The effectiveness of lower thoracic spinal manipulation on lumbar extensor muscle endurance and range of motion in asymptomatic males – a placebo controlled study

By

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I, Lindelwe Matsebula, do declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate the contrary)

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_____ _____

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DEDICATION

To my mother Maud and my brother Gagz. Your continued prayers, sacrifice, support, love, endless pep talks and belief in me has made all this possible. Through your example, you have given me the courage, inspiration and determination to reach my goals. I dedicate this dissertation to you; for you believed, without a doubt, that I would achieve my dream.

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ABSTRACT

Background: Spinal manipulative therapy (SMT) is a commonly used treatment for many musculoskeletal conditions although the exact mechanism explaining its effectiveness is not well understood. Several studies have investigated the effect of SMT on the paraspinal muscles where neuromuscular effects have been observed, however few studies have assessed whether these changes result in a change in the functioning of the paraspinal muscles. This study aimed to determine the effect of lower thoracic spinal manipulation compared to a placebo intervention on lumbar extensor muscle endurance in asymptomatic participants.

Methodology: This was a quantitative, pre-test post-test, placebo controlled trial involving 40 male participants between the ages of 20 and 40 years. The participants were randomly allocated to either the lower thoracic spinal manipulation group or a placebo group. Manipulation was delivered using the Impulse Adjusting Instrument®. Objective measures included lumbar spinal range of motion, a paraspinal muscle endurance test, and surface electromyography readings. Subjective measures were the verbalisation of pain and/or discomfort during the paraspinal muscle endurance test. IBM® SPSS® statistics version 21 and STATA 11 were used to analyse the data. A p-value of <0.05 was considered statistically significant.

Results: There were no statistically significant differences between the groups in terms of subjective and objective measurements. A trend of treatment effect was observed for paraspinal muscle endurance where the intervention group showed noticeable improvements in endurance scores.

Conclusion: Further studies need to be conducted to determine if the trends observed would occur in a larger study population.

Key words: spinal manipulative therapy, paraspinal endurance

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LIST OF ABBREVIATIONS

SMT: spinal manipulative therapy

SM: spinal manipulation

NSAIDs: non-steroidal anti-inflammatory drugs

TVPs: transverse processes

SP: spinous process

Z-joint: zygapophyseal joint

IV discs: intervertebral discs

Z-capsules: zygapophyseal capsules

IVF: intervertebral foramen

ALL: anterior longitudinal ligament

SEMG: surface electromyography

Kgs: kilograms

ROM: range of motion

GTO: Golgi tendon organs

Std: standard

mVs: micro volts

%: percentage

P: p-value

α: alpha

γ: gamma

DEFINITIONS

MANIPULATION: A passive manual force imparted on the joint, moving the joint beyond the normal physiological range of movement, into the paraphysiologic space to the anatomical limit of safe joint play, with the objective of restoring normal joint mobility (Haldeman, 2005: 275).

SPINAL MANIPULATIVE THERAPY (SMT): A non-operative treatment modality commonly used by chiropractors and other manual therapists in the management of musculoskeletal conditions (Dishman, Dougherty and Burke, 2005: 650; Haldeman, 2005: 150; Cramer *et al*., 2006: 726).

MOBILISATION: A passive movement of the joint within its normal range of motion, involving repetitive, vibratory-type movements against a restrictive barrier (Bialosky *et al*., 2009: 532).

MUSCLE ENDURANCE: The ability to sustain effort, or produce work over time (Kankaanpaa *et al.,* 1998a: 1070).

DYNAMIC ENDURANCE: The ability of a muscle to contract and relax repeatedly (Tortora and Derrickson, 2006: 555).

STATIC ENDURANCE: the ability of a muscle to remain contracted for a long time (Tortora and Derrickson, 2006: 555).

FIXATION: The state whereby an articulation has become temporarily immobilized in a position that it may normally occupy during any phase of physiological movement (Haldeman, 2005: 274).

JOINT DYSFUNCTION: The disturbance of function without structural change, affecting range of motion. It can present as a change in motion, be it an increase or decrease (Bergman and Peterson, 2002: 41; Liebler *et al.,* 2001: 207)

ERECTOR SPINAE MUSCLES: Muscle group responsible for the principal movement of spinal extension; used interchangeably with the term ‘paraspinal muscles’ due to the grouping of muscles being based on the general direction of the muscle bundles and their function (Tortora and Derrickson, 2006: 379; McGill, 2007: 62).

CHAPTER ONE: INTRODUCTION

1.1 INTRODUCTION

Spinal manipulative therapy (SMT) is a commonly used modality in the treatment of many musculoskeletal conditions (Koppenhaver *et al.,* 2011: 389; Boal and Gillette, 2004: 314; Herzog, Scheele and Conway, 1999: 147), resulting in decreased pain, disability and improved muscle function (Herzog, 2005; Pickar, 2002; Symons *et al*, 2000). The exact mechanism through which SMT brings about healing is not thoroughly understood (Dishman and Bulbulian, 2000: 2519), however neurophysiological changes following SMT have been documented (Cao *et al*., 2013; Pickar, 2002; Herzog, Scheele and Conway, 1999; Floman, Liram and Gilai, 1997) and are proposed to be responsible for the effectiveness of SMT (Haavik-Taylor and Murphy, 2006; Potter, McCarthy and Oldham, 2005). The biomechanical changes caused by SMT, such as improving joint dysfunction, appear to have physiological consequences affecting the inflow of sensory information to the central nervous system (CNS) and altering motor output (Pickar, 2002: 357). This neurological change may be assessed through the use of surface electromyography (sEMG), which has been utilised to detect muscle electrical activity during different postures and/or movements in both healthy and low back pain patients (Dankaerts *et al*., 2004).

The paraspinal muscles play an important role in maintaining upright posture (Moore and Dalley, 2006: 30; Ebraheim *et al*., 2004: 131). A lack of endurance capabilities in these muscles has been associated with predicting future episodes of low back pain and are therefore considered as important muscles to be tested for endurance in the clinical setting (Kankaanpaa *et al*., 1998a; Ito *et al*., 1996). There are several studies that show changes in the paraspinal muscles following SMT, yet little information exists regarding whether these changes can alter muscle function. Keller and Colloca (2000: 591) found that manually assisted SMT elicited neuromuscular responses in the paraspinal muscles of patients with low back pain, which was demonstrated by an increase in maximum voluntary contraction (MVC) of the paraspinal muscles recorded by surface, linear-enveloped EMG, demonstrating that spinal manipulation could affect muscle functioning.

The paraspinal muscles play a role in the stabilisation of the spine and any pathology or weakness of these muscles may translate as pain, finding out ways in which to prevent the onset has been an area of interest to many researchers, hence the decision for this study. However the effect of SMT on paraspinal muscle endurance has yet to be investigated.

1.2 AIMS AND OBJECTIVES

1.2.1 Aim of the study

This study aimed to determine the effect of lower thoracic spinal manipulation compared to a placebo intervention on lumbar extensor muscle endurance in asymptomatic males, in terms of subjective (pain/discomfort rating) and objective (endurance time, surface electromyographic readings and active lumbar spine range of motion) measurements.

1.2.2 Study objectives

The objectives of the study were:

1. To determine the effect of lower thoracic spinal manipulation on lumbar extensor muscle endurance in terms of subjective and objective measurements.
2. To determine the effect of a placebo intervention on lumbar extensor muscle endurance in terms of subjective and objective measurements.
3. To compare the effect of lower thoracic spinal manipulation to a placebo intervention on lumbar extensor muscle endurance in terms of subjective and objective measurements.

1.3 THE HYPOTHESIS

The null hypothesis states that there will be no difference between the group receiving lower thoracic spinal manipulation compared to the placebo intervention in terms of subjective and objective measurements.

1.4 THE SCOPE OF THE STUDY

This was a randomised, placebo controlled pre-test post-test study design, utilising 40 asymptomatic, right hand dominant males between the ages of 20-40 years, who met the study inclusion criteria. Signed informed consent was obtained from each participant. The intervention group received SMT in the form of the Impulse Adjusting Instrument® (IAI) to a joint fixation between T8-10, and the placebo group received the pre-load force that the IAI administers without receiving the actual manipulative thrusts. The primary outcomes were paraspinal endurance time and surface electromyography (mV). Secondary outcomes were lumbar spine range of motion and a subjective indication of pain or discomfort. IBM® SPSS® statistics version 21 and STATA 11 were used to analyse the data.

This study was limited to asymptomatic participants in order to eliminate the interference of pain mechanisms and the physiology that occurs within the muscle when pain is a factor. It is acknowledged that the results may have been different if the study was conducted in a symptomatic sample.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

Spinal manipulation is a complex event that affects the spine, the over lying soft tissues and the nervous system. In order to provide a comprehensive review of the literature a brief overview of the anatomy of the thoracolumbar spine will be presented. This will be followed by a discussion on muscle physiology, especially muscle endurance, will be discussed detailing how a muscle contracts and those structures responsible for maintain length-tension relationships of a muscle. This will be followed by a review of the literature relevant to the research question.

2.2 BRIEF OVERVIEW OF THE VERTEBRAL COLUMN

The vertebral column is divided into four parts consisting of seven cervical, 12 thoracic, five lumbar vertebrae and the sacrum. It is made up of bone, muscle, the spinal cord, and connective tissue (Tortora and Derrickson, 2006: 212). As illustrated in Figure 2.1 a typical vertebra consists of a vertebral body, vertebral arch, and seven processes (Cramer and Darby, 2005: 244). The vertebral arch is formed by the left and right pedicles and laminae. The pedicles are short processes that join the vertebral arch to the vertebral body, projecting posteriorly to meet two broad, flat plates of bone known as the laminae. The spinous process (SP) and transverse process (TVP) project from the vertebral arch and allow for the attachment of deep muscles (Moore and Agur, 2002: 279).

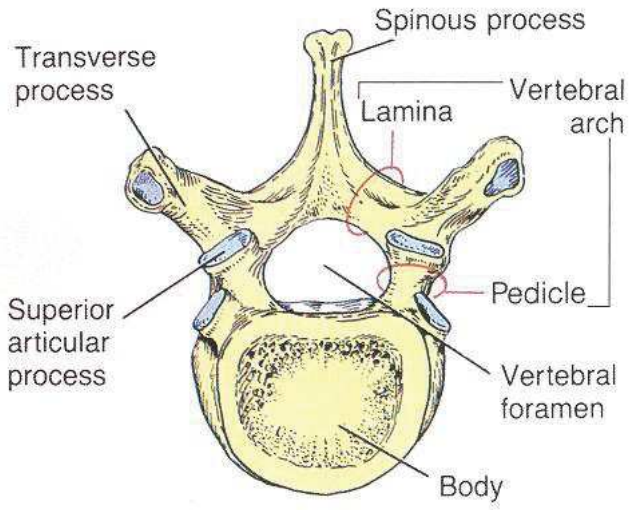

Figure 2.1: A typical spinal vertebra (Typical vertebra, 2006)

The intervertebral discs (IVD) are located between adjacent vertebrae, they are avascular, allow movement between the vertebrae, and act as shock absorbers (Moore and Dalley, 2006: 499). The IVD consist of an annulus fibrosus (outer fibrous part) and a nucleus pulposus (gelatinous central mass with high water content) (Moore and Agur, 2002: 279). They attach to cartilaginous end plates adjacent to the surfaces of the vertebral bodies.

The zygapophyseal joints (commonly known as the facet joints) are made up of the adjacent inferior and superior articular processes of the vertebrae (Ebraheim *et al*., 2004: 133). These joints are synovium-lined extensions of the capsule (Moore and Agur, 2002: 31), and allow gliding movements between the articular processes (Moore and Daley, 2006: 504). Spinal manipulation is targeted to these joints.

2.2.1 The thoraco-lumbar spine

2.2.1.1 The thoracic spine

The thoracic spine forms the posterior part of the thorax providing articulations for the ribs (Cramer and Darby, 2005: 277). The thoracic spine is concave anteriorly and is considered a primary curve (Moore and Dalley, 2006: 513); its intervertebral discs (IVD's) are thin, relative to the large vertebral bodies (Moore and Dalley, 2006: 511). The unique features of the thoracic spinal vertebrae are highlighted in Table 2.1.

The facet joints in the thoracic spine lie on an arc that is centred on the vertebral body, allowing for vertebral rotation, which, when combined with cervical spine rotation,

enables torsion of the axial skeleton (Cramer and Darby, 2005: 231). The upper thoracic spine exhibits more axial rotation when compared to the lower and the lower has the ability to flex and extend increasingly as it approximates the lumbar spine (White and Panjabi, 1990: 118).

Table 2.1: Features of thoracic vertebrae

Part	Distinctive characteristics
Body	Heart-shaped, and has one or two facets for articulation with the ribs
Vertebral foramina	Circular and smaller than in cervical and lumbar regions
TVP	Long and strong and extend posterolaterally, with length decreasing from T1-T12
Articular processes	Superior facets are directed posteriorly and slightly laterally, while the inferior facets are directed anteriorly and slightly medially
Spinous processes	Long, and slope posteroinferiorly and tips extend to the vertebral body below

(Adapted from Moore and Dalley, 2006: 489)

The ninth through to the twelfth vertebrae have some features that make them similar to lumbar vertebrae (Moore and Dalley, 2006: 488). The twelfth thoracic vertebra has most of the transitional characteristics, with its superior half having characteristics of a thoracic vertebra, while the lower half is lumbar in character (Moore and Dalley, 2006: 488). Thoracic vertebrae are different to cervical and lumbar vertebrae, in that they have articulations for the ribs (Tortora and Derrickson, 2006: 216). Except for the eleventh and twelfth thoracic vertebrae, the transverse processes have facets for rib articulation.

2.2.1.2 The lumbar spine

The lumbar spine is convex anteriorly forming the lumbar lordosis (Cramer and Darby, 2005: 276), and is classified as a secondary curvature. The vertebral bodies are designed so as to have the ability to bear loads (White and Panjabi, 1990: 106). The unique features of the lumbar spinal vertebrae are described in Table 2.2.

Table 2.2: Features of lumbar vertebrae

Part	Distinctive characteristics
Body	Kidney-shaped
Vertebral foramina	Triangular; smaller than in cervical and larger than in thoracic vertebrae
TVP	Long and slender with an accessory process on the posterior surface of base of each process, but that of the fifth lumbar vertebra are much wider from anterior to posterior and from superior to inferior
Articular processes	Superior facets are directed posteromedially and slightly laterally, while the inferior facets are directed anterolaterally
Spinous processes	Short, thick, broad and hatchet shaped

(Adapted from Moore and Dalley, 2006: 491)

The lumbar spine provides additional flexibility to the vertebral column (Moore and Dalley, 2006: 513), with flexion and extension range of motions gradually increasing towards the sacrum (White and Panjabi, 1990: 106). This may be influenced by the size of the IVD's (White and Panjabi, 1990: 118).

2.2.1.3 Range of motion of the thoracic and lumbar spine

The total range of motion, in degrees, for each movement in the thoracic and lumbar spines is summarised in Table 2.3.

Table 2.3: Total range of motion for the thoracic and lumbar regions

Direction	Thoracic spine	Lumbar spine
Flexion	60˚	60˚
Extension	25˚	20˚ - 30˚
Lateral flexion	35˚	30˚
Axial rotation	50˚	10˚ - 15˚

(Adapted from Cramer and Darby, 2005 and Vizniak, 2010)

2.2.2 Ligaments of the vertebral column

There are many ligaments that play an important role in the stabilisation of the vertebral column, as described in Appendix K. They facilitate smooth motion and energy conservation during normal full spinal range of motion, provide protection to the spinal cord by limiting motion, and by absorbing significant loads placed on the spine during trauma (Cramer and Darby, 2005: 35).

2.2.3 Musculature of the low back

The muscles of the low back are divided into three groups; the superficial, intermediate and deep. The superficial and intermediate are considered extrinsic muscles and are involved in limb movement and respiration, while the deep group are intrinsic and are responsible for movement of the vertebral column (Ebraheim *et al*., 2004: 137; Moore and Dalley, 2006: 534). For the purpose of this study only the intrinsic group will be discussed.

The intrinsic back muscles are further divided into three groups: superficial, intermediate and deep (Moore and Dalley, 2006:534). The superficial group consists of the splenius capitis and cervicis, and will not be discussed in this study, the intermediate muscle group, otherwise known as the erector spinae are presented in table 2.5, and the deep layer are presented in appendix L.

Table 2.4: Intermediate layer of back muscles

Muscle	Origin	Insertion	Action
Iliocostalis	The posterior iliac crest, posterior surface of sacrum, sacroiliac ligaments, lower lumbar and 11th and 12th thoracic vertebrae, and the supraspinous ligament	Iliocostalis lumborum, thoracis, and capitis – Give muscle slips to the ribs and the TVP's of the lower cervical spine	Bilaterally, they extend the vertebral column, and laterally flex the vertebral column (unilaterally)
Longissimus		Longissimus thoracis, cervicis and capitis- Gives muscle slips to the TVP of the thoracic and cervical spine as well as the mastoid process, with fibres running superiorly	
Spinalis		Spinalis thoracis, cervicis and capitis- gives muscle slips to the spinous processes above, with the fibres running superiorly	

(Adapted from Moore and Dalley, 2006: 538-539; McGill, 2007: 51).

The erector spinae muscles are the main extensors of the thoraco-lumbar spine, together with multifidus (McGill, 2007: 51). Forces in these muscles produce the greatest amount of extension, and have the greatest possible extensor moment arm (McGill, 2002: 61). Since the multifidi span only a few joints, their action only affects local areas of the spine (McGill, 2002: 63; Ebraheim *et al*., 2004: 137) compared to

the intermediate layer which spans the lumbar spine, 11th and 12th thoracic vertebrae and inserts into the upper thoracic and cervical area, placing them in an optimal position to result in spinal extension.

The erector spinae muscles are especially important for maintaining the upright posture of the trunk, and because they are attached at multiple sites, some parts of the muscle have been found to have a greater mechanical advantage over other parts. Sung, Lammers, and Danial (2009) found that the mechanical advantage seemed to decrease from inferior to superior attachments. Therefore, measuring the different parts of the erector spinae muscles was essential to researchers in the understanding of the anatomical and biomechanical characteristics of the lumbar spine, hence the decision of the researcher in this study to try and assess the effectiveness of manipulating the lower thoracic spine in an attempt to improve lumbar spine muscle endurance.

2.4 MUSCLE PHYSIOLOGY

Muscles are responsible for producing movement, postural support, heat generation (thermogenesis) and resisting gravity. They attach either directly or indirectly to bones, cartilage, ligaments, or fascia (Moore and Dalley, 2006: 30). When contracting, one of their attachments is pulled while the other remains fixed (Moore and Dalley, 2006: 32).

In order for a muscle to perform its function it must receive neurological information from the central nervous system. Cranial or spinal nerves are responsible for transmitting these afferent and efferent signals and consist of a bundle of peripheral nerve fibres, connective tissue coverings, and blood vessels (Moore and Dalley, 2006: 50).

2.4.1 Overview of the nerve supply to a muscle

A muscle receives its nerve supply through the spinal nerve which is formed in the IVF by the anterior and posterior nerve roots joining to form a mixed nerve (Tortora and Derrickson, 2006: 446), as illustrated in Figure 2.2.

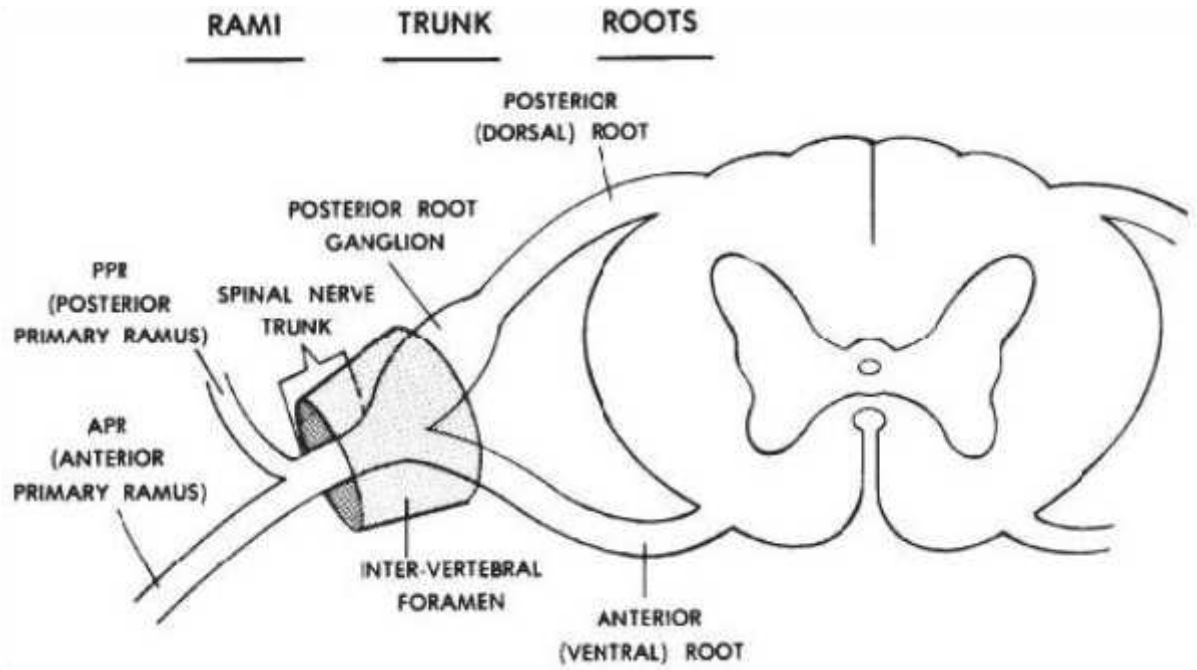

Figure 2.2: Typical spinal nerve formations (Typical spinal nerve, with a cross section of the spinal cord, 2004)

The anterior nerve root consists of motor fibres from the anterior horn of the spinal cord grey matter; and the posterior nerve root, extends from the posterior horn of the spinal cord grey matter through the posterior root ganglion, which contains the cell bodies of sensory neurons, and carries mostly sensory signals to the spinal cord (Tortora and Derrickson, 2006:442).

When the spinal nerve exits the IVF, the spinal nerve divides into several branches, known as rami. The anterior ramus supplies the muscles and structures of the upper limb as well as the lower limbs, and the skin of the lateral and ventral surfaces of the trunk, while the posterior ramus supplies the deep muscles and the skin of the dorsal surface of the trunk (Tortora and Derrickson, 2006: 447). In addition to the rami, the spinal nerve also gives off a meningeal branch that innervates vertebral ligaments, vertebrae, blood vessels of the spinal cord and the meninges (Tortora and Derrickson, 2006).

The sensory, or afferent neurons, are responsible for relaying information from the sensory receptors, through the spinal nerve, to the brain and spinal cord (Tortora and Derrickson, 2006:404). They are classified into five types, as seen in table 2.6.

Table 2.5: Classification of sensory neurons

Type	Myelinated	Conduction velocity m/s	Associated receptors
Ia	Yes	80–120	Primary receptors of muscle spindle
Ib	Yes	80–120	Golgi tendon organ
II	Yes	33–75	Secondary receptors of muscle spindle. All cutaneous mechanoreceptors
III	Thinly	3–30	Free nerve endings of touch and pressure. Nociceptors of spinothalamic tract
IV	No	0.5-2.0	Nociceptors of spinothalamic tract. Warmth receptors

(Adapted from Leach, 2004; Pickar, 2002)

Sensory receptors are found at the distal ends of the sensory neurons, and respond to specific stimuli by producing a graded potential called a generator potential (Tortora and Derrickson, 2006: 460). Sensory receptors are classified into mechanoreceptors, thermoreceptors, proprioceptors, pain receptors and chemoreceptors. Those related to this study are discussed in Table 2.6.

Table 2.6: Selected types of sensory receptors

Receptor type		Location	Sensations	Adaption rate
Mechano-receptors	Meissner corpuscles	Hairless skin.	Fine touch, pressure & slow vibrations.	Rapid.
	Merkel discs	Epidermis.	Fine touch and pressure.	Slow.
	Type I:Ruffian 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 & 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 Wyke, 1972; Hogervorst and Brand, 1998; Liebler *et al*., 2001; Peterson and Bergmann, 2002; Leach, 2004; Gatterman, 2005; Tortora and Derrickson, 2006

Microscopically, they may have free or encapsulated nerve endings of first order neurons, or they may be separate cells that synapse with first order neurons. Their ability to adapt varies between receptors, and the adaption occurs when the generator potential decreases in amplitude during a maintained stimulus. This influences the perception of a sensation which may fade or disappear even though the stimulus is still persisting (Tortora and Derrickson, 2006:548).

The variation in adaptation may be separated into either rapidly or slowly adapting. Rapidly adapting receptors are specialised for signalling change in a stimulus and adapt quickly, while slowly adapting receptors adapt slowly and continue to trigger

nerve impulses for as long as the stimulus persists (Tortora and Derrickson, 2006: 549-550).

Following a sensory input into the CNS, a motor response (efferent) will be sent to the effector organ/s, resulting in muscular contraction (Tortora and Derrickson, 2006: 405). There are four types of motor neurons, but for this study, the focus was on three of them, as seen in table 2.7.

Table 2.7: Classification of motor neurons

Type	Characteristics	Location	Function
Alpha	Large diameter lower motor neurons with a high conduction velocity	Extrafusal muscle fibres of skeletal muscle	Innervation of extrafusal muscle fibres, and responsible for the initiation of skeletal muscle contraction
Beta	Lower motor neurons with myelinated axons	Originate from the anterior horn of the spinal cord	Innervation of the intrafusal muscle fibres
Gamma	Lower motor neurons with a slower conduction when compared to alpha motor neurons	Cell bodies are located in the anterior horn of the spinal cord	Have a role in keeping the muscle spindles taut, allowing the alpha neurons to fire continuously, leading to muscle contraction. Also have a role in adjusting muscle spindle sensitivity

(Purves, Augustine and Fitzpatrick, 2001; Leach, 2004; Mosby, 2012; Zatsiorsky and Prilutsky, 2012)

2.4.2 Contraction of a skeletal muscle

The CNS controls muscle contraction by sending an action potential along the alpha motor neuron to the muscle fibre. Together they make up a motor unit, which then makes up the functional unit of the muscle (Jones and Greig, 2009: 60). The action potential activates the voltage-gated sodium channels along the axon toward the neuromuscular junction (NMJ). At the NMJ, a rush of calcium ions through the voltage-gated channels occurs, resulting in acetylcholine (Ach) containing vesicles fusing with the plasma membrane releasing Ach into the extracellular space between the motor neuron terminal and the NMJ of the skeletal muscle fibre.

The Ach diffuses across the synapse to enable it to bind to and activate the nicotinic Ach receptors on the NMJ, which then opens the sodium-potassium channel. The action potential spreads through the muscle fibres' network of T-tubules, causing a depolarisation of the inner portion of the muscle fibre, which causes activation of the

calcium channels in the T-tubule membrane. The activated voltage-gated calcium channel interacts with calcium causing the sarcoplasmic reticulum to release calcium, which binds to the thin filaments of the myofibrils allowing tropomysin to move, unblocking the binding sites. These newly uncovered binding sites then allow myosin to attach to them (Hopkins, 2006: 2; Tortora and Derrickson, 2006:300).

When the myosin heads attach along the thin filaments at both ends of a sarcomere, they actively pull the filaments toward the m-line, causing the filaments to slide inward and meet at the centre of a sarcomere. The z-discs then become closer, shortening the sarcomere, as the filaments slide inward, but the lengths of the individual (thick and thin) filaments remains the same. When the sarcomere shortens, the entire muscle fibre shortens, resulting in muscle contraction (Tortora and Derrickson, 2006: 299). During maximal contraction, the z-disc inter-distance can decrease to about half of the resting muscle length (Tortora and Derrickson, 2006: 300). This process is known as the sliding filament theory. Figure 2.4 demonstrates the muscle fibre and the components of the sliding filament theory

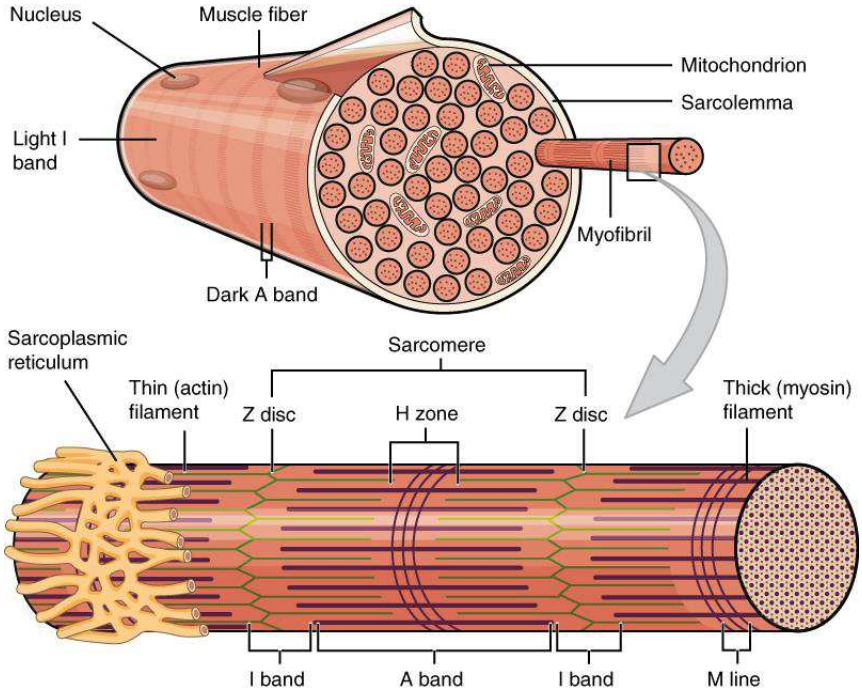

Figure 2.3: Skeletal muscle fibre (Muscle fibre, 2013)

Contraction of a skeletal muscle is mainly voluntary, but there are non-voluntary aspects which are controlled by part of the somatic nervous system (Tortora and Derrickson, 2006:291). When a muscle undergoes a concentric contraction, the

antagonist to that muscle undergoes an eccentric contraction, which is the gradual lengthening and relaxation of the contracting muscle while still maintaining a force output (Moore and Dalley, 2006: 35). For example when the paraspinal muscles contract the abdominal and psoas muscle must relax.

In order for a muscle to be able to function optimally other properties of the muscle must be considered, namely contractility, excitability, elasticity and extensibility. Contractility is the muscles ability to contract when stimulated by an action potential. If there is damage to the muscle fibre, the nerve, or if there are changes to the CNS due to an inadequate release of calcium ions from the sarcoplasmic reticulum the muscle may be unable to contract (Tortora and Derrickson, 2006: 308). Elasticity refers to the ability of the tissue to return to its original length post-contraction, which can be affected by overuse resulting in delayed onset muscle soreness (DOMS). DOMS may be accompanied by stiffness, tenderness and swelling, as a result, affecting elasticity. Extensibility is its ability to stretch without any resultant damage to the muscle tissue (Tortora and Derrickson, 2006: 292) which can be affected by torn sarcolemmas or disrupted Z-discs as a result of overuse (Tortora and Derrickson, 2006: 297).

2.4.3 Monitoring of muscle tone and length

The muscle spindles and the golgi tendon organs are important for proprioception (Haldeman, 2005: 251) and maintaining muscle length–tension relationships (Haldeman, 2005:251; Tortora and Derrickson, 2006: 554).

- **Muscle spindles**

These are specialised stretch-sensitive mechanoreceptors found in skeletal muscles that are activated by changes in muscle length. They lie parallel to the extrafusal muscle fibres and consist of specialised striated fibres known as intrafusal muscle fibres that are enclosed in a connective tissue capsule (Haldeman, 2005: 251).

For motor innervation, muscle spindles receive supply from the gamma motor neurons, collectively known as the fusimotor system when combined with the beta motor neuron. The gamma motoneurons only innervate the intrafusal muscle fibres,

whereas beta motoneurons innervate both the extrafusal and intrafusal muscle fibres, being labelled as skeletofusimotor neurons (Haldeman, 2005:251; Tortora and Derrickson, 2006:555).

When a muscle is stretched, either statically or dynamically, the muscle spindle is activated, signalling an afferent response to the CNS. Static stretching occurs when the muscle is slowly stretched, while dynamic stretching occurs when the length of the muscle is suddenly changed (Haldeman, 2005: 253).

When a muscle is stretched, the intrafusal muscle fibres deform resulting in the initiation of action potentials by activating mechanically gated ion channels in the large diameter Ia afferent axon wrapped around the spindle. This information is then sent to

Golgi tendon organs are sensitive mechanoreceptors located within skeletal muscle fibres, at the musculotendinous junctions (Haldeman, 2005: 251). They are spindle-shaped proprioceptive sensory receptor organs, made up of collagen strands enclosed within a connective tissue capsule, and are often found with other sensory end organs. When the tension in a muscle changes suddenly, the tendon organ will respond with a dynamic response, and this information is then relayed to the nervous system through the Ib afferent neuron. This activates a negative feedback loop that regulates muscle contraction during movement (Haldeman, 2005: 256). The Ib afferents synapse with the Ib inhibitory interneuron which synapses with the alpha motor neuron innervating the same muscle that initiated the Ib afferent, resulting in relaxation of that muscle fiber. This is known as the autogenic inhibition reflex. The Ib sensory feedback aids in evoking spinal reflexes as well as supraspinal reflexes that assist with the control of muscle contraction (Mileusnic *et al*., 2006: 1772), and modulates their action on target motoneurons, and effector organs (Prochazka, Gillard, Bennet, 1997; Tortora and Derrickson, 2006:462-463).

2.5 FACTORS AFFECTING MUSCLE CONTRACTION

2.5.1 Joint dysfunction

Liebler *et al.* (2001: 207) state that muscle length, strength and function may become altered due to spinal joint dysfunction. When a joint has a loss of range of motion it impacts on the muscles ability to work correctly, therefore joint mobility must be restored to improve muscle function. With the origin of the erector spinae muscles spanning the lumbar spine, 11th and 12th thoracic vertebrae, joint dysfunction in these areas may affect the muscles ability to function optimally.

2.5.2 Muscle fascicle length

The arrangement of the fascicles may affect range of motion, as well as power output (Tortora and Derrickson, 2006: 329), due to the length of the fibres in a muscle determining range of motion, therefore, the longer the fibres, the greater the range of motion. However, the power output of a muscle not only depends on its length, but also on its cross-sectional area (Tortora and Derrickson, 2006: 328).

2.5.3 Repetitive muscle contractions

When a muscle is required to repeatedly contract, it may lead to overt skeletal muscle injury and/or mal-adaptation of the muscle (Morris, 2006: 190) and fatigue, exhausting its motor function, which is a decline in the ability to exert force. Although the decline is due to changes in the actual muscle, a change in the CNS occurs. When the muscle is in a state of fatigue the CNS cannot generate an adequate response even though it may have reached maximal strength (Storti *et al*., 2014:173). Further discussion on this is presented in section 2.6.3.3.

2.5.4 Length-tension relationships

Length-tension of a muscle refers to the ability of the muscle to contract based on the length of the sarcomeres within the muscle before contraction (Tortora and Derrickson,

by the length of time one is able to hold a certain position (Haldeman, 2005:253-254), while dynamic endurance is measure by the amount of time a certain activity can be performed using the right technique before fatigue sets in (Haldeman, 2005:255).

When considering muscle endurance the physiological types of muscle fibres must be considered. The slow-twitch fibres are better suited for low levels of force and are more resistant to fatigue when compared to fast-twitch fibres. Individuals with a higher percentage of slow-twitch fibres typically have the ability to perform more repetitions (Vøllestad, 1997: 222). Therefore, when assessing a muscle for endurance capacity, the physiologic composition of the muscle should be taken into account along with the activity being assessed.

2.6.1. Paraspinal muscle endurance

A decrease in paraspinal muscle endurance has been associated with low back pain, and has also been found to predict the future development of mechanical low back pain (MLBP) (Biering-Sorensen, 1984; Joseph and Richardson, 1996: 260; Demoulin *et al*., 2006). Assessing the paraspinal muscles for endurance has been used as a tool to discriminate between healthy individuals and those with MLBP (Biering-Sorensen, 1984). Kankaanpaa *et al*. (1998b: 414) found that low back pain was associated with an increase in fatigability of the lumbopelvic extensor muscles as demonstrated by shorter back muscle endurance test duration, leading to an imbalance of the low back musculature, which can be measured. MLBP is the most prevalent musculoskeletal condition and one of the most common causes of disability in developed countries, commonly occurring in people under the age of 45 (Jette *et al*., 1994), with a lifetime prevalence of 60-90% (Kirkaldy-Willis and Bernard, 1999). Due to the high disability and costs associated with MLBP, more research is needed to improve the management of MLBP (Mannion *et al*., 1997: 881).

2.6.1.1 Measures of paraspinal muscle endurance

Clinical tests are commonly used to assess paraspinal muscle endurance as a mechanism to prevent future low back pain episodes (Mannion *et al*., 2011: 850). There are various ways to assess paraspinal muscle endurance, however the clinicians must be aware that besides assessing for fatigability of the muscles, other

factors in the clinical setting such as pain, dysfunction, and physical disability could influence the outcome (Ali, Bandpei and Watson 2001:470; Mannion *et al*., 2011: 850).

- **Electromyography**

EMG can be used to assess the functional anatomy of muscular structures, the excitability of neurons and the firing characteristics of motor units (Türker, 1993: 698; Ito *et al*., 1996: 75; Daube and Rubin 2009: 249). The EMG activity of skeletal muscle has been of interest to researchers due to it being a representation of the outflow of motoneurons in the spinal cord to the muscle (Türker, 1993: 698).

Surface electromyography (sEMG) has been utilised as a tool to provide objective assessments of the changes occurring in paraspinal muscle function and to quantify endurance (Peterson and Bergman, 2011: 81). It can be used to study biofeedback and the excitability of motoneurons (Türker, 1993: 698), and has become a common tool in the assessment of lumbar musculature (Ali, Bandpei and Watson, 2001: 470). Duchateau *et al.* (2002) stated that longer duration contractions seem to involve greater neural adaptations, hence utilising sEMG enables one to determine the individual frequencies of the EMG signal, enabling the ability to distinguish the fatigability of the different muscles. Duchateau *et al* (2002) and Dankaerts *et al* (2004) have stated that there is limited research on the reliability of MVC and submaximal voluntary contractions (sub MVC) for muscles in healthy as well as low back patients, however, MVC are still utilised to provide the basis for normalisation when evaluating muscle dysfunction and/or pathology, as was done in this study.

When utilising sEMG, the technique utilised has to be designed in a way that minimises noise and any artefacts in order to obtain correct readings, due to sEMG being more susceptible to artefacts when compared to intramuscular or fine-needle EMG (Türker, 1993: 698). The reliability of this tool relates to the spectral parameters of the sEMG signal which are not under voluntary control by the participant when performing a sustained contraction, but rather influenced by metabolic fatigue processes (Roy *et al*., 1995:39).

With sEMG, surface electrodes are used to obtain data from the areas, or muscles, being assessed, and these can either be active or passive. Passive surface electrodes have a lower input resistance than do active electrodes, and are also affected by any

change in skin resistance (Türker, 1993: 699). Surface electrodes are commonly used when assessing the erector spinae musculature and not deeper lying muscles like the multifidus or rotatores, due to them being more sensitive to superficial lying muscles. For deeper lying muscle groups, wire or fine-needle EMG is preferred for more accurate readings (Fryer *et al*., 2006: 438).

The use of needle EMG requires a therapist who is knowledgeable in anatomy, physiology, pathophysiology, and the peripheral nervous system as specific points must be found (Daube and Rubin, 2009: 244). Needle EMG is associated with greater risk due to its invasive nature and one must assess for skin infection, bleeding due to a disorder and cardiac valvular disease (Daube and Rubin, 2009: 244). These risks make the use of needle EMG less favourable.

- **Biering-Sorensen test**

The Biering-Sorensen (B-S) test has been used to measure fatigability of the paraspinal muscles based on measuring the endurance time (Kankaanpaa *et al*., 1998a: 1069; Pääsuke *et al*., 2002: 17). The Biering-Sorensen test is considered the gold standard for measuring isometric lower back muscle endurance (Müller, Strassle and Wirth, 2010: 845), and is commonly used in clinical practice (Latimer, Maher and Refshauge, 1999: 2086). It is a test that is easy to perform, and requires no special equipment (Müller, Strassle and Wirth, 2010: 845). It has been shown to be a valid and reliable (Latimer, Maher and Refshauge, 1999: 2086) measure of spinal extensor muscle endurance used in clinical practice, and discriminates healthy individuals from patients with low back pain (Demoulin *et al*., 2006: 47).

As outlined by Kankaanpaa *et al*. (1998a), the Biering- Sorensen test is performed by having the participant lie prone on an examination table with the upper edges of the iliac crests aligned with the edge of the table and their upper body extended beyond the edge of the table. Their lower body is strapped to the table at the hips, knees and ankles. The participant is then instructed to fold their arms across their chest and hold their upper body in the horizontal position as illustrated below in figure 2.4, during which the participant is timed to see the duration that they can sustain the contraction.

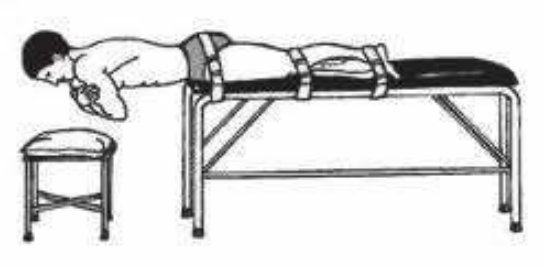

Figure 2.4 Biering-Sorensen Test (Biering- Sorensen test, 2013)

Kankaanpaa *et al*. (1998a) found that women demonstrated better extensor muscle endurance when compared to men, therefore only males were recruited for this study. Mannion *et al*. (1997) showed that right hand dominance can result in different sEMG readings when compared to left hand dominant individuals (Mannion *et al.,* 1997), therefore only right handed individuals were recruited for this study.

- **Ito test**

The Ito test was first described in 1996 for evaluating isometric lower back muscle endurance (Ito *et al*., 1996: 76). The test is performed by the participant lying prone with a small pad beneath the abdomen, with their arms at their sides as demonstrated in figure 2.5. The participant lifts the sternum off the table while flexing the neck and contracting the gluteus maximus muscle for stabilising the pelvis. This test has been hypothesized to result in less spinal loading when compared to the Biering-Sorensen test (Müller Strassle and Wirth, 2010: 845), and does not seem to induce any pain (Demoulin *et al*., 2006: 47).

Figure 2.5 The ITO test (Ito test, 2001)

- **Other tests**

There have been other methods such as dynamometric measurements and evaluations where a dynamometer is utilised to evaluate the isometric spinal endurance (Demoulin *et al*., 2006: 46). Previous authors reported that these measurements were superior to the Biering-Sorensen test in several ways, namely better reproducibility, greater discriminative validity, smaller influence for anthropometric factors, and less time required to carry out the test. However, due to the need to determine the maximal voluntary force, this test may be inappropriate for some patients (Demoulin *et al*., 2006: 46).

Another method was repetitive arch-up tests that provided a dynamic evaluation of the trunk extensor muscles without requiring the use of a dynamometer. The position was derived from that of the Biering-Sorensen, and consists of flexing the trunk at a 45 degree angle, then returning to horizontal as many times as possible, at a rate of one arch-up every two to three seconds (Demoulin *et al*., 2006: 47).

2.6.2 Muscle fatigue

Muscle fatigue has been defined as a reduction in the ability of the muscle to generate force or power output, more especially the maximal capacity (Vøllestad, 1997:219). This may be due to an imbalance between Sodium (Na) and Potassium (K) ions over the sarcolemma and t-tubule membrane occurring during exercise, which may also impair the propagation of the action potentials. As a result, the amount of calcium (Ca^{2+}) released from the sarcoplasmic reticulum decreases, resulting in the attenuation of the binding abilities of Ca^{2+}. Due to the decreased Ca^{2+}, fewer cross-bridges will be formed between actin and myosin molecules, resulting in a lower force or power output (Vøllestad, 1997:221; Tortora and Derrickson, 2006: 302). In order to accurately measure human muscle fatigue, one has to utilise reliable and valid measurement tools that should include the assessment of maximum voluntary control (MVC), or the force generated by electric stimulation.

The pattern of motor unit activation has proven to be a challenge when assessing muscle fatigue in human participants (Vøllestad, 1997; Gandevia, 2001). When a submaximal contraction is performed, the type I muscle fibers are recruited from the beginning, and as the exercise progresses, the type II muscle fibers will be recruited. By the end of the exercise, or at exhaustion, most, if not all, motor units will be recruited

to help the muscle sustain the exercise. As a result, the physiological response of the whole muscle is altered, but without any change to the individual muscle fibres (Carmins and O'Leary, 1987; Shirley, Lee and Ellis, 1999).

This physiological response is what is assessed in order to collect data that aids in quantifying fatigue, and is where sEMG is commonly utilised. The surface electrodes have the ability to pick up the electrical activity of superficial muscles, enabling the researcher to determine the amplitude and power spectrum of the signal. The amplitude reflects the size as well as the number of the action potentials in the muscle during sustained effort (Vøllestad, 1997:225). During maximal isometric contractions, the amplitude falls progressively due to a gradual decline in the number of excitable motor units, which might suggest that EMG is a good marker for fatigue assessment, hence the decision to use it in this study.

2.7 SPINAL MANIPULATIVE THERAPY (SMT)

Spinal manipulative therapy (SMT) is a non-operative treatment modality commonly used by chiropractors and other manual therapists in the management of musculoskeletal conditions (Dishman, Dougherty and Burke, 2005: 650; Haldeman, 2005: 150; Cramer *et al*., 2006: 726). The term SMT encompasses soft tissue techniques, manipulation and mobilisation (Maigne and Vautravers, 2002: 336). SMT has been found to decrease pain, improve joint function, and restore normal joint motion (Brenner *et al*., 2007: 613).

When SMT is applied, it is applied to either a part of the body that acts as a lever, or directly to a spinous or transverse process (Maigne and Vautravers, 2002: 336), often resulting in the separation of the articular structures, causing them to gap (Pickar, 2002: 359; Cramer *et al*., 2006: 727). This is referred to as a joint cavitation and is often associated with a 'cracking' sound (Herzog, 1994:270).

SMT is intended to impart a force on the joint which forces the joint surfaces beyond the initial barrier of resistance to the anatomical limit of safe joint play (Millan et al., 2012:2), whereas mobilisation moves the joint passively back and forth up to its barrier of resistance and no further (Leach, 2004:32).

SMT is directed at spinal segments that demonstrate a loss of normal motion (joint hypomobility), often associated with tenderness over the spinous process (Leach, 1994: 32; Haldeman, 2005: 750), and referred to as joint subluxations. A joint subluxation affects the connective tissue, nerve, blood vessel, and muscles around the involved joint (Cramer et al., 2006: 727). They may result from immobilisation, intercapsular adhesions, muscle spasm and intraarticular meniscoid entrapment (Gatterman, 2005: 233). Generally, SMT is directed at spinal segments in the direction of motion lost to enable normal motion in that joint in all directions (Maigne and Vautravers (2002); Haldeman, (2005)). Therefore for maximum result, these authors have hypothesised that moving the joint in the direction of its 'natural' motion yields a better result.

The most commonly used spinal manipulation in the clinical setting is the high velocity low amplitude (HVLA) thrust which when delivered to the spine involves the therapist contacting the paraspinal tissues overlying the processes of the vertebra at the segment being manipulated (Pickar, 2002: 358). There is short term distraction of the facet joints, stretching of the paraspinal tissues which may induce relaxation and a disruption of the pain cycle (Maigne and Vautravers, 2002: 336). This type of manipulation is more often than not accompanied by an audible crack, caused by activity occurring within the synovial fluid of the joint, termed a cavitation (Evans, 2002: 251).

The thrust-like force of the HVLA manipulation breaks down adhesions that may be in the joint by separating the articular surfaces of the facet joints, increasing the mobility in the joint, establishing normal range of motion (Evans, 2002: 251; Cramer *et al*., 2006: 727). It may also release entrapped meniscoids as well as reduce the mechanical stress in paraspinal tissues (Peterson and Bergman, 2002; Cramer *et al*., 2006: 727).

Herzog (1994) reported a temporary deformation of the vertebral column when HVLA SMT was applied to the tissues, and found that the peak forces ranged from 300 -600 Newtons (N) when SMT was applied to the lower thoracic spine, at levels T10, T11 and T12. A reflex response was observed in the surrounding muscles within 100 msec that was quantified using sEMG. Hessel *et al*. (1990) examined preload and peak forces applied to the cervical and lumbar spines, and found that the preload forces

ranged from 20 to 180 N, while the impulse forces peaked from 200 to 420 N, with the impulse duration being between 30 and 120 ms. When utilising this type of SMT in research there are several variables that need to be controlled such as the skill of the clinician (Haldeman, 2005:752), the force utilised to delivered the thrust (Kawchuk *et al*., 2006: 611) and the position of the patient (Symons *et al*. (2000: 158).

An alternative to HVLA thrust manipulation is the use of a mechanical device to deliver spinal manipulation. These devices are often favoured in the clinical setting as they alleviate the stress that manual HVLA thrusting imparts to clinicians hands therefore decreasing the likelihood of injury (Keller and Colloca, 2000: 586). There are two devices on the market that are commonly used. The first is the activator instrument

The Activator Methods Chiropractic Technique (AMCT) assessment protocol was utilised in the application of the IAI thrusts to the paraspinal muscles. The authors of the protocol stated that applying the thrust in a combination of directions yielded better results than when a single direction thrust was applied (Fuhr *et al*., 1997). Therefore, the choice to use multiple directions for the intervention for this study.

Keller and Colloca (2000:585) demonstrated an increase in erector spinae isometric activity after administering SMT using a similar device. They found that the benefit of using this type of manipulative instrument in research is that it aids in the administration of a standardised force as opposed to manual HVLA manipulation which may be clinician dependant. However, Kawchuk *et al.* (2006) found that using force-producing instrumentation decreased the variation in force magnitude as well as duration when compared to manual techniques, but differences still occurred between operators.

Due to the pragmatic nature of this study, the IAI was chosen over both the activator instrument and the HVLA thrust to administer the manipulation in this study in an attempt to standardise the preload force and the thrust delivered. However, due to it still being operator dependant i.e. the clinician utilising the instrument does not utilise the same force consistently, variability in the results may still occur however this would occur in regular clinical practice.

2.7.1 The neurophysiological effects of SMT

The exact mechanism underlying the effectiveness of SMT is not well understood (Dishman and Bulbulian, 2000). Currently there are three main theories for the mechanisms of SMT, namely, mechanical (realignment of vertebral motion segments), reflexogenic (relief of pain with a decrease in muscle hypertonicity and improvement in functional ability), and neurophysiological (the release of neurotransmitters) (Herzog, Scheele and Conway, 1999; Maigne and Vautravers, 2002).

Fryer, Morris and Gibbons (2004) suggested that manipulation activates mechanoreceptors and proprioceptors from structures surrounding the joint being manipulated, resulting in reflex relaxation of the paraspinal muscles adjacent to the manipulable lesion, or, subluxation. This physiological response affects the inflow of sensory information to the central nervous system (CNS), altering neural pathways

(Pickar, 2002: 357). The mechanical input could either stimulate or silence mechanosensitive receptive endings in the skin, muscle, tendons, facet joints and IVD (Pickar, 2002:359).

Korr (1975) originally theorised that when there was a joint subluxation, both the motor and autonomic functions were affected, resulting in the neurons becoming hyper responsive to any input from the CNS. When this facilitation occurred, the afferents from the tissues adjacent to the subluxation were involved. It was proposed that the muscle spindle mainly co-ordinated either an increase or decrease in muscular contraction according to the direction of joint motion. The fusimotor systems were implicated. The CNS would adjust the imbalance in the muscle spindle during extrafusal contraction by adjusting the level of activity in the fusimotor system. The imbalance in the spindle was taken up by the gamma motor activity and the CNS adjusted the level of fusimotor activity based on the needs of the muscle, be it an increase or decrease (Leach, 2004:29).

Korr (1975) proposed that spinal manipulation increases joint mobility by producing impulses in muscle afferents, decreasing pain, restoring joint function and silencing gamma-motoneurons. He proposed that this was achieved by having the intrafusal muscle fibres stretched against their spindle-maintained resistance, which would then produce “a barrage of afferent impulses intense enough to signal the central nervous system (CNS) to reduce the gamma motoneuron discharge” (Pickar, 2002: 359).

Initial investigations into the neurophysiological effects of spinal manipulation, as seen in table 2.8, showed that a neuromuscular reflex response occurred following spinal manipulation irrespective of the type of manipulation used. However, these preliminary trials consisted of one group investigations with no placebo or control group to compare the results.

Table 2.8: A summary of the studies investigating the reflexogenic effect of SMT

Author	Sample size	Study design	Type of Intervention	Outcome measures	Results
Herzog, Scheele and Conway,1999	*n =10* Asymptomatic male participants	Pre-test, post-test	Clinically relevant SMT	EMG reflex responses of back and limb muscles	Reflex responses post SMT treatment

Symons *et al.*,2000	*n =9* Asymptomatic volunteers	Pre-test, post-test	Activator	EMG responses of paraspinal and proximal limb muscles	68% had a detectable reflex response post SMT thrust
Colloca and Keller, 2001	*n = 20* 10 males and 10 females with low back pain (LBP)	Pre-test, post-test	MFMA SMT	Magnitude of EMG reflex responses in the paraspinal muscles	Consistent reflex responses

Pickar and colleagues (as described below) conducted a series of studies to determine the effect of SM on muscle spindles and GTO's and whether the mechanical properties of SM influenced the neurophysiological outcome. Pickar and Wheeler (2001) found that single unit activity from muscle spindles and GTO afferents were recorded following a HVLA SMT on 10 felines. The muscle spindles discharged at rest, they responded to the preload force and to the impulse thrust, with the impulse thrust resulting in the most activity. Following this, Pickar and Kang (2006) (n = 46 felines) demonstrated that when loads were applied that were similar to HVLA SM to the lumbar paraspinal muscles, the HVLA SM affected the MS sensitivity to velocity more than to length change. Pickar *et al*. (2007) further investigated the duration and amplitude of SM (n = 54) confirming the earlier findings of Pickar and Kang (2006), but illustrated a curvilinear relationship of thrust duration and MS activity peaking at 50 to 100 ms, and that the MS were more sensitive to lower amplitude thrusts (1 mm compared to 2 mm). The authors concluded that the HVLA SM takes advantage of the properties of MS which may result in this clinical effect. The findings of these studies support Korr's theory where afferent bombardment of the dorsal horn results in altered efferent motor output.

Following these studies Cao *et al*. (2013), using anesthetised cats (n = 112), found that relatively low-amplitude thrust displacements applied during HVLA SM produced sustained increases in the resting discharge of the paraspinal muscle spindles. They found that when HVLA SM is imparted on the lumbar region, the preload forces range from 20 to 180 N and generally last between 0.5 and 2.2 seconds. This finding supports Pickar and Wheeler (2001). This study investigated whether changes in peripheral sensory signalling persisted beyond the duration of the actual manipulative thrust. These studies illustrate that when HVLA manipulation is utilised there is an

effect on the MS and GTO, however these studies were conducted on felines and not humans.

Nougarou *et al*. (2014) (n = 23), conducted a similar study, but on human participants. They also found that applying a preload force to the paraspinal muscles resulted in neuromuscular responses, further demonstrating the effect of SM on the MS. In addition, they also found that with increasing preload forces, an increase in neuromuscular responses followed. Pickar and Bolton (2012) concluded that SM appeared to alter mechanosensitive paraspinal afferent neurons resulting in prolonged alterations in the efficacy of central neurons. Niazi *et al* (2015) conducted a study on investigating the effect of SM on neural plastic changes by assessing the H-reflex (n = 10). They found that following SM of the spine and sacro-iliac joints that the MVC of the soleus muscle statistically ($p = 0.03$) improved, together with a decrease in the H-reflex ($p = 0.018$) when compared to a control group. Indicating that the SM affected the modulation and/or increased the descending drive of the afferents, this resulted in decreasing the fatigue level of the soleus muscle when maximally contracted.

Clark *et al.* (2011) investigated SM in human participants by using transcranial magnetic stimulation to motor evoked potentials (MEP) in the paraspinal muscles of 10 asymptomatic and 10 symptomatic participants (with low back pain), pre and post SM. They found no changes to the paraspinal MEP, or the stretch reflex amplitude, in either group, interestingly, on subgroup analysis based on joint cavitation. They found a 20% decrease in the stretch reflex indicating that cavitation may be necessary to decrease MS activity or the Ia reflex pathway. Similarly, Indahl *et al*. (1997) had found that after injecting saline into porcine facet joints, it resulted in a reduction in action potential amplitude of the motor units in the paraspinal muscles (using needle EMG), indicating that mechanoreceptors in the joint capsule may have a role in the effects of SM.

Milan *et al.* (2012) hypothesised that SMT alters motoneuron excitability, affecting pain regulation in the dorsal horn of the spinal cord, as well as the periaqueductal grey area. The manipulation aids in turning down the excitability of the motoneurons, bringing about relief as a result. Haavik and Murphy (2012) have also supported these findings by stating that SMT has an effect on sensory processing and sensorimotor integration of the CNS, resulting in improved motor output, as well as functional

performance, due to a number of activities being dependent on appropriate sensorimotor integration. These integrations between the sensory and motor systems are what enable us to engage with the environment around us.

One of the diagnostic features of a joint dysfunction is altered tissue texture (Fryer *et al*., 2006: 437) often associated with decreased muscle strength and/or function (Liebler *et al*., 2001: 207). In order for the corresponding muscles to work and return to their normal texture, the joint has to have normal mobility (Liebler *et al*., 2001: 207), and this can be achieved with SM, due to it acting on the various components of the motion segment (Maigne and Vautravers, 2003: 336).

Keller and Colloca (2000) investigated changes in maximum voluntary contraction (MVC) of the paraspinal muscles in a SM (using a MFMA) and sham/control group in participants with low back pain (n = 40). Those receiving SM had a significant increase in sEMG erector spinae isometric MVC muscle output (21% from pre- to post-) compared to only 5.8% in the sham group, indicating that SM may alter muscle function due to its effect on the somatosensory system.

Limited evidence is available to show that SM may affect the functioning of the spine. Lehman and McGill (2001) conducted a study to determine the influence of a manipulation on trunk kinematics and myoelectric activity in the paraspinal and abdominal muscles. They measured the trunk kinematics of 14 participants with LBP while they performed range of motion tasks using sEMG. The sEMG signals were recorded both pre and post manipulation. They found that although no significant, consistent kinematic or sEMG changes were observed; individual changes were observed, often more noticeable in those participants whose pain and dysfunction was more severe.

Bicalho *et al*. (2010) conducted a study on nonspecific chronic LBP participants (n = 40). They analysed the immediate effects of HVLA manipulation on paraspinal muscle activity during flexion and extension movements. They found that the EMG activity during the static relaxation phase was reduced post manipulation for the intervention group but not the control. Similarly, extension EMG activity decreased but not for flexion in the SM group. The authors proposed that following SM either the alpha motor unit ‘drive’ was reduced or that there was an increase in alpha motor unit inhibition. More commonly, SM is associated with inhibited neuromuscular activity.

Following this study, Harvey and Descarreaux (2013) assessed flexion and extension movements pre and post SM in participants with LBP (n = 60) compared to a control group. However, they found that significant differences occurred in the control group with an increase in EMG activity at L2 after 30 minutes. The authors suggested that one of the effects of SM may be the ability of the erector spinae muscles to recruit and in so doing become less fatigue resistant. They suggested that SM may modulate the sensitization that occurs in chronic low back pain suffers. These studies provide some evidence that SM may affect muscle function.

Other models have been proposed to explain the effect of SM, this involves the sensitisation of nociceptors and other mechanosensitive receptive endings that occur during injury, resulting in the release of endogenous substances which may reduce the stimulus threshold of nociceptors, suggesting that even a weak stimulus can excite nociceptive receptors and elicit muscular pain. These neural inputs have been reported to maybe have an effect on pain-producing mechanisms that are controlled by the nervous system (Pickar, 2002). Potter, McCarthy, and Oldham (2005) stated that SMT resulted in an increase in beta- endorphins, when compared to sham manipulation. These beta- endorphins have been found to exert their anti- nociceptive effects by decreasing the effectiveness of endogenous substances, e.g. substance P, in the dorsal horn, effectively decreasing afferent nociceptive input. They concluded that there is evidence for the effect of SMT on the anti-nociceptive properties of endogenous substances. However this model involves pain and as the participants in this study were pain free the relevance to this study may be limited.

What is not yet clear is the extent to which the changes associated with SM correlate with beneficial clinical outcomes, due to there being limited evidence on the effects of SM on muscle function with even less literature on whether SM affects muscle endurance. The current study was designed in a manner that would attempt to assess whether SM of the lower thoracic spine would affect paraspinal muscle endurance in an asymptomatic population. This area was selected due it being the area where the thoracic component of the paraspinal muscles, the pars thoracis, produces the greatest amount of extension (McGill, 2007).

2.8 Placebo

The use of placebo in research has been considered as a gold standard for non-bias results (Hill, 1994:394). Though there have been arguments about the ethical considerations of having placebo, Hill (1994) stated that “one can argue that withholding an accepted treatment may not lead to serious harm”, that if participants are fully aware of the risks involved and they give their informed consent, then the participants should not be prevented from taking part. Hill (1994) also stated that placebo allowed the researcher to determine the efficacy of an already tested treatment, or intervention, protocol, and that placebo offers the researcher a “clear benchmark”.

Colloca and Keller (2000) utilised a placebo group in their study, and found that the outcomes observed in the treatment group provided an additional insight toward understanding the hypothesised physiologic mechanisms associated with SMT. Studies based on a sham-SMT effectively control for any influence associated with the doctor-patient interaction (Colloca and Keller, 2000).

CHAPTER THREE: METHODOLOGY

3.1 STUDY DESIGN

The current study was a randomised placebo-controlled pre-test post-test experimental design. The study was approved by the Institutional Research Ethics Committee of the Durban University of Technology (084/13, Appendix I) and was registered with the South African Clinical trials register (registration number: DOH-27-0114-4605; Appendix J). The study was conducted at the Durban University of Technology Chiropractic Clinic, after permission was obtained from the Clinic director (Appendix H).

3.2 STUDY POPULATION

Right handed, male participants, between the ages of 20-40 were recruited from the greater Durban area in the eThekwini Municipality of KwaZulu-Natal.

3.3 SAMPLING PROCEDURE

3.3.1 Sample recruitment

Advertisements (Appendix A) were placed, once appropriate permissions was sought, at the Durban University of Technology (DUT) campus, the DUT Chiropractic Clinic, and local sporting clubs informing potential participants of the research. Potential participants were required to contact the researcher or the Chiropractic Clinic telephonically, where they were screened for eligibility via the following questions:

- Are you between the ages of 20-40?
- Are you male?
- Are you right handed?
- Are you currently experiencing low back pain?
- Have you experienced any low back pain in the last six weeks?
- Have you had any major trauma/ surgery to your back?

- What is your weight in kilograms and height in metres? (for body mass index (BMI) determination)

On answering “YES” to the first three questions, and “NO” to the next three, an appointment was arranged at the DUT Chiropractic Clinic for a consultation. At the consultation the participant was given a verbal explanation of the research as well as a letter of information and informed consent (Appendix B), which was required to be signed prior to joining the research. The participant was given the opportunity to ask any questions, and was made aware that they could withdraw from the study at any time without any repercussions for future care at the DUT Chiropractic Clinic.

3.3.2 Sample size

A sample size of 40 participants was utilised for this study based on studies in the literature that had been conducted using smaller samples and similar measurement tools (Keller and Colloca, 2000; Colloca and Keller, 2001; Krekoukias, Petty and Cheek, 2009; Bicalho *et al*., 2010). A pilot study was performed whereby 20 participants were recruited with 10 being allocated to the intervention and 10 in the placebo group. A priori analysis using a power of 80%, with alpha 0.05, and effect size calculated at 1.39 for the Biering-Sorensen test for paraspinal extensor endurance, resulted in a minimum of 11 participants being required in each group to detect post-intervention changes. The sample of 20 per group was selected, as the sample size calculation for the surface EMG readings was unattainable given the feasibility constraints, therefore the surface EMG readings would be assessed for trends and to provide provisional data for future studies.

3.3.3 Sample allocation

The participants were randomly allocated using a random allocation chart that was drawn up by a statistician into two equal groups of 20:

- Group A – Intervention group
- Group B – Placebo group

A random allocation chart is the easiest type of probability sampling that provides the unpredictability of intervention assignment. In this type of probability sampling, intervention assignment is made by chance without regard to prior allocation (Dettori,

2010). For this study, the allocation chart was kept by the research assistant for the duration of the study to minimise the effect of bias.

3.4 SAMPLE CHARACTERISTICS

The following sample characteristics were necessary for inclusion into the study, as were determined through a case history (Appendix C), physical examination (Appendix D), thoracic regional (Appendix E), and lumbar regional examinations (Appendix F).

3.4.1 Inclusion criteria

1. Participants were included in the study once they had given their signed informed consent (Appendix B).
2. Participants were male, between the ages of 20-40, and right hand dominant. The 20 – 40 age group was selected to exclude those who would potentially have degenerative changes (Jette *et al*., 1994).
3. Participants would need to have at least one manipulable lesion between T8-T10, determined by motion palpation performed according to the techniques of Peterson and Bergman (2002).
4. Poor ability to perform the Biering Sorensen test i.e. weak extensor muscle endurance.
5. Participants were required to have a BMI that fell within the normal range of between 18.5 kg/m² and 24.9 kg/m² due to previous studies having demonstrated that BMI has an effect on paraspinal muscle endurance (Kankaanpaa et al, 1998a).

3.4.2 Exclusion criteria

1. Individuals with any contraindication to manipulation, as determined through the case history, physical, regional and orthopaedic examination, including, but not limited to: tumours, bone infections, metabolic disorders (osteoporosis) and traumatic injuries.
2. Individuals who had received spinal manipulation of either the thoracic or lumbar spine within the last three weeks.
3. History of spinal surgery.

4. Any trauma to the spine e.g. fractures.
5. Individuals experiencing any spinal pain or utilising non-steroidal anti-inflammatory drugs (NSAIDS) and muscle relaxants.
6. Patients with chronic conditions that were at risk for physical activity, including, but not limited to cardiac and/or respiratory disease, neurological symptoms and hypertension.
7. Contra-indications for surface electromyography (sEMG), including, but not limited to cardiac pacemakers, open wounds, or skin conditions of any region of electrode placement (NeuroTrac^{TM} ETS: Operators manual, 2007).

3.5 MEASUREMENT TOOLS

3.5.1 Subjective measurement

The participant was asked to verbally communicate any discomfort or pain they felt while performing the Bering-Sorensen test. This was recorded along with the time at which the pain/discomfort was felt.

3.5.2 Objective Measurements

3.5.2.1 The Biering-Sorensen test

The Biering-Sorensen test was conducted as outlined by Kankaanpaa *et al*. (1998: 1070) and described in Chapter Two. Prior to collecting the research data the participant was taught, by the researcher, how to correctly perform the Biering-Sorensen endurance test.

3.5.2.2 Surface electromyography

The NeuroTrac™ ETS (Verity Medical LTD, Uplands Place, Drove Road, Chilbolton, England, ISO9001: 2000, MDD93/42/EEC) was utilised to obtain sEMG readings. The unit was set to the EMG mode, where duration of five minutes was selected in template training in the open display mode.

NeuroTrac^{TM} ETS is a dual channel surface EMG with an EMG range from 0.2 to 2000 microvolts RMS (continuous), the sensitivity is 0.1 microvolts RMS, with an accuracy of 4% of microvolts reading +/-0.3 microvolts at 200 Hz. It has a selectable bandpass

filter, with 3 db bandwidth using a PP3 Alkaline battery (Neurotrac TM operators manual (2007: 25). Self-adhesive hypo-allergenic electrodes (VS .30 30mm diameter, round) were utilised. The skin where the sEMG electrodes were to be placed was cleaned with alcohol, and if necessary, the hair in the area was shaved using a new disposable razor (NeuroTrac^{TM} ETS: Operators manual, 2007). The 30mm round, non-latex sEMG electrodes, channel A and B, were placed on the muscle bellies of the erector spinae muscles at the level of T10 and at L3, respectively, on either side of the spine, with electrode pads being placed seven centimetres apart, with Channel A and B were placed on the left and the right, respectively. The mean micro volts (μV) were recorded for both channel A and channel B.

The NeuroTrac^{TM} ETS may be subject to electromagnetic interference; as a result during the test the lights were turned off and there was no conversation between the researcher, research assistant and participant, except when the participant communicated discomfort, to minimise any effect on the sEMG readings. The NeuroTrac^{TM} ETS unit was kept as close to the subject's body as possible, and not left to hang free in the space away from the subject (NeuroTrac^{TM} ETS: Operators manual, 2007: 3).

Before the test session, the participant was asked to perform the Biering-Sorensen test to set their individual threshold limits, due to varying levels for each individual. The threshold level is a target which a patient/ participant aim's to achieve when they contract their muscles, in this case, the paraspinal musculature, when performing the exercise. This was achieved by having the participant perform the Biering-Sorensen test in order to contract the paraspinal muscles. They were to hold the Biering-Sorensen test contraction for five seconds, rest for ten seconds, and then repeat the contraction. The reading for this contraction was done in microvolts and was recorded by channel A. The researcher then took the average of these two readings; calculated 40% of that average, and that was then set as the threshold for that participant by adjusting the value that was on the top of the LCD screen, by means of pressing B-THRS+ or B-THRS- (NeuroTrac^{TM} ETS: Operators manual, 2007) buttons until the desired value was reached.

This was done so as to set the individual threshold levels for each participant, due to individuals having different threshold levels. This threshold calculation was used to

determine the activation intervals for each of the muscles. These intervals are helpful in that they aid in demarcating the beginning as well as the end of each contraction of each participant. To ensure the correct EMG parameters for the NeuroTrac^{TM} ETS were set the researcher pressed the SET button until WDE FLTR or NRW FLTR was displayed on the LCD screen. The researcher 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 (NeuroTrac^{TM} ETS: Operators manual, 2007).

The sEMG was only able to give a peak, minimum and mean reading. Therefore, the study was designed so that the sEMG would only be actively recording myoelectric readings while the participant was actively engaged in the BS test and making contact with the rope. This would allow the mean reading to be representative of the muscle response while engaged in the BS test, this mean reading was then used to normalise the data to compare changes between pre- and post-measurements.

3.5.2.3 Lumbar spine range of motion

The Saunders digital inclinometer was utilised in this study. It has been found to be an objective, valid, reliable tool (Saur *et al*., 1996: 133). Between each measurement the participant would return to neutral and the researcher would zero the inclinometer. An average of three readings was taken per movement. The following measurements were taken for the lumbar spine:

- Flexion: the participant would lean forward from the upright position as much as they could, during which time the researcher would measure the lumbar range with the inclinometer.
- Extension: the participant would lean back as much as possible without pushing their pelvis forward, and the researcher would measure that angle.
- For left and right lateral flexion, the participant would once again start at the neutral position and would tilt to the side being measured as much as they could without rotating their shoulders to aid further flexion.

3.6 INTERVENTIONS

3.6.1 Intervention group

The Impulse Adjusting Instrument® (IAI) (101 S. Roosevelt Avenue, Chandler, AZ 85226 USA) was utilised to deliver the spinal manipulation in this study. Each participant in the intervention group received a manipulation by the research assistant, in order to try and standardise the operator, with the IAI, whereby 12 consecutive thrusts were delivered at a rate of 6Hz, per 2 seconds, with the force adjustment switch set to setting two, resulting in the unit imparting a 200N force per thrust (Colloca and Keller, Impulse Adjusting Instrument® Operations manual, 2009: 4).

The line of drive was anterosuperior and medial to lateral (The Neuromechanical System, 2008). Prior to delivering the thrusts the research assistant made the IAI contact the paraspinal tissues, between T8- T10, by contacting the facet joints of the segment that was found to be fixated. Once the nosepiece made contact with the skin the preload phase of the IAI was activated resulting in the LED light adjacent to the Force Adjustment Switch turn to amber. The research assistant continued to press into the skin until the spring was fully compressed resulting in the LED light changing from amber to green, indicating that the preload pressure, of 20N, had been met and the IAI was now ready to deliver the thrusts. The electronic trigger was then compressed activating the rapid pulse mode to deliver the manipulative thrusts. Once the IAI delivered the 12 thrusts the spinal manipulation was complete.

3.6.2 Placebo group

The above procedure was followed in the placebo group however once the preload light changed from amber to green no thrust was delivered but a second IAI was used to thrust into the air resulting in the participant hearing the click, but not actually receiving the manipulative thrusts.

3.6.3 Blinding

A research assistant, a registered chiropractic student who had completed all their clinical training and who was seeing patients in the clinic, was utilised to allocate the participants to one of two groups using a computer generated random allocation chart

(Brink, 2006) that was drawn up by a statistician. This chart was given to the researcher in a sealed envelope that the researcher passed onto the research assistant. The research assistant was also utilised to check the researcher's level of found restrictions, as well as administer the various interventions. Double blinding was used so the researcher would not know which group the participant was allocated to, and the participants were also blinded because they were unaware of which group they belonged to. Participants were naive to an adjustment with the IAI as this device is relatively new in South Africa and not readily available.

3.7 RESEARCH PROCEDURE

Once the participant met the research requirements they were randomly allocated to one of the two groups, using the random allocation chart. Lumbar spine active range of motion (flexion, extension, and right and left lateral flexion) was then measured, using the Saunders Digital Inclinometer. The participants were then made to lie on an examination bed, lying face down (prone), with the top half of their bodies off the table. They were then strapped onto an examination table at the hips, knees and ankles.

Once the electrodes were in place, the sEMG was turned on and the EMG mode selected, with the computer display showing template training. The time allowed was five minutes. During this time, there was no talking, save for communication of discomfort from the participant, to reduce any effect this may have had on the sEMG. The correct EMG parameters for the NeuroTrac^{TM} ETS were set by pressing the SET button until it got to WDE FLTR or NRW FLTR on the screen. Then the B+ or B- button was pressed continuously in order to select the narrow filter (NRW FLTR) which is appropriate for use over the back in order to eliminate interference from the heart (NeuroTrac^{TM} ETS: Operators manual, 2007: 3). While this was done, the same protocol for the test was observed.

The participant was then instructed to perform the Biering-Sorensen endurance test for the purpose of this study. When they lost contact with the rope they were instructed to stop and were allowed to relax for 15 minutes, to allow for muscle recovery from fatigue (Larivière *et al*., 2003: 171), during which time they remained prone.

The participants then either received a lower thoracic extension, or placebo, manipulation. Post-intervention, not more than two minutes, participants in both groups re-performed the Biering-Sorensen test monitored by the sEMG, and thereafter had their lumbar active range of motion (flexion, extension, and left and right lateral flexion) assessed using the Inclinometer. To minimise the participants trying to achieve better results the second time they were not told their endurance time until after the test i.e. after they had held the Biering-Sorensen contraction pre and post intervention.

3.8 DATA PROCESSING AND ANALYSIS

The collected data was extracted, and the data recorded accordingly i.e. the paraspinal endurance scores were recorded in seconds, the range of motion measures were recorded in degrees, and the sEMG readings were recorded in mean microvolts. The sEMG data was then normalised by converting all pre-sEMG intervention readings to 100 percent. Then, to get the change pre-post, the post EMG reading was divided by the pre reading and multiplied by 100 to get a percentage. Then 100 was subtracted from the calculated percentage to get an overall view of the difference, if any, from pre to post readings. Following this the information was then put into an excel spreadsheet and was analysed by a qualified statistician using IBM® SPSS® statistics version 21 and STATA 11 to analyse the data.

The data was tested using Q-Q plots and formal quantitative normality tests (Kolmogorov- Smirnov test). Most of the variables tested were found to be acceptably normally distributed and met the assumptions of the performed parametric tests. Comparisons of the groups at baseline were performed using independent sample t-tests. Repeated measures ANOVA assessed the group, time and time by group effect between the placebo and intervention groups. The interaction was analysed with quantitative tests to indicate the direction and trend of the effect. Where possible, variables were reported with their 95% confidence intervals and p-values. Non-parametric tests were not performed (email communication on 23 April 2014, McCaul).

3.9 CONSORT DIAGRAM

Figure 3.1 outlines the research procedure post ethical approval.

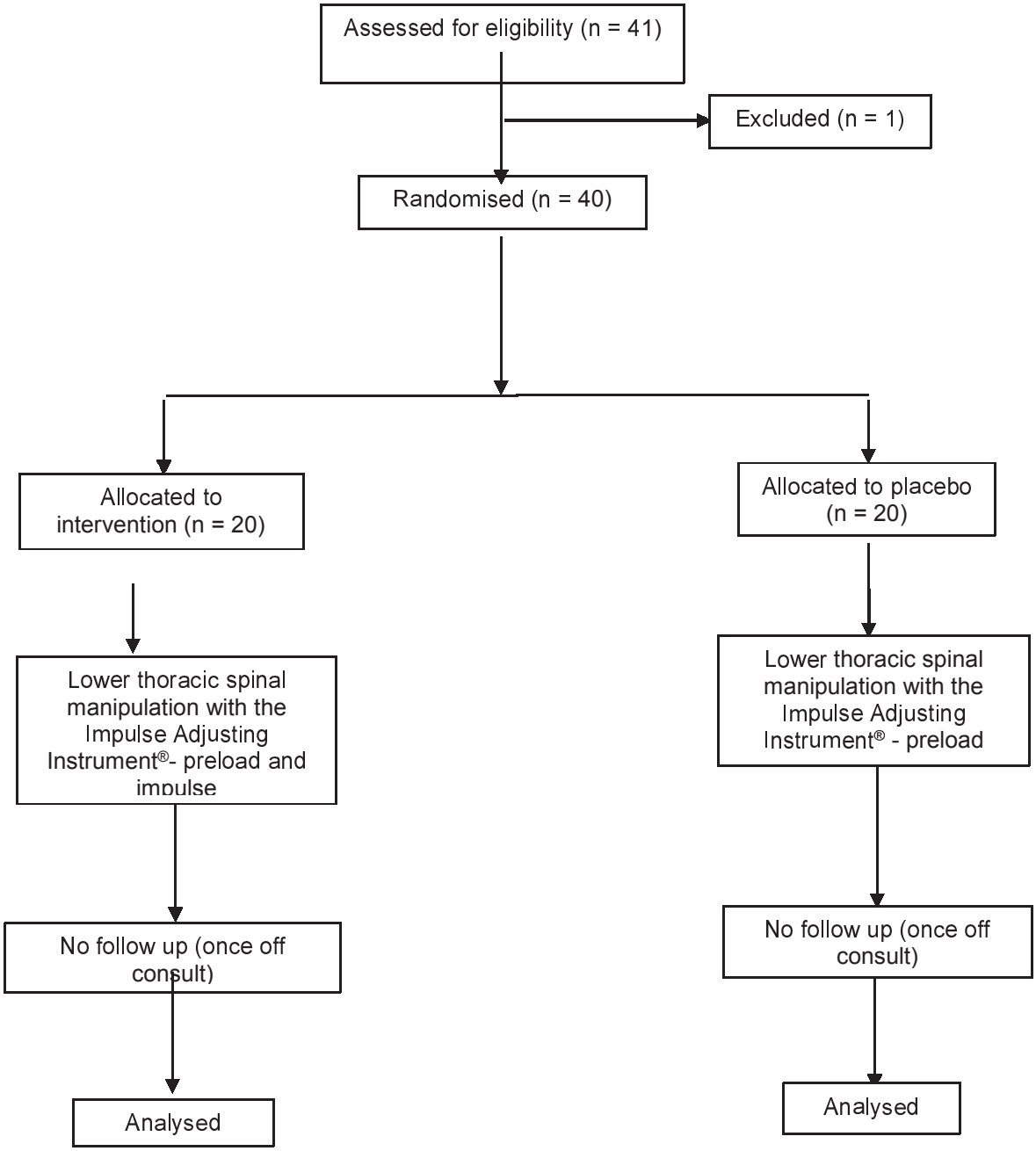

Figure 3.1: Consort diagram outlining research trial post ethical approval

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 DEMOGRAPHICS

4.2.1 Age

There was no statistically significant difference between the groups in terms of age (p =0.944). The mean age for the intervention group was 25.6 years (± 3.61, CI 23.91- 27.29), and for the control group was 25.7 years (± 5.12, CI 23.30- 28.10).

4.2.2 Height, Weight and Body Mass Index (BMI)

There were no statistically significant differences between the groups in terms of height, weight and BMI, as shown in Table 4.1.

Table 4.1: Height, weight and body mass index (BMI) of the participants

Variable	Group	Mean	SD	CI	p-value
Height (m)	Intervention	1.7	0.06	1.70- 1.77	0.733
	Placebo	1.7	0.04	1.71- 1.75	
Weight (kg)	Intervention	68.8	7.58	65.30- 72.40	0.321
	Placebo	66.6	5.9	63.93- 69.45	
BMI	Intervention	22.76	1.88	21.88-23.65	0.377
	Placebo	22.2	1.7	21.43-23.07	

(Independent two tailed-test)

4.3 SUBJECTIVE MEASUREMENT

None of the participants experienced pain and/or discomfort before the test, during the test, or after. Therefore no statistical analysis for subjective pain/discomfort was performed.

4.4 OBJECTIVE MEASUREMENTS

4.4.1 Paraspinal muscle endurance assessment (seconds)

At baseline there was no significant difference observed between the groups (p = 0.629, independent t-test). Repeated measures analysis of variance showed a significant within-subject time effect (p = 0.004), with the intervention group showing a statistically significant change over time (p = 0.027), whereas the placebo group failed to have a significant change over time (p = 0.060). Mean score obtained pre and post intervention as given in table 4.2.

Table 4.2: Paraspinal muscle endurance score

	Pre-intervention			Post-intervention		
	Mean	**SD**	**CI**	**Mean**	**SD**	**CI**
Intervention	41.25	26.63	28.79-53.71	49.45	27.62	36.53-62.37
Placebo	36.40	30.71	22.03-50.77	41.25	28.02	28.14-54.36

Both groups showed an increase in endurance scores over time, as seen in figure 4.1, however when compared to each other, no significant time by group effect was observed (p = 0.429; repeated measures analysis of variance). Indicating that the intervention did not result in improved paraspinal muscle endurance scores, although there is a trend of an effect seen in the intervention group.

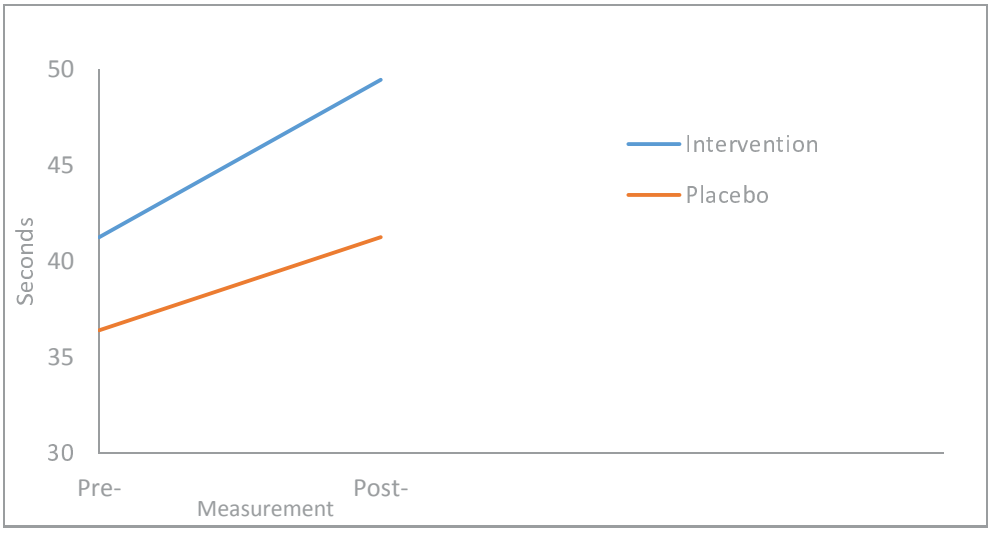

Figure 4.1: Paraspinal muscle endurance score changes over time

4.4.2 Surface electromyography readings (sEMG)

The sEMG readings were normalised in order to compare the effect of the intervention. Repeated measures analysis of variance for channel A showed a significant within-subject time effect ($p = 0.004$), with the intervention group showing a statistically significant change over time ($p = 0.004$), as can be seen in table 4.3, whereas the placebo group failed to have a significant change over time ($p = 0.190$). No significant within-subject time effect ($p = 0.052$) was observed for channel B.

Table 4.3: Normalised surface electromyographic results (%)

Group		Pre-intervention	Post-intervention	
		Mean	Mean	SD
CH A	Intervention	100	106.05	1.82
	Placebo	100	103.38	2.49
CH B	Intervention	100	103.78	2.13
	Placebo	100	102.95	2.85

When the two groups were compared over time there was no statistically significant difference found for both channel A ($p = 0.392$) and B ($p = 0.804$) readings, the normalised data is presented in figure 4.2, indicating that the intervention did not significantly change the sEMG readings.

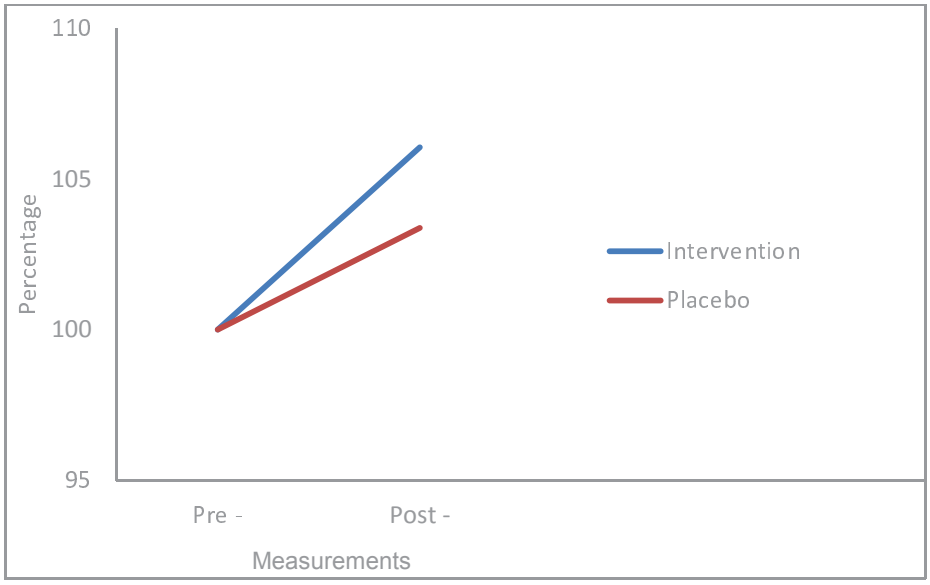

Figure 4.2: Changes observed in the surface electromyographic results over time for channel A, with the data normalised

4.4.3 Lumbar spine range of motion (ROM)

Using independent t-test, there were no significant differences found between the groups at baseline for all the range of motion measures: flexion (p= 0.64), extension (p = 0.43), right lateral flexion (p = 0.90), and left lateral flexion (p = 0.71). Using repeated measures analysis of variance, only left lateral flexion was found to have a significant within-subject time effect (p = 0.001), with the intervention group showing a statistically significant change over time (p = 0.007), whereas the placebo group failed to have a significant change over time (p = 0.104). The differences in range of motion were very small, yielding this finding clinically insignificant. Most range of motion values increased, irrespective of the group the participants were in, with no statistically significant differences in range of motion found between the groups over time as seen in table 4.4, indicating that the intervention did not significantly improve lumbar spine range of motion.

Table 4.4: 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	26.65	4.41	24.59-28.71	26.65	4.20	24.68-28.62	0.401
	Placebo	27.31	4.26	25.32-29.30	28.02	5.82	25.30-30.74	
Extension	Intervention	25.22	4.99	22.88-27.56	25.53	5.87	22.78-28.28	0.475
	Placebo	26.41	4.44	24.33-28.49	27.40	5.00	25.06-29.74	
Right lateral flexion	Intervention	19.18	3.19	17.69-20.67	19.55	3.88	17.74-21.36	0.905
	Placebo	19.28	2.22	18.24-20.32	19.61	2.40	18.49-20.73	
Left Lateral flexion	Intervention	19.30	3.04	17.88-20.72	19.93	3.16	18.45-21.41	0.111
	Placebo	19.51	2.01	18.57-20.45	19.73	1.84	18.87-20.59	

CHAPTER FIVE: DISCUSSION

5.1 PARTICIPANT CHARACTERISTICS

5.1.1 Age, height, weight and body mass index (BMI)

Age was an important variable to consider in this study as with increasing age there is a greater likelihood of having degenerative processes occurring, which is why the age range for this study was limited to 20-40 years. Radiographic analysis was not conducted to exclude participants with degeneration so it is possible that some of the participants may already have had degenerative spinal changes. There were no significant differences between the groups for age, making the groups comparable.

Body mass index has been shown to influence electromyography (EMG) readings (Kankaanpaa *et al*., 1998a:1073). Therefore it was a controlled variable in this study allowing the groups to be homogenous. Baseline assessment showed no significant difference between the groups. Other characteristics such as activity level of the participants should have been recorded, as this may have influenced the results.

5.2 DISCUSSION OF RESULTS

5.2.1 Paraspinal muscle endurance

The Biering-Sorensen test was used to assess paraspinal muscle endurance. It has been shown to be a valid and reliable (Latimer, Maher and Refshauge, 1999: 2086) measure of spinal extensor muscle endurance used in clinical practice. The scores obtained by the participants in this study are lower than those documented in other studies (Kankaanpaa *et al*., 1998a; Pääsuke *et al*., 2002; Demoulin *et al.,* 2006). This may be because the participants were not given verbal encouragement to continue to hold the contractions, possibly resulting in the participants losing contact with the rope earlier and ultimately termination of the test.

No significant differences were observed between the intervention or placebo group, indicating a lack of treatment effect. However, the intervention group did have a significant improvement in endurance time from pre to post measurement, indicating

a possible trend. Both groups showed an increase in their scores which may indicate a learning effect as they became more comfortable performing the test. In this study both groups received a pre-load force applied over the area of joint dysfunction.

Preload forces have been found to result in increased muscle spindle discharge (Pickar and Wheeler (2001), indicating that although no treatment was given to the placebo group the preload force may still have altered the afferent discharge from the muscles spindles, which may have masked the treatment effect. Therefore the use of a placebo that did not contact the skin may have resulted in a different outcome. Pickar and Wheeler (2001) also found that when the manipulative thrust was delivered, it had a more pronounced effect, which is contrary to the results of this study.

The device used in this study to administer the HVLA thrust has not been associated with the cavitation noise often associated with manual SM. Clark *et al*. (2011) observed a greater change in the stretch reflex in participants who had experienced joint cavitation, indicating that joint cavitation may play a role in sufficiently stimulating the joint mechanoreceptors to increase the afferent bombardment to the dorsal horn to bring about the effects of SM. In contrast to this, Keller and Colloca (2000) found when using a similar device that maximum voluntary contraction of the paraspinal muscles improved post lumbar spinal manipulation. This device was selected over manual manipulation in an attempt to standardise the force of the manipulative thrust and the preload.

Kawchuk *et al*. (2006) found that force-producing instrumentation exhibited less variation in terms of force duration as well as absolute force, when compared to manual manipulation. However the person administering the SM may still influence the outcome due to the force they used to apply the preload, in this study a research assistant administered all treatments in an attempt to standardise the force application, however its effect could have influenced the results.

A nine second improvement in endurance may not be statistically significant, but it may be clinically relevant for different individuals, or for a particular function. Functional assessments are widely used to evaluate the functional capacity of the trunk. Inadequate activation of the local stabilising trunk muscles, including the core musculature, may lead to instability of the lumbar spine (Ito *et al*., 1996). Paraspinal muscle endurance and trunk muscle stabilisation have been linked; therefore, a

change in paraspinal muscle endurance, however minimal, may also affect trunk muscle function (Ito *et al*., 1996). This study failed to assess the patients' core strength and future studies of this nature should address this. Koumantakis *et al*. (2001) and Roy and Oddsson (1998) have suggested that retraining these muscles may lead to a delayed onset, or a decrease in low back pain (LBP), be it short term, or long term. Therefore further investigation is warranted.

5.2.2 Surface electromyography

SM has been associated with a decrease in sEMG activity (Herzog, Scheele and Conway, 1999). However, with this study there was an increase in sEMG readings in both groups. All sEMG readings were obtained while the paraspinals were actively contracting in the Biering-Sorensen test, as opposed to in other studies where they were taken at rest (Herzog, Scheele and Conway, 1999; Symons *et al*., 2000; Keller and Colloca, 2000). There was no significant treatment effect observed with both groups showing an increase in sEMG activity, indicating muscle fatigue. The participants performed the Biering-Sorensen test three times; once, to set up the sEMG, and twice for testing. Between the pre- and post-test, an interval of 15 minutes was allowed for recovery from fatigue (Larivière *et al*., 2003: 171). Given the results, it is possible that a longer time frame may have been necessary to ensure that the muscles recovered prior to obtaining the post-measurements.

Another factor that could affect the outcome of the sEMG readings could be whether the measurements were taken with MVC or sub MVC. According to Dankaerts *et al* (2004) who investigated the reliability of sEMG readings for MVC and sub MVC of the trunk muscles, found that when done on the same day there was good reliability in both health participants and those with chronic LBP. When assessing between day difference sub MVC readings showed better reliability. Based on this it is unlikely that measuring MVC affected the results. The design of this study was similar to other studies where the effect of SM on muscle activity have utilised MVC (Keller and Colloca, 2000; Symons et al., 2000; Colloca and Keller, 2001), where participants were assessed on the same day.

Lehman and McGill (2001), when assessing trunk kinematics following SM, failed to find significant sEMG changes in low back pain participants, however they did observe individual changes. This was in contrast to Harvey and Descarreaux (2013) who found

that post SM, the paraspinal muscles were ‘normalised’ in symptomatic low back pain participants when assessing repetitive flexion and extension movements using sEMG. The authors suggested that SM may have reduced the muscle fatigue effects associated with repetitive movements in LBP patients. These studies, unlike the current study were conducted on participants with low back pain. Had the current study utilised low back pain participants, it is possible that the results may have been different.

Surface EMG readings may be affected by muscle tonicity. Long-term preferential use of muscles of one side of the body may result in changes in the membrane of the muscle fibre, as well as its control properties (Adam, De Luca and Erim, 1998; Evans, 2002; Farina *et al*., 2003). The change in muscle fibre membrane also leads to changes in the electrical activity of the muscles, whereby there is prevalence of slow twitch type I fibres in the dominant muscle (Farina *et al*., 2003), meaning that the non-dominant side will fire more readily when doing work. All participants in this study were right hand dominant, however, muscle tonicity was not assessed, therefore, it is possible that differences in paraspinal hypertonicity within and between the groups could have altered these readings.

5.2.3 Lumbar spinal ROM

Range of motion was included in this study as an objective measure to determine the mechanical effect of the SM. The result showed no significant differences between the groups in terms of lumbar spine range of motion except for the within group left lateral flexion measurement for the intervention group.

ROM is considered controversial as a sign of successful SM, however, previous studies (Lehman and McGill, 2001; Potter, McCarthy and Oldham, 2005; Ernst and Canter, 2006; Harvey and Descarreaux, 2013) have found that although the result is often temporary, it still occurs. The changes in ROM in this study were negligible, whether this is due to manipulation being performed at the thoraco-lumbar junction and not the lumbar spine, or that the instrument did not result in improved joint range of motion is unknown.

5.2.4 Subjective measurement

The participants recruited in this study were asymptomatic; however they were required to have joint dysfunction. When performing the B-S test, although easy to perform it may result in some pain or discomfort. However none of the participants experienced any pain while doing the pre- or post-test, or after the test, indicating that for this study, there were no adverse effects upon performing the test.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The aim of this study was to investigate the effectiveness of lower thoracic spinal manipulation compared to a placebo intervention on lumbar extensor muscle endurance in asymptomatic males, in terms of subjective and objective measurements. The outcome was that there was no statistically significant difference between the groups; therefore the null hypothesis was unable to be rejected. A trend of an effect was observed in paraspinal muscle endurance time for the intervention group, which warrants further investigation.

6.2 RECOMMENDATIONS

The following recommendations can be made:

1) Future studies should use a larger sample size to account for the sEMG readings.
2) A more advanced electromyographic device should be utilised, allowing for more detailed measures of amplitude and frequency to be recorded.
3) Conducting the study on different populations such as females or a symptomatic population may yield different results.
4) The level of activity of participants could be noted, or standardised e.g. select sports men, or, sedentary patients
5) Controlling for core strength and paraspinal muscle length may further enhance the validity of the study.
6) A longer timeframe should be allowed between Bering Sorenson's tests to allow for fatigue recovery

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APPENDICES

Appendix A1 – Advertisement (English)

WOULD YOU LIKE TO KNOW HOW STRONG YOUR BACK MUSCLES ARE?

ARE YOU A HEALTHY, RIGHT-HANDED MALE, BETWEEN THE AGES OF

20 AND 40?

RESEARCH IS BEING CONDUCTED AT THE CHIROPRACTIC CLINIC

AT THE DURBAN UNIVERSITY OF TECHNOLOGY.

IF YOU ARE INTERESTED

CONTACT LINN

031 373 2512/2205

Appendix A2 – Advertisement (isiZulu)

UNGATHANDA UKWAZI AMANDLA OMSIPHA WOMGOGODLA WAKHO NA?

UPHILILE, UWUMUNTU WESILISA, OBHALA NGESANDLA SOKUDLA, PHAKATHI KOMNYAKA WA 20 KUYA KU 40?

UCWANINGO LWENZIWA E-CHIROPRACTIC CLINIC

E-DURBAN UNIVERSITY OF TECHNOLOGY.

UMA UFUNU'KWAZI KABANZI, THINTA U-LINN

031 373 2512/2205

Appendix B1 – Letter of Information and Informed Consent (English)

Dear Participant,

Thank you for expressing interest in my research project.

Title of the Research Study: The effectiveness of lower thoracic spinal manipulation on lumbar extensor muscle endurance and range of motion in asymptomatic males- a placebo controlled study.
Researcher: Lindelwe Matsebula, B.Tech: Chiropractic.
Supervisor/s: Dr Laura O'Connor, M.Tech: Chiropractic

Brief Introduction and Purpose of the Study: Spinal manipulation is often used by chiropractors and other manual practitioners to improve movement of the spine. When spinal manipulations are performed they have been documented to change the surrounding muscles, it is unclear if this change will be associated with an increased output of the muscle. 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 lower thoracic spine.

Outline of the Procedures: In order to participate in this research you will need to consent to having a case history, physical and low back examination. This will enable the researcher to determine if you meet the study inclusion criteria. Should you meet the requirements, you will then be randomly allocated into one of two groups. You will receive either lower thoracic spinal manipulation or a placebo. You will be shown how to contract you back extensor muscles, by lying on a bench with your trunk off the edge of the bench, supported by your arms, you will then be required to lift your back so it is in line with your legs and hold this position for as long as you can. You will be required to do this twice, once before the intervention and once after. A surface electromyographic device will be placed over the back extensor muscles to allow the researcher to measure the activity of the back muscles while performing the exercise. This is a safe device and will pose no harm to you. The researcher will also assess the range of motion of your low back before and after the intervention.

Risks or Discomforts to the Participant: The treatment given to you will be under the supervision of a qualified chiropractor at all times. The Chiropractic manipulation you will be receiving is a non-invasive (i.e. non-surgical and non- injectable) form of manual therapy and is considered to be a safe treatment.

The Biering-Sorensen endurance test, the test you will have to perform, is also non-invasive; however, there are instances where low back discomfort may occur while you are performing the test, but this discomfort will only last for a short while. Should you feel the pain is too much to bear, you must inform the researcher and the test will be stopped immediately.

Benefits: You will benefit from the study by receiving treatment, finding out if you have strong or weak back extensor muscles, and gaining more value in the role of extensors in low back pain and its development, and I, the researcher will benefit by completing my dissertation.

Reason/s why the Participant May Be Withdrawn from the Study: If you suffer from any adverse reactions and wish to withdraw from the study you are free to do so. If you are not compliant with what is expected of you during the course of the study, you will be withdrawn. You are free to withdraw from the study at any time. Withdrawal from the study does not prevent you from receiving further treatment at the Chiropractic Clinic at the normal clinic rates.

Remuneration: There will be no form of remuneration offered to you.

Costs of the Study: You will be not expected to pay, as the study is free. Once the study is completed, you will be expected to pay normal clinic rates should you wish to receive further treatment at the Chiropractic Clinic.

Confidentiality: All patient information pertaining to the study will be coded to maintain confidentiality and will be stored in the Chiropractic Clinic. Results of the study will be made available at the Durban University of Technology library, without revealing any of the patients' details.

Research-related Injury: there is no foreseeable injury occurring with this study, but, should there be a research-related injury, e.g. exacerbation of low back pain, you will be entitled to receive treatment at the Chiropractic Clinic for that injury.

Persons to Contact in the Event of Any Problems or Queries: Please contact the researcher, Lindelwe on 031 373 2512, my supervisor, Dr. L. O'Connor, on 031 373 2923, or the Institutional Research Ethics administrator, Ms. L. Deonarain 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,

Lindelwe Matsebula
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, Lindelwe Matsebula, about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: 084/13, 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, Lindelwe Matsebula, 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 – Letter of nformation and Informed Consent (isiZulu)

INCWADI YOLWAZI NEMVUME

Mbandakanyi Othandekayo

Ngibonge ukuveza kwakho intshisekelo kulolucwaningo.

Isihloko socwaningo:
The effectiveness of lower thoracic spinal manipulation on lumbar extensor muscle endurance in asymptomatic males- a placebo controlled study.

Igama lomcwaningi: Lindelwe Matsebula**,** 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, ngikuhlole, bese ngihlola nomgogodla wakho. Lokhu kuzosiza ekutheniumcwaningi abone ukuthi unayo imibandela edingekayo kulolucwaningo.Uma unayo yonke lemibandela 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 ngokuqinisela 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 yokuhlolwa kwemisipha yomqolo ingenza ukungenami/ubuhlungu besikhashana, okusho ukuthiukungenami/ubuhlungu obesikhashana futhi

kuzothatha isikhashana nje. Uma ubuhlungu buqhubeka kumele utshele umcwaningi ukuze angaqhubeki nokukuhlola.

Uzozuzani? Ucwaningo lizosiza mina mcwaningi ukuthi ngiphothule lolucwaningo, kanti luphinde likusize uthole ukulashwa iqolo, nokwazi ukuthi imisipha yomgogodla wakho isezingeni elanele.

Izizathu ezingenza ukuthi umuswe kulolucwaningo ngaphandle kwemvume: Uma uzizwela imiphumela engemihle ekwenza ungazizweli nokuqhubeka nocwaningo, uvumelekile ngokungempoqo ukungaqhubeki. Uma uphambana nemigomo yocwaningo, uzovinjelwa ukuqhubeka. Uma ufuna ukungabi inxenye nocwaningo kepha usuqalile ukuthatha iqhaza, uvumelekile ukuyeka futhi ngeke unqatshelwe ukulashywa kuwona umtholampilo wamathambo ngendlela ejwayelekile.

Ukukhokhelwa imali: Asikho isinxephezelo ozosizuza ngoba inxenye yalolucwaningo.

Kungabe uzokhokha yiningokuzibandakanye kulolucwaningo?

Ayikho imali okulindeleke ukuba uyikhokhe njengoba ukuthatha inxenye kumahhala. Uma udinga ukulashwa emva kokuba ucwaningo luphelile, kuzofanela ukhokhe njengokujwayelekile.

Imfihlo(izogcinwa kanjani):
Yonke imininingwane yeziguli ezingaphansi kocwaningo izogcinwa iyimfihlo kanti amagama alabo abathathe inxenye ocwaningweni ngeke asetshenziswe uma sekubhalwa umbiko wocwaningo ongatholakala emtapweni wolwazi waseDurban University of Technology.

Ukulimala kulolucwaningo: Akukho ukulimala okulindelekile kuolcwaningo, kodwa uma ngabe ulimala noma kuba nobungozi ngenxa yokuzibandakanya kulolucwaningo ngesikhathi ucwaningo lusaqhubeka, ungathola usizo emtholampilo wamathambo ekuthiwa yiChiropractic Clinic.

Ongabathinta uma kuba nenkinga noma imibuzo:
Ngicela uxhumane nomcwaningi uLindelwe Matsebula kulenombolo (031) 373 2512, owengamele lolucwaningo D kLaura O'Connor (031) 373 2923 noma unobhala wekomiti elimele amalungelo kwezocwaningo uLavisha Deonarian – 031 373 2900. Izikhalo zingabikwa kwiDVC:TIP, Prof F. Otieno kulenombolo 031 373 2382 noma dvctip@dut.ac.za.

Ozithobayo
Lindelwe Matsebula
Umcwaningi

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
CONSENT

Isitatimende sesivumelwano sokuzibandakanya kulolucwaningo:

- Ngiyaqinisekisa ukuthi ngitsheliwe ngumcwaningi, Lindelwe Matsebula, ngohlobo, ngokuziphatha, nangosizo, nangobungozi balolucwaningo – Research Ethics Clearance Number: 084/13
- 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.
- Ngiyaqonda ukuthi imiphumela ebalulekile etholakele ngesikhathi lolucwaningo luqhubeka egaphathelana name ngizikwaziswa ngayo.

_____

Igama lozibandakanya kulolucwaningo **Usuku**

isiginisha/isithupha

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

_____

Igama lomucwaningi **Usuku** **Isiginisha yomcwaningi**

_____

Igama lafakazi **Usuku** **Isiginisha kafakazi**

_____

Igama lomlondolozi(uma ekhona) **Usuku** **Isiginisha kafakazi**

CHIROPRACTIC PROGRAMME

CHIROPRACTIC DAY CLINIC CASE HISTORY

Patient: _____ Date: _____

File #: _____ Age: _____

Sex: _____ Occupation: _____

Student: _____ 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:

Student's Case History:

1. Source of History:

2. Chief Complaint: (patient's own words):

3. Present Illness:

	Complaint 1(principle complaint)	**Complaint 2 (additional or secondary complaint)**
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:
Other (please list):

Tobacco
Alcohol
Social Drugs

7. Immediate Family Medical History:

Age of all family members
Health of all family members
Cause of Death of any family members

	Noted	Family member		Noted	Family member
Alcoholism			Headaches		
Anaemia			Heart Disease		
Arthritis			Kidney Disease		
CA			Mental Illness		
DM			Stroke		
Drug Addiction			Thyroid Disease		
Epilepsy			TB		
Other (list)					

8. Psychosocial history:

Home Situation and daily life
Important experiences
Religious Beliefs

9. Review of Systems (please highlight with an asterisk those areas that are a problem for the patient and require further investigation)

General

Skin

Head

Eyes

Ears

Nose/Sinuses

Mouth/Throat

Neck

Breasts

Respiratory

Cardiac

Gastro-intestinal

Urinary

Genital

Vascular

Musculoskeletal

Neurologic

Haematological

Endocrine

Psychiatric

APPENDIX D

CHIROPRACTIC PROGRAMME

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

THORACIC SPINE REGIONAL EXAMINATION

Patient:_____ File:_____ Date:_____

Student:_____ Signature:_____

Clinician: _____ Signature:_____

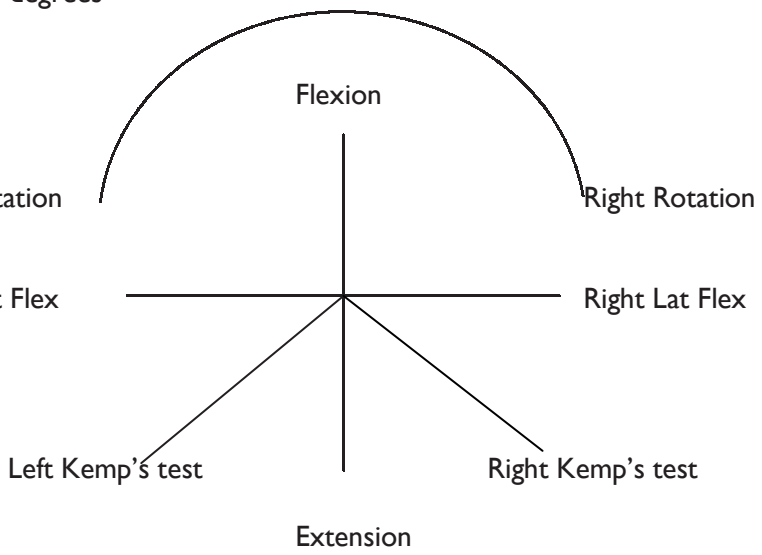
STANDING:

Posture (incl. L/S & C/S)
Muscle tone
Skyline view – Scoliosis
Spinous Percussion
Breathing (quality, rate, rhythm, effort)
Deep Inspiration

Scars
Chest deformity
(pigeon, funnel, barrel)

RANGE OF MOTION:

Forward Flexion	20 – 45 degrees (15cm from floor)
Extention	25 – 45 degrees
L/R Rotation	35 – 50 degrees
L/R Lat Flex	20 – 40 degrees



RESISTED ISOMETRIC MOVEMENTS: (in neutral)

Forward Flexion
L/R Rotation
Extension
L/R Lateral Flexion

SEATED:

Palpate Auxillary Lymph Nodes
Palpate Ant/Post Chest Wall
Costo vertebral Expansion (3 – 7cm diff. at 4th intercostal space)
Slump Test (Dural Stretch Test): LOCAL PAIN (T/S) DISTAL PAIN (L/S) DISTAL PAIN (LEG)

SUPINE:

Rib Motion (Costo Chondral joints)
Soto Hall Test (#, Sprains)
SLR
Palpate abdomen

PRONE:

Passive Scapular Approximation
Facet Joint Challenge
Vertebral Pressure (P-A central unilateral, transverse)
Active myofascial trigger points:

	Latent	Active	Radiation Pattern		Latent	Active	Radiation Pattern
Rhomboid Major				Rhomboid Minor			
Lower Trapezius				Spinalis Thoracic			
Serratus Posterior				Serratus Superior			
Pectoralis Major				Pectoralis Minor			
Quadratus Lumborum							

COMMENTS:_____

NEUROLOGICAL EXAMINATION:

DERMATOMES												
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	T 11	T 12
Left												
Right												

Basic LOWER LIMB neuro:

Myotomes	T11	T12	L1	L2	L3	L4	L5	S1	S2	S3
Dermatomes	T11	T12	L1	L2	L3	L4	L5	S1	S2	S3
Reflexes	Patella – Left					Achilles – Left				
	Patella - Right					Achilles – Right				

MOTION PALPATION:

			Right	Left
Thoracic Spine				
Ribs	Calliper (Costo-transverse joints)			
	Bucket Handle	Opening		
		Closing		
Lumbar Spine				
Cervical Spine				

BASIC EXAM	History	ROM	Neuro/Ortho
LUMBAR			
CERVICAL			

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

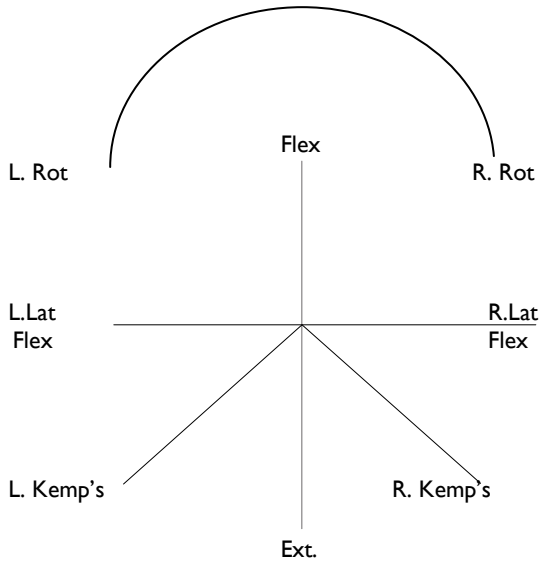
GAIT:

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 SI, +, ++		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:

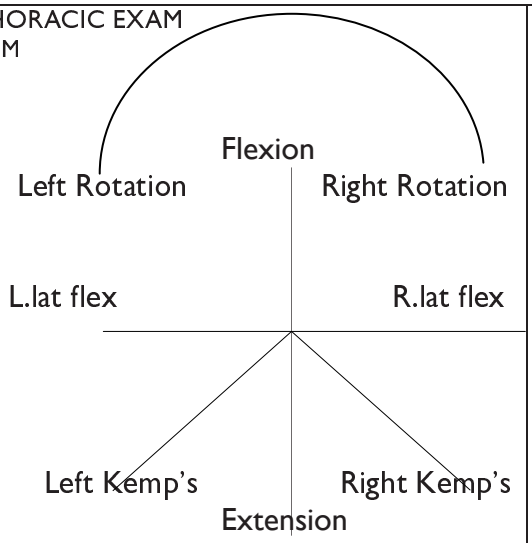
Pin point pain
Trunk rotation
Flip Test
Ankle dorsiflexion test
Axial compression
Burn's Bench test
Hoover's test
Repeat Pin point test

NEUROLOGICAL EXAMINATION

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 ROM



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 G – Letter of Permission

Dear Sir/Madam

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

Yours sincerely,

Lindelwe Matsebula

Researcher

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

_____

Signed Date

APPENDIX H

MEMORANDUM

To : Prof Puckree
Chair : RHDC

Prof Adam
Chair : IREC

From : Dr Charmaine Korporaal
Clinic Director : Chiropractic Day Clinic : Chiropractic and Somatology

Date : 10.09.2013

Re : Request for permission to use the Chiropractic Day Clinic for research purposes

---

Permission is hereby granted to :

Ms Lindelwe Matsebula (Student Number: 20500897)

Institutional Research Ethics Committee
Faculty of Health Sciences
Room MS 49, Mansfield School Site
Gate 8, Ritson Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2900
Fax: 031 373 2407
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

23 October 2013

IREC Reference Number: **REC 67/13**

Ms L N Matsebula
P O Box 4183
Manzini
Swaziland
M200

Dear Ms Matsebula

The effectiveness of lower thoracic spinal manipulation on lumbar extensor muscle endurance in asymptomatic males- a placebo controlled study

I am pleased to inform you that Full Approval has been granted to your proposal REC 67/13.

The Proposal has been allocated the following Ethical Clearance number IREC 084/13. 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 IREC. 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 IREC 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 IREC as outlined in the IREC SOP's.

Yours Sincerely

[redacted]
Dr M N Sibiya
Deputy- Chairperson: IREC

NHREC
South African Human Research Electronic Application System

TRIAL APPLICATION

Application ID:	3605	DOH Number	Pending	Page:	1/2

Applicant Details

Organisation :	Durban University of Technology
Applicant Type :	Academic Investigator
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Trial Application Details

Issue Date :	2013/11/08
Sponsors :	Durban University of Technology
Primary Sponsor :	
FundingType :	Commercial
Research Site Names :	Durban University of Technology Chiropractic Clinic
Primary Research Site Name :	
Total National Budget for Trial :	R 6992.00
Protocol / Grant Reference Number	REC 67/13

Study Descriptive Information

Brief Tiltle of Study :	The effectiveness of lower thoracic spinal manipulation on lumbar extensor muscle endurance in asymptomatic males- a placebo controlled study
Full Title of Study :	
Anticipated Start Date :	2013/11/01
Anticipated End Date :	2013/11/30
Target Sample Size :	40
Study Phase :	Other
Study Scope :	Single Site
Study Type :	Interventional
Disease Type Heading :	Muscle, Bone and Cartilage Diseases
Disease Type Condition :	Musculoskeletal Diseases
Intervention Name (Generic) :	Spinal Manipulation
Intervention Duration :	No. Type 1 Days

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South African Human Research Electronic Application System

TRIAL APPLICATION

Application ID:	3605	DOH Number	Pending	Page:	2/2

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:	2013/11/01
Recruitment Status :	Recruiting
Gender :	Males
Ethnicity :	All
Age :	From 20 Years To 40 Years
Qualifying Disease Condition for Inclusion :	Asymptomatic health participants: 1. Participants must be male, 20 – 40 years of age and right hand dominant 2. Participants will need to have at least one manipulable lesion between T8-T10, determined by motion palpation 3. Poor ability to perform the Biering Sorensen's test i.e. weak extensor muscle endurance; inability to hold the contraction for less than 176 seconds 4. Participants must be of a similar height and weight
Major Exclusion Criteria :	1. Any contraindication to manipulation determined through the case history, physical, regional and orthopaedic examination, including, but not limited to: tumours, bone infections, metabolic disorders (osteoporosis) and traumatic injuries 2. Patients who have received spinal manipulation of either the thoracic or lumbar spine within the last three weeks 3. History of spinal surgery. 4. Any trauma to the spine e.g. fractures. 5. Experiencing any spinal pain or utilising NSAIDS and muscle relaxants 6. Patients with chronic conditions that are at risk for physical activity, including, but not limited to cardiac and/or respiratory disease, neurological symptoms and hypertension. 7. Contra-indications for sEMG, including, but not limited to cardiac pacemakers, open wounds, or skin conditions of any region of electrode placement
Key Primary Outcome :	The aim of this study is to investigate the effectiveness of lower thoracic spinal manipulation compared to a sham manipulation on lumbar extensor muscle endurance in asymptomatic males, in terms of objective (endurance time, fatigue using a sEMG and active lumbar spine range of motion) measurements.
Key Secondary Outcomes :	To determine the effect on subjective (pain/discomfort) outcomes

Appendix K – Ligaments of the vertebral column

Table 2.1: Ligaments of the vertebral column

Ligament	Attachment	Action and Innervation
Anterior Longitudinal Ligament	The anterior aspect of vertebral bodies from the base of the skull to the upper part of the sacrum	Limits hyperextension; branches of grey communicating rami of the lumbar sympathetic trunk
Posterior longitudinal ligament	The posterior surface of the vertebral bodies and discs, from the base of the skull to the first sacral segment	Stabilises the spinal column during flexion; recurrent meningeal nerve
Ligamentum flava	Yellow fibres present in the laminae of adjacent vertebrae, and fuse with each other in the midline	Resists the separation of the laminae, and assists with the straightening of the vertebral column after flexing
Interspinous ligaments	Extends from the lower border of one spinous process to the upper border of the next	Connect the spinous processes to each other
Supraspinous ligaments	Extends over the spinous processes from the occipital bone to the sacrum	Connect the superior aspect of the spinous processes to each other
Intertransverse ligaments	The posterior lamellae of these ligaments pass medially to the posterior aspect of the facet joint, becoming continuous with the aponeurosis of the transverse abdominis muscle and with the middle layer of the thoracolumbar fascia	Connect adjacent transverse processes.
Iliolumbar ligaments	From the transverse processes of the fifth lumbar vertebrae to the sacrum and iliac crest on the same side.	Stabilise the L5-S1 junction; posterior primary divisions of the neighbouring spinal nerves

(Adapted from Cramer and Darby, 2005; Ebraheim *et al*., 2004; Moore and Agur, 2002: 285-288).

Appendix L – Deep Layer of Back Muscles

Muscle	Origin	Insertion	Action
Transversospinal Semispinalis	Arises from the TVP of the fourth cervical through to the twelfth thoracic vertebrae	Semispinalis- fibres run superomedially to the occipital bone and spinous processes in the thoracic and cervical regions	Extension, mainly. Aids extension of the head, cervical, and thoracic regions
Multifidus	Posterior sacrum, superior iliac spine of the ilium, erector spinae aponeurosis, sacroiliac ligaments, TVP of the first through to the third thoracic vertebrae, and the articular processes of the fourth through to the seventh cervical vertebrae	Multifidus – is thickest in the lumbar region and inserts the entire length of spinous processes of vertebrae, with the fibres passing obliquely	Due to local action, stabilises vertebrae during vertebral column movement
Rotatores (brevis and longus)	Best developed in the thoracic region and arise from the TVP of the vertebrae	Rotatores – attach to the junction of the lamina and TVP of vertebrae, with the fibres passing superomedially	Also stabilise vertebrae, and assist with minute rotator movements of the vertebral column