Despite this little is known about the effect that SMT may have on muscle function. Increased maximum voluntary contraction (MVC) of the paraspinal muscles has been observed following lumbar SMT compared to a control and sham treatment; however its effect on muscle endurance has not been investigated. The aim of this study was to determine the effect of lumbar SMT compared to a placebo treatment on lumbar extensor muscle endurance in asymptomatic individuals.

METHOD

This study was a quantitative double blinded, pre-test and post-test placebo controlled experimental trial. Forty asymptomatic participants were randomly allocated to one of two treatment groups. One group received a single SMT applied to the L3 vertebrae and the other received the pre-load force of the SMT but no thrust. Subjective (a self-report of pain/discomfort while performing the Biering-Sorensen test) and objective [surface electromyography (sEMG), paraspinal muscle endurance time and lumbar spine range of motion] measurements were taken pre- and post-intervention. The latest version of SPSS version (IBM SPSS Inc.) was used to analyse the data. A p-value < 0.05 was considered statistically significant. Independent t-tests were used to compare means and two-way factor ANOVA (for repeated measures) was used to compare the change in the two time points between the two treatment groups (intervention and control).

RESULTS

There were no statistically significant differences between the intervention and placebo groups in terms of subjective reports of pain/discomfort and objective evidence of surface EMG readings, paraspinal muscle endurance time and lumbar spine range of motion.

CONCLUSION

This study was unable to supply evidence that spinal manipulation results in improved paraspinal muscle endurance. It is possible that the choice and number of SMT applications was insufficient to bring about a change in paraspinal muscle endurance. Future investigations are necessary to further determine the effect of spinal manipulation on muscle endurance.

KEY WORDS

Spinal manipulation, surface electromyography, lumbar extensor muscle endurance

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GLOSSARY OF TERMS

Arthrogenic muscle inhibition (AMI): the inability of a functional muscle group to recruit all of their motor units during a maximal voluntary contraction (MVC) (Suter, *et al.*, 2000).

Biering-Sorensen (B-S) test: a commonly used test to assess paraspinal muscle endurance. The B-S test involves positioning a participant prone on a table such that his or her upper body, above the level of the anterior superior iliac spine, is unsupported during the test. The pelvis, knees, and ankles are secured to the table with straps. The participant is then requested to cross their arms against their chest and keep their head in neutral position by focusing on a fixed point. The participant then holds their torso in a horizontal position against the force of gravity for as long as possible, during which they will be timed (Kankaanpaa *et al.*, 1998).

Joint dysfunction/fixation: a result of posterior joint or intradiscal derangements, intercapsular adhesions, segmental muscle spasm and/or soft tissue fibrosis (Bergmann and Peterson, 2011). Initially the patient may experience no clinical symptoms, but will present with aberrant mechanics (Leach, 2004).

Muscle endurance: the ability of a muscle to sustain effort, or produce work over time (Kankaanpaa *et al.*, 1998).

Muscle strength: “the rotational effect of the force generated by a single muscle or muscle group about the joint under consideration, and is also termed the moment” (Dvir, 2004).

Spinal manipulative therapy (SMT): a commonly used therapeutic modality (Potter, McCarthy and Oldham, 2005) involving the movement of a joint beyond the end range of motion, but not beyond its anatomic range of motion (Bergmann and Peterson, 2002).

Surface electromyography (sEMG): an objective technique that can be used to examine back muscle endurance (Biedermann *et al.*, 1991).

The erector spinae muscles: together with the multifidus these muscles are the main extensors of the thoraco-lumbar spine (McGill, 2007). The line of action of these muscles over the lower thoracic and lumbar region is just underneath the fascia, resulting in an increased mechanical advantage therefore allowing for the greatest amount of extensor moment with a minimum of compressive penalty to the spine (McGill, 2002).

CHAPTER ONE: INTRODUCTION

1. BACKGROUND OF THE STUDY

Spinal Manipulative Therapy (SMT) is directed at joint fixations (Haldeman, 2005) which may result from posterior joint or intradiscal derangements (Morris, 2006), intercapsular adhesions (Vernon and Mrozek, 2005), segmental muscle spasm (Korr 1975) and/or soft tissue fibrosis (Bergmann and Peterson, 2011; Yap, 2007; Szymanski and Voss, 2007; Leach, 2004). Initially the patient experiences no clinical symptoms from a joint fixation, but will present with aberrant mechanics (Morris, 2006; Leach, 2004). These aberrations in normal function are thought to be the basis for the development of symptoms due to biochemical, histological, kinesio-pathological and neuropathophysiological changes that occur to varying degrees in the motion segments (Bergmann and Peterson, 2011; Morris, 2006; Vernon and Mrozek, 2005; Leach, 2004). As a result, these dysfunctional motion segments can be characterised clinically by point tenderness (Fischer, 1987; Fischer, 1986), altered pain sensitivity over the spinous process with increased muscle tone, pain in the paraspinal musculature, increased/decreased or aberrant joint movement (Bergmann and Peterson, 2011; Haldemann, 2005; Leach, 2004), altered range of motion (Nansel, Peneff and Quitoriano, 1992) and electromyography (EMG) readings (Leach, Owens and Giesen, 1993).

In order to prevent symptoms developing from a dysfunctional motion segment, an appropriate combination of manipulation, mobilization, traction and / or continuous passive motion are required / recommended [Dagenais and Haldeman, 2012; National Institute for Health and Clinical Excellence (NICE), 2009; Negrini *et al.*, 2006; Haldeman, 2005; Leach, 2004; Australian Acute Musculoskeletal Pain Guidelines Group, 2003; The Norwegian Back Pain Network, 2002]. With particular reference to SMT it is well documented that SMT modulates pain (Melzack and Wall, 1965; Wyke, 1980; Willis and Coggeshall, 1991), inhibits hypertonic muscles (DeVocht, Pickar and Wilder 2005) and can improve functional ability (Bergmann and Peterson, 2011). However, the exact physiological mechanism through which SMT brings about clinical changes is not well understood (Koppenhaver *et al.*, 2011; Colloca and Keller, 2001; Herzog *et al.*, 1999).

One theory to describe the mechanism of SMT proposed by Korr (1975) is that when a joint fixation occurs, the segmental muscles related to the level of the spinal joint fixation increase their gamma gain to restore the muscle spindle afferent discharge; this results in a contraction of the muscle and restriction of the involved motion segment. Therefore, when SMT is applied the surrounding hypertonic muscles are stretched affecting their extrafusal and intrafusal muscle fibres resulting in a bombardment of afferent impulses to the central nervous system resulting in a 'turning down' of the gamma efferents. This then re-establishes normal gamma gain and muscle tone (Gatterman, 2005; Leach, 2004).

Although Korr's (1975) theory pertains to segmental muscles (Schmidt, Kniffki and Schomburg 1981), research has shown reflexogenic responses in the paraspinal musculature (Simmons and Hong, 1989; Skoglund, 1989) following SMT. Herzog, Scheele and Conway (1999) found that high-speed, low-amplitude SMT applied to asymptomatic participants produced reflexogenic responses in muscles surrounding the spine which could be detected by surface electromyography (sEMG); these responses were both measurable and reproducible. Symons *et al.* (2000) in a similar study found that similar reflexes were found in muscles which had their origin or insertion at the vertebral levels that were being manipulated. Krekoukias, Petty and Cheek, (2009) performed a central posteroanterior (PA) mobilisation at L3 which resulted in a statistically significant decrease in the sEMG activity of erector spinae of asymptomatic individuals. This L3 level was selected because of its approximate central position in the lumbar lordosis, by applying a PA force the vertebrae would translate anteriorly (Harms and Bader, 1997; Lee, Moseley and Refshauge, 1990) resulting in maximal impact into the lumbar lordosis.

Although studies have shown reflexogenic effects following SMT, the effect of SMT on the functionality of muscle is scarce. Keller and Colloca (2000) observed changes in erector spinae isometric maximum voluntary contraction (MVC) output in participants with mechanical LBP after manually assisted SMT compared with placebo manipulation and a control group. The results showed that manually assisted SMT resulted in a significant increase in sEMG readings of paraspinal isometric MVC output when compared to the placebo and control group, indicating

that SMT appeared to improve muscle function. Another study that assessed changes post-SMT was Lehman and McGill (2001) who attempted to observe changes in trunk movements of 14 participants with LBP while they performed range of motion tasks to determine if SMT had an effect on trunk kinematics and myoelectric activity in the paraspinal and abdominal muscles. They observed no significant changes, although individual changes that were noted were more apparent in the participants whose pain and dysfunction was more severe. These studies were conducted in participants with LBP, due to the mechanism of pain and how it may influence the neurophysiological reactions further investigation would need to be done in a pain free populations. Similarly there is little to no evidence determining if SMT may affect the endurance capacity of muscles.

Previous evidence suggests that the ability of the trunk muscles to maintain appropriate levels of activation (over an extended period of time) may be more important than maximum strength in terms of protecting the passive structures of the lumbar spine from injury (McGill *et al.*, 2003). It has been suggested that sufficient trunk muscle endurance contributes to spinal stability whilst the patient is engaged in strenuous and / or prolonged physical tasks (Koumantakis, Watson and Oldham, 2005). Therefore if SMT can affect the paraspinal muscles by altering their ability to have endurance there may be an overall favourable effect on spinal health, which together with the clinical effects of SMT would result in a beneficial improvement in the patient when SMT is applied. Therefore the purpose of this study was to determine the effect of L3 lumbar spinal manipulation compared to a placebo treatment on lumbar extensor muscle endurance.

1.2 AIMS AND OBJECTIVES

The aim of this study was to determine the effect of lumbar spinal manipulation at L3 compared to a placebo treatment at L3 in terms of subjective (pain or discomfort experienced whilst performing the Biering-Sorensen test for paraspinal muscle endurance) and objective (paraspinal muscle endurance time, surface electromyography of the paraspinal muscles and lumbar spine active ranges of motion) measurements.

Objectives:

1. To determine the effect of lumbar spinal manipulation of L3 on lumbar extensor muscle endurance in terms of subjective and objective measurements.
2. To determine the effect of placebo treatment of L3 on lumbar extensor muscle endurance in terms of subjective and objective measurements.
3. To compare the effect of lumbar spinal manipulation and placebo treatment of L3 on lumbar extensor muscle endurance in terms of subjective and objective measurements.

1.3 HYPOTHESES

The null hypothesis stated that there would be no difference between lumbar spinal manipulation compared to a placebo treatment of L3 on lumbar extensor muscle endurance in terms of subjective and objective findings.

The alternate hypothesis stated that lumbar spinal manipulation would be more effective than placebo treatment of L3 on lumbar extensor muscle endurance in terms of subjective and objective findings.

1.4 SCOPE OF THE STUDY

The study took the form of a quantitative double blinded, pre-test post-test placebo controlled experimental design. Forty male participants from the greater Durban area were selected based on the inclusion and exclusion criteria set out for the trial. The participants were randomly sampled into one of two groups, the intervention or placebo, with one group received spinal manipulative therapy of L3 and the other group received a placebo treatment. Subjective and objective measurements were taken pre- and post-intervention. Data was statistically analysed using SPSS with a p-value of < 0.05 for significance.

1.5 FLOW OF THE DISSERTATION

This chapter provided an introduction to the research topic with regards to its problem and context within the field of chiropractic. Chapter Two reviews the relevant literature related to the study, Chapter Three describes in detail the study methodology, Chapter Four provides the results of data analysis and Chapter Five presents the discussion. Chapter Six concludes the dissertation and provides recommendations.

1.6 DELIMITATIONS

It is acknowledged that in clinical practice SMT is seldom used as a “once off” treatment, rather as a series of SMT applied over time. In the context of this research SMT will only be applied once in order to determine the effect of a single SMT on paraspinal muscle endurance.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter outlines the relevant anatomy and biomechanics of the vertebral column and its related structures. Muscle endurance is discussed and the literature related to the basic concepts and theories of spinal manipulative therapy (SMT) and its proposed effects are presented.

2.2 OVERVIEW OF THE VERTEBRAL COLUMN

The vertebral column consists of five regions which are made up of a series of irregular bones or vertebrae. There are 33 vertebrae in total: seven cervical, 12 thoracic, five lumbar, five fused to form the sacrum and four coccygeal (Cramer and Darby, 2005; Moore, Dalley and Agur, 1999).

2.2.1 Anatomy and Characteristics of vertebrae

For the purpose of this research the anatomy of the thoracic, lumbar and pelvic regions are discussed. A typical vertebra consists of a vertebral body, vertebral arch and seven processes as illustrated in Figure 2.1.

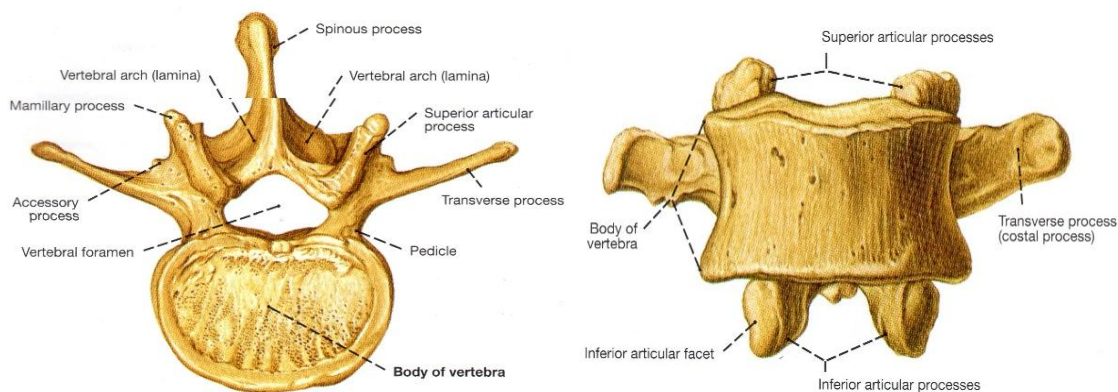


Figure 0.1: Caudal and anterior view of a typical lumbar vertebrae (Clemente, 1997)

In each area of the spine the vertebrae have unique characteristics; those of the thoracic and lumbar spine are highlighted in Table 2.1.

Table 0.1: Unique characteristics of the thoracic and lumbar vertebrae

STRUCTURE	DESCRIPTION AND CHARACTERISTICS	
	Thoracic	Lumbar
Body	Intermediate size	Large kidney shaped
Pedicles	Large and stout	Large and stout
Transverse process (TVP)	Project from the pediculo-laminar junctions in a posterolateral direction. Shorten as one moves down the thoracic spine	Originating from the laminae-pedicle junction are long, slender and flattened on the anterior and posterior aspect
Spinous Process (SP)	The spinous processes (SPs) are long, slender and are angled horizontally (T1-T2; T11-T12), obliquely (T3-T4; T9-T10) and directly inferiorly from T5-T8. The upper SPs may reflect characteristics of cervical SPs as is true for the lower SPs that may reflect lumbar SPs	Thick and broad, hatchet shaped and point posteriorly
Articular processes	Posteriorly, superiorly and laterally at 30 degrees to the vertical plane	Large, thick and strong. Facilitate flexion, extension and lateral bending of the spine, whilst prohibiting rotation
Laminae	Tall from superior to inferior	Sturdy and without costal facets
Intervertebral foramina	An inverted pear shaped structure with the nerve root occupying approximately one twelfth of the aperture	Inverted pear shaped, with approximately one third filled with the spinal nerve root
Vertebral canal	Round in shape and generally seen as the smallest in the vertebral column	This is trefoil in shape and of intermediate size when compared to thoracic and cervical vertebral canals
Costal articular facet on the body	Small smooth areas at the junction of the body and the vertebral arch. Most thoracic vertebrae have 2 costal facets on each side (one superior and one inferior); the superior costal facet of one vertebrae and the inferior costal facet of the adjacent vertebrae both articulate with the head of the same rib; also known as demifacets	None noted on the lumbar vertebra
Costal articular facet	A small smooth area on the transverse process of the thoracic vertebra. It	None noted on the lumbar vertebra.

articulates with the articular facet on the tubercle of the rib.

(Adapted from Moore and Dalley, 2006; Cramer and Darby, 2005)

The lumbar vertebrae generally increase in size from L1 to L5 as the load that they support increases towards the inferior aspect of the vertebral column (Standring, 2008; Cramer and Darby, 2005; Moore, Dalley and Agur, 1999). The anatomical and physiological motion unit of the spine is known as the functional spinal unit (FSU) (Leach, 2004) or a vertebral motion segment (Bergmann and Peterson, 2011) and consists of two adjacent vertebral bodies, the intervertebral disc (IVD) and posterior facet joints that connect them through articulations as well as all ligamentous structures that support these articulations.

2.2.2 Joints of the vertebral column

2.2.2.1 The Zygapophyseal joint

The zygapophyseal joints or facet joints are classified as true diarthrodial and are therefore synovial planar joints and are formed by the articulation between the superior articular process of the vertebral body below and the inferior articular process of the vertebral body above (Bergmann and Peterson, 2011; Moore and Dalley, 2006; Cramer and Darby, 2005). The facet joints allow gliding movements based on their structure and orientation between the vertebrae and per motion segment, bear a third of the axial load, sharing this function with an intervertebral disc (Bergmann and Peterson, 2011; Moore, Dalley and Agur, 1999).

With specific reference to the thoracic spine, the facet joints in this region of the spine lie at 60 degrees to the coronal plane and 20 degrees to the sagittal plane, allowing mainly for lateral flexion and rotational movements and limited flexion and extension movements (Williams, Newell and Collins, 2005; Bergmann, Peterson and Lawrence, 1993). The plane of these articular facets undergo a change in orientation from the thoracic to the lumbar type (principally sagittally orientated) at the level of T11 (the transitional vertebra), however this can also occur at T10 or T12 (Moore and Dalley, 2005).

In the lumbar spine the biplanar zygapophyseal joints have superior facets that are concave and face posteromedially whilst the inferior facets are convex and face anterolaterally (Magee, 2006; Cramer and Darby, 2005). According to Bergmann, Peterson and Lawrence (1993), the plane of the upper lumbar articular facets are principally sagittal, whereas the lower lumbar articular facets are principally in the coronal plane. This transition occurs from T12-L1 level through to the L5-S1 articulation (Cramer and Darby, 2005; Bergmann, Peterson and Lawrence, 1993). The normal thoracic and lumbar ranges of motion values are shown in Table 2.2.

Table 0.2: Thoracic and Lumbar ROM values in asymptomatic individuals (Magee, 2002)

Region	Flexion	Extension	Lateral flexion	Rotation
Thoracic	20-45°	25-45°	20-40°	35-50°
Lumbar	40-60°	20-35°	15-20°	3-18°

To support the vertebral motion segments during motion, the posterolateral aspect of each zygapophyseal joint is surrounded by a thick, fibrous articular capsule and the anteromedial aspect is covered by a thin capsule, which is supported by the ligamentum flavum (Cramer and Darby, 2005; Xu *et al.*, 1991). The joint is further stabilised by the ligaments which unite the laminae (ligamentum flavum), TVPs (intertransverse ligaments) and SPs (interspinous and supraspinous ligaments) (Cramer and Darby, 2005). The anterior longitudinal ligament (ALL) provides stability to the joints and aids in preventing hyperextension whereas the posterior longitudinal ligament (PLL) helps to prevent posterior protrusion of the IVDs and limits hyperflexion of the vertebral column (Moore, Dalley and Agur, 1999).

The above structure of the zygapophyseal joints has two distinct patterns of nerve supply (as is common for any articulation), firstly by articular nerves that innervate the joint capsules as independent branches of adjacent peripheral nerves and secondly by nonspecific articular branches from innervation directed at the muscles that are responsible for moving the joint (Hilton's Law) (Standring, 2008; Guyton and Hall, 1996). These stem from within some of the muscles which are attached to each joint capsule and arrive at the joints by running through the components of muscles embedded in the interfascicular connective tissue (Leach, 2004; Wyke, 1981).

Specifically for the zygapophyseal joints, the sensory innervation (afferent fibres) is derived from the medial branch of the posterior primary division (dorsal ramus) at the level of the joint as well as the level above and the level below (Cramer and Darby, 2005; Jeffries, 1988). Usually sensory information from the zygapophyseal joints (Cavanaugh *et al.*, 1996) is derived from free nerve endings [associated with nociception (McLain and Pickar, 1998)] and complex unencapsulated nerve and encapsulated nerve endings [associated with proprioception and protective muscular reflexes (McLain and Pickar, 1998)]. It is clinically important to note that the thoracic and lumbar spines have fewer mechanoreceptive sensors than the cervical spine, but similar numbers of nociceptive sensors (Cramer and Darby, 2005; McLain and Pickar, 1998). This sensory information travels to the spinal cord via the dorsal rami, prior to entering the dorsal root ganglion (Polit and Beck, 2008), before travelling via the Rexed's laminae V and VI (which are thought to be related to the multimodal integration and regulation of motion) or the Rexed's laminae I-IV [which are thought to collate primary afferent information (e.g. nociception)] (Polit and Beck, 2008) and ending in the respective portions of the thalamus, hypothalamus, cerebellum and cerebrum (Polit and Beck, 2008; Crossman and Neary, 2005; Norkin and Levangie, 2001).

In the above manner, information is captured via receptors in the joint capsules, ligaments, and tendons and sent via afferent pathways to the supra-spinal structures (Levangie and Norkin, 2001).

2.2.2.2 Intervertebral disc

The intervertebral discs, which are the main load bearing units of the spine, are located between the bodies of two adjacent vertebrae (Cramer and Darby, 2005). The disc consist of an internal nucleus pulposus that is formed by a gel-like mucoid substance and an external annulus fibrosis that is composed of layers of lamellae which insert into the ring apophysis of the vertebral bodies. These lamellae run at right angles to each other, allowing the annulus to be deformed by different rotary forces, without the nucleus pulposus being damaged (Martini, Timmons and Tallitsch, 2012; Standring, 2008; Moore, Dalley and Agur, 1999).

The discs vary in shape, thus producing the secondary curvatures of the vertebral column which help to reduce downward forces applied to the spine (Moore, Dalley and Agur, 1999). They act as a shock absorber by distributing some of the load applied to the spine. They also separate the vertebrae, allowing the nerve roots to pass freely from the spinal cord through the intervertebral foramina (Magee, 2006).

2.2.3 Ligaments of the Vertebral Column

The vertebral column has strong ligaments, as summarised in Table 2.3, which help to maintain the curvatures of the spine and provide stability during movement (Moore, Dalley and Agur, 1999).

Table 0.3: Ligaments of the Spine

LIGAMENT	ATTACHMENTS	FUNCTIONS
Anterior Longitudinal	From superior to inferior along the anterior surfaces of all vertebral bodies	Broadens to fuse with the anterior lamellae of the disc for support, before narrowing over the vertebral body again
Posterior Longitudinal	From superior to inferior along the posterior surfaces of all vertebral bodies	Expands at the level of the disc to provide support and then narrows as it passes between the pedicles on either side
Supraspinous	Connects the tips of the SP of thoracic and lumbar vertebrae	Provide stability and serves as a muscle attachment site
Interspinous	Connects the SP of two adjacent vertebra	Provides stability between adjacent vertebra
Intertransverse	Runs between the TVP	Provides stability between adjacent vertebra

(Adapted from Moore, Dalley and Agur, 1999; Gray, Williams and Bannister, 1995)

2.3 OVERVIEW OF THE PELVIS AND SACRUM

The bony pelvis consists of the pelvic girdle, made up of two hip bones which are part of the appendicular skeleton, and the pelvic region of the spine including the sacrum and coccyx, which are part of the axial skeleton (Moore, Dalley and Agur, 1999). The sacrum is a triangular shaped bone located at the base of the spine

formed through the fusion of the five sacral segments. It articulates laterally with the ilium. The sacral base, which is formed by the superior surface of S1, articulates with the coccyx by means of a disc. It has two superior facets that articulate with L5. The sacral tubercles are situated in the midline and correspond with the spinous processes of the fused vertebrae. The tubercles on the posterolateral aspect correspond with the transverse processes. The weight of the body is transferred via the sacrum to the pelvis and provides strength and stability along with providing support for the vertebral column (Moore, Dalley and Agur, 1999).

2.3.1 Joints and ligaments of the sacrum

Posteriorly the lumbosacral joint, formed by the articulation between the L5 vertebrae and S1, and the bilateral sacroiliac joint allow articulation between the ala of the sacrum and the auricular surface of the ilium. These important joints assist in translating the weight from the spine to the lower limbs. Anteriorly there is the pubic symphysis in the midline uniting the superior rami of the two pubic bones; it provides elasticity to the pelvic ring. Laterally, the acetabulum articulates with the hip bilaterally (Moore and Dalley, 2005). The pelvis is stabilised by many ligaments, some of which are highlighted in Figure 2.3.

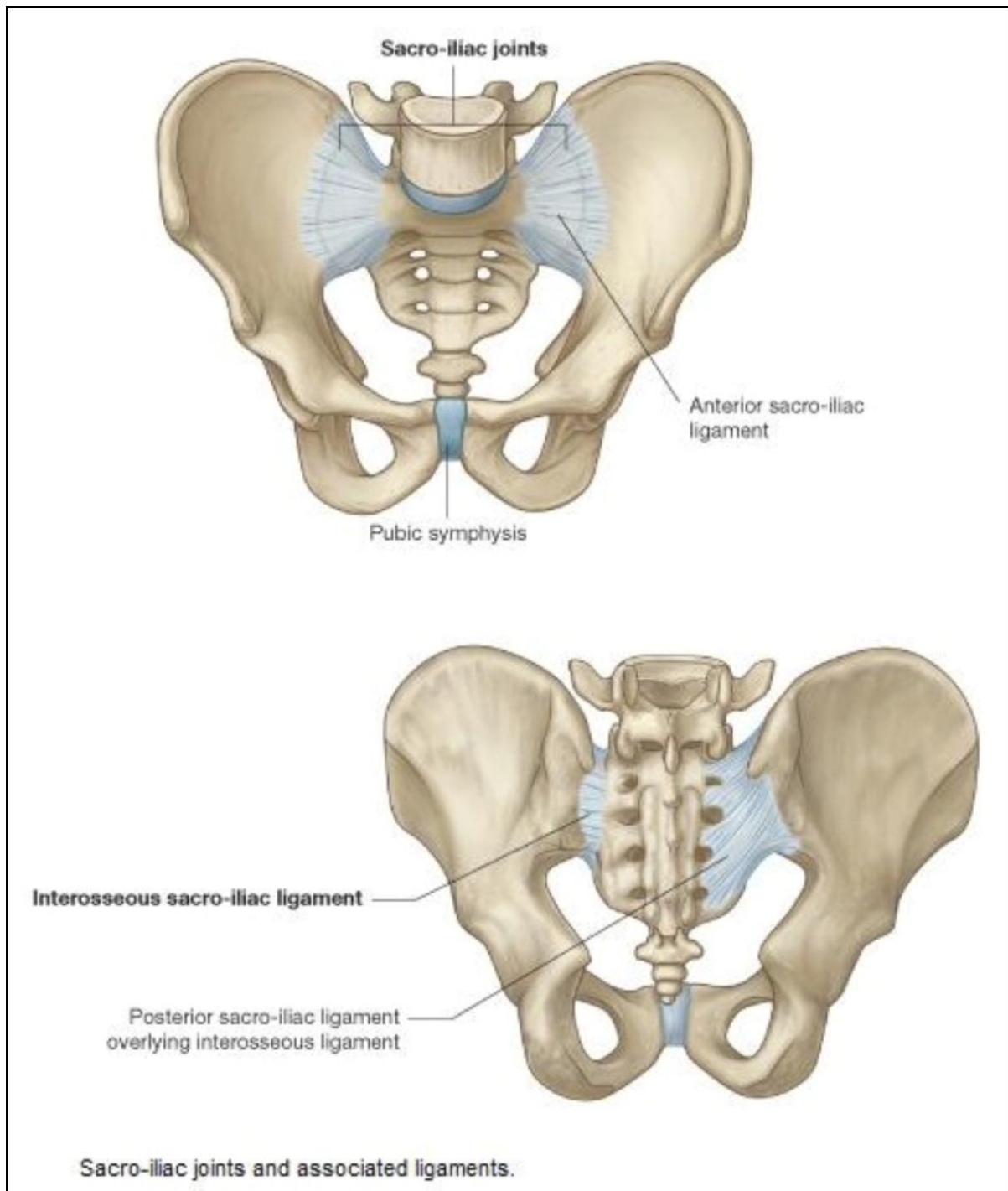


Figure 0.2: Anterior and Posterior view of pelvis and pelvic ligaments (Physical Therapy Protocols, <http://therapyprotocols.webs.com/SIjointdysfunction.htm>, 2008)

2.4 OVERVIEW OF THE MUSCULATURE OF THE LOW BACK

The muscles of the back are divided into the superficial, intermediate and intrinsic. The superficial and intermediate muscles are extrinsic back muscles and are responsible for movement of the limbs and respiration, whereas the intrinsic back muscles function to maintain posture and control movement of the vertebral column (Moore and Dalley, 2006). For the purpose of this study only the intrinsic back muscles will be discussed.

2.4.1 Intrinsic back muscles

This group of muscles is further divided into three layers namely superficial, intermediate and deep (Moore and Dalley, 2006) (Table 2.1). For the purposes of this research the intermediate and deep layers will be discussed.

Table 0.4: Intermediate and deep layers of back muscles

Layer	Muscle	Origin	Insertion	Action
Intermediate	Erector Spinae: Iliocostalis	All three have a common tendon of origin that attaches inferiorly to the posterior aspect of the iliac crest and sacrum, the sacroiliac ligament and the lower lumbar and sacral SP	Lumborum, thoracis, and capitis insert into the angle of lower ribs and cervical TVPs	For the layer: Bilaterally: extension of the spine and head. Unilaterally: Lateral flexion of the spine
	Longissimus		Longissimus thoracis, cervicis and capitis insert into the TVPs of the cervical and thoracic regions and into the mastoid process.	
	Spinalis		Spinalis thoracis, cervicis and capitis insert into SP in the upper thoracic area and to the skull	
Deep Layer	Transversospinal Semispinalis	TVPs of C4-T12 vertebrae	Attaches to the SP of the thoracic and cervical spine and inserts into the occipital bone	Extension of the head, cervical and thoracic regions
	Multifidus	Sacrum, ilium, TVPs of T1-T3 and articular processes of C4-C7	SP 2-4 vertebral levels superior to their origin	Assists in stabilizing spine during local movement. Stabilise individual vertebrae and aid in local extension and rotation
	Rotatores (brevis and longus)	Arises from the TVPs of the vertebrae	Attaches to the lamina and TVPs of the vertebra above.	

(Adapted from McGill, 2007; Moore and Dalley, 2006).

The erector spinae muscles, together with the multifidus are the main extensors of the thoraco-lumbar spine (McGill, 2007). The line of action of these muscles over the lower thoracic and lumbar region is just underneath the fascia, resulting in an increased mechanical advantage therefore allowing for the greatest amount of extensor moment with a minimum of compressive penalty to the spine (McGill, 2002). These muscles are illustrated in Figure 2.4.

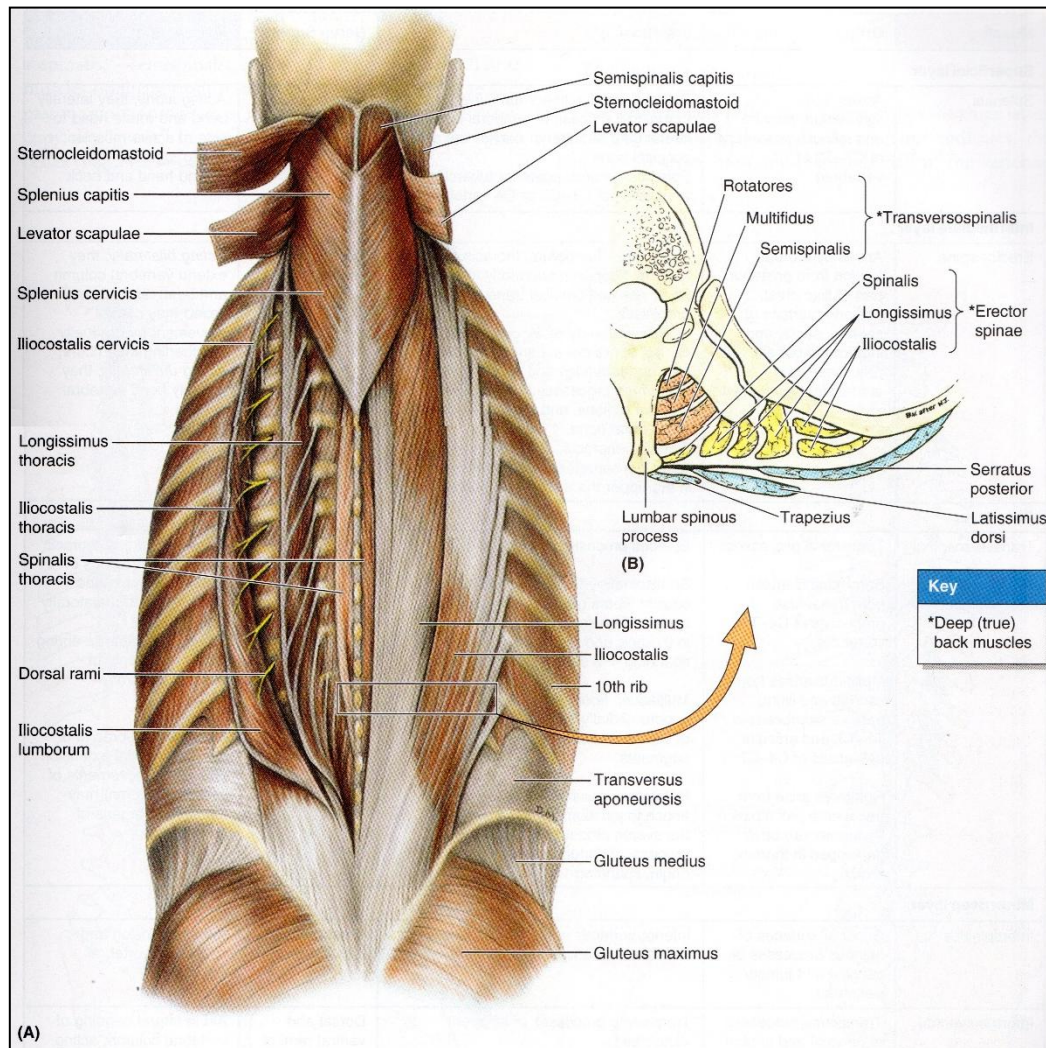


Figure 0.3: Muscles of the back: splenius, erector spinae and transversospinalis (Moore and Dalley, 2009)

2.5 FASCIA OF THE BACK

The thoracolumbar fascia is a tough fibrous sheath-like mass of connective tissue which encases the spinal extensors and extends downward from the thoracic spine to the ilial and sacral attachments of the hip extensor musculature. It is essential in

the preservation of normal spinal mechanics (Bogduk, 1984). It consists of three layers: the anterior, middle and posterior. The posterior layer has an important role in supporting the lumbar spine and abdominal musculature. It consists of two laminae: a superficial lamina with fibres passing inferiorly and medially and a deep lamina with fibres passing inferiorly and laterally.

The aponeurosis of the thoracolumbar fascia with the latissimus dorsi muscle above and the gluteus maximus muscle below provides a link between the lower and upper limb. Its deeper layers which are directed caudi-laterally from the midline encase the erector spinae and connect with the internal oblique muscle and transverse abdominus (TA) (Young *et al.*, 1996; Akuthota and Nadler, 2004). The TA has large attachments to the middle and posterior layers of the thoracolumbar fascia (Akuthota and Nadler, 2004) through which they aid spinal stability.

2.6 OVERVIEW OF THE NERVOUS SYSTEM

The nervous system is made up of two parts, the central nervous system (CNS) consisting of the brain and spinal cord and the peripheral nervous system (PNS) made up of all the nervous tissue outside of the CNS. The PNS is divided into the somatic nervous system (SNS), the autonomic nervous system (ANS), and the enteric nervous system (ENS) (Tortora and Derrickson, 2006).

2.6.1 Peripheral nervous system

The PNS is responsible for transporting messages or impulses to and from the CNS. This is achieved via peripheral nerves that link the CNS with peripheral structures working together to collect, transmit and process information from various neurophysiological systems of the body, in order to co-ordinate movement (Hopkins and Ingersoll, 2000). The nerves of the PNS are classified as either cranial or spinal. There are 12 pairs of cranial nerves and 31 pairs of spinal nerves. Each spinal nerve is formed by the combination of nerve fibres from the dorsal and ventral roots of the spinal cord. The dorsal roots carry afferent sensory neurons while the ventral roots carry efferent motor neurons (Moore, Dalley and Agur, 1999). Dorsal root ganglia are located on the dorsal root of the spinal nerve where the cell bodies of the afferent

neurons are found (Haldeman, 2005). Anatomically, these are situated within the intervertebral foramen (IVF) in close proximity to the facet joints (Gatterman, 2005) as illustrated in Figure 2.5

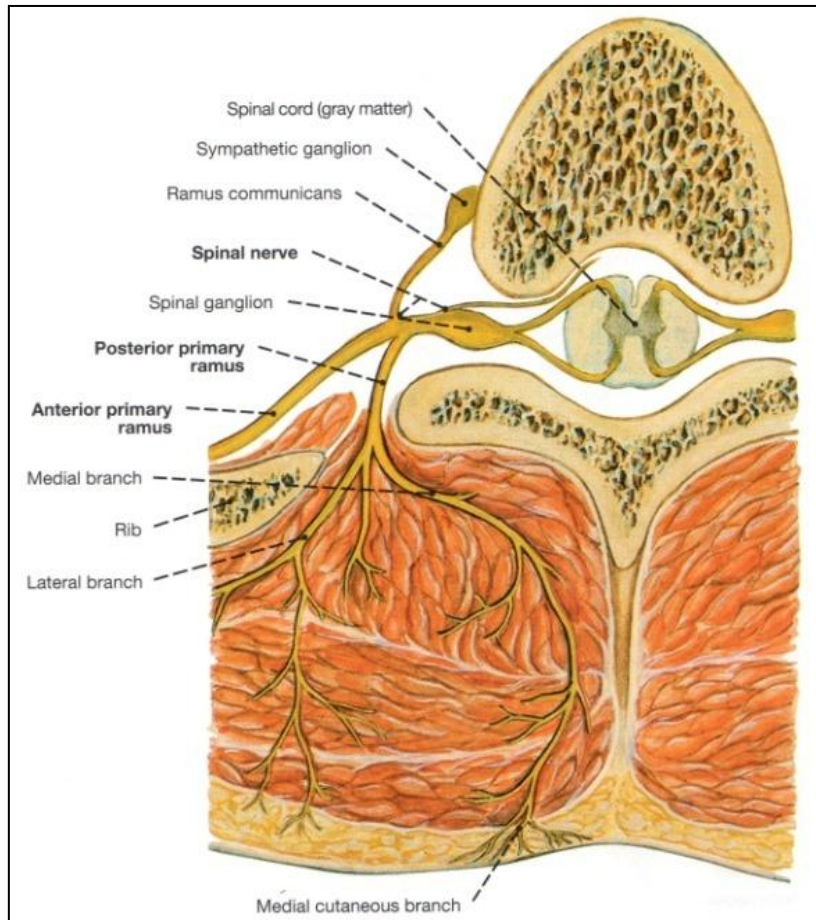


Figure 0.4: A typical spinal nerve (Clemente, 1997)

2.6.1.1 Sensory receptors

In order for the nervous system to work effectively and for coordinated movement to occur, substantial information needs to be relayed from the sensory receptors via the sensory nerves to the CNS, where the information is assessed and a reflex action is initiated (Moore, Dalley and Agur, 1999). The sensory receptors are divided into pain and mechanoreceptors as seen in Table 2.5.

Table 0.5: Types of receptors

RECEPTOR TYPE	LOCATION	SENSATIONS	ADAPTION RATE	
MECHANO-RECEPTOR	Meissner corpuscles	Hairless skin	Fine touch, pressure and slow vibrations	Rapid
	Merkel discs	Epidermis	Fine touch and pressure	Slow
	Type I: Ruffini corpuscles	Deep in the dermis, in ligaments and tendons, periosteum and superficial layer of the joint capsule	Stretching of skin. Static joint position. Active and passive joint movements	Static and dynamic, low threshold, slow adapting
	Type II: Pacinian corpuscles	Dermis, subcutaneous layer, submucosal tissues, joint capsule and articular fat pad, periosteum and some viscera	Pressure, fast vibrations. Active and passive joint movements	Dynamic, low threshold, rapid adapting
	Muscle spindles	Within most striated skeletal muscles	Muscle length	Slow
	Type III: Golgi tendon organs	Ligaments and tendons	Muscle tension	Dynamic, high threshold, slow adapting
PAIN RECEPTORS	Type IV	Joint capsule, joint fat pads and blood vessels walls. Free nerve endings – intrinsic and extrinsic ligaments	Pain	High threshold, non-adapting

(Adapted from Muscolino, 2011; Tortora and Derrickson, 2006; Gatterman, 2005; Leach, 2004; Peterson and Bergmann, 2002; Liebler *et al.*, 2001; Hagervorst and Brand, 1998; Wyke, 1972)

2.6.1.2 Sensory Nerve Fibres

These are different afferent nerves which transmit stimuli from the sensory receptors to the spinal cord; Table 2.6 shows the classification of these nerves.

Table 0.6: Classification of sensory nerves

TYPE	VELOCITY(M/S)	MYELIN	CHARACTERISTICS	ASSOCIATED RECEPTOR
Ia	70-120	Yes	Responds to rate of length changes of a muscle	Muscle spindle
Ib	70- 120	Yes	Responds to tension changes of a muscle	Golgi tendon organ
II	30-62	Yes	Stretch receptor, non adapting	Secondary receptors of muscle spindles, all cutaneous mechanoreceptors
III	6-30	Thin	Responds to pain	Free nerve endings for touch and pressure, nociceptors of neospinothalamic tract (deep pressure and touch) and cold receptors
IV	6-16	No	Nociceptor	Nociceptors of paleospinothalamic tract (crude touch, pressure and pain) and warmth receptors

(Adapted from Leach, 2004; Pickar, 2002; Hagervorst and Brand, 1998; Guyton *et al.*, 1997; Kingsley, 1996; Darby *et al.*, 1995)

When the afferent nerves enter the spinal cord they divide into medial and lateral branches. The medial branches enter the dorsal column of the spinal cord and travel to the brain. The lateral branch enters the lateral horn and divides multiple times to provide terminals that synapse with the intermediate and anterior portions of the cord gray matter (Guyton and Hall, 2006). A large portion of these neurons enter the dorsal column and ascend to the brain, some are fairly short and synapse locally to elicit local spinal cord reflexes and others enter the spinocerebellar tracts. The fibres that ascend to the sensory cortex via the thalamus first decussate in the medulla (Guyton and Hall, 2006).

2.6.1.3 Motor neurons

Motor neurons are the efferent fibres found within the CNS that project their axons outside the CNS directly or indirectly to innervate and control skeletal muscle (Schacter, Gilbert and Wegner, 2011). There are three types of motor neurons which can be classified according to their diameter as seen in the Table 2.7.

Table 0.7: Classifications of Motor Neurons

FIBRE TYPE	DIAMETER (MICRON)	MYELINATION	FUNCTION
Alpha (α)	12-20	Heavily myelinated	Skeletal muscle extrafusal muscle fibre
Beta (β)	5	Myelinated	Innervate the slow (for posture) twitch fibres of the extrafusal muscle fibres, and intrafusal fibres of muscle spindles
Gamma (γ)	3-6	Myelinated	Intrafusal muscle fibre of the muscle spindle

(Leach, 2004; Jacobs, van Praag and Gage, 2000; Snell, 1997; Darby and Daley, 1995;)

Skeletal muscle innervation is achieved when the two types of motor neurons come together to create a motor neuronal pool. The muscle and the motor neuron pool work together to form a single efficient unit (Darby and Daley, 1995) and the strength of the muscle contraction is ultimately dependant on the number of motor units working on that particular muscle (Iyer, Mitz and Winstein, 1999).

2.6.1.4 The interneuron

These make up the vast majority of neurons found within the CNS (Crossman and Neary, 2005) and can be described as a relay or link between the neurons, receiving information from one neuron and transmitting it to another (Hopkins and Ingersoll, 2000). After entering into the dorsal horn of the spinal cord, the sensory fibres usually branch off to synapse with several interneurons. This interneuron network is an incredibly intricate and complicated system as there is a huge amount of information from sensory fibres and supraspinal centres travelling through these interneurons. They form the connections of pathways to α - and γ -motorneurons, autonomic efferent neurons and to the ascending pathways (Hopkins and Ingersoll, 2000).

Interneurons have been classified as being either Ia which are inhibitory or Ib which can be inhibitory or excitatory (Hopkins and Ingersoll, 2000). Ib interneurons receive information from the (Hopkins *et al.*, 2002):

1. Golgi tendons;
2. Joint and cutaneous efferents;

3. Inhibitory Ia interneurons; and
4. Descending tracts from the brain stem.

The Ib inhibitory interneurons are stimulated by any injury of the joint which in turn inhibits the large type A α motor neurons which are responsible for force contraction of skeletal muscle.

2.7 SKELETAL MUSCLE

Skeletal muscles are voluntary muscles which produce movements of the skeleton and other parts of the body. Due to the striated appearance of the muscle fibres when viewed under a microscope they are also referred to as striated or striped muscles. They consist of bundles of muscle fibres which can be seen as the structural units of a muscle. Each muscle fibre contains numerous myofibrils (Moore, Dalley and Agur, 1999), as seen in Figure 2.5.

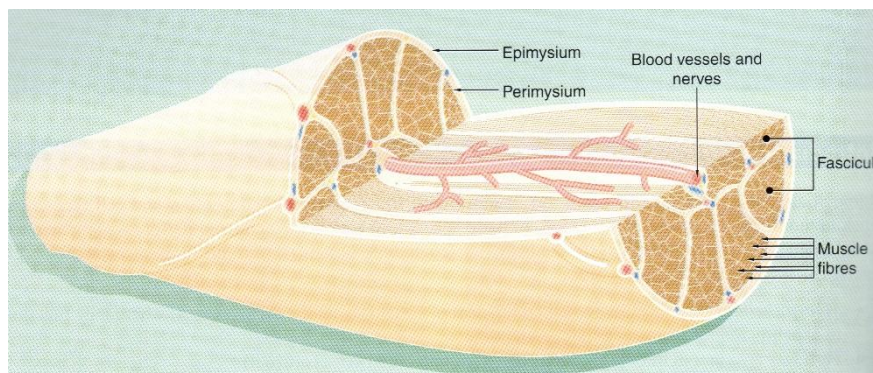


Figure 0.5: Muscle fibre (Young and Heath, 2000)

Each muscle fibre contains myosin and actin myofilaments that are arranged in a specific manner when viewed in a transverse section. This arrangement includes six actin (thin) filaments surrounding one myosin (thick) filament. These filaments are responsible for the contraction of a muscle via the sliding filament theory (Guyton and Hall, 2006). Troponin and tropomyosin, proteins found on the helical intertwined chain of actin proteins, regulate muscle contraction (Vander, Sherman and Luciano, 2001).

2.7.1. Contraction of skeletal muscle

Muscle contraction occurs in sequential steps (Guyton and Hall, 2006). An action potential nerve impulse travels along a motor nerve to its endings on the muscle fibre. At each ending, the nerve secretes a small amount of the neurotransmitter acetylcholine. The acetylcholine acts on a local area of the muscle fibre membrane to open multiple channels. Once these acetylcholine-gated channels open they allow large quantities of sodium ions to diffuse to the interior of the muscle fibre via its membrane. This initiates an action potential at the membrane. The action potential travels along the muscle fibre membrane resulting in depolarization of the membrane releasing large quantities of calcium ions from the sarcoplasmic reticulum. The ions initiate attractive forces between the actin and myosin filaments, causing them to slide alongside each other, which is the contractile process. After a fraction of a second, the calcium ions are pumped back into the sarcoplasmic reticulum by a calcium membrane pump, and they remain stored in the reticulum until a new muscle action potential comes along; the removal of calcium ions from the myofibrils causes the muscle contraction to cease. Tropomyosin covers the myosin-binding site on each actin molecule, preventing the cross-bridges (the myosin-extension heads) from binding to actin. Each tropomyosin molecule is held in this blocking position by troponin, a smaller protein that is bound to both actin and tropomyosin.

The functional unit, known as the motor unit, is comprised of a motor neuron and the muscle fibres it controls. The size of these motor units depend entirely on the size and function of the muscles they supply, thus larger muscles such as those found in the trunk will have one motor neuron supplying a large number of muscle fibres. Contraction of these fibres occurs simultaneously once the nerve impulse generated within the spinal cord reaches the motor neuron (Moore, Dalley and Agur, 1999).

2.7.1.1 Factors affecting the ability of a muscle to contract

- Arthrogenic muscle inhibition (AMI)

Arthrogenic muscle inhibition (AMI) is defined as the inability of a functional muscle group to recruit all of their motor units during a maximal voluntary contraction (MVC)

(Suter, *et al.*, 2000). This results from the activity of many different joint receptors, which act on inhibitory interneurons synapsing on the motorneuron pool of a joint's musculature. More specifically it is a presynaptic, ongoing reflex inhibition of muscles surrounding a joint after damage or distension to structures of that joint (Hopkins and Ingersoll, 2000). The information from inhibitory interneurons impedes the recruitment within the motorneuron pool, decreasing the force of any contraction originating from that motorneuron pool. Free nerve endings and specialised nociceptors may play a role in inhibition, but the primary effect seems to be as a result of mechanoreceptor activity (Ingersoll, Palmieri and Hopkins, 2003). Possible causes of AMI are injuries/damage to joint structures (Hopkins *et al.*, 2002), joint effusion and pain (Hopkins *et al.*, 2002), osteoarthritis (Arokoski, Juntunen and Luikku 2002) and immobilization (Reid, 1992). Ingersoll, Palmieri and Hopkins (2003) suggested that the interneurons were responsible for the development of AMI.

Cervero, Schaible and Schmidt (1991) proposed that the sensory input received from the joints could be disrupted if there was any injury to the joint. This could have an inhibitory effect on the joint's motor neurons due to a reflex arc mechanism that is mediated by supraspinal structures (Guyton and Hall, 1997). This arc causes a decrease in the inhibition of the inhibitory mechanism, allowing inhibition of the motor neurons and the presence of AMI (Hopkins and Ingersoll, 2000). This explanation was supported by Valeriani *et al.* (1996), who explained how the functioning of the central somatosensory pathways were modified by lesions to peripheral mechanoreceptors. Werner, Bauswein and Fromm (1991) suggested that stimulation of afferent neurons showed primary cortex activity that directly correlated to the EMG of the muscle. Although the cortex has been seen to be involved in the complex integration of articular inputs from proprioceptors, it has also been shown that joint afferents could influence the cortex response (Hopkins and Ingersoll, 2000).

- Length tension relationships

This refers to the relationship between the length of a single muscle fibre and the force that it is able to produce at that particular length (Tortora and Derrickson, 2006). This length is related to the degree of overlapping of the actin and myosin filaments, the more the muscle fibre is stretched the less these filaments will overlap

and vice versa. If a muscle fibre is overstretched, it cannot develop tension, and if a muscle fibre is compressed, shortening will be limited (Marieb, 2004).

- Limbic system

Certain emotions and stressors have been shown to have an effect on muscle contraction by influencing the level at which spindle sensitivity is set, causing the muscle gain to be set too high or too low in the fusimotor system (Leach, 2004).

- Muscle fascicle length and diameter

Both the length and cross-sectional area of the muscle fascicles have been shown to affect the force of muscle contraction with longer fibres also allowing for an increased range of motion (Tortora and Derrickson, 2006).

2.7.2 Classification of skeletal muscle fibres

There are two types of skeletal muscle fibres, as seen in Table 2.8; slow twitch (type one) and fast twitch (type two). Type two fibres can be further divided into 2A (fast oxidative), 2X (fast intermediate) and 2B (fast glycolytic). These fibres differ in oxidative enzymes and mitochondrial content. Velocity of contraction is dictated by fibre type, whereas resistance to fatigue is related to oxidative enzyme content (Schiaffino and Serrano, 2002).

Table 0.8: Muscle fibre characteristics (Adapted from Schiaffino and Serrano, 2002)

Fibre Type	Type I	Type II	
		A	B
Resistance to fatigue	High	Intermediate	Low
Number of Mitochondria	High	Medium	Low
Contraction speed (milliseconds)	Slow (90-140 ms)	Fast (50-100 ms)	Very Fast (40-90 ms)
Activity	Endurance	Short (less than 2 minutes) high intensity	Very short (1-30 seconds max) maximal intensity
Oxidative capacity	High	Intermediate	Low

2.7.3 The role of muscles spindles and golgi tendon organs

When a muscle is stretched, the muscle spindles are activated, sending sensory impulses to the spinal cord and CNS. In order to resist this stretch, impulses are sent from the CNS and spinal cord to the muscle, which causes the muscle to reflexively contract. If the stretch persists for an extended period of time, this change in length and tension within the muscle causes the Golgi tendon organs to respond by sending sensory impulses to the spinal cord and CNS. These impulses have the ability to override the impulses coming from the muscle spindles, allowing the muscle to relax after the initial resistance to the change in length (Arnheim and Prentice, 1993).

2.7.4 Muscle strength

Strength “is defined as the rotational effect of the force, generated by a single muscle or muscle group, about the joint under consideration, and is also termed the moment” (Dvir, 2004). The response of a muscle to a particular load is directly proportionate to the magnitude of that load thus the greater the load the greater the increase in muscle strength required. Response to loading also depends on the initial status of that muscle (Bruton, 2002; Sverdlova and Witzel, 2010). Maximum voluntary contraction (MVC) is a way in which a person’s ability to exert maximum muscular force, statically or dynamically, can be measured (De Ste Croix, Deighan and Armstrong, 2003).

2.7.5 Muscle endurance

This is defined as the ability of a muscle to sustain effort, or produce work over time (Kankaanpaa *et al.*, 1998) and can be increased through activities which require the repetition of contractions against a mild resistance, below maximum strength (Tonkonogi *et al.*, 2000). Static muscle endurance refers to the ability of a muscle to contract for an extended period of time whereas dynamic muscle endurance refers to the ability of a muscle to contract and relax repeatedly (Haldeman, 2005). Muscle endurance is particularly important in athletes as it can lead to greater success in

their chosen field as well as being important in everyday life in preventing fatigue from work and other daily activities (Ito *et al.*, 1996).

2.7.5.1 Paraspinal muscle endurance and its clinical relevance

The paraspinal musculature plays a role in ensuring adequate support for the vertebral column (Moore, Dalley and Agur, 1999). The medial and lateral vestibulospinal tracts function to control the extensor muscles that are responsible for maintaining an upright posture (Guyton and Hall, 2005); they do this through transmissions to the interneurons and the motor neurons (Hopkins and Ingersoll, 2000). In order to maintain an upright posture the extensor muscles need to maintain an active tone. Prior to movement there needs to be postural reflex changes within these muscles and these are mediated at the interneuron by the vestibular system and the cerebral cortex (Hopkins and Ingersoll, 2000).

Evidence suggests that the ability of the trunk muscles to maintain appropriate levels of activation over an extended period of time may be more important than maximum strength in terms of protecting the passive structures of the lumbar spine from injury (McGill *et al.*, 2003). It has been suggested that sufficient trunk muscle endurance contributes to spinal stability over strenuous and prolonged physical tasks (Koumantakis, Watson and Oldham, 2005). Chok *et al.* (1999) found that an endurance training programme involving the muscles of the trunk had a positive effect on decreasing pain and improving function over a short term indicating how improved muscle endurance will increase fatigue thresholds and improve performance, thus reducing disability.

The function and coordination of the lumbar spine stabilizing muscles, in particular the lumbar extensor muscles, are often impaired in patients with low back pain (LBP) (Arokoski *et al.*, 2004). A clinical assessment of back extensor muscle endurance and low back mobility showed that weakness of the back extensors associated with a high lumbar mobility could predict future LBP in adolescents aged 14 and 16 years (Sjölie and Ljunggren, 2001). Nourbakhsh and Arab (2002) found a number of mechanical factors, including poor extensor muscle endurance affected back pain, supporting Biering-Sorensen's (1984) findings that a decrease in back extensors

muscle endurance influenced back pain in middle-aged adults. These studies indicate that clinical treatments should be directed at the paraspinal muscles to help prevent LBP and to assist in the management of patients with LBP. Therefore endurance training of the back extensor muscles is important in order to help prevent future episodes of lower back pain (Liebensen, 1997).

2.7.5.2 Measures of paraspinal muscle endurance

There are various ways to determine paraspinal muscle endurance:

- Biering-Sorensen test

The Biering-Sorensen (B-S) test is a commonly used test to assess paraspinal muscle endurance. It has been shown to be valid and reliable (ICC= <0.75) (Demoulin *et al.*, 2006) and is less costly for use in a clinical setting than other fatigue inducing tests (da Silva *et al.*, 2005). The B-S test involves positioning a participant prone on a table such that his or her upper body, above the level of the anterior superior iliac spine, is unsupported during the test. The pelvis, knees, and ankles are secured to the table with straps. The participant is then requested to cross their arms against their chest and keep their head in neutral position by focusing on a fixed point, as illustrated in Figure 2.4. The participant then holds their torso in a horizontal position against the force of gravity for as long as possible, during which they will be timed (Kankaanpaa *et al*, 1998).

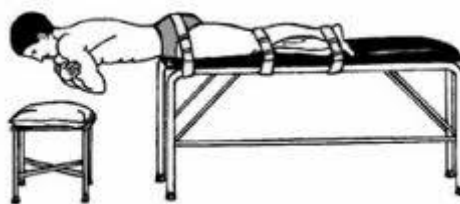


Figure 0.6: Illustration of the Biering-Sorensen test (2013)

A modification of this test involves using a piece of string secured between two vertical stands and placed directly over the T7 vertebra in such a way that when the participant suspends their torso horizontal to the floor the string makes contact with the T7 vertebra. This allows for a more accurate way of recording the participants

endurance. The endurance time is determined as the time instant when the participant can no longer hold the horizontal position, and the contact between the T7 vertebra and the string is lost. Although not included in the original B-S test, this tactile feedback method has been shown to be highly effective in determining the endurance time of the Biering-Sorensen test in addition to being a simple method which can be used in the field of research (Coorevits *et al.*, 2008a; Coorevits *et al.*, 2008b; Koumantakis *et al.*, 2001).

Should the participant hold the extensor position with no pain or discomfort for longer than 240 seconds the test should be terminated (Demoulin *et al.*, 2006), indicating that the participant has good extensor muscle endurance. Holding the extensor position for 176 seconds or less indicates decreased extensor muscle endurance (Demoulin *et al.*, 2006; Kankaanpää *et al.*, 1998). The B-S test has been shown to be affected by gender, with research showing that women can hold the endurance test for a longer period of time than men (Kankaanpää *et al.*, 1998). Age has also been shown to affect the B-S test outcome with increasing age affecting muscle fatigability (Kankaanpää *et al.*, 1998)

- Electromyography

Surface electromyography (sEMG) is an objective technique that can be used to examine back muscle endurance (Biedermann *et al.*, 1991). Localized muscle fatigue is associated with a shift of the frequency content toward lower values (Merletti, Knaflitz and De Luca, 1990) whereby the rate of decline in the median frequency slope of the sEMG power spectrum is indicative of the extent of fatigability of the muscle, i.e. the greater the decline the greater the fatigue (Mannion *et al.*, 1997; Roy *et al.*, 1997). The correlation between endurance time and the rate at which the sEMG values decrease has been seen in tests where fatigue related sEMG readings decreased during contractions which were sustained in a variety of muscles over a period of time (Maton and Gamet, 1989). Similar results were found in the back extensors (Roy *et al.*, 1995; van Dieen, Oude Vrielink and Toussaint, 1993). Previous research involving sEMG has shown that it can accurately record signals from the erector spinae muscles (Stokes, Henry and Single 2003; Wolf *et al.*, 1991).

When examining deep muscle groups intramuscular or fine-needle EMG is used as this ensures more accurate readings (Fryer *et al.*, 2006). This form of EMG relies on specific points being found and thus must be performed by a professional who has a thorough understanding of anatomy, physiology, pathophysiology, and the peripheral nervous system (Daube and Rubin, 2009). Due to its invasive nature there are greater risks associated with this form of EMG and thus care must be taken by the therapist to assess for any conditions such as bleeding disorders, skin infections or cardiac valvular disease prior to the insertion of the needle (Daube and Rubin, 2009).

- The Ito test

This is an alternative test for evaluating the isometric lower back muscle endurance. The patient begins by lying in the prone position with a pad placed beneath their abdomen and with their arms at their sides. The subject is then asked to lift their sternum off the examination table while fully flexing their neck and contracting the gluteus maximus muscle in order to stabilize the pelvis. The extent for which this contraction can be held is then measured. This test is also easy to perform and does not require any specialised equipment. Its test-retest reliability was reported to be very high without inducing any pain. Its discriminative validity has also been proven in a trial involving 190 healthy subjects and subjects with chronic LBP, respectively (Ito *et al.*, 1996).

2.8 SPINAL MANIPULATIVE THERAPY

Spinal manipulative therapy (SMT) is a commonly used therapeutic modality (Potter, McCarthy and Oldham, 2005) involving the movement of a joint beyond the end range of motion, but not beyond its anatomic range of motion (Bergmann and Peterson, 2002). Edmond (2006) defines manipulation as a specific technique in which the articular capsule is passively stretched through the delivery of a high velocity low amplitude (HVLA) thrust.

SMT is directed at a joint fixation which may result from posterior joint or intradiscal derangements, intercapsular adhesions, segmental muscle spasm and/or soft tissue fibrosis (Bergmann and Peterson, 2011). Initially the patient may experience no clinical symptoms, but will present with aberrant mechanics (Leach, 2004). These aberrations in normal function are thought to be the basis for the development of symptoms due to biochemical, histological, kinesio-pathological and neuropathophysiological changes that occur to varying degrees in the motion segments (Bergmann and Peterson, 2011; Morris, 2006; Vernon and Mrozek, 2005; Leach, 2004). This dysfunctional state can be characterised by point tenderness and altered pain sensitivity over the spinous process with increased muscle tone and pain in the paraspinal musculature (Haldemann, 2005; Leach, 2004). In order to prevent symptoms developing early mobilization, traction and continuous passive motion is required (Leach, 2004).

Sandoz (1976) identifies several phases of a joint's total motion, which includes active range, passive range and a para-physiological space. The para-physiological range was described as being beyond the passive range but less than the anatomic limit of the joint. The end of this para-physiological range is said to be the limit of anatomical integrity and the point beyond which injury would occur. According to Sandoz (1976), spinal manipulation of a normal vertebral segment occurs within this para-physiological space and he proposed that when the articular capsule is stretched to the limit of the anatomical space it most likely results in an intense stimulation of the joint receptors. Vernon and Mrozek (2005) referred to this space as a zone of elasticity at the end of normal range of motion and agreed that this is where manipulation occurs. They noted that this space may be altered or rather decreased in a joint which is fixated i.e. has lost some of its flexibility and mobility. They also state that if joint dysfunction results in reduced mobility of the joint then that joint will not move into the end range of motion and thus manipulation will not occur in the paraphysiological space.

2.8.1 Methods of delivering SMT

There are several ways that SMT can be delivered using either hands or mechanical devices.

2.8.1.1 High velocity low amplitude manipulation

This type of manipulation makes use of high velocity low amplitude (HVLA) thrusts and has a specific direction or vector (Bergmann *et al.*, 2002). This procedure results in the rapid distraction of the facet joints, resulting in an auditory cavitation. The magnitude of forces exerted by a clinician during a HVLA manipulation has an average of 100 N (Newton) for cervical spine manipulations and 400 N for the thoracic, lumbar spine and sacroiliac joint although the forces vary extensively between 200 N to 1600 N (Herzog *et al.*, 1993).

2.8.1.2 Mobilization

Mobilizations are movements applied singularly or repetitively within or at a physiological end point of joint motion, without a thrust being imparted to the joint (Scaringe and Kawaoka, 2005; Gatterman *et al.*, 2001). This particular modality is used to restore the physiologic articular relationship within a joint (Dutton, 2002) and has been shown to be effective in pain relief, decreasing muscle guarding, stretching tissues around the joint, improving proprioceptive awareness and influencing muscle tone via neuromuscular influences (Dutton, 2002).

2.8.1.3 Instrument assisted manipulation

- Activator instrument

This is a manual manipulative instrument which is capable of providing a dynamic thrust that includes a controlled force of adjustment at a precise and specific line of drive at high speed (Fuhr, 1990). The thrusts generated by the activator instrument are low-force and are thus regarded by many as being clinically safer and less traumatic than manual thrusts as there is no torque or stretching of the ligament or joint capsule (Osterbauer, 1995; Kleynhans, 1980).

Symons *et al.*, (2000) showed that SMT with the activator instrument produced local reflex responses. This form of manipulation has also been seen to yield similar preload and peak forces to manual SMT (Herzog, 2000).

- Neuroimpulse adjusting instrument

The Impulse[®] Adjusting Instrument (IAI) is a handheld electronic adjusting device which has been shown to be effective in the mobilisation and manipulation of the musculoskeletal joints and/or extremities. It produces impulses at six hertz (6 Hz) for two seconds, and has three force settings, high, medium and low depending on the region and/or condition to be treated i.e. for the lumbar spine the high setting, which is 400 N, is recommended (Impulse[®] Adjusting Instrument user manual, 2012; Colloca and Keller, 2009).

The Preload Control Nosepiece is pressed down until the spring is fully compressed resulting in a preload force being applied prior to the actual manipulation. This has the positive effect of removing any tissue slack and achieving optimal tissue compression prior to the adjustment. An LED light located next to the Force Adjustment Switch turns from amber to green once this compression has been achieved indicating that the IAI is ready to deliver the manipulation (Impulse[®] Adjusting Instrument user manual, 2012; Colloca and Keller, 2009).

2.8.2 Effects of spinal manipulation

It is documented that SMT modulates pain (Willis and Coggeshall, 1991; Wyke, 1980; Melzack and Wall, 1965), inhibits hypertonic muscles (DeVocht, Pickar and Wilder 2005) and improves functional ability (Bergmann and Peterson, 2011). However, the exact physiological mechanism through which SMT brings about clinical changes is not well understood (Koppenhaver *et al.*, 2011; Colloca and Keller, 2001; Herzog, Scheele and Conway, 1999).

Manipulation has been hypothesised to work according to several different theories including mechanical, analgesic, neurobiological and circulatory (Peterson and Bergman, 2002). Although mechanical and neurophysiological mechanisms are thought to be the dominant effects, psychological responses can also be expected (Triano, 2005). As this study was conducted on asymptomatic participants the

discussion will focus on the mechanical, psychological and neurophysiological effects of SMT.

2.8.2.1 Mechanical effects

When a manipulative thrust is applied to a specific contact point along the spine, a vertebral movement occurs which may affect the involved segment and the joints above and below the particular contact level both mechanically (Lee *et al.*, 1993) and neurophysiologically (Cramer and Darby, 2005). Associated with this is joint gapping, where there is an increase in the joint space with an associated formation of a “gas bubble”, resulting in an audible crack, which is proposed to be responsible for improved segmental range of motion following joint manipulation (Sandoz 1976; Potter, McCarthy and Oldham, 2005; Vernon and Mrozek (2005).

This results in normalisation of spinal alignment (Bergman and Peterson, 2011; Haldeman, 2005), alteration in spinal curvature dynamics (Haldeman, 2005; Cox, 1990) and / or nerve entrapment (Bergman and Peterson, 2011; Gatterman, 2005; Cox, 1990; Hadley, 1964). Other mechanical effects of SMT are the removal of adhesions around the joint (Szymanski and Voss, 2007; Vernon and Mrozek, 2005; Phillips *et al.*, 1992; Peng, Sun and Zhou, 1999;); the release of entrapped meniscoids (Jones, James Adams, 1990; Zusman, Edwards and Donaghy, 1989) and the removal of AMI establishing normal motion around a joint (Hopkins and Ingersoll, 2000; Hillermann *et al.*, 2006).

In terms of SMTs mechanical effects, the spine has been viewed as an integrated functioning unit (Bergman and Peterson, 2011), therefore the development of asymmetrical functional barriers, such as joint dysfunction, may impact the remaining joints in the spine, due to it being a closed kinematic chain (Peterson and Bergman, 2002). Thus the effects of vertebral motion segment manipulation has been recorded to have an effect both within the segment and within the kinetic chain of joints that are anatomically and functionally linked to the segment that was manipulated (Bergmann and Peterson, 2011; Sahrman, 2010; Pollard *et al.*, 2008; Currier *et al.*, 2007; Cliborne *et al.*, 2004; Bergmann and Peterson, 2002).

In order to measure these spinal intra-segmental and inter-segmental changes in the ranges of motion that may be attributable to the SMT, an inclinometer is often utilised (Williams *et al.*, 2010; Jordan, 2000). An inclinometer is a tool which is used to measure active lumbar ranges of motion i.e. flexion and extension. It is non-invasive and has been shown to be both valid and reliable when compared to other methods of measuring lumbar spine mobility (Newton and Waddell, 1991), and when comparing measurements based on anatomic reference points determined by radiographs (Saur *et al.*, 1996). Previous research has found that these measurements are reliable when taken by the same examiner (Williams *et al.*, 2010; Witvrouw *et al.*, 2001). It is also easy to use (Newton and Waddell, 1991).

2.8.2.2 Psychological effects

Psychological responses to SMT occur due to the effect of touching the patient, or as a result of placebo and will be influenced by patient satisfaction (Gatterman, 2005). The use of placebos in clinical research is common as it allows the researcher to differentiate between the non-specific effects, which are those experienced by the patients due to the interaction with the physician, the comforting effect of the physicians hands on the patient prior to the adjustment and even the sound of the adjustment itself, and the specific effects caused by the actual intervention such as the reduction in muscle hypertonicity, restoration of normal joint motion and additional neurophysiological effects (Leach, 2004). The placebo treatment used by Collocca and Keller (2000) involved the use of the adjusting instrument whereby it was set in the zero position and applied to the segmental contact point, although this produced the same 'clicking' sound as in the active intervention group no impulse would have been administered to the tissues.

2.8.2.3 Neurophysiological effects

During SMT the mechanical stimulus is proposed to have physiological consequences, by affecting the inflow of sensory information to the CNS (Pickar, 2002). It is estimated that there could be about 40 types of mechanoreceptor nerve endings in the surrounding tissues of the paraspinal area that have thresholds below the level of mechanical forces that are applied during SMT, that may be activated

during SMT (Gillette, 1987). The input from these receptors to the CNS is then suggested to alter neural integration either directly through reflex activity or by central neural integration of motor, nociceptive and maybe autonomic neuronal pools, ultimately affecting efferent neuronal output changing somatomotor and visceromotor activity (Picker, 2002). Several theories have been proposed to explain how neurophysiological mechanisms may create joint dysfunction.

Korr (1976) proposed that when a motion segment dysfunction occurs, the segmental muscles of the spine increase their gamma gain to restore the muscle spindle afferent discharge which then results in a contraction of the muscle and restriction of the involved motion segment. These changes are then followed by the neurological and muscular sequelae of the altered functional state. Therefore when manipulation is applied, the surrounding hypertonic muscles are stretched affecting their extrafusal and intrafusal muscle fibres resulting in a bombardment of afferent impulses to the central nervous system resulting in a 'turning down' of the gamma efferents, which re-establishes normal gamma gain and muscle tone.

Central facilitation occurs when there is increased excitability of the dorsal horn to sensory input. It was been found that alpha motor neurons can be continuously facilitated when the corresponding afferent neurons from related paraspinal structures 'bombard' the dorsal horn, this results in a sensitisation of the receptor field. SMT has been proposed to remove this sub-threshold activity (Pickar, 2002).

The pain-spasm-pain cycle describes how the accumulation of metabolites in a muscle alters the sensitivity of the muscles spindles, altering the sensitivity to stretch and ultimately increasing alpha motor neuron activity (Potter, McCarthy and Oldham, 2005). This would then affect the tone of the muscle, and when SMT is applied result in a break of this cycle. Patterson and Steinmetz (in Leach, 2004) found that a joint fixation can be produced by either central or peripheral inputs to segmental circuits, and if there was a sufficient stimulus an abnormal reflex could be created in a short-time. They suggested that SMT would break the cycle, especially if applied soon after the cycle started.

2.8.3 Research supporting the neurophysiological effects of SMT

Herzog, Scheele and Conway (1999), Symons *et al* (2000) and Colloca and Keller (2001) were among the first to document neuromuscular reflexes in muscles around the spine (including the paraspinal muscles) either manual HVLA thrusts or instrument assisted SMT, using sEMG. These were pre-test post-test designs using one group of participants therefore there was no control or placebo group with which to compare. Hertzog *et al.*, (1999) suggested that these neurological reflexes may be responsible for the improved functional ability of a patient, pain reduction and the inhibition of a hypertonic muscle following SMT.

Indahl *et al.* (1999), experimented with 10 adolescent pigs by inserting wire electrodes bilaterally into the ventral space of the sacroiliac joints, directly under the surface of the capsular membrane. A further six EMG electrodes were inserted unilaterally into the multifidus, gluteus medius, gluteus maximus, and quadratus lumborum. It was noted that on stimulation within the ventral area of the joint, the predominant responses occurred in both the gluteus maximus and quadratus lumborum muscles whereas when the capsule was stimulated the greatest muscular responses were detected in the multifidus. They concluded that the sacroiliac joint is involved in activating muscles responsible for overall posture control. This study shows how stimulation of a joint capsule can alter muscle responses and potentially influence muscle function in a positive manner.

Suter *et al.* (2000) and Suter and McMorland (2002) investigated the effect of SMT on muscle inhibition in the extremities. They found that following SMT there was an improvement in muscle function. They postulated that as a result of altered afferent input following SMT there was restoration of motoneuron excitability, and possibly an interruption of the pain-spasm-pain cycle which altered muscle inhibition. These effects have a direct impact on the AMI that is often displayed by muscles that have the responsibility for imparting motion into a motion segment (Hopkins and Ingersoll, 2000; Hillermann *et al.*, 2006). This AMI has the ability to decrease the functional ability of the muscle, thereby reducing its strength, power, activity and effect (Suter *et al.*, 2000). In a later study assessing Hoffman reflexes following sacro-iliac joint manipulation, Suter *et al.* (2005) found that there was no change in healthy controls

but in participants with LBP there were changes in motoneuron excitability. Dishman, Donald and Bulbulian, (2000) assessed, in non-human participants, the amplitude of the Hoffman reflex of the gastrocnemius following SMT and mobilisation (without thrust), they found that both treatments suppressed alpha motoneuronal excitability, they proposed that this in turn may affect the pain-spasm-pain cycle. Their study also highlighted that irrespective of joint cavitation the effect occurred.

Pickar and Wheeler (2001) in a series of studies investigated the effect of a mechanical load, with force-time profiles similar to SMT, on muscle spindle (MS) and golgi tendon organ (GTO) in the paraspinal muscles of anaesthetised cats. They found that MS discharged at rest, increasing their firing during a preload force with the firing increasing to the impulse thrust, in contrast the GTO did not fire at rest or during the preload but during the impulse thrust. The MS fired more during distraction than compression, with the GTO organs responding irrespective of compression or distraction (Pickar and Wheeler, 2001). This study showed that even without the thrust component of SMT there is likely to be proprioceptive input to the CNS, however with the thrust component a greater proprioceptive input will occur. The authors concluded that sensory bombard of the CNS occurs from muscle proprioceptors following SMT. In another study it was found that the impulse loads, with force time profiles similar to HVLA SMT, have the ability to cause higher frequency lumbar paraspinal muscle spindle activity than similar force profiles with slower velocities (Pickar and Kang, 2006). When duration and amplitude were investigated it was found that shorter duration, low amplitude thrusts resulted in increased MS activity, mimicking HVLA SMT, the authors suggested that the characteristics of HVLA SMT resonated with the signalling properties of MS (Pickar *et al.*, 2007; Cao *et al.*, 2013). The findings of these studies support Korr's theory.

Krekoukias, Petty and Cheek (2009) investigated the effects of lumbar spine mobilisation on sEMG activity of the erector spinae of 36 asymptomatic subjects. sEMG measurements were recorded following a control, placebo and central posteroanterior (PA) mobilisation to L3 each for two minutes. The L3 level was selected because of its approximate central position in the lumbar lordosis which suggests that a PA directed force would mainly translate the vertebra anteriorly (Harms and Bader,1997; Lee, Moseley and Refshauge, 1990). They found

statistically significant reductions in mean sEMG values following mobilisation compared with the control and placebo.

Clark *et al.*, (2011) used neurophysiological techniques such as transcranial magnetic stimulation and electro mechanical tapping of the erector spinae musculature to elicit motor evoked potentials (MEP's) and short latency stretch reflexes respectively which were measured before and after a single manipulation. There were 10 asymptomatic (control group) and 10 chronic LBP symptomatic (intervention group) participants. There were no significant changes in reflexes or MEP's between the two groups however there was a significant decrease in the stretch reflex when audible cavitation occurred. Thus they concluded that although a single manipulation did not appear to bring about changes in corticospinal or reflex excitability of the erector spinae muscles, SMT that produced an audible cavitation appeared to decrease the sensitivity of muscle spindles as well as other segmental sites of the Ia reflex pathway. This is in contrast to Dishman, Donald and Bulbulian (2000); however a possible explanation may stem from Sandoz's work and the role of SMT in reaching the parapsychological space in order for an effect to occur, and it is possible that had their participants received more than one SMT the results may have been different. This study also relates to the study by Indahl *et al.* (1999), illustrating the role of the joint capsule in SMT.

These studies have mainly been conducted on non-human participants and in those without LBP, and assessing the reflex effects of SMT. Lehman and McGill (2001), utilised sEMG to measure trunk movements of 14 participants with LBP while they performed range of motion tasks in order to determine the effect manipulation had on trunk kinematics and myoelectric activity in the paraspinal and abdominal muscles. They observed no significant changes although individual changes that were noted were more apparent in the participants whose pain and dysfunction was more severe. Bicalho *et al.* (2010) investigated, in chronic LBP participants, the effect of SMT on paraspinal muscle activity during flexion and extension trunk movements. They found a decrease in sEMG activity during the static relaxation phase and during the active extension phase following SMT which did not occur in the control group, indicating that SMT could alter abnormal sEMG activity, possibly due to a

decrease in alpha motor unit 'drive' or in an increase in alpha motor unit inhibition. The latter view is more supported by the literature.

In another study assessing the effect of SMT on flexion and extension motions of the lumbar spine in participants with LBP, Harvey and Descarreaux (2013) found that the control group showed significant increases in sEMG readings of the paraspinal muscles during the last 30 minute flexion and full flexion phase with increased reporting of pain compared to the group receiving SMT. They reported that SMT appeared to reduce muscle fatigue related to repetitive spinal motion thereby strengthening the supposition that it could increase overall muscle endurance.

In a comparative clinical trial Keller and Colloca (2000) assessed the erector spinae isometric MVC output (using sEMG) in 40 participants with mechanical LBP after mechanical force [manually assisted (MFMA) SMT] compared with placebo manipulation and a control group. Surface EMG readings were taken whilst participants performed MVC isometric trunk extensions pre and post intervention. The results showed that manually assisted SMT resulted in a significant increase in sEMG readings of paraspinal isometric MVC output when compared to the placebo and control group, indicating that SMT improved muscle function either through facilitation or disinhibition of neural pathways. They concluded that these findings indicate that altered muscle function could possibly be a short-term therapeutic effect of manually assisted SMT, and that this result forms a basis for additional clinical trials to further investigate acute and long-term changes following SMT.

Therefore this study aims to add to the literature on the neurophysiologic effects of SMT by assessing the effect of SMT on extensor muscles endurance in asymptomatic participants.

CHAPTER THREE: METHODOLOGY

3.1 STUDY DESIGN

This study was designed as a randomised, placebo-controlled pre-test post-test experimental design. This design was selected to enable the effect of the intervention to be assessed by comparing the post-test results between the two groups. It also allowed the changed over time from pre-test to post-test to be assessed in each group to determine the effect of each intervention in isolation (Mouton, 2001). The study was approved by the Institutional Research Ethics Committee (IREC 094/13, Appendix H) and was registered on the South African Clinical Trials register (registration number: DOH-27-0114-4654, Appendix I). The study was conducted at the Durban University of Technology Chiropractic Clinic, after permission was obtained from the Clinic Director (Appendix G).

3.2 POPULATION

The study population were males residing in the greater Durban area.

3.3 RECRUITMENT

Participants were recruited through advertisements (Appendix A) which were placed around the Durban University of Technology (DUT) campus, the DUT Chiropractic Day Clinic and local sports clubs and other places of gathering after permission to place the advertisement was obtained (Appendix G). Participants were also recruited via word of mouth.

Those people who responded to the advertisements were requested to contact the researcher telephonically where they were screened using the questions which appear in Table 3.1.

Table 0.1: Screening questions for potential participants

Questions asked of participants	Expected answers from the participants in order to qualify for the study.
May I ask you a few questions in order to determine your eligibility into this study?	Yes
Are you between the ages of 20 and 40 years old?	Yes
Are you currently healthy?	Yes
Are you male?	Yes
Are you right handed?	Yes
Have you suffered from lower back pain in the last three months or are you currently undergoing any treatment for LBP by other health care providers?	No
Have you had any previous spinal surgery/trauma?	No
Do you know your height and weight in order for me to calculate your body mass index?	Participant must be between 18.5 and 24.9 kg/m ²

If the respondent did not meet the qualifying criteria they were thanked for their time and appropriately referred if necessary. If the respondent was eligible for the study they were then scheduled for a consultation at the DUT chiropractic clinic.

3.4 SAMPLE SIZE AND ALLOCATION

A sample size of 40 participants was selected for this study based on similar studies in the literature (Bicalho *et al.*, 2010; Krekoukias, Petty and Cheek, 2009; Colloca and Keller, 2001; Keller and Colloca, 2000) and a pilot study. The pilot study entailed 10 participants, five in each group (the intervention and the placebo group) undergoing the Biering-Sorenson test and surface EMG and paraspinal muscle endurance scores being recorded. A power analysis (performed at 80%) was then performed on the data obtained to estimate a sample size. Based on the pre-test post-test changes in the Biering-Sorenson test for paraspinal endurance a sample size of between 11 and 36 was recommended per group, therefore a sample size of 20 participants per group was selected.

Participants were randomly allocated to one of two groups using a random allocation chart (Brink, 2006):

- Group one – Intervention group
- Group two – Placebo group

The random allocation chart was drawn up by the research assistant, whereby the group allocation of either one or two was randomly allocated to 45 numbers, so that when a participant joined the study they were pre-allocated a group number. Once the participant was eligible for the study the research assistant consulted this list and then administered the appropriate intervention. This was done to remove researcher bias.

3.5 SAMPLE CHARACTERISTICS

Participants were required to meet inclusion and exclusion criteria which were determined by means of case history (Appendix C), physical examination (Appendix D) and an orthopaedic examination of the lumbar spine (Appendix E) which included a core strength assessment.

3.5.1 Inclusion criteria

- 1) Participants were required to sign the Letter of Information and Informed Consent (Appendix B).
- 2) Participants had to be male to ensure homogeneity. The B-S test has been shown to be affected by gender, with research showing that women can hold the endurance test for a longer period of time than men (Kankaanpää *et al.*, 1998).
- 3) Participants had to be between the ages of 20 and 40 years of age.
- 4) Participants had to have a body mass index (BMI) between 18.5kg/m² and 24.9 kg/m².
- 5) Participants had to be right hand dominant.
- 6) Participants who held the Biering-Sorensen extensor muscle endurance test for less than 176 seconds were included in the study.
- 7) Participants had to have been free of low back pain (LBP) for the past three months.
- 8) Participants had to have a lumbar joint restriction at the level of L3. This restriction was determined by motion palpation, performed according to the techniques of Bergman and Peterson (2011). This was checked by a research assistant to ensure reliability.

3.5.2 Exclusion criteria

- 1) Previous spinal surgery.
- 2) Medical conditions which could make physical activity unsafe for the participant, including but not limited to uncontrolled hypertension, cardiac or respiratory disease, certain musculoskeletal disorders and neurological symptoms (Champagne, Descarreaux and Lafond, 2009; Bergmann *et al.*, 1993)
- 3) Any mechanical or manual intervention to the thoracic or lumbar spine three weeks prior to the study were excluded.
- 4) Significant trauma affecting the low back or if the clinical assessment warranted that the participant required radiographs.
- 5) The use of any pain medication or muscle relaxants for any reason were excluded from the study, unless they had a 72 hour (three day) wash out period before commencement of the study (Seth, 1999; Poul *et al.*, 1993).
- 6) Contraindications to lumbar joint manipulation (as determined by the case history, physical and regional examination) included, but were not limited to (Bergmann and Peterson, 2011; Gatterman, 1990):
 - Abdominal aortic aneurysm.
 - Metabolic disorders (osteomalacia, osteoporosis, clotting disorders etc).
 - Tumours (thyroid, lung, breast and bone).
 - Bone infections (osteomyelitis, tuberculosis).
 - Arthritis (rheumatoid arthritis, psoriatic arthritis).
 - Traumatic injuries (fractures, instability, severe sprains and strains).
 - Neurological complications.
- 7) Contraindications to surface EMG including, but were not limited to:
 - Skin irritation occurs from the hypoallergenic self-adhesive electrodes which will be used in this study.
 - Open wounds, rashes or skin conditions of any kind in the region of electrode placement.

3.6 MEASUREMENT TOOLS

3.6.1 Subjective measurements

Participants were asked to verbally communicate any discomfort or pain they may have experienced while performing the Biering-Sorensen endurance test. The time at which the discomfort/pain was experienced was recorded.

3.6.2 Objective measurements

3.6.2.1 Paraspinal muscle endurance

The Biering-Sorensen (B-S) test was utilised to determine paraspinal muscle endurance in seconds. It was performed according to the procedure as outlined by Demoulin *et al.*, (2006) and discussed in Chapter Two under Section 2.8.4.2. Prior to data collection participants in both groups were taught how to perform the Biering-Sorensen test by the researcher.

3.6.2.2 Surface electromyography (sEMG)

This study made use of the Neuro TracTM ETS unit (Verity Medical LTD, Uplands Place, Drove Road, Chilbolton, England, ISO9001:2000, MDD93/42/EEC). The unit was a dual channel, with EMG Range of 0.2 to 2000 uV RMS (continuous), accuracy of 4% of uV reading +/-0.3 uV at 200 Hz. It had a selectable bandpass filter – 3db Bandwidth, which was 18 Hz +/- 4 Hz to 370 Hz +/- 10% wide (reading below 235 microvolts) and 10 Hz +/- 3 Hz to 370 Hz +/- 10% (reading above 235 microvolts) and when narrow 100 Hz +/- 5% to 370 Hz +/- 10%. The notch filter was 50 Hz (Canada 60 Hz) – 33 dbs (0.1% accuracy), with a common mode rejection ratio of 130 dbs Minimum @ 50 Hz. It utilised a PP3 Alkaline battery (Neuro TracTM ETS: Operators manual, 2007).

The researcher set it to EMG setting allowing the endurance time and fatigability of the extensor muscles to be determined. The Neuro TracTM unit was linked up to a computer using the training template mode, which was set for five minutes, and

recorded the endurance time, and the average, peak and minimum microvolt's (mV) (Neuro Trac™ ETS: Operators manual, 2007). Self-adhesive hypo-allergenic surface electrodes (VS.30 30 mm diameter round) were used (Neuro Trac™ ETS: Operators Manual, 2007).

During the test the researcher ensured that all lights were switched off and that there were no additional noises such as talking as these may have adversely affected the EMG readings. The researcher also ensured that any power cables from the computer were run as far away as possible from the connection wires and electrodes of the Neuro Trac™ ETS in order to limit any possible interference these may have caused.

In order to record the effect of manipulation on the thoracic and lumbar regions of the longissimus and iliocostalis muscles, the main extensor muscles of the trunk, the pairs of electrodes were placed bilaterally at the level of T10 and L3 (Dolan and Adams, 1993; Dolan and Adams, 1998; Mannion *et al.*, 1997) with an inter-electrode distance of approximately 3.5 cm (Krekoukias, Petty and Cheek, 2009) in the midline of the muscle belly (De Luca, 1997). The electrode Channels A and B were used on the left and right side respectively. The red and black surface electrodes were placed bilaterally on either side of T10 and L3 respectively.

The threshold level was then set up. This was done by asking the participant to perform the Biering-Sorensen test in order to contract the lumbar extensor muscles, this position was then held for approximately five seconds, following which they were asked to relax for five to 10 seconds before repeating the same extensor muscle contraction. The microvolt reading was recorded on Channel A. The average of the two peak readings was worked out by the researcher, and 40% of this figure was the threshold level. The threshold setting, which can be found at the top of the LCD screen, was then adjusted to this value by the researcher, accomplished by pressing either the B-THRS+ or the B-THRS- buttons (Neuro Trac™ ETS: Operators manual, 2007). To ensure the correct EMG parameters for the Neuro Trac™ ETS were set the researcher pressed the SET button until WDE FLTR or NRW FLTR were displayed on the LCD screen then used the B+ or B- buttons to select the narrow

filter (NRW FLTR) which is the appropriate setting for use over the back in order to eliminate interference from the heart (Neuro Trac™ ETS: Operators Manual, 2007).

The researcher ensured that the electrode wires did not hang in free space but instead ran as close to the surface of the subject's body as possible, all the way from the electrodes to the Neuro Trac™ ETS (Neuro Trac™ ETS: Operators Manual, 2007).

The surface EMG recorded myoelectric activity from the moment the participant's back touched the rope to the time that their back lost contact with the rope. The Neuro Trac™ ETS then calculated the mean myoelectric activity for this time. This value was then recorded, and used for data analysis.

3.6.2.3 Lumbar spine range of motion

This study made use of the Saunders Digital Inclinator, which has been shown to be valid and reliable (Mayer *et al.*, 1997). It consists of a sensor with a digital display, an alternate zero button (to 'zero' the unit), a hold button, an on/off button and two Velcro straps. If the sensor is tilted e.g. 10° in any direction, then it will read 10°. If it is zeroed at 10° and then moves e.g. to 20° in any direction, then it will read 20°.

The researcher took time to explain the use of the inclinometer to the participants before any measurements were taken, thereafter all spinal movements measured were in relation to a neutral position and were taken on a flat, firm surface as outlined in the Saunders Digital Inclinator User's Guide (1998).

For the purposes of this study the lumbar flexion and extension range of motion was assessed pre- and post-intervention in the following manner:

- Flexion: The Saunders Digital Inclinator was placed at the level of the L5/S1 midpoint with the subject fully flexed, and zeroed. The inclinometer was then placed at the T12-L1 interspace, and the reading recorded (Saunders, 1998).

- Extension: The same steps as per the flexion measurements were followed except the subject was asked to extend as far as possible (Saunders, 1998).

3.7 BLINDING

Double blinding was used in this study to minimise any potential bias and to enhance the validity of the study (Brink, 2007). The research assistant, a chiropractic student registered for their M.Tech Chiropractic and carrying out a similar study, was responsible for allocating the participants to one of the two groups. The research assistant had completed all undergraduate training for their chiropractic qualification, in addition had completed all the course-work requirements (both clinical and theoretical) for their master's degree in chiropractic. The assistant also administered the interventions while the researcher stepped out of the room. This ensured that the researcher did not know which group the participant belonged to. The participants were also blinded as they were naive to the form of SMT used in this study, thus were not aware to which group they belonged. The participants were requested to not discuss the treatment interventions with the researcher.

3.8 INTERVENTIONS

3.8.1 Spinal manipulative therapy

The research assistant used the Impulse Adjusting Instrument[®] (IAI) (101 S. Roosevelt Avenue, Chandler, AZ 85226 USA) to deliver spinal manipulation to the L3 vertebrae. The IAI was set to position three on the Force Adjustment Switch which administers 12 thrusts at 400 N, which is recommended for lumbar joint manipulation.

Participants were placed in the prone position; the dual stylus of the IAI was placed in contact with the mammillary processes of the L3 vertebrae, using an anterosuperior line of drive (The Neuromechanical System, 2008). The assistant then pressed into the skin of the participant activating the Preload Control Nosepiece, activating the LED light located next to the Force Adjustment Switch

which turned amber, once the spring was fully compressed the light turned to green indicating the IAI was ready to deliver the manipulation.

The assistant then initiated the rapid pulse mode by holding down the Electronic Trigger of the Impulse Adjusting instrument, this resulted in 12 consecutive thrusts being delivered into the Lumbar joint (6Hz, 2sec) (Collocate and Keller, Impulse Adjusting Instrument Operations Manual, 2009). The rapid pulse mode was chosen as repeated thrusts have been found to be beneficial in inducing greater joint motion and for resetting neuromuscular reflexes (Introducing Impulse, 2009). After the thrusts were delivered the manipulation was complete.

3.8.2 Placebo

The above procedure was followed for the placebo group as well however once the preload light turned from amber to green the assistant then activated a second Impulse Adjusting Instrument in the air above the patient causing the participant to hear a clicking sound, but no treatment was actually administered. The participants' limited experience with such an adjustment technique further ensured that they did not know that they did not have an actual treatment (Symons *et al.*, 2000).

3.9 RESEARCH PROCEDURE

Prior to the participants being included in the study as part of the lumbar spine regional examination their transverses abdominal muscle strength was assessed, as a means to indirectly assess their core strength. This was done by placing the biofeedback unit under the participants' abdomen and inflating it to a baseline of 70 mmHg. The participant was then asked to draw their abdomen up and in without moving their spine or pelvis (Richardson *et al.*, 1999). A decrease in pressure readings from 6-10 mmHg was considered normal and was noted by the researcher.

Once participants were eligible for the study they were allocated to their group. The participants were then asked to remove the appropriate clothing in order to expose the sites where the electrodes were attached. The area of skin was then cleaned with alcohol and where necessary hairy skin was shaved using a disposable razor

(Neuron Trac™ ETS: Operators manual, 2007; DeVocht, Pickar and Wilder, 2005; Bicalho *et al.*, 2010). Each participant had their seventh and tenth thoracic vertebrae (T7 and T10) and third lumbar vertebrae (L3) marked using a water soluble marker with an 'X' over the spinous process (DeVocht, Pickar and Wilder, 2005).

The objective measurements were then taken starting with the Inclinator (Appendix F). Participants were requested to lie prone and the sEMG electrodes were placed as described in Section 3.6.2. The researcher then switched on the Neuro Trac™ ETS unit and selected the EMG mode. The EMG Threshold Level (THRS) was set and the training template mode was chosen and set for five minutes. The participant was then asked to perform the Biering-Sorenson extensor endurance test.

After the test the researcher allowed the participant to remain in the prone position and recover for 15 minutes, as previous research found that this is the time taken for muscles to recover from fatigue (Larivière *et al.*, 2003). The research assistant was then called to administer the intervention. Directly after the intervention (i.e. less than one minute after), the participants in both groups were asked to re-perform the Biering-Sorensen test again while being monitored by the sEMG for data collection purposes. The researcher used the inclinometer to re-assess the lumbar active ranges of motion in flexion and extension, the results of which were recorded on the data collection sheet (Appendix F). The participant was only required for a single consultation which lasted approximately two and half hours. Data was collected pre- and post-intervention.

3.10 CONSORT FLOW DIAGRAM

The consort flow diagram shows that there were no drop outs or people excluded from the study.

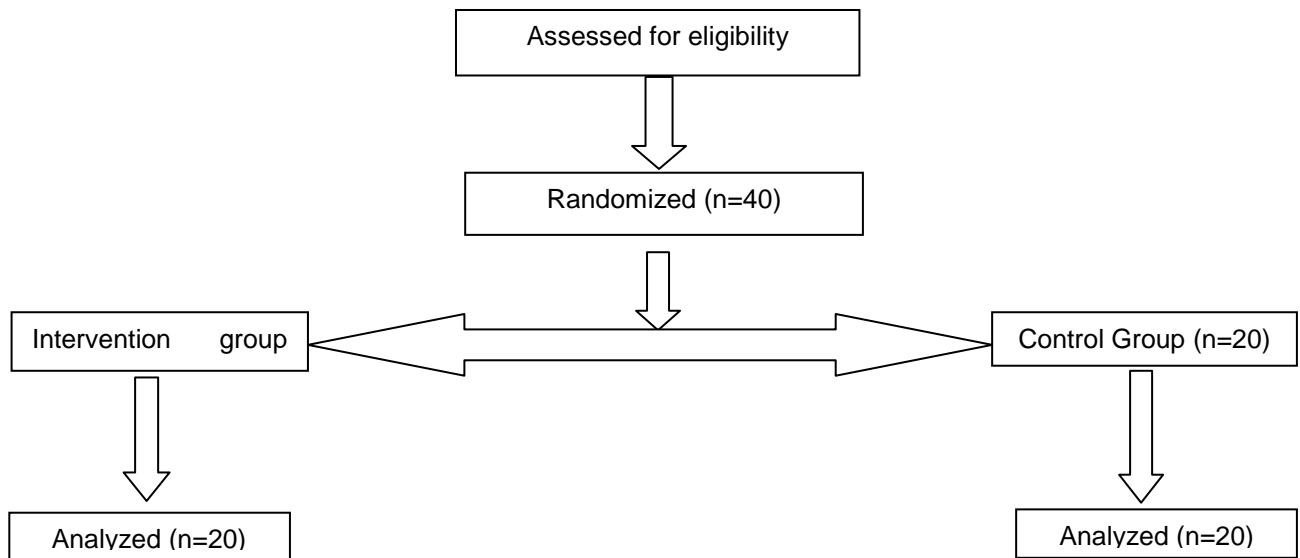


Figure 0.1: Consort Flow diagram of participation in the research study

3.11 DATA ANALYSIS

The collected data was then coded where necessary and entered into an excel spreadsheet for data analysis. IBM® SPSS® Statistics version 21 and STATA 11 was used to analyse the data. A p-value of < 0.05 was considered statistically significant. Quantitative outcome data was tested using Q-Q plots and formal quantitative normality tests (Kolmogorov-Smirnov test). All outcome variables were found to be acceptably normally distributed and met the assumptions of the performed parametric tests. Independent t-tests were used to compare means and two-way factor ANOVA (for repeated measures) was used to compare the change in the two time points between the two treatment groups (intervention and control). Interaction was analysed with quantitative tests. Where possible, variables were reported with their 95% confidence intervals and p-values. Non-parametric test was not performed (McCaul, 2014).

3.12 ETHICAL CONSIDERATIONS

Ethical clearance was obtained to conduct the study. All data that were recorded from the participants for the duration of the study was stored on the Neuro Trac™ ETS software system, which is password protected. The names of the participants were coded to ensure confidentiality. The participants had the right to withdraw from the study at any time without suffering any repercussions. The data was collected and transferred onto a data collection sheet (Appendix F). Once the study was completed all data was transferred onto a hard drive, which is password protected, and deleted off the software system. All research data will be stored for 15 years in the Department of Chiropractic and Somatology.

CHAPTER FOUR: DATA ANALYSIS

4.1 INTRODUCTION

This chapter outlines the results of the data that was analysed from 40 participants, 20 per group.

4.2 PARTICIPANT CHARACTERISTICS

4.2.1 Age

The age of the participants in the study ranged from 20 to 39 years of age with a mean age of 25.65 (\pm SD 4.98). There were no statistically significant differences between the two groups in terms of age as demonstrated in Table 4.1.

Table 0.1: Mean age (years) of participants by group

Group	N	Mean	Std. Deviation	<i>p</i> -value
Intervention	20	26.350	5.430	0.380
Control	20	24.950	4.520	

(Two sample t-test with equal variances)

4.2.2 Height, weight and body mass index (BMI)

Table 4.2 shows that there were no statistically significant differences in terms of height or weight between the two groups. The difference in body mass index (BMI) was very small and considered not to be clinically significant to require adjustment.

Table 0.2: Height, Weight and Body Mass Index (BMI) of the participants

Category	Group	N	Mean	Std. Deviation	p-Value
Height (m)	Intervention	20	1.770	0.100	0.880
	Control	20	1.760	0.080	
Weight (kg)	Intervention	20	73.480	10.990	0.270
	Control	20	69.850	9.390	
BMI (kg.m ²)	Intervention	20	23.350	1.370	0.050
	Control	20	22.350	1.670	

(Independent two tailed-test)

4.2.3 Core muscle assessment

Participants were graded as having either 'good' or 'poor' core muscle contractibility. The ability of the participant to reduce the biopressure cuff pressure by 6-10mmHg was considered a 'good' test, all other readings were considered 'poor'. There were no statistically significant ($p = 0.519$; t-test) differences between the groups in terms of core muscle assessment, with 60% of the population having a good core rating.

Table 0.3: Core assessment grading per group

Core assessment	Intervention		Placebo	
	N	%	N	%
Good	11	55	13	65
Poor	9	45	7	35

(Two-sample test of proportion)

4.3 Objective measurements

4.3.1 Paraspinal muscle endurance (secs)

Table 4.4. shows that there were no statistically significant differences observed within or between the two groups in terms of paraspinal muscle endurance measured using the Bering-Sorensens test.

Table 0.4: Paraspinal muscle endurance results (secs)

Group	Pre-intervention			Post-intervention			p-value
	Mean	SD	CI	Mean	SD	CI	
Intervention	60.900	18.621	52.185 - 69.615	66.950	12.927	60.900 – 72.999	0.091**
Placebo	61.400	32.859	46.021- 76.779	66.400	30.744	52.011 – 80.789	0.475**
p-value	0.953*			0.942*			
	0.543***						

*independent two tailed t-test

**paired two tailed t-test

***Repeated measures ANOVA

4.3.2 Electromyography readings (mV)

Both groups showed a statistically significant increase in sEMG readings from pre- to post-test measurement. When the intervention and placebo groups were compared there were no statistically significant differences between the groups, as seen in Table 4.5.

Table 0.5: Electromyographic results (mVs)

Group		Pre-intervention			Post-intervention			p-value
		Mean	SD	CI	Mean	SD	CI	
CH A	Intervention	120.045	38.391	102.078 - 138.012	131.570	42.984	114.294 – 148.846	0.002**
	Placebo	128.940	26.488	116.543 - 141.337	143.370	33.611	127.008 – 159.731	0.002**
	p-value	0.399*			0.340 *			
0.573***								
CH B	Intervention	119.470	40.447	100.540 - 138.400	126.565	44.061	111.270 – 141.861	0.006**
	Placebo	126.265	17.727	117.968 - 134.562	139.400	25.101	123.326 – 155.474	0.001**
	p-value	0.050*			0.264 *			
0.137***								

*independent two tailed t-test

**paired two tailed t-test

*** Repeated measures ANOVA

4.3.3 Lumbar spine range of motion (ROM)

There were statistically significant increases in all range of motion measures except for flexion in the placebo group. However when compared to each other there were no significant differences between the groups, as represented in Table 4.6.

Table 0.6: Active lumbar spinal range of motion results (degrees)

Range of motion (degrees)	Group	Pre-intervention			Post-intervention			p-value
		Mean	SD	CI	Mean	SD	CI	
Flexion	Intervention	26.447	5.079	24.070 - 28.824	26.897	4.965	24.573 - 29.221	0.035**
	Placebo	29.180	8.230	25.328 - 33.032	29.647	8.369	25.730 - 33.564	0.053**
	p-value	0.214			0.387*			
								0.954***
Extension	Intervention	43.297	4.391	41.242 - 5.352	46.280	4.705	44.078 - 48.482	<0.001*
	Placebo	44.980	7.404	41.515 - 48.445	47.313	7.898	43.617 - 51.009	<0.001*
	p-value	0.214*			0.618*			
								0.378***

*independent two tailed t-test

**paired two tailed t-test

***Repeated measure ANOVA

4.4 Subjective measurements

No discomfort or pain was reported to the researcher by any of the participants at any stage during or following the B-S test.

CHAPTER FIVE: DISCUSSION OF RESULTS

5.1 INTRODUCTION

This chapter discusses the results obtained in relation to the available literature.

5.2 PARTICIPANT CHARACTERISTICS

Age, height, weight and body mass index (BMI) were controlled variables in this study to minimise their effect on the results. Ageing has been related to changes in the neuromuscular system. These changes include a loss of muscle force generation capacity (Rubinstein and Kamen 2005; Merletti *et al.*, 2002) which may affect the way the participants responded to the Biering-Sorensen (B-S) test. In this regard age has been shown to influence paraspinal muscle endurance levels, with younger men having an increased fatigability compared to older men (Kankaanpaa *et al.*, 1998). It is therefore suggested by Kankaanpaa *et al.*, (1998) that older white collar workers (to 50 years of age) are more likely to have higher endurance and lower fatigability than younger blue collar workers. This association is possible as it has been found that blue collar workers are more likely to have low back pain (LBP) (Roffey *et al.*, 2010; Wai *et al.*, 2010). According to Patterson and Steinmetz (1986), persons with a previous history of LBP are likely to have altered neurological function (referred to by these authors as a 'neurological scar') and therefore have a greater likelihood to have compromised neuromuscular function (Hopkins and Ingersoll, 2000).

In terms of this study, the effect of age was minimised in that both the intervention (26.350 years) and the control groups (24.950 years) had relatively young participants and the groups were comparable in terms of their presentation ($p = 0.380$). Therefore the effects that age may have represented in this research study were equitable between the groups. However history of LBP was not an exclusion criteria, the participants only needed to not have had LBP in the last three months. Therefore this could have had an effect on the results.

In terms body mass index (BMI), surface electromyography (sEMG) readings may have been affected by depth of subcutaneous fat (Baars *et al.*, 2006), which has

been shown to impede the transmission of signals to the skin. As a result a normal range for BMI was necessary for inclusion of the participants in this study. Height, weight and BMI have also been found to influence spinal extensor endurance capabilities (Kankaanpaa *et al.*, 1998) and therefore it was important to control. There was a very small difference ($p = 0.05$) between the groups in terms of BMI which may have influenced the results.

Due to the nature of the B-S test, the ability of the participants to contract their core musculature may have influenced the results. Well-developed core stability allows for greater force output, increased neuromuscular efficiency and a decrease in the incidence of overuse injuries (Hedrick, 2000). There were no significant differences between the groups for the core assessment even though it was not a controlled variable.

5.3 OBJECTIVE MEASUREMENTS

5.3.1 Paraspinal muscle endurance

There is a paucity of literature investigating if SMT can alter muscle endurance, therefore making the results of this study difficult to compare. Although the participants were asymptomatic healthy young males It was noted that the overall endurance times were fairly low, this could be due to the fact that there was no prompting or encouragement at any stage during the test. There were no significant differences observed within or between the groups in terms of paraspinal muscle endurance, in spite of it being well documented that SMT is associated with improved functional capacity. A possible explanation could be that one treatment using SMT was not sufficient to move the dysfunctional joint into the end range of motion, and therefore not reaching the parapsychological space, as discussed by Vernon and Mrozek (2005). This implies that the effect on the joint mechanoreceptors may have been insufficient to bombard the dorsal horn to result in a noticeable change. However, Keller and Colloca (2000) using a similar manipulative instrument found an increased maximum voluntary contraction (MVC) of the paraspinal muscles following instrument assisted SMT, may indicate that SMT may affect MVC but not endurance capabilities of a muscle.

Similar findings were observed by Clark *et al.*, (2011) where they found no significant effect of SMT on motor evoked potentials and stretch reflexes until they sub-analysed the results based on whether cavitation was heard. Once they did this they found that there was significance, with cavitation being associated with decreased muscle spindle sensitivity over segmental sites of the Ia reflex pathway compared to when it was not heard. The AIA adjusting instrument utilised in this study did not result in audible cavitation, which is often associated with a manually HVLA manipulation (Bergmann and Peterson, 2011; Bergmann *et al.*, 1993). Therefore the lack of the cavitation may indicate that the joint was not adequately “gapped” reducing the input stimulation, although Keller and Colloca (2000) utilised the same/similar instruments and found that maximum voluntary contraction (MVC) did increase following SMT. This therefore warrants further investigation.

In addition to the above, Kankaanpaa *et al.* (1998) noted that if the function of the hip extensors were compromised in any way, it could affect paraspinal muscle endurance due to the link between the thoracolumbar fascia and gluteus maximus muscle. They found a correlation between fatiguability of the hip extensors and that of the paraspinal extensors. This study did not take the state of the hip extensors into account and thus this could have played a role in influencing the results of the B-S test. In addition it is not possible to determine whether the compromised / non-compromised hip extensor muscles were equally represented between the groups and therefore it is not possible to determine the effect of this difference on the outcomes of this study (particularly as it is seen that the intervention groups trended towards a larger degree of improvement).

From a methodological vantage point, both the control and intervention groups had a slight increase in endurance holding times. This could also be due to the preload received by both the intervention and placebo groups, which has the potential to activate mechanoreceptors in and around the manipulated joint which may have altered the afferent input to the motoneuron pool. This, in turn, may have had the ability to change motoneuron excitability, resulting in an increase in motor neuron recruitment (Suter *et al.*, 2000). Pickar and Wheeler (2001) found that with preload forces muscle spindles were activated, which may have been responsible for the

changes observed. Otherwise it could be an artefact of time, but one would have expected the time to decrease due to fatigue, but may have also improved due to the participants being more confident in performing the test.

5.3.2 Electromyography readings (mVs)

SMT has been associated with a change in sEMG activity (Symons *et al.*, 2000; Herzog, Scheele and Conway, 1999). In this study both channel A and B readings increased significantly from pre- to post-intervention. The study methodology only assessed sEMG readings once the paraspinal muscles were contracted and the torso made contact with the rope (i.e. the paraspinal muscles were isometrically contracted). This finding indicates that the paraspinal muscles after either intervention had a higher electrical activity, whether this was as a result of increased motor unit recruitment or enhanced activity of the already active motor units is unclear. This finding indicates that both the preload (received by the placebo group) and the actual manipulative thrusts (received by the intervention group) altered the muscle electrical activity with neither being more effective than the other. This however did not result in a statistically significant increased function of the paraspinal muscles as was anticipated.

5.3.3 Lumbar spine range of motion (ROM)

Improvements of spinal range of motion have been associated with SMT (Lehman and McGill, 1999). In this study extension ROM measures improved for both the placebo and intervention groups, with only the intervention group showing significant improvement in flexion; however when compared there were no significant differences, indicating that neither intervention was superior to the other in altering lumbar spine ROM. As the placebo group received a preload force, this may have been sufficient to activate the muscle spindles as observed by Pickar and Wheeler (2001). However this would not have affected the joint directly but rather indirectly through its reflex effect on the local muscles as observed by Herzog, Scheele and Conway (1999) Symons (2000) and Keller and Colloca (2000).

As both groups received the preload it was expected that the intervention group would have greater improvements in ROM due to the HVLA thrust. As discussed above a possible explanation may be due to the SMT not moving the joint into the parapsychological space, and as a result not restoring the joint to normal ROM.

Lehman and McGill (2001) also observed no significant changes when they used sEMG to measure trunk movements of 14 participants with LBP while they performed range of motion tasks in order to determine the effect manipulation had on trunk kinematics and myoelectric activity in the paraspinal and abdominal muscles. They did however note individual changes in the participants whose pain and dysfunction was more severe. The fact that this study included only asymptomatic participants could thus account for the lack of significant findings.

5.4 SUBJECTIVE MEASUREMENTS

The participants in this study were asymptomatic, therefore it is not surprising that there was no pain experienced. Although having joint dysfunction which is often associated with hypertonic muscles may have made the participants vulnerable to discomfort while performing the B-S test. This finding supports that the B-S test is safe and comfortable to perform.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

This study aimed to determine the effect of spinal manipulation at L3 on lumbar paraspinal extensor muscle endurance in asymptomatic participants. The study found no statistically significant difference between the intervention and placebo groups, in terms of the outcome measures (surface electromyography (sEMG), paraspinal endurance score, lumbar range of motion and subjective report of pain/discomfort), resulting in the null hypothesis being accepted. This study was unable to supply evidence that spinal manipulation results in improved muscle function in terms of endurance. It is possible that the choice and number of SMT applications was insufficient to bring about a change in paraspinal muscle endurance. This together with possible deficits in the participant's hip flexors may have affected the results. Future investigations are necessary to further determine the effect of spinal manipulation on muscle endurance.

6.2 STUDY LIMITATIONS

- Due to the exploratory nature of this study a small sample size ($n = 40$) was used. The sample size was calculated on the changes in the Biering Sorensen's test and therefore the effect size of the surface EMG readings may have been under powered. Therefore using a large sample may have resulted in more significant results for the surface EMG.
- It should be acknowledged that other factors such as the state of the hip extensors may have affected the results of this study and should be taken into consideration in future studies.
- This study only made use of one type of endurance test, namely the Biering-Sorensen's test, other tests could possibly have showed more significant results.

6.3 RECOMMENDATIONS

Recommendations for future research:

1. More advanced sEMG equipment should be utilised to obtain more detailed measures.
2. The addition of a control group, receiving no treatment, and using a cross over design would strengthen the outcome.
3. Occupational demographics and recreational activity should be taken into account.
4. Future research should consider including participants that are both pain free and have full range of motion and compare these to participants that are pain free but have restricted range of motion, in order to determine the differential effect of sensory receptors on the degree to which sEMG may change.

Clinical practice recommendations:

1. The effect of SMT on improving paraspinal muscle endurance was not supported by this study however further investigation is warranted, therefore practitioners should be cautious to emphasis improvements in paraspinal muscle endurance following SMT.

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APPENDIXES

Appendix A: Advertisement

**ARE YOUR BACK MUSCLES
FUNCTIONING OPTIMALLY?**

WOULD YOU LIKE TO FIND OUT?

**IF YOU ARE YOU MALE, HEALTHY
AND RIGHT-HANDED BETWEEN
THE AGES OF 20 AND 40**



**RESEARCH IS BEING CONDUCTED AT THE
CHIROPRACTIC DAY CLINIC
AT THE DURBAN UNIVERSITY OF
TECHNOLOGY**

**IF YOU ARE INTERESTED
CONTACT GREG
0313732205**

Appendix B1: Letter of Information and Informed Consent



Dear Participant,

Thank you for very much for showing an interest in my research project.

Title of the Research Study: The effectiveness of spinal manipulation at L3 on lumbar paraspinal extensor muscle endurance in asymptomatic males

Researcher: Greg Thiel, B.Tech: Chiropractic.

Supervisor/s: Dr Laura O'Connor, M.Tech: Chiropractic

Brief Introduction and Purpose of the Study: Various health practitioners such as chiropractors use spinal manipulation to improve spinal mobility. Although changes have been noted in muscles surrounding the joints following manipulation, it is still uncertain what effect this has on the work load that the muscles are able to maintain. Therefore, this study aims to determine if there will be an increased endurance in your back muscles after you have received spinal manipulation applied to the L3 joint.

Outline of the Procedures: To ensure that you are eligible to participate in the study i.e. that you meet all the inclusion criteria; you will need to agree to have a case history, physical and low back examination. Once the researcher is confident that you are eligible they will then randomly allocate you into one of two groups. One group will consist of manipulation at L3 and the other a placebo. You will then be asked to lie face down on a bed and move forward into a position whereby your lower torso i.e. from your waist down, is supported with straps and the upper part of your torso hangs off the end of the bed and is supported by your arms on a rest. You will then be asked to lift your back until it is in line with your legs and to maintain this position for as long as possible. As soon as you can no longer hold the contraction the test will be stopped. This will be done twice, once before and once after the intervention. During the test a surface electromyographic device will be placed over the back muscles which will allow the researcher to measure the activity of these muscles while performing the exercise. Any excess body hair preventing the electrodes from adhering to the skin will be removed. This is a safe device and will pose no harm to you. The range of motion of your low back will also be assessed by the researcher before and after the intervention.

Risks or Discomforts to the Participant: Performing the back extensor test may cause transient pain or discomfort, meaning any pain or discomfort should be temporary and last for a short time only. Should the pain become severe you must inform the researcher and the test will be stopped immediately.

Benefits: By participating in this research you will be able to find out if you have weak or strong back extensor muscles. If you have weak back extensor muscles, the researcher will show you what exercises you can do to improve this. Studies have shown that weak back extensor muscles can lead to future episodes of low back pain. Therefore should you strengthen these muscles, you may be able to prevent future low back pain.

Reason/s why the Participant May Be Withdrawn from the Study: Should you not meet the inclusion criteria you will be excluded from the study. If during the study you wish to withdraw you may do so with no adverse consequences for future treatment at this facility.

Remuneration: There is no remuneration for participating.

Costs of the Study: The participant will not be expected or required to cover any costs towards the study, the costs of the study will be covered by Durban University of Technology.

Confidentiality: All data will be collected in a manner that ensures participant information is kept confidential. Participants' names will not be revealed in the data sheets; they will be coded and used as such during data analysis. Only the researcher and the supervisor will have access to the data.

Research-related Injury: Should you develop any adverse reaction to participating in this study please contact me immediately.

Persons to Contact in the Event of Any Problems or Queries:

Please contact the researcher Greg Thiel (031 373 2205), my supervisor Dr Laura O'Connor (031 373 2923) or the Institutional Research Ethics administrator on 031 373 2900. Complaints can be reported to the DVC: TIP, Prof F. Otieno on 031 373 2382 or dvctip@dut.ac.za.

Yours sincerely,

Greg Thiel
Researcher



**INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
CONSENT**

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, _____ (name of researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: _____,
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

Full Name of Participant **Date** **Time** **Signature / Right Thumbprint**

I, _____ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

Full Name of Researcher **Date** **Signature**

Full Name of Witness (If applicable) **Date** **Signature**

Full Name of Legal Guardian (If applicable) **Date** **Signature**

Appendix B2: incwadi yolwazi nemvume



Mbandakanyi Othandekayo

Ngibonge ukuveza kwakho intshisekelo kulolucwaningo.

Isihloko socwaningo:

The effectiveness of spinal manipulation at L3 on lumbar paraspinal extensor muscle endurance in asymptomatic male participants

Igama lomcwaningi: Greg Thiel, B.Tech: Chiropractic

Igama lowengamele lolucwaningo: Dk Laura O'Connor, M.Tech: Chiropractic

Incazelo nenhloso ngalolucwaningo: Ukunyakaziswa komgogodla kujwayelwe ukusetshenziswa amachiropractors (odokotela bamathambo, umgogodla namalunga omzimba), nabanye ukwenza ngcono umgogodla. Kunemibhalo eshoyo ukuthi uma umgogodla unyakaziswa kushintsha imisipha esendolene nomgogodla, kepha akucacile noma lolushintsho lunyusa indlela imisipha esebenza ngayo. Ngakho ke lolucwaningo luhlose ukuthola ukuthi ngabe ukunyakaziswa komgogodla kunyusa indlela imisipha yomqolo esebenza ngayo.

Inqubo yalolucwaningo: Ukuze ukwazi ukuba ingxenye yalolucwaningo kuzomele usayine incwadi yemvume ukuthi ngizothatha umlando wakho wempilo, ngikuhlale, bese ngihlala nomgogodla wakho. Lokhu kuzosiza ekutheni umcwaningi abone ukuthi unayo imibandela edingekayo kulolucwaningo. Uma unayo yonke imibandela edingekayo, uzobe usuyafakwa kwelinye lamaqembu amabili. Uzobe usuthola ukunyakaziswa komgogodla noma i-placebo. Uzotshengiswa ukuthi uqinisa/ufinyeza kanjani imisipha yomqolo, ngokuthi ulale isiqu somzimba sibe sequgcineni kwebhentshi, ubambelele ngezingalo, kuzobe sekudingeka ukuthi uphakamise umqolo wakho uze uqondane nemilenze bese uma kanjalo ngokuqiniseka kwakho. Kuzodingeka ukuthi lokhu ukwenze kabili, kanye ngaphambi kokwelashwa nangemva kokwelashwa. Kunomshini ozobekwa emqolowakho ukuze kubonakale ukuthi imisipha yomqolo isebenza kanjani. Lomshini uphephile angeke ukulimaze. Umcwaningi uzohlola ukuthi umgogodla wakho unyakaza kangaka nani ngaphambi kokwelashwa nangemva kokwelashwa.

Ukulimala okuqondene nocwaningo: Lenqubo yokuhlola kwemisipha yomqolo ingenza ukungenami/ubuhlungu besikhashana, okusho ukuthi ukungenami/ubuhlungu obesikhashana futhi kuzothatha isikhashana nje. Uma ubuhlungu buqhubeka kumele utshele umcwaningi ukuze angaqhubeki nokuhlola.

Uzozuzani?

Ngokuzibandakanya kulolucwaningo uzothola ukuthi imisipha yakho inamandla yini noma cha. Uma ngabe imisipha yakho ingenamandla umcwaningi uzokutshengisa ukuthi ungavocavoca kanjani imisipha ukuze ibe namandla. Upheno luyatshengisa ukuthi imisipha engenamandla ingadala ukuthi uphathwe iqolo. Ngakhoke uma imisipha yakho iba namandla, lokhu kungavimbela ukuthi ungaphathwa iqolo.

Izizathu ezingenza ukuthi umuswe kulolucwaningo ngaphandle kwemvume: Uma ungenayo yonke imibandela edingekayo kulolucwaningo angeke ukwazi ukuba ingxenye yalo. Uma udinga ukushiya phakathi lolucwaningo ungenze njalo ngale kokuhlukumezeka kulelikliniki.

Ukukhokhelwa imali: Angeke uze ukhokhelwe ngokuzibandakanya kulolucwaningo.

Kungabe uzokhokha yini ngokuzibandakanye kulolucwaningo?

Angeke uze ukhokhe lutho ngokuzibandakanya kulolucwaningo, konke okumayelana nalolucwaningo kukhokhelwe i-Durban University of Technology.

Imfihlo(izogcinwa kanjani):

Imininingwane yakho ezotholakela kulolucwaningo izogcinwa iyimfihlo. Igama lakho ngeke livezwe kuleminingwane yocwaningo, kuzosetshenziswa inombolo ukuze kuhlaziywe imiphumela yocwaningo. Yimina kanye nowengamele lolucwaningo abazokwazi ukuyibona kuphela.

Ukulima kulolucwaningo: Uma ngabe ulimala noma kuba nobungozi ngenxa yokuzibandakanya kulolucwaningo ngesikhathi ucwaningo lusaqhubeka ngazise ngokushesha,

Ongabathinta uma kuba nenkinga noma imibuzo:

Ngicela uxhumane nomcwaningi uGreg Thiel kulenombolo (031) 373 2205, owengamele lolucwaningo Dk Laura O'Connor (031) 373 2923 noma unobhala wekomiti elimele amalungelo kwezocwaningo(Lavisha Deonarian – 031 373 2900). Izikhalo zingabikwa kwiDVC: TIP, Prof F. Otieno kulenombolo 031 373 2382 noma dvctip@dut.ac.za.

Ozithobayo
Greg Thiel
Umcwaningi



**INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
CONSENT**

Isitatimende sesivumelwano sokuzibandakanya kulolucwaningo:

- Nginyaqinisekisa ukuthi ngitsheliwe ngumcwaningi, **Greg Thiel**, ngohlobo, ngokuziphatha, nangosizo, nangobungozi balolucwaningo – Research Ethics Clearance Number: _____,
- Ngiyitholile, futhi ngayifunda, ngayizwa incwadi (incwadi yombandakanyi) echaza ngalolucwaningo (incwadi yombandakanyi).
- Ngiyazi futhi ukuthi imiphumela yalolucwaningo, imininingwane yami ephathelene nobulili, iminyaka, usuku lokuzalwa, amagama afingqiwe (initials) and isifo esingiphethe kuzodalulwa kumbiko walolucwaningo ngale koludalula amagama ami.
- Ngokubuka okudingekayo kulolucwaningo, ngiyavuma ukuthi imininingwane etholakele ngesikhathi lolucwaningo luqhubeka umcwaningi alufake kuhlelo lwekhompuyutha.
- Noma ngasiphi isikhathi, ngale kokucwaseka, ngingayeka ukuba umbandakanyi kulolucwaningo.
- Ngibe nesikhathi esanele sokubuza imibuzo (ngentando yami) nokuzilungiselela ukuba yingxenye yalolucwaningo.
- Nginyaqonda ukuthi imiphumela ebalulekile etholakele ngesikhathi lolucwaningo luqhubeka egaphathelana name ngizikwaziswa ngayo.

Igama lozibandakanya kulolucwaningo

Usuku

isiginisha/isithupha

Mina **Greg Thiel** ngiyaqinisekisa ukuthi lombandakanyi ongaphezulu uthole incazelo egcwele mayelana nohlobo, ngokuziphatha, nangosizo, nangobungozi balolucwaningo

Igama lomcwaningi

Usuku

Isiginisha yomcwaningi

Igama lafakazi

Usuku

Isiginisha kafakazi

Igama lomlondolozisi (uma ekhona)

Usuku

Isiginisha kafakazi

Appendix C: Case History



CASE HISTORY



DURBAN UNIVERSITY OF TECHNOLOGY
CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient:

Date:

File #: __

Age:

Sex: _

Occupation:

Intern:

Signature:

FOR CLINICIANS USE ONLY:

Initial visit

Clinician:

Signature :

Case History:

Examination:

Previous:

Current:

X-Ray Studies:

Previous:

Current:

Clinical Path. lab:

Previous:

Current:

CASE STATUS:

PTT:	Signature:	Date:
------	------------	-------

CONDITIONAL: Reason for Conditional: ----- ----- Signature: _____ Date: _____
--

Conditions met in Visit No:	Signed into PTT:	Date:
-----------------------------	------------------	-------

Case Summary signed off:	Date:
--------------------------	-------

Intern's Case History:

- 1. **Source of History:**
- 2. **Chief Complaint : (patient's own words):**
- 3. **Present Illness:**

	Complaint 1	Complaint 2
< Location		
< Onset : Initial:		
Recent:		
< Cause:		
< Duration		
< Frequency		
< Pain (Character)		
< Progression		
< Aggravating Factors		
< Relieving Factors		
< Associated S & S		
< Previous Occurrences		
< Past Treatment		
< Outcome:		

4. Other Complaints:

5. Past Medical History:

- < General Health Status
- < Childhood Illnesses
- < Adult Illnesses
- < Psychiatric Illnesses
- < Accidents/Injuries
- < Surgery
- < Hospitalizations

6. Current health status and life-style:

- < Allergies
- < Immunizations
- < Screening Tests incl. x-rays
- < Environmental Hazards (Home, School, Work)
- < Exercise and Leisure
- < Sleep Patterns
- < Diet
- < Current Medication
- < Analgesics/week:
- < Tobacco
- < Alcohol
- < Social Drugs

7. Immediate Family Medical History:

- < Age
- < Health
- < Cause of Death
- < DM
- < Heart Disease
- < TB
- < Stroke
- < Kidney Disease
- < CA
- < Arthritis

- < Anaemia
- < Headaches
- < Thyroid Disease
- < Epilepsy
- < Mental Illness
- < Alcoholism
- < Drug Addiction
- < Other



8. Psychosocial history:

- < Home Situation and daily life
- < Important experiences
- < Religious Beliefs

9. Review of Systems:

- < General
- < Skin
- < Head
- < Eyes
- < Ears
- < Nose/Sinuses
- < Mouth/Throat
- < Neck
- < Breasts
- < Respiratory
- < Cardiac
- < Gastro-intestinal
- < Urinary
- < Genital
- < Vascular
- < Musculoskeletal
- < Neurologic
- < Haematologic
- < Endocrine
- < Psychiatric

Appendix D: Physical Examination, Senior

 D U R B A N UNIVERSITY of TECHNOLOGY	APPENDIX D: PHYSICAL EXAMINATION	 D U R B A N UNIVERSITY of TECHNOLOGY		
Durban University of Technology PHYSICAL EXAMINATION: SENIOR				
Patient Name : _____ File no : _____				
Date : _____				
Student : _____		Signature : _____		
VITALS:				
Pulse rate:			Respiratory rate:	
Blood pressure:	R	L	Medication if hypertensive:	
Temperature:			Height:	
Weight:	Any recent change? Y / N		If Yes: How much gain/loss	Over what period
GENERAL EXAMINATION:				
General Impression				
Skin				
Jaundice				
Pallor				
Clubbing				
Cyanosis (Central/Peripheral)				
Oedema				
Lymph nodes	Head and neck			
	Axillary			
	Epitrochlear			
	Inguinal			
Pulses				
Urinalysis				

SYSTEM SPECIFIC EXAMINATION:

CARDIOVASCULAR EXAMINATION

RESPIRATORY EXAMINATION

ABDOMINAL EXAMINATION

NEUROLOGICAL EXAMINATION

COMMENTS

Clinician:

Signature :

Appendix E: Regional Examination Lumbar spine and Pelvis



CHIROPRACTIC PROGRAMME

**REGIONAL EXAMINATION
LUMBAR SPINE AND PELVIS**

Patient: _____ File#: _____ Date: _____
 Student: _____ Clinician: _____

STANDING:

Posture– scoliosis, antalgia, kyphosis
 Body Type
 Skin
 Scars
 Discolouration

Minor’s Sign
 Muscle tone
 Spinous Percussion
 Schober’s Test (6cm)
 Bony and Soft Tissue Contours

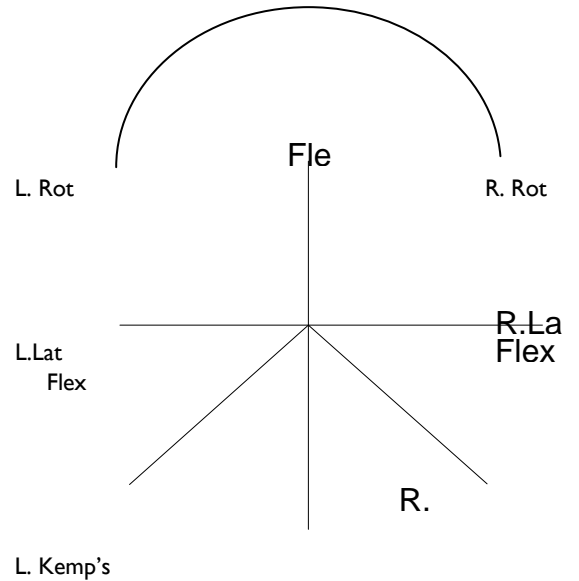
GAIT:

Normal walking
 Toe walking
 Heel Walking
 Half squat

ROM:

Forward Flexion = 40-60° (15 cm from floor)
 Extension = 20-35°
 L/R Rotation = 3-18°
 L/R Lateral Flexion = 15-20°

- - **Which movement reproduces the pain or is the worst?**
 - Location of pain
- Supported Adams: Relief? (SI)
 Aggravates? (disc, muscle strain)



SUPINE:

Observe abdomen (hair, skin, nails)
 Palpate abdomen/groin
 Pulses - abdominal
 - lower extremity
 Abdominal reflexes

		Degree	LBP?	Location	Leg pain	Buttock	Thigh	Calf	Heel	Foot	Braggard
SLR	L										
	R										

	L	R
Bowstring		
Sciatic notch		
Circumference (thigh and calf)		
Leg length: actual - apparent -		
Patrick FABERE: pos\neg – location of pain?		
Gaenslen's Test		
Gluteus max stretch		
Piriformis test (hypertonicity?)		
Thomas test: hip \ psoas \ rectus femoris ?		
Psoas Test		

SITTING:

Spinous Percussion
Lhermitte

Valsalva

TRIPOD Sl, +, ++		Degree	LBP?	Location	Leg pain	Buttock	Thigh	Calf	Heel	Foot	Braggard
	L										
	R										

SLUMP 7 TEST											
	L										
	R										

LATERAL RECUMBENT:

L

R

Ober's		
Femoral n. stretch		
SI Compression		

PRONE:

L

R

Gluteal skyline		
Skin rolling		
Iliac crest compression		
Facet joint challenge		
SI tenderness		
SI compression		
Erichson's		
Pheasant's		

MF tp's	Latent	Active	Radiation
QL			
Paraspinal			
Glut Max			
Glut Med			
Glut Min			
Piriformis			
Hamstring			
TFL			
Iliopsoas			
Rectus Abdominis			
Ext/Int Oblique muscles			

NON ORGANIC SIGNS:

Pin point pain
 Trunk rotation
 Flip Test
 Ankle dorsiflexion test

Axial compression
 Burn's Bench test
 Hoover's test
 Repeat Pin point test

NEUROLOGICAL EXAMINATION

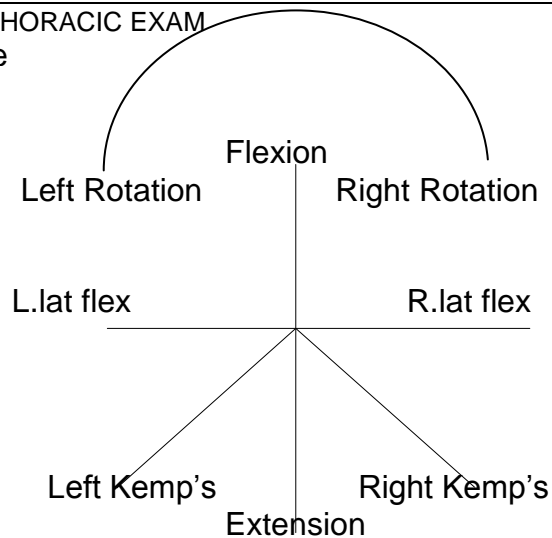
Fasciculations						
Plantar reflex						
level	Tender?	Dermatomes		DTR	L	
		L	R		L	R
T12				Patellar		
L1				Achilles		
L2						
L3				Proprioception		
L4						
L5						
S1						
S2						
S3						

MYOTOMES

Action	Muscles	Levels	L	R	
Lateral Flexion spine	Muscle QL				
Hip flexion	Psoas, Rectus femoris				5+ Full strength
Hip extension	Hamstring, glutes				4+ Weakness
Hip internal rotation	Glutmed, min, TFL, adductors				3+ Weak against grav
Hip external rotation	Gluteus max, Piriformis				2+ Weak w/o gravity
Hip abduction	TFL, Glut med and minimus				1+ Fascic w/o gross movt
Hip adduction	Adductors				0 No movement
Knee flexion	Hamstring,				
Knee extension	Quad				W - wasting
Ankle plantarflexion	Gastrocnemius, soleus				
Ankle dorsiflexion	Tibialis anterior				
Inversion	Tibialis anterior				
Eversion	Peroneus longus				
Great toe extensor	EHL				

BASIC THORACIC EXAM

Passive



History :

Orthopedic assessment:

BASIC HIP EXAM

History

ROM: Active

Passive: Medial rotation: A) Supine (neutral) If reduced

- hard \ soft end feel

B) Supine (hip flexed):

- Trochanteric bursa

MOTION PALPATION AND JOINT PLAY	L	R
Thoracic Spine		
Lumbar Spine		
Sacroiliac Joint		

Appendix F: Data Collection Sheet

Date: _____

Participant's code: _____

File no: _____

BMI (Body mass index): _____ kg/m²

Subjective measurement:

Pre-intervention: Did you experience any pain or discomfort? Y / N _____ seconds.

Post-intervention: Did you experience any pain or discomfort? Y / N _____ seconds.

Objective measurements:

Pre-intervention: Muscle length assessment of the paraspinal muscles: _____ cm

Post-intervention: Muscle length assessment of the paraspinal muscles: _____ cm

	Pre-intervention	Post-intervention
Endurance time (seconds)		
Average sEMG reading (mV) Channel A		
Average sEMG reading (mV) Channel B		
Peak sEMG reading (mV) Channel A		
Peak sEMG reading (mV) Channel B		
Minimum sEMG reading (mV) Channel A		
Minimum sEMG reading (mV) Channel B		

Active lumbar ROM pre-intervention:

	Flexion	Extension
Reading 1		
Reading 2		
Reading 3		
Average reading		

Active lumbar ROM post-intervention:

	Flexion	Extension
Reading 1		
Reading 2		
Reading 3		
Average reading		

Appendix G: Letter of Permission

Dear Sir/Madam

I am currently registered for my Masters in Chiropractic at the Durban University of Technology. I would like permission to place an advertisement on your premises to recruit participants for my research project.

Yours sincerely,

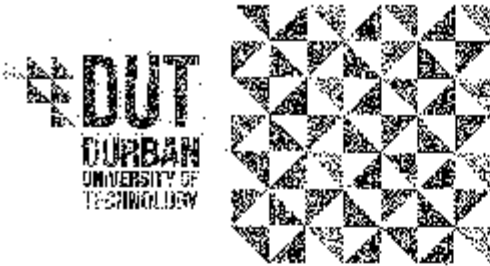
Greg Thiel.

Researcher

I,give permission for an advert to be placed on my premises.

Signed

Appendix H: IREC Clearance Certificate



Institutional Research Ethics Committee
Faculty of Health Sciences
Room ME-5, Mandlil School St.
Glen & Riala Campus
Durban University of Technology

P.O. Box 1324, Durban, South Africa, 4001

tel: 031 271 2000
fax: 031 271 2400
Email: ethics@durban.ac.za
http://www.dut.ac.za/ethics/ethics%20and%20research_ethics
www.dut.ac.za

22 November 2013

IREC Reference Number: REC 80/13

Dr G.J Thiel
2 Robinson Street
Umkomaas
4170

Dear Dr Thiel

The effectiveness of spinal manipulation at L3 on lumbar paraspinal extensor muscle endurance in asymptomatic males

I am pleased to inform you that Full Approval has been granted to your proposal REC 80/13

The Proposal has been allocated the following Ethical Clearance number **IREC 094/13**. Please use this number in all communication with this office.

Approval has been granted for a period of one year, before the expiry of which you are required to apply for safety monitoring and annual recertification. Please use the Safety Monitoring and Annual Recertification Report form which can be found in the Standard Operating Procedures (SOP's) of the REC. This form must be submitted to the IREC at least 3 months before the ethics approval for the study expires

Any adverse events (serious or minor) which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the REC SOP's. In addition, you will be responsible to ensure gatekeeper permission.

Please note that any deviations from the approved proposal require the approval of the REC as outlined in the REC SOP's.

Yours Sincerely

A black rectangular box redacting the signature of Prof J.K. Adam.

Prof J.K Adam
Chairperson: IREC

NHREC

South African Human Research Electronic Application System

Appendix I: Trial Application

TRIAL APPLICATION

Application ID:	3654	DOH Number	DOH-27-0114-4654	Page:	1/2
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Applicant Details

Organisation : Durban University of Technology
Applicant Type : Academic Investigator
Contact Name : Laura O'Connor
Address : Chiropractic Programme
Durban University of Technology
PO Box 1334
Durban
4000
Telephone : 0313732923
Fax : 0865324209
E-mail : lauraw@dut.ac.za
Responsible Contact person
(for public) L. O'Connor
Telephone : 03137372923
Research contact person
Telephone : G. Theil
0313732923

Trial Application Details

Issue Date : 2014/02/26
Sponsors : DUT
Primary Sponsor :
FundingType : Not Funded
Research Site Names : DUT, Chiropractic Clinic
Primary Research Site Name :
Total National Budget for Trial : R 6938
Protocol / Grant Reference
Number REC 80/13

Study Descriptive Information

Brief Title of Study : The effectiveness of spinal manipulation at L3 on lumbar paraspinal extensor muscle endurance in asymptomatic males
Full Title of Study :
Anticipated Start Date : 2013/11/25
Anticipated End Date : 2013/12/14
Target Sample Size : 40
Study Phase : Other
Study Scope : Single Site
Study Type : Interventional
Disease Type Heading : Bacterial and Fungal Diseases
Disease Type Condition : Actinomycetales Infections
Intervention Name (Generic) : Spinal manipulation
Intervention Duration :
No. Type
1 Hours

TRIAL APPLICATION

Application ID:	3654	DOH Number	DOH-27-0114-4654	Page:	2/2
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Interventional

Intervention Type : Procedure
 Purpose : Treatment
 Allocation : Randomised
 Masking : Single Blind
 Control : Placebo
 Assignment : Parallel
 Endpoints : Efficacy

Study Descriptive Information

Recruitment Status as at Date: 2013/11/25
 Recruitment Status : No Longer Recruiting
 Gender : Males
 Ethnicity : All
 Age : From 20 Years To 40 Years
 Qualifying Disease Condition for Inclusion :
 1) Participants must agree to and sign the Letter of Information and Informed Consent
 2) Participants must be male
 3) Participants must be between the ages of 20 and 40 years of age
 4) Participants must have a Body Mass Index (BMI) between 18.5kg/m² and 24.9 kg/m²
 5) Participants must be right hand dominant
 6) Participants who hold the Biering-Sorensen extensor muscle endurance test for less than 176 seconds will be included in the study.
 7) Participants must have been free of low back pain (LBP) for the past three months
 8) Participants must have a Lumbar joint restriction at the level of L3.
 Major Exclusion Criteria :
 1) Previous spinal surgery.
 2) Medical conditions which could make physical activity unsafe for the participant
 3) Any mechanical or manual intervention to the thoracic or lumbar spine three weeks prior to the study will be excluded. 4) Significant trauma affecting the low back or if the clinical assessment warrants that the participant needs x-rays.
 5) The use of any pain medication or muscle relaxants for any reason may be excluded from the study, unless they have a 72 hour (three day) wash out period before commencement of the study 6) Contraindications to lumbar joint manipulation
 Key Primary Outcome : To determine the effectiveness of lumbar spinal manipulation at L3 compared to a placebo treatment at L3 in terms of objective (measuring the endurance time of the lumbar extensor muscles and lumbar spine active ranges of motion) measurements taken pre and post-intervention
 Key Secondary Outcomes : To determine the effectiveness of lumbar spinal manipulation at L3 compared to a placebo treatment at L3 in terms of subjective (pain or discomfort experienced whilst performing the Biering-Sorensen test)

Committees

Ethics Committee :	Approval Status	Ethics Number	Ethics Date
---------------------------	------------------------	----------------------	--------------------

Durban University of Technology Approved REC80/13 2013/11/22
 Institutional Research Ethics Committee