THE EFFECT OF CHIROPRACTIC MANIPULATION AND/OR A COMBINATION OF ABDOMINAL STRENGTHENING EXERCISES ON THE FEED-FORWARD REACTION OF THE DEEP ABDOMINAL MUSCLES IN PEOPLE WITH CHRONIC MECHANICAL LOW BACK PAIN.

A dissertation submitted to the Faculty of Health Sciences, University of Johannesburg, in partial fulfilment of the requirements of Master of Technology in the programme of Chiropractic by

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DECLARATION

I, Celia Meldrum, declare that this dissertation is my own, unaided work. It is being submitted in partial fulfillment for the Master’s degree in Technology, in the programme of Chiropractic, at the University of Johannesburg. It has not been submitted before for any degree or examination in any other Technikon or University.

______________________________________

Celia Meldrum

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ABSTRACT

Purpose: Chiropractic adjustment has been shown to be an effective treatment for low back pain (Cox, 1999 and Lawrence et al, 2008). The role that the transverse abdominus plays in low back pain is not clear. Sacroiliac adjustment changes the activation speed (Marshall and Murphy, 2006) and the strength of contraction of transverse abdominus. This study aims to determine the short-term effects of chiropractic manipulative treatment on the feed-forward activation of the deep abdominal muscles in patients with chronic low back pain.

Method: Forty five participants with chronic mechanical low back pain were used in this study. The primary cause of their back pain was mechanical. The study consisted of three randomly selected groups of participants. Group one was treated using abdominal exercise only. Group two was treated using both chiropractic manipulation and abdominal exercise. Group three was treated using chiropractic manipulation only.

Procedure: The effect on the feed-forward activation of transverse abdominus and internal oblique was measured and recorded using surface electromyography in each group. The participants also completed an Oswestry Low Back Pain and Disability Questionnaire and a Numerical Pain Rating Scale in order to record any change in back pain. Participants were seen seven times over a maximum four week period. Readings were taken on the first, third and fifth and seventh visits.

Results: Statistically significant (p<0.05) results were seen in all three groups for the Oswestry Pain and Disability Questionnaire and Numerical Pain Rating Scale. Minimum EMG results were not statistically significant, however group three showed improvement clinically. Maximum EMG results were also did not show a statistically significant change. Feed-forward activation of the transverse abdominus muscle showed no statistically significant change.

Conclusion: Favourable results were obtained clinically for all three groups. Group three (chiropractic manipulation only) was shown to be the most effective in terms of patient perception of pain and disability. Objectively, the results were less definitive. Chiropractic manipulation alone had the most favourable effect on the resting surface EMG readings of
the transverse abdominus, while chiropractic manipulation combined with abdominal exercises and abdominal exercises alone did not show this change. This too was seen in the results for the maximum EMG readings. Onset times of the transverse abdominus muscle showed no improvement.
DEDICATION

I would like to dedicate this to my family, without whose quiet support and patience this long process would never have been completed.
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CHAPTER 1 INTRODUCTION

1.1 Introduction

Low back pain is a very common problem experienced by adults. A review conducted by Papageorgiou, Croft, Ferry, Jayson, and Silman (1995), stated that, 60-80% of the general world population will suffer from low back pain in some stage of their life. In addition, a study by De Wet, Losco and Moodley (2003), showed that the lifetime incidence and prevalence of LBP in the South African workplace is similar to other countries in the world. The Centre for Pain Management also stated that almost three out of four South Africans will at some stage suffer from low back pain (Bass, 2001). This is a significant number of the population who will then possibly seek treatment and lasting solutions for their pain.

The lumbar spine can be said to be the core and foundation for the body, supporting the trunk and making all movements of the head, arms, and legs possible (Bergman, Peterson and Lawrence, 1993; Cramer and Darby, 1995). Given this important role the lumbar spine plays in the functioning of the body it is not difficult to understand why pain and dysfunction in this area has become the focus of much research and discussion.

According to McGill (2007), spinal stability is a most important factor in the treatment of low back pain. Key to achieving this stability is motor control, endurance and strength training (McGill, 2010). Cox (1999), emphasises the importance of rehabilitation of both the muscular and joint systems. Low back pain can be linked with muscular dysfunction. Decreased spinal stability co-exists with altered contraction of agonist-antagonist muscle groups, decreased speed of contraction, and atrophy of stabiliser muscles. Certain muscles have been found to be prone to inhibition due to low back pain. Both the transverse abdominus and oblique abdominals are prone to inhibition. This is significant as these muscles are considered important stabilisers of the lumbar spine (Cox, 1999). Research has shown significant reduction in pain and increase in functionality with exercise programs. Evidence also supports spinal manipulation as a method of treatment of chronic low back pain (Cox, 1999). In a synthesis of research conducted, Lawrence, Meeker, Branson, Bronfort, Cates, Haas, Haneline, Micozzi, Updyke, Mootz, Triano, and Hawk (2008), concluded that spinal manipulation reduces symptoms and improves function in patients with chronic low back pain. The same review also concluded that spinal
manipulation in conjunction with exercise therapy was likely to speed recovery and aid in prevention of reoccurrence of pain.

This inhibitory action can be altered by spinal manipulation. Spinal manipulation is thought to affect reflex neural outputs to both muscle and visceral organs. There is also evidence that spinal manipulation evokes paraspinal muscle reflexes and alters motoneuron excitability (Pickar, 2002). This effect is particularly evident when manipulating the lower thoracic spine and upper lumbar spine. The transverse abdominus and internal oblique are innervated by fibres from the T10, 11, 12 and L1 nerve roots. Sacroiliac manipulation changes the activation speed and the strength of contraction of transverse abdominus (Marshall and Murphy, 2006).

Many chiropractic researches focus on the mode of treatment of low back pain (Lawrence et al, 2008). Researched methods of treatment of chronic mechanical low back pain have been used in this research. This research has used these modes of treatment to understand the complex role the deep abdominal musculature plays in the cause and relief of chronic mechanical low back pain.

1.2 Problem Statement

Given the high prevalence of the occurrence of low back pain in the adult population it seems that the contribution which various structures play is not well understood. Much research into treatment methods has been conducted by Chiropractors, Biokinetisists and Physiotherapists, with the general conclusion that in most cases conservative intervention into acute and chronic low back pain is effective. Chiropractic specifically has been shown to be highly effective in treating low back pain (Redwood, 2003).

Research has been conducted to fully understand the neurophysiologic and mechanical mechanisms of deep muscle control of the spinal segment. Additional information is needed to understand the nature of these motor-control problems in the deep muscles in patients with low back pain and particularly their implications for persistent and recurrent low back pain (Jull and Richardson, 2000).

The focus of this research study is to determine how integral the feed-forward abdominal reaction is in the epidemiology of low back pain.
1.3 Aims

This study aims to determine the short-term effects of chiropractic manipulative treatment on the feed-forward activation of the deep abdominal muscles in patients with chronic low back pain. Previous research into this area has raised doubts as to the role of the deep abdominal musculature; as a possible cause, or result of low back pain (Marshall and Murphy, 2006).

1.3 Possible Outcomes

The aim of this research study is to help determine the possible role that the feed-forward reaction plays in low back pain. In so doing it may help to better understand the progression of low back pain.

1.4 Benefits of this Study

The current study may help to understand the role the deep abdominal musculature plays in the perpetuation of low back pain.

A better understanding of the role the patient can play in their own back health. This may lead to patient awareness in terms of their own contribution to the healing process and maintenance of health.
CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Webster’s Universal Medical Dictionary (Geddes and Grosset, 2007) describes back pain as ‘pain in the back, which may vary in intensity, sharpness and cause’. From this broad definition it is clear that low back pain is a very large and complex problem, with any one of numerous structures or a combination thereof causing pain. Many of these structures potentially causing pain can be viewed radiologically, and therefore are easily identifiable as causes. The structures which cannot be viewed radiologically are often the major cause of continuing pain. The ligaments, joint capsules and surrounding musculature can act together to produce a persistent and often costly low back pain (Porter 1993, and Porterfield and DeRosa 1998).

The deep abdominal musculature is thought to play an important role in the treatment of low back pain. Many studies have confirmed that the use of abdominal strengthening exercises in conjunction with chiropractic treatment greatly reduces chronic non-traumatic lower back pain. Studies have also demonstrated an immediate increase in transverse abdominus contraction following spinal manipulation without previous instruction in abdominal bracing exercises (Marshall and Murphy, 2006).

2.2 Anatomy

Understanding the relevant anatomy is a vital basis for research. In this chapter the anatomy of the lower back and abdominal muscles will be presented. The neurological and physiological links between elements will also be explored.

2.2.1 The Deep Abdominal Musculature

The musculature of the trunk and pelvis contribute to the control of lumbar spine movement. Key role players are the lumbar spine stabilisers. These include the abdominals, erector spinae, multifidi and quadrates lumborum muscles. These stabilisers provide vital support and control. The carefully designed corset-like structure provides dynamic stabilisation and support (Taylor and Twomey 1994).
The deep abdominal musculatures are specifically concerned with dynamic support of the lumbar spine during limb movement.

2.2.1.1 The Transverse Abdominus

The transverse abdominus muscle is the deepest of the abdominal muscle group. It lies immediately beneath the internal oblique. It attaches to fibres from the outer third of the inguinal ligament, the anterior two-thirds of the iliac crest and the cartilages of ribs 7-12, where it also integrates with the diaphragm. Posteriorly it attaches via a broad aponeurosis to the transverse and spinous processes of the lumbar spine. The lower fibres, together with fibres from the internal oblique, insert onto the crest of the os pubis and pectineal line. The fibres of the transverse abdominus run horizontally across the abdomen towards the outer margin of the rectus abdominus, where they then form an aponeuerosis and insert into the linea alba (Figure 2.1 and 2.2).

The innervation for this muscle arrives via the thoracoabdominal nerves. These arise from the inferior six thoracic ventral rami and the first lumbar nerves (Moore and Dalley, 2006).

![Figure 2.1: Posterior view of the Deep Abdominal Musculature (Netter, 2010)](image)
2.2.1 2 Internal Oblique Muscles

The internal oblique muscle lies just superficial to the transverse abdominus. It attaches to the outer half of the inguinal ligament, the anterior two-thirds of the iliac crest and the lumbar fascia. The fibres of the internal oblique run in different directions from their origin. The fibres arising from the inguinal ligament run downwards and inwards to converge with fibres from the tranversalis and insert into the os pubis. Fibres from the anterior superior iliac spine run horizontally. Fibres from the iliac crest travel upwards and inwards. These fibres terminate in the aponeurosis which then terminates in the linea alba. The posterior fibres travel upwards to insert on the lower borders of the cartilages of the lower four ribs (Figure 2.3).
The innervation for the internal oblique is also derived from the thoracoabdominal and first lumbar nerves (Moore and Dalley, 2006).

**Figure 2.3: Anterior view of the Internal oblique muscle (Netter, 2010)**

### 2.2.1.3 Function and Biomechanics of the Deep Abdominals

The internal oblique and transversus abdominis play a direct role in stabilising the spine. These muscles function to compress the abdominal contents posteriorly against the spine, increase tension through the thoracolumbar fascia which then supports the lower back and reduces the strain on the posterior erector spinae muscles (Norris 2000).
A rigid corset is created by transverse abdominus contraction. Two very important stabilising effects are thus created; enhanced the stiffness of the lumbar spine, and restricted translatory and rotational forces of the spine through lateral tension on the transverse processes of the lumbar vertebrae (Richardson, Toppenberg and Jull, 1999). Hodges and Richardson (1999) found that dysfunction of the transverse abdominus muscle results in inadequate control of the spine against rotational and translatory forces. This places the spine at an increased risk to injury.

It has been found that the response of transverse abdominus is not influenced by the direction of upper limb moments and may contribute to a non-direction specific control of trunk stiffness and ultimately lumbar stability. Also, the generation of intra-abdominal pressure by transverse abdominus has been suggested to contribute to spinal control (Hodges, Cresswell, Daggfeldt and Thorstensson, 2000).

The contraction of the internal and external oblique abdominal muscles produces force in a direction that suggests a direct contribution to the stability of the sacroiliac joint. This comes about via their attachment to the ilium. Via this attachment the oblique muscles draw both the ilia toward the midline. This potentially places the sacroiliac joint in a more close-packed position of joint compression, thus increasing frictional forces between the sacral and iliac surfaces and enhancing joint stability (Hamill and Knutzen 1995).

According to Chapman-Smith (1990), dysfunction of the sacroiliac joint appears to be the single greatest cause of low back pain. Sacroiliac joint fixation or hypermobility to any degree causes a disturbance in the reciprocal motion bilaterally. Increased rotary forces are also produced in the lumbar spine (Hodges et al, 2000).

### 2.2.2 The Joints of the Lumbar Spine

The structure of the lumbar spine is directly linked to its function. The bodies of the lumbar vertebrae are larger than in any other area of the spine, this is in order to support the weight-bearing function they perform.

There are five lumbar vertebrae. Each is linked to the next via three joints; the intervertebral disc and two zygapophyseal joints.
The articulations between the intervertebral disc and the vertebral body are cartilaginous. The outer third of the adult intervertebral disc is innervated by branches from the vertebral and sinuvertebral nerves.

The zygapophyseal joints are synovial joints which lie between the articular processes of the laminae. In the lumbar region, the zygapophyseal joints lie in the sagittal plane, the superior facets face posteriorly and medially and the inferior facets anteriorly and laterally.

The zygapophyseal joints protect the intervertebral discs by resisting shear forces placed on the spine. They also restrain excessive flexion, and axial rotation. The orientation of the facets changes at the lumbosacral junction. The zygapophyseal joint moves into the frontal plane and the inferior facets on L5 face anteriorly. This permits a greater range of rotation and also prevents the vertebral column from sliding forward on the inclined upper surface of the sacrum (Hamill and Knutzen 1995), (Figure 2.4 and 2.5).

![Figure 2.4: Lateral view of Lumbar spine (Netter, 2010)]
2.2.3 The Sacroiliac Joints

The sacroiliac joints are the final joints in the spinal column. They form part of the pelvic ring. The sacroiliac joints are two C-shaped joints on either side of the sacrum. They are part fibrous and part synovial (Norkin and Levangie, 2005). These bear the full weight of the head, upper limbs and trunk, and transmit this weight through to the pelvic ring. The sacroiliac joints are supported by several ligaments; the iliolumbar, anterior plane, intermediate plane and deep sacroiliac, sacrospinous, and sacrotuberous ligaments. The movement of these joints is small. It is described as nutation and counter-nutation.

Figure 2.5: Lateral view of Lumbar spine without ligaments (Netter, 2010)
Nutation can be described most simply as a rotation of the sacrum about a transverse axis so that the promontory moves anteriorly and inferiorly and the apex moves posteriorly. Counter-nutation would then also be simply described as a rotation in the opposite direction previously described (Norkin and Levangie, 2005).

2.2.4 Biomechanics and Loading of the Lumbar Spine

The lumbar spine and pelvis function as unit. The pelvis serves to transmit the force of the trunk, via the sacroiliac joints, from the spine to the legs (Norkin and Levangie, 2005).

The lumbar spine must endure a great compressive load from the trunk and upper limbs above it. This load changes with position of the trunk and limbs. The centre of gravity is altered, thus changing the forces acting on the lumbar spine (Norkin and Levangie, 2005).

Muscular contraction provides additional compression and support, thereby decreasing the potential for excessive torsional and shear forces. In this way injury to the lumbar spine is largely prevented (Norkin and Levangie, 2005).

2.3 Low Back Pain

According to Chapman-Smith (1992), most back pain does not arise from identifiable structural abnormalities. Instead it arises from a functional pathology, i.e. a loss of range of motion in the joints and/or a weakness in muscles of the lumbar spine and pelvis.

Croft and Raspe (1995), described low back pain as pain between the 12th rib and the gluteal folds. Mechanical low back pain can broadly be defined as activity related low back pain (Walker and Williamson, 2009). Pain on lifting, bending, walking, sitting or standing for extended periods, and twisting. Structures that can cause mechanical low back pain include the intervertebral disc, zygapophyseal joints, including the joint capsule and joint ligaments, the anterior and posterior longitudinal ligaments and musculature surrounding the spine (Porterfield and DeRosa, 1998). Pain which does not extend beyond the knees is most likely referral pain from the lower back (Bogduck, 1992).
2.3.1 Causes and Diagnosis of Chronic Mechanical Low Back Pain

Roughly 80% of the adult population will develop low back pain at some point in their lifetime (Diamond and Borenstein, 2006). According to Lurie (2005), over 95% of patients presenting with low back pain, have a ‘benign musculoskeletal pain syndrome’. A basic distinction can be made between specific and non-specific ('idiopathic' or 'mechanical') back pain (Croft and Raspe, 1993). The characteristic of specific back pain is that it can be attributed to a particular cause. The pathomechanism can be identified, the irritated structure found and a clinical diagnosis can be made. By contrast, in non-specific or mechanical low back pain no specific cause is apparent. The diagnosis of mechanical low back pain is made via a thorough history and physical examination of the patient.

2.3.2 Chiropractic Treatment of Chronic Mechanical Low Back Pain

Low back pain is a common complaint among adults (Porter 1993; Porterfield and DeRosa 1998). In one comparison of patients’ perceptions of care delivered by family physicians and chiropractors, patients were much more satisfied with the care delivered by chiropractors. The patients of chiropractors felt more satisfied with the amount of time spent listening to their description of the pain; they felt the chiropractor believed their pain to be real. They also felt they were understood when voicing their concerns about the cause of pain, and rated the chiropractor as more confident in the care they delivered (Cherkin and MacCornack, 1989).

Studies have shown that chiropractic treatment is effective when compared to most other forms of treatment. The current emphasis with regards to treatment and prevention of lower back pain is on the strengthening and correct activation of core muscles (transverse abdominus specifically). A review of literature conducted by Lawrence, Meeker, Branson, Bronfort, Cates, Haas, Haneline, Micozzi, Updyke, Mootz, Triano, and Hawk (2008), found that the high velocity, low amplitude thrust delivered in a chiropractic manipulation combined with strengthening exercise was as effective for pain relief as nonsteroidal anti-inflammatory drugs with exercise. It was indicated that the chiropractic manipulation (manipulation) is better than physical therapy and home exercise for reducing disability. It
also showed that manipulation improves outcomes more than general medical care or placebo in the short-term and physical therapy in the long-term.

2.4. The Chiropractic Subluxation

Gatterman and Hansen (1994), state that a subluxation can be defined as a motion segment in which alignment, movement integrity, or physiological function is altered, but contact between the joint surfaces remains intact. This situation causes a change in the biomechanical and neurological functioning of the joint and surrounding tissue.

The body is affected in two ways by the subluxed joint. Like a set of dominoes this sets up a chain reaction of changes within connected body tissues; the ‘chain’ being the nervous system connecting each working part of the body. Secondly the altered biomechanics directly affect the joints in the immediate vicinity by forcing compensatory motion and fixation along the spine and pelvis (Chapman-Smith, 1997). Pain is referred throughout the soma and viscera which can mimic other conditions, as well as, effect general health due to the restricted capacity of the nervous system to perform its full regulatory functions.

2.5 The Vertebral Subluxation Complex (VSC)

The VSC can be defined as a theoretical model of motion segment subluxation which involves a complex interaction of pathological changes in nerve, muscle, ligamentous, vascular and connective tissue. Since all tissues are closely integrated, a dysfunctional spine will affect all its elements (Leach, 1994).

The VSC model brings together the concept of the spinal motion segment and the clinical change in the connective tissue, musculature, neurological components and vasculature (Ebrall, 2004). It hypothesises that segmental dysfunction often progresses to intervertebral subluxation and degeneration (Leach, 1994)

Several theories suggest that it is not the segmental dysfunction alone which causes pain and continued disturbance in joint movement but the resulting effects on the surrounding tissues (Leach, 1994)
Schafer and Faye (1990), proposed that a subluxation is caused by any physical, functional, or psychological mechanism resulting in a loss of segmental mobility within one or more of its normal physiological ranges of motion. For a joint to remain in this abnormal state of reduced motion, it must be physically held there to restrict its mobility; otherwise it would spontaneously reduce and produce minimal clinical concern. This is referred to as a fixation (Schafer and Faye, 1990). Gatterman (2004), defines a fixation to be a reversible mechanical joint derangement and a primary indicator for manipulation.

2.5.1 Components of the Subluxation Complex

2.5.1.1 Neuropathophysiology

Subluxation of the spinal joints causes a compromise to its neural elements. This can produce irritation and/or compression of these structures. While neural compression leads to tissue damage and decreased neural function, nerve irritation leads to increased nervous activity through facilitation (Gatterman, 2004).

Korr (1991), suggests that neurons in the spinal cord adjacent to the fixated segment are in a state of hyper excitability. These neurons may be responsible for sensory, motor and autonomic function (Gatterman, 2004).

Motor function is controlled by cells in the anterior horn. Therefore facilitation of these neurons leads to continued muscular tension, postural asymmetries and limited and painful motion. The muscles, tendons and joint capsules are richly innervated. These may then produce aberrant afferent impulses, which also lead to pain. The posterior horn cells transfer impulses to the central nervous system, intensifying painful stimuli. Pain impulses can refer locally to intensify muscle spasm or continue to the brain stem. Some impulses may continue to the cortex where they are also interpreted as pain. This bombardment of pain leads to a functional pathology; myofascial trigger points, painful muscle spasm and reduced motion (Gatterman, 2004).

Autonomic function can be affected by facilitation of the lateral horn cells. Hyperactivity of the sympathetic pathways produce a wide range of symptoms. Hyperactivity of
sympathetic areas seem to correlate with the segmental distribution of myofascial dysfunction of the paraspinal muscles (Gatterman, 2004).

5.2.1.2 Kinesiopathology

Kinesiopathology refers to the fixation of the dysfunctional segment. The vertebra can be said to be fixed within its normal range of motion (Gatterman, 2004).

Figure 2.6 shows very clearly how aberrant movement within the three joint complex of the vertebral subluxation complex can lead either to joint sprain and hypermobility or joint fixation and hypomobility. The goal of Chiropractic care is to restore mobility to the fixated joint while avoiding or aggravating areas of hypermobility (Gatterman, 2004).

Myofascial trigger points contribute to restricted segmental movement (Gatterman, 2004). Neurological facilitation has been discussed as a cause of myofascial trigger points. Korr proposes that a central nervous system phenomenon is responsible muscle spasm and subsequently for joint fixation (Gatterman, 2004). This theory centres on the fusimotor background discharge, which is seen during type A alpha motor neuron activity (Leach, 1994).
The short intervertebral muscles are controlled involuntarily by the central nervous system (CNS). A ‘low-gain’ gamma motoneuron activity is used to contract the muscle (A on Figure 2.7). If the vertebral attachments of these muscles are approximated by unguarded movement it silences the annulospinal receptor activity. The CNS, receiving a lack of feedback from these receptors, is fooled into interpreting this as a sign that the muscle has not contracted (B on Figure 2.7). It therefore turns up the ‘gain’ on the gamma motoneuron and the muscle contracts further and fixes the joint in that position (C on Figure 2.7). Movement into other directions is now opposed by the resistant muscle. Continued ‘high-gain” activity causes the affected muscle to spasm (Leach, 1994).

Figure 2.7: Korr Model of Segmental Dysfunction (Leach, 1994).

Spinal joints provide major input for postural and kinaesthetic sensation, which is then used for regulation of postural muscle tone. This is referred to as the arthrokinetic reflex. The static and dynamic mechanoreceptors (type 1 and 2 fibres) inhibit the afferent input of nociceptive fibres (type 4 fibres). Therefore activity of the mechanoreceptors inhibits activity on the nociceptors. Similarly inactivity of the mechanoreceptors results in increased
activity in the nociceptors and therefore pain at the site of segmental fixation (Gatterman, 2004).

Gatterman (2004), proposes that long-standing joint fixation is a degenerative process, resulting first in ligamentous shortening, followed by articular adhesion. Articular adhesion resulting from joint immobility is caused by a reduction in the production of glycosaminoglycans, a reduced water content and increase in the intermolecular cross-links in collagen fibres (Gatterman, 2004).

2.6 The Chiropractic Manipulation

Chiropractic manipulative therapy (CMT) is the generic term given to a group of manual therapeutic interventions. They are usually applied with the aim of inducing intervertebral movement by manually directing specific forces to vertebrae (Evans and Breen, 2006).

Gatterman and Hansen (2002), define the manipulation as a specific form of joint manipulation using either long or short-leverage techniques with specific anatomical contacts. It is characterized by a low-amplitude dynamic thrust of controlled velocity, amplitude, and direction used to restore normal nervous function. According to Schafer and Faye (1990), an manipulation is applied at the point of resistance to restore adequate mobility to the area to initiate the recovery process.

The subluxation is an abnormal biomechanical relation within the spine, which stimulates the receptors within the spinal, and paraspinal tissues. The stimulation of the muscles, ligaments and facets, generates impulses, which activate neural reflex centres within the spinal cord or higher centres, causing somatovisceral responses in sympathetic and parasympathetic nerves, resulting in muscle spasm (Haldeman, 2000).

There are several theories for mechanisms as to how CMT translates into clinical effects for the treatment of spinal pain. This makes the selection of techniques difficult to explain or justify (Evans and Breen, 2006).

Statistically, the clinical outcomes of CMT for spinal pain are significantly greater than those of placebo or sham. Consequently, there must be some explanation for the clinical results attained from the mechanical intervention (Evans and Breen, 2006).
Various theories have been proposed to explain the clinical effects of spinal manipulation. Essentially, 4 main theories can be drawn from the published literature.

- Release of trapped intra-articular material such as synovial folds or meniscoids
- Relaxation of hypertonic muscle by sudden stretching, the mechanoreceptor-pain gate or reflexogenic theory
- Disruption of articular or periarticular adhesions
- Unbuckling of motion segments that have undergone disproportionate displacements (Evans and Breen, 2006).

Bolton (2000), reviewed the segmental afferent input from spinal structures in detail, and found that spinal structures are richly innervated. There are multiple sensory receptors in muscle, ligaments, facet joints, paraspinal skin, the meninges, and the outer fibers of the intervertebral disc. These receptors are responsive to mechanical (position, motion, and tissue distortion), inflammatory (nociceptive), and temperature changes. Each spinal structure has its own neural receptors with different characteristics and sensitivities. Stimulation of these receptors has been shown to activate central reflex pathways and specific somato-somatic reflexes in experimental animals. Research by Herzog, Scheele and Conway (1999), has demonstrated that these reflexes can be activated by a spinal manipulation.

Previous research suggests that chiropractic manipulations create sufficient force to simultaneously activate both superficial and deep somatic mechanoreceptors, proprioceptors and noiceceptors, thereby inducing stimulus-produced analgesia. This stimulation produces a strong afferent barrage of sensory neurons capable of inhibiting the central transmission of pain (Bergmann and Peterson, 2002).

Gillette (2002), has suggested that chiropractic manipulations may produce a brief phasic response which is triggered by the stimulation of both deep and superficial mechanoreceptors. A longer-lived tonic response may also be initiated, which is triggered by the noxious stimulation of noiceceptive receptors.
Sensory receptors are present in muscle, ligaments, facet joints, skin, meninges and the periphery of the intervertebral disc. These receptors are sensitive to mechanical, inflammatory and temperature changes. (Bergmann and Peterson, 2002)

Spinal manipulative therapy has been shown to produce a consistent reflex from a multi-receptor origin resulting in clinical observed benefits, which include the reduction of pain and muscle hypertonicity. A specialized receptor referred to as the golgi organ is present within gross muscle structures inhibits the muscle when excessively tensed (Martini, 1998). The chiropractic manipulation therefore causes a reflex inhibition of the golgi organ by immediately causing relaxation in the hypertonic muscle (Pickar, 2002).

2.7 Feed-forward Activation

Feed-forward activation is an activation of the transverse abdominus and the internal oblique muscles before limb movement occurs. This pre-activation occurs at 30-100ms before the prime mover of the limb.

Links have been shown between low back pain and motor control deficits in muscles of the local supporting system of the lower back, notably the transversus abdominis and lumbar multifidus. These muscles appear to lose their normal anticipatory function in patients with low back pain, showing delays in activation and therefore a loss of their normal preprogrammed function for support (Jull and Richardson, 2000).

Studies have shown that there is a decrease or lack of this feed-forward activation in patients with low back pain (Marshall and Murphy, 2006). Several studies have also shown that there is an increase in this abdominal feed-forward activation immediately after sacroiliac manipulation.

Questions have been raised as to whether this is a cause or an effect of lower back pain (Marshall and Murphy, 2006). One review of literature has challenged the theory that the transverse abdominus plays a significant role in lower back pain and suggests that core stabilisation is simply a popular fad amongst health care providers with no real clinical significance (Lederman, 2010).
2.8 Manipulation and the Effect on the Transverse Abdominus

Sacroiliac manipulation has been shown to have an effect on the transverse abdominus (Marshall and Murphy, 2006). Manipulation of the upper lumbar spine will also have an effect on the transverse abdominus as the innervation for this muscle is derived from T12 and L1 spinal nerves (Martini et al 2001), therefore adjusting that segment will have a direct effect on the muscle (Pickar 2002). By the same token, manipulation of the lower segments of the lumbar spine will also affect the transverse abdominus as spinal manipulation alters the afferent signals of paraspinal tissue (Pickar 2002).

It can therefore be proposed that adjusting any segment of the lumbar spine will affect the transverse abdominus and the internal oblique.

2.7 Summary

In summary it can be seen that each element of the lumbar spine is linked so that if there is dysfunction in one element, dysfunction will develop in another. It should therefore follow that correcting one element of dysfunction will also correct other elements. This study will investigate and help to explain the link between dysfunction in the lumbar spine and the transverse abdominus muscle.
CHAPTER 3 METHODOLOGY

3.1 INTRODUCTION

In this chapter the procedure and process of data collection will be discussed and the process of statistical analysis briefly outlined.

Data was collected from two sources. Objective data was collected by means of surface electromyography. Subjective data was collected using the Oswestry Low Back Pain and Disability Questionnaire (Appendix A) and a Numerical Pain Rating Scale (Appendix B).

3.2 Study Design

This study is a randomised, comparative and explorative trial.

3.3 Participant Selection

Participants were recruited by word of mouth, advertising in the University of Johannesburg Health Centre and on the University of Johannesburg, Doornfontein Campus and advertising at various schools and recreational venues (Appendix C).

3.4 Sample Size

A sample size of forty five participants, with chronic non-traumatic low back pain, was selected for this study. Participants were divided into three groups of fifteen. Patients presenting to the Chiropractic Clinic of the University of Johannesburg were also screened as potential participants. A case history, full physical and lumbar regional was performed (Appendix D).

Group one received treatment in the form of abdominal exercises only. Group two received chiropractic manipulative treatment of the lumbar spine according to restrictions found in each individual and abdominal exercise. Group three received chiropractic manipulative treatment of the lumbar spine only.

Three groups allowed an adequate comparison of abdominal muscle reaction to intervention, enabling a determination of greatest improvement.
Participant consent was obtained before beginning with screening. All participants were requested to read and complete the information and consent form (Appendix E).

3.5 Inclusion Criteria

Participants were included according to the following criteria:

- They were between the ages of 18 and 35 years
- Participants were experiencing chronic mechanical low back pain. The criteria for this diagnosis to be made are discussed below.

Participants in this study presented with mechanical low back pain where the back pain was felt between the 12th rib and the gluteal folds (Croft and Raspe, 2005). Traditionally chronic pain is described as pain of 3 months duration or more (Singer and Giles, 1997). Croft and Raspe (2005), however suggest that recurrent episodes of low back pain can be classed as chronic. Therefore for the purposes of this study, participants experiencing initial episodes of low back pain of 3 months or more were included, as well as participants experiencing a recurrence of pain.

Participants also presented with at least two of the clinical features of joint dysfunction as described by Peterson and Bergman (2002):

- Localised pain which commonly changes with movement
- Local tissue hypersensitivity
- Altered alignment
- Decreased, increased or aberrant joint motion
- Altered joint play
- Altered joint end-feel
- Local palpator muscle rigidity

According to Kirkaldy-Willis and Bernard (1999), chronic mechanical low back pain may present in phase 1, where back pain is often localised, referred pain may be present and
movement is painful. The examiner should find local tenderness, muscle contraction, hypomobility, painful extension, and usually an unremarkable neurological examination (Kirkaldy-Willis and Bernard, 1999).

Participants were screened using Kemp’s test or Yeoman’s. A positive from any of these tests indicates a joint dysfunction and therefore an indicator of mechanical low back pain (Walsh, 1998).

3.5 Exclusion Criteria

- Participants who were aware of any spinal bony abnormality were excluded.

- As surface EMG comparison requires the use of the upper limb as well as the lower back; any injury or obvious decrease in shoulder range of motion was also excluded.

- Participants falling outside the specified age group were not included.

- Participants with contraindications to spinal manipulative therapy were also excluded:
  - Abdominal Aortic Aneurysm,
  - Tumours,
  - Bone Infection,
  - Fractures of the Spine,
  - Inflammatory Conditions: Rheumatoid Arthritis, Psoriatic Arthritis, Ankylosing Spondylitis (these conditions are contraindicated in the inflammatory stages),
  - Osteoporosis,
  - Cauda Equina Syndrome,
  - Lumbar disc herniation with progressive neurological deficit (Gatterman, 2004).
Female patients who were pregnant or recently pregnant. The causes for low back pain in pregnancy both mechanical and hormonal. The presence of relaxin causes connective tissue softening in the pelvic area. It softens the sacroiliac joints and pubic symphysis. The increasing weight of the trunk on the pelvis forces the sacrum down. This causes increased pressure on the sacroiliac joints and consequently pain in the sacroiliac and lumbar region (Sands, 1958). Since both the mechanical and hormonal causes of this type of low back pain are transient, these participants were excluded.

3.6 Randomisation

Participants were assigned to three groups of fifteen by the researcher while attempting to match mean age, sex and severity of symptoms in order to eliminate variables. While this is not actual random placement it enabled the comparison of the groups.

3.7 Treatment Approach

3.7.1 First and Follow-up Visits

Participants were seen seven times within a maximum of a four week period. On the first visit each participant was assessed using the University of Johannesburg Chiropractic Clinic Case History, Pertinent Physical and Lumbar Regional Examinations (Appendix D, E and F). Each participant also completed an Oswestry Low Back Pain and Disability Questionnaire (Appendix A) and a Numerical Pain Rating Scale (Appendix B). Before treatment, surface EMG readings were taken. The onset time and peak value of the internal oblique and transverse abdominus contraction was measured and compared to the onset time and peak value of deltoid contraction during rapid limb movement. Each participant was also required to complete a consent form (Appendix E).

In group one the participants were then treated using abdominal strengthening exercise (Appendix F) only. The exercises used are basic lumbar stabilising exercises which can be easily performed by the participant.
In group two the participants were treated using chiropractic manipulative treatment according to each individual’s lumbar restrictions and abdominal exercises.

Group three received chiropractic manipulative treatment only.

On the second, fourth and sixth follow-up visits the participants were treated only. No measurements were taken.

On the first, third, fifth and seventh follow-up visits measurements were taken before treatment. The participants were also required to complete the Oswestry Low Back Pain and Disability Questionnaire (Appendix A) and Numerical Pain Rating Scale (Appendix B) on these follow-up visits. The seventh follow up visit was used for final measurements only.

Surface EMG readings were also taken on the first, third, fifth and seventh follow up visits. Placement and method of EMG data collection will be discussed later in this chapter.

### 3.8 Subjective Data

Subjective data was recorded using a Numerical Pain Rating Scale (NPRS) (Appendix B) and an Oswestry Low Back Pain and Disability Questionnaire (Appendix A).

a) Numerical Pain Rating Scale

The NPRS (Appendix B) is a numerical rating used to determine the participants’ perception of their level of pain. It was modified from the Visual Analogue Scale for easier use by patients and more accurate interpretation by examiners.

Each participant selected the number which best represented their current pain, 10 representing the worst pain ever felt and 0 representing no pain. Validity and reliability for the NPRS (Appendix B) has been demonstrated by Bolton and Wilkinson (1998).
b) Oswestry Low Back Pain and Disability Questionnaire

The Oswestry Low Back Pain and Disability Questionnaire (ODI) (Appendix A) was designed to measure both assessment and outcome (Roland and Fairbank, 2000). The ODI can be considered to be a good functional measure as it assesses activities of daily living and can therefore measure the participants’ quality of life (Magee, 2006).

This questionnaire is ideal as it can be completed in less than five minutes and scored in less than one minute. It is comprised of ten sections, each consisting of six statements scored from zero to five. For each section, the total score is five; the first statement score is zero; the last statement score is five. Intervening statements are scored accordingly. If more than one box is marked per section, the highest score is selected. If all ten sections are completed the questionnaire is scored as follows:

- Total score out of fifty x 100 = %

If one section is missed or considered as not applicable the score would be calculated as follows:

- Total score out of (fifty minus 5 per section skipped/missed) x 100 = %

When scoring the ODI, the following guideline is used to determine the level of disability:

- 0-20% = Minimal Disability - No Treatment Necessary
- 22-40% = Mild Disability - Conservative Treatment Recommended
- 42-60% = Severe Disability - Detailed Investigation Required
- 62-80% = Crippling Disability - Severe Intervention Required
- 82-100% = Complete Disability - Bed Bound

The Oswestry Low Back Pain and Disability Questionnaire is a simple and easily completed questionnaire which is also easily and swiftly scored by the examiner (Fairbank and Pysent, 2000). Fisher and Johnson, (1997) found that both the face and content validity was valid for this questionnaire. Roland and Fairbank also concluded that physical
tests correlate with the Oswestry Low Back Pain and Disability Questionnaire (Appendix A).

The revised Oswestry Low Back Pain and Disability Questionnaire (Appendix A) was used. This questionnaire helped to determine the level of impact of the participants’ lower back pain had on their daily activities and any changes that occurred during this study.

3.9 Objective Data

Objective data was collected and recorded using surface electromyography (EMG).

a) Validity and Reliability

Previously, the only reliable method of measuring deep abdominal musculature activity was via fine-wire electromyography. This method, while accurate, is not practical or patient-friendly as it involves ultrasound guided needle insertion into the abdominal wall. Surface electromyography (EMG) is far more practical as it is non-invasive and it does not require the specific laboratory settings or the specialised skill of fine-wire electromyography.

Surface EMG is a technique used to measure muscle activity. Surface electrodes placed on the skin overlying the target muscle measure the action potential of the muscle fibres. Surface EMG is able to record voluntary and involuntary muscle activity (Pullmann, Goodin, Marquinez and Tabbal, 2000).

Surface EMG has been shown to be valid and reliable when electrodes are placed 2cm inferior and medial to the anterior superior iliac spine (McGill et al, 1996).

Surface EMG of the combined activity of transverse abdominus and internal oblique can be said to be accurate with an error margin of 10-15% when compared to fine-wire EMG (McGill et al, 1996). This site (approximately 2cm inferior and medial to the anterior superior iliac spine) has been shown to have a high re-test reliability (Marshall and Murphy, 2003). Development of this method of surface EMG is allowing much more extensive research into the role the transverse abdominus plays in low back pain (McGill et al, 1996).
b) EMG Testing Method

Readings were taken on the first, third and fifth follow-up visits. Electrodes were placed on the combined transverse abdominus and internal oblique site on the same side as the sacroiliac manipulation is performed. Electrodes were also placed on the deltoid muscle in order to compare onset of contraction of each muscle. Each measurement was also compared to previous measurements to ascertain if any long-term changes occur. Resting surface EMG readings will be taken before each task is performed. These will be taken with the participant standing in a comfortable position. Resting readings will serve to establish a latency reading for both the deltoid and the transverse/internal oblique.

The electrodes were placed on the skin once each area had been cleaned with an alcohol swab. A pair of electrodes was placed on the abdomen 2cm medial and inferior to the anterior superior iliac spine. Another pair of electrodes was placed over the deltoid muscle on the same side (Marshal and Murphy, 2006). The participant was then asked to rapidly abduct the upper limb. This was performed five times in order to obtain a mean value.

The upper limb on the same side as the transverse/internal oblique muscle was tested. Readings from the transverse/internal oblique site and the deltoid site were recorded on computer. Further analysis is discussed in detail in forthcoming chapters.

The Neurotrack ETS unit was used for this study. It is a dual channel EMG and neuromuscular stimulation unit. The unit and software were supplied by the University of Johannesburg.

3.10 Ethical Considerations

All participants who took part in this study were requested to read and sign the information and consent form specific to this study. The information and consent form with outline the names of the researcher, purpose of the study and the benefits of partaking in the study, participant assessment and treatment procedure, any risks, benefits and discomforts pertaining to the treatments involved was also explained. Any questions that the participants had were answered to the best ability of the researcher. The participants’ safety was ensured at all times. The information and consent form also explained that the
participant's privacy was protected by ensuring their anonymity and confidentiality when compiling this research dissertation.

Participant confidentiality and anonymity was accomplished by using only participant file numbers when reporting results. The participants were informed that their participation was on a voluntary basis and that they were free to withdraw from the study at any stage. Should the participant have had any further questions, these were answered by the researcher; contact details were made available. The participants were then required to sign the information and consent form, signifying that they understood what was required of them for this particular study.

Participant privacy was ensured by using a private treatment room. No observers were allowed during this study.

Results of the study will be made available on request.

3.11 Data Analysis

EMG information was recorded and stored on computer using the Neurotrack ETS software. Scores from the Oswestry Disability Questionnaires (Appendix A) and NPRS (Appendix B) was calculated and collated by the researcher. All the information was sent to the University of Johannesburg Statistical Department for analysis.

Frequencies and descriptive analysis was used to describe the sample statistically. Tests for normality were performed; the Shapiro-Wilk test was used. Intergroup comparisons were made using the Kruskal-Wallis test. Intragroup comparisons were made using the Friedman test and the more specific Wilcoxon signed ranks test.

The Shapiro-Wilk test compares a set of measures against the normal distribution. It is usually used before parametric tests to ensure the data being used follows a normal distribution.

Non-parametric tests were used to analyse the information because this set of tests do not make assumptions about the population distribution. This was done because the sample sizes were relatively small. All commonly used nonparametric tests rank the outcome
variable from low to high and then analyze the ranks. These tests are also called distribution-free tests.

The Wilcoxon signed ranks test applies to two sample designs involving repeated measures, matched pairs, or "before" and "after" measures. It ranks the absolute values of the differences between the paired data in sample 1 and sample 2 and calculates a statistic on the number of negative and positive differences (Shapiro and Wilk, 1965).

Statistical information will be discussed in detail in forthcoming chapters.
CHAPTER 4: RESULTS
CHAPTER 4: RESULTS

The data analysis will be discussed in this chapter. It will be presented with the aim of determining whether there were any statistically significant changes to the measured criteria. The specific tests used were briefly discussed in Chapter 3. All the information was analysed for normal or non-normal distribution before continuing with further statistical analysis.

A statistical significance level of $p > 0.05$ was set for this analysis.

4.1 Demographics

Participants recruited for this study were between the ages of 18 and 35 years, with a mean age of 25.29 years. The gender distribution for the entire sample group was 36 female and 9 male participants (Figure 4.1).

![Figure 4.1: Bar graph representing the gender distribution](image-url)
Group 1 consisted of 4 Male and 11 Female participants. The age of group 1 ranged from 18 to 29 years, with a mean age of 24.4 years (Table 4.1). The age range was found to be normally distributed. Group 2 consisted of 3 male and 12 female participants. The age of this group ranged between 18 and 35 years, with a mean age of 25.4 years (Table 4.1). The age range was found to be normally distributed for this group. Group 3 consisted of 2 male participants and 13 female. The age of this group ranged from 19 to 35 years with a mean age of 26.07 years (Table 4.1). This age range was found to be normally distributed.

Therefore these groups were comparable

Table 4.1: Age Distribution for Groups 1, 2 and 3

<table>
<thead>
<tr>
<th>GROUP 1</th>
<th>GROUP 2</th>
<th>GROUP 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Range</td>
<td>18- 29years</td>
<td>18- 35years</td>
</tr>
<tr>
<td>Mean Age</td>
<td>24.4years</td>
<td>25.4years</td>
</tr>
</tbody>
</table>

4.2 Subjective Results

Subjective readings were in the form of an Oswestry Low Back Pain and Disability Questionnaire and a Numerical Pain Rating Scale questionnaire. These questionnaires were completed at the 1\textsuperscript{st}, 3\textsuperscript{rd}, 5\textsuperscript{th} and 7\textsuperscript{th}/final Visits.

Results from these questionnaires were tabulated and statistically analysed.
a) Intra-group Analyses of the Oswestry Pain and Disability Scores

Table 4.2: Oswestry Pain and Disability Scores: Intra-group Statistical Analyses

<table>
<thead>
<tr>
<th>Factor</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1 mean</td>
<td>19.02%</td>
<td>21.96%</td>
<td>23.47%</td>
</tr>
<tr>
<td>Visit 3 mean</td>
<td>15.33%</td>
<td>13.47%</td>
<td>14.80%</td>
</tr>
<tr>
<td>Visit 5 mean</td>
<td>12.53%</td>
<td>10.27%</td>
<td>12.41%</td>
</tr>
<tr>
<td>Visit 7 mean</td>
<td>9.73%</td>
<td>8.00%</td>
<td>2.83%</td>
</tr>
<tr>
<td>Mean Change: Visit 1 - Visit 7</td>
<td>9.29%</td>
<td>13.96%</td>
<td>20.64%</td>
</tr>
<tr>
<td>Normal Distribution: (p&gt;0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visit 1</td>
<td>p=0.445</td>
<td>p=0.100</td>
<td>p=0.268</td>
</tr>
<tr>
<td>Visit 3</td>
<td>p=0.513</td>
<td>p=0.684</td>
<td>p=0.024</td>
</tr>
<tr>
<td>Visit 5</td>
<td>p=0.055</td>
<td>p=0.070</td>
<td>p=0.864</td>
</tr>
<tr>
<td>Visit 7</td>
<td>p=0.068</td>
<td>p=0.067</td>
<td>p=0.127</td>
</tr>
<tr>
<td>Statistical Significance between Follow-Ups : (p&lt;0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=0.000</td>
<td>p=0.000</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Multiple Comparison of Statistical Significance for Paired Groups: (p&lt;0.05)</td>
<td>Visit 1 - 5: p=0.013</td>
<td>Visit 1 - 3: p=0.001</td>
<td>Visit 1 - 3: p=0.001</td>
</tr>
<tr>
<td></td>
<td>Visit 1 - 7: p=0.007</td>
<td>Visit 1 - 5: p=0.001</td>
<td>Visit 1 - 5: p=0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Visit 1 - 7: p=0.001</td>
</tr>
</tbody>
</table>
Table 4.2 shows the intra-group analysis of the Oswestry Disability scores for the three groups.

There was a mean change of 9.29% in group one, 13.96% in group two and 20.64% in group three.

There was a statistically significant difference (p<0.05) noted on intra-group analysis for all three groups. Specific significant difference (p<0.05) was noted in group one between visit 1 and 5, and visit 1 and 7. In group two and three a statistically significant difference (p<0.05) was noted between visit 1 and 3, 1 and 5 as well as visit 1 and 7.

Significantly all three groups showed a statistically significant change (p<0.05) between visit 1 and 7.

b) Inter-group Analyses of the Oswestry Pain and Disability Scores

Table 4.3: Oswestry Pain and Disability Scores: Inter-group Statistical Analyses

<table>
<thead>
<tr>
<th>Factor</th>
<th>1st Visit</th>
<th>3rd Visit</th>
<th>5th Visit</th>
<th>7th/Final Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Difference:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1-2</td>
<td>-2.933</td>
<td>1.867</td>
<td>2.267</td>
<td>1.733</td>
</tr>
<tr>
<td>Group 1-3</td>
<td>-4.445</td>
<td>0.533</td>
<td>0.120</td>
<td>3.009</td>
</tr>
<tr>
<td>Group 2-3</td>
<td>-1.511</td>
<td>-1.333</td>
<td>-2.147</td>
<td>1.276</td>
</tr>
<tr>
<td>Normal Distribution:</td>
<td>p&gt;0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>p=0.445</td>
<td>p=0.513</td>
<td>p=0.055</td>
<td>p=0.068</td>
</tr>
<tr>
<td>Group 2</td>
<td>p=0.100</td>
<td>p=0.684</td>
<td>p=0.070</td>
<td>p=0.067</td>
</tr>
<tr>
<td>Group 3</td>
<td>p=0.268</td>
<td>p=0.024</td>
<td>p=0.864</td>
<td>p=0.127</td>
</tr>
<tr>
<td>Statistical Significance between Paired Groups:</td>
<td>p=0.672</td>
<td>p=0.930</td>
<td>p=0.757</td>
<td>p=0.746</td>
</tr>
</tbody>
</table>
Table 4.3 shows the inter-group comparison of the Oswestry Disability scores of visits 1, 3, 5 and 7.

There was no statistically significant difference in the Oswestry Low Back Pain and Disability Questionnaire scores for the inter-group analysis.

Figure 4.2: Line Graph representing the Mean Oswestry Pain and Disability Scores of Groups 1, 2 and 3

Figure 4.2 is the graphical representation of the mean Oswestry scores of group one, two, and three for each visit.

Each group’s mean scores decreased at every visit, with group three showing the greatest decrease of 21.64%.
a) Intra-group Analyses of the Numerical Pain Rating Scale Scores

Table 4.4: Numerical Pain Rating Scale Scores: Intra-group Statistical Analyses

<table>
<thead>
<tr>
<th>Factor</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1 mean</td>
<td>4.13</td>
<td>4.40</td>
<td>4.67</td>
</tr>
<tr>
<td>Visit 3 mean</td>
<td>3.60</td>
<td>3.73</td>
<td>3.13</td>
</tr>
<tr>
<td>Visit 5 mean</td>
<td>2.87</td>
<td>2.87</td>
<td>2.67</td>
</tr>
<tr>
<td>Visit 7 mean</td>
<td>2.13</td>
<td>2.47</td>
<td>1.73</td>
</tr>
<tr>
<td>Mean Change: Visit 1- Visit 7</td>
<td>2</td>
<td>1.93</td>
<td>2.94</td>
</tr>
<tr>
<td>Normal Distribution: (p&gt;0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visit 1</td>
<td>p=0.261</td>
<td></td>
<td>p=0.251</td>
</tr>
<tr>
<td>Visit 3</td>
<td>p=0.692</td>
<td>p=0.117</td>
<td>p=0.036</td>
</tr>
<tr>
<td>Visit 5</td>
<td>p=0.057</td>
<td>p=0.008</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Visit 7</td>
<td>p=0.007</td>
<td>p=0.001</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Statistical Significance between Follow-Ups : (p&lt;0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=0.000</td>
<td>p=0.000</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Multiple Comparison of Statistical Significance for Paired Groups: (p&lt;0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visit 1- 5: p=0.004</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visit 1- 7: p=0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visit 1- 3: p=0.013</td>
<td>Visit 1- 3: p=0.002</td>
<td>Visit 1- 5: p=0.002</td>
<td></td>
</tr>
<tr>
<td>Visit 1- 7: p=0.001</td>
<td>Visit 1- 5: p=0.001</td>
<td>Visit 1- 7: p=0.001</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.4 shows the intra-group analysis of the Numerical Pain Rating scores for the three groups.

Group three shows the greatest mean decrease of 2.94 from visit 1 to visit 7, with group one showing a mean decrease of 2 and group two showing a mean decrease of 1.93.

There was a statistically significant difference (p<0.05) noted on intra-group analysis for all three groups. Specific significant difference (p<0.05) was noted in group one between visit 1 and 5, and visit 1 and 7. In group two and three a statistically significant difference (p<0.05) was noted between visit 1 and 3, 1 and 5 as well as visit 1 and 7.

Significantly all three groups showed a statistically significant change (p<0.05) between visit 1 and 7.

b) Inter-group Analyses of the Numerical Pain Rating Scale Scores

**Table 4.5: Numerical Pain Rating Scale Scores: Inter-group Statistical Analyses**

<table>
<thead>
<tr>
<th>Factor</th>
<th>1st Visit</th>
<th>3rd Visit</th>
<th>5th Visit</th>
<th>7th/Final Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Difference:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1-2</td>
<td>-0.267</td>
<td>-0.133</td>
<td>0.000</td>
<td>-0.333</td>
</tr>
<tr>
<td>Group 1-3</td>
<td>-0.533</td>
<td>0.467</td>
<td>0.200</td>
<td>0.400</td>
</tr>
<tr>
<td>Group 2-3</td>
<td>-0.267</td>
<td>0.600</td>
<td>0.200</td>
<td>0.733</td>
</tr>
<tr>
<td>Normal Distribution: p&gt;0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>p=0.261</td>
<td>p=0.692</td>
<td>p=0.057</td>
<td>p=0.007</td>
</tr>
<tr>
<td>Group 2</td>
<td>p=0.096</td>
<td>p=0.117</td>
<td>p=0.008</td>
<td>p=0.001</td>
</tr>
<tr>
<td>Group 3</td>
<td>p=0.251</td>
<td>p=0.036</td>
<td>p=0.000</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Statistical Significance between Paired Groups: p&lt;0.05</td>
<td>p=0.697</td>
<td>p=0.490</td>
<td>p=0.764</td>
<td>p=0.104</td>
</tr>
</tbody>
</table>
Table 4.5 shows the inter-group comparison of the Numerical Pain Rating Scale scores of visits 1, 3, 5 and 7.

There was no statistically significant (p<0.05) difference in the Numerical Pain Rating Scale scores for the inter-group analysis.

![Figure 4.3: Line Graph representing the Mean Numerical Pain Rating Scale Scores](image)

Figure 4.3 shows the graphical representation of the mean Numerical Pain Rating Scale scores of group one, two and three for each visit.

Each group's mean scores decreased at every visit.

### 4.3 Objective Results

A number of readings were taken using a Neurotrack ETS surface EMG machine. The data recording transverse abdominal muscle activity and the difference between deltoid onset and transverse abdominal muscle onset was of specific interest in this study.

This data was tabulated and statistically analysed.
a) Intra-group Analyses of the Minimum EMG Activity of the Transverse Abdominus Muscle

Table 4.6: Minimum EMG Activity of the Transverse Abdominus Muscle: Intra-group Statistical Analyses

<table>
<thead>
<tr>
<th>Factor</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1 mean</td>
<td>4.63</td>
<td>2.94</td>
<td>3.05</td>
</tr>
<tr>
<td>Visit 3 mean</td>
<td>2.13</td>
<td>3.36</td>
<td>3.59</td>
</tr>
<tr>
<td>Visit 5 mean</td>
<td>2.68</td>
<td>2.34</td>
<td>4.09</td>
</tr>
<tr>
<td>Visit 7 mean</td>
<td>2.51</td>
<td>2.27</td>
<td>3.56</td>
</tr>
<tr>
<td>Mean Change Visit 1-7</td>
<td>2.12</td>
<td>0.67</td>
<td>-0.51</td>
</tr>
</tbody>
</table>

Normal Distribution: (p>0.05)

<table>
<thead>
<tr>
<th>Factor</th>
<th>p</th>
<th>p</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1</td>
<td>0.000</td>
<td>0.108</td>
<td>0.876</td>
</tr>
<tr>
<td>Visit 3</td>
<td>0.263</td>
<td>0.072</td>
<td>0.000</td>
</tr>
<tr>
<td>Visit 5</td>
<td>0.043</td>
<td>0.275</td>
<td>0.001</td>
</tr>
<tr>
<td>Visit 7</td>
<td>0.055</td>
<td>0.004</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Statistical Significance between Follow-Ups: (p<0.05)

<table>
<thead>
<tr>
<th>p</th>
<th>p</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.144</td>
<td>0.065</td>
<td>0.852</td>
</tr>
</tbody>
</table>

Multiple Comparison of Statistical Significance for Paired Groups: (p<0.05)

<table>
<thead>
<tr>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
</tr>
</tbody>
</table>

Table 4.6 shows the intra-group analysis of the Minimum EMG Activity of the Transverse Abdominus Muscle for the three groups.

The mean decrease for group one was 2.12uV, group two was 0.67uV and group three showed a mean increase of 0.51uV

There is no statistical difference (p<0.05) between the follow-up visits of the three groups.
b) Inter-group Analyses of the Minimum EMG Activity of the Transverse Abdominus Muscle

Table 4.7: Minimum EMG Activity of the Transverse Abdominus Muscle: Inter-group Statistical Analyses

<table>
<thead>
<tr>
<th>Factor</th>
<th>1st Visit</th>
<th>3rd Visit</th>
<th>5th Visit</th>
<th>7th/Final Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Difference:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1-2</td>
<td>1.693</td>
<td>-1.227</td>
<td>0.340</td>
<td>0.240</td>
</tr>
<tr>
<td>Group 1-3</td>
<td>1.587</td>
<td>-1.460</td>
<td>-1.407</td>
<td>-1.053</td>
</tr>
<tr>
<td>Group 2-3</td>
<td>-0.107</td>
<td>-0.233</td>
<td>-1.747</td>
<td>-1.293</td>
</tr>
<tr>
<td>Normal Distribution:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>p=0.000</td>
<td>p=0.263</td>
<td>p=0.043</td>
<td>p=0.055</td>
</tr>
<tr>
<td>Group 2</td>
<td>p=0.108</td>
<td>p=0.072</td>
<td>p=0.275</td>
<td>p=0.004</td>
</tr>
<tr>
<td>Group 3</td>
<td>p=0.876</td>
<td>p=0.000</td>
<td>p=0.001</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Statistical Significance between Paired Groups:</td>
<td>p=0.883</td>
<td>p=0.431</td>
<td>p=0.780</td>
<td>p=0.643</td>
</tr>
</tbody>
</table>

Table 4.7 shows the inter-group comparison of the Minimum EMG Activity of the Transverse Abdominus Muscle readings of visits 1, 3, 5 and 7.

There was no statistically significant (p<0.05) difference in the Minimum EMG Activity of the Transverse Abdominus Muscle readings for the inter-group analysis.
Figure 4.4: Line Graph representing the Mean Minimum EMG Readings from the Transverse Abdominus Muscle

Figure 4.4 shows the graphical representation of the mean minimum EMG readings from the transverse abdominus muscle of group one, two and three for each visit.

The readings from groups one and two fluctuate between visits. Readings from group three however show a steady increase on each visit.
a) Intra-group Analyses of the Maximum EMG Activity of the Transverse Abdominus Muscle

**Table 4.8: Maximum EMG Activity of the Transverse Abdominus Muscle: Intra-group Statistical Analyses**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1 mean</td>
<td>64.85</td>
<td>28.53</td>
<td>32.83</td>
</tr>
<tr>
<td>Visit 3 mean</td>
<td>39.36</td>
<td>34.17</td>
<td>35.23</td>
</tr>
<tr>
<td>Visit 5 mean</td>
<td>47.51</td>
<td>29.85</td>
<td>51.20</td>
</tr>
<tr>
<td>Visit 7 mean</td>
<td>44.48</td>
<td>26.35</td>
<td>38.87</td>
</tr>
<tr>
<td>Mean Change Visit 1-Visit 7</td>
<td>20.37</td>
<td>2.35</td>
<td>-6.04</td>
</tr>
</tbody>
</table>

Normal Distribution: (p>0.05)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1</td>
<td>p=0.000</td>
<td>p=0.000</td>
<td>p=0.052</td>
</tr>
<tr>
<td>Visit 3</td>
<td>p=0.098</td>
<td>p=0.067</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Visit 5</td>
<td>p=0.0001</td>
<td>p=0.010</td>
<td>p=0.004</td>
</tr>
<tr>
<td>Visit 7</td>
<td>p=0.298</td>
<td>p=0.002</td>
<td>p=0.000</td>
</tr>
</tbody>
</table>

Statistical Significance between Follow-Ups: (p<0.05)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical Significance for Paired Groups: (p&lt;0.05)</td>
<td>p=0.944</td>
<td>p=0.457</td>
<td>p=0.079</td>
</tr>
</tbody>
</table>

Table 4.8 shows the intra-group analysis of the Maximum EMG Activity of the Transverse Abdominus Muscle for the three groups.

Groups one and two showed a mean decrease of 20.37uV and 2.35uV respectively, while group three showed a mean increase of 6.04uV.
There is no statistical difference (p<0.05) between the follow-up visits of the three groups.

b) Inter-group Analyses of the Maximum EMG Activity of the Transverse Abdominus Muscle

**Table 4.9: Maximum EMG Activity of the Transverse Abdominus Muscle: Inter-group Statistical Analyses**

<table>
<thead>
<tr>
<th>Factor</th>
<th>1st Visit</th>
<th>3rd Visit</th>
<th>5th Visit</th>
<th>7th/Final Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Difference:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1-2</td>
<td>36.320</td>
<td>5.193</td>
<td>17.660</td>
<td>18.127</td>
</tr>
<tr>
<td>Group 1-3</td>
<td>32.013</td>
<td>4.133</td>
<td>-3.693</td>
<td>5.607</td>
</tr>
<tr>
<td>Group 2-3</td>
<td>-4.307</td>
<td>-1.060</td>
<td>-21.393</td>
<td>-12.520</td>
</tr>
<tr>
<td>Normal Distribution: p&gt;0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>p=0.000</td>
<td>p=0.098</td>
<td>p=0.0001</td>
<td>p=0.298</td>
</tr>
<tr>
<td>Group 2</td>
<td>p=0.000</td>
<td>p=0.067</td>
<td>p=0.010</td>
<td>p=0.002</td>
</tr>
<tr>
<td>Group 3</td>
<td>p=0.052</td>
<td>p=0.000</td>
<td>p=0.004</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Statistical Significance between Paired Groups: p&lt;0.05</td>
<td>p=0.412</td>
<td>p=0.402</td>
<td>p=0.399</td>
<td>p=0.244</td>
</tr>
</tbody>
</table>

Table 4.9 shows the inter-group comparison of the Maximum EMG Activity of the Transverse Abdominus Muscle readings of visits 1, 3, 5 and 7.

There was no statistically significant (p<0.05) difference in the Maximum EMG Activity of the Transverse Abdominus Muscle readings for the inter-group analysis.
Figure 4.5: Line Graph representing the Mean Maximum EMG Readings from the Transverse Abdominus Muscle

Figure 4.6 shows the graphical representation of the mean maximum EMG readings from the transverse abdominus muscle of group one, two and three for each visit.

The readings from group one fluctuate between visits. Readings from group two show a steady increase on each visit following the third visit, while readings from group three show an increase on each visit until visit 7, where the mean EMG reading decreases.

The following readings have been analysed separately and then compared together using the Wilcoxon Paired test.
a) Intra-group Analyses of the Onset Times of the Transverse Abdominus Muscle

Table 4.10: Onset Times of the Transverse Abdominus Muscle: Intra-group Statistical Analyses

<table>
<thead>
<tr>
<th>Factor</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1 mean</td>
<td>0.41</td>
<td>0.19</td>
<td>0.24</td>
</tr>
<tr>
<td>Visit 3 mean</td>
<td>0.35</td>
<td>0.26</td>
<td>0.26</td>
</tr>
<tr>
<td>Visit 5 mean</td>
<td>0.41</td>
<td>0.16</td>
<td>0.25</td>
</tr>
<tr>
<td>Visit 7 mean</td>
<td>0.32</td>
<td>0.23</td>
<td>0.31</td>
</tr>
<tr>
<td>Mean Change Visit 1-7</td>
<td>0.09</td>
<td>-0.04</td>
<td>-0.07</td>
</tr>
<tr>
<td>Normal Distribution: (p&gt;0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visit 1</td>
<td>p=0.002</td>
<td>p=0.000</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Visit 3</td>
<td>p=0.005</td>
<td>p=0.001</td>
<td>p=0.004</td>
</tr>
<tr>
<td>Visit 5</td>
<td>p=0.016</td>
<td>p=0.000</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Visit 7</td>
<td>p=0.003</td>
<td>p=0.000</td>
<td>p=0.001</td>
</tr>
<tr>
<td>Statistical Significance between Follow-Ups : (p&lt;0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>p=0.426</td>
<td>p=0.642</td>
<td>p=0.858</td>
</tr>
<tr>
<td>Multiple Comparison of Statistical Significance for Paired Groups: (p&lt;0.05)</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
</tbody>
</table>

Table 4.10 shows the intra-group analysis of the Onset Times of the Transverse Abdominus Muscle for the three groups.

Group one showed a mean decrease in onset time of 0.09s. Group two and three showed a mean increase in onset times of 0.04s and 0.07s respectively.

There is no statistical difference (p<0.05) between the follow-up visits of the three groups.
b) Inter-group Analyses of the Onset Times of the Transverse Abdominus Muscle

Table 4.11: Onset Times of the Transverse Abdominus Muscle: Inter-group Statistical Analyses

<table>
<thead>
<tr>
<th>Factor</th>
<th>1st Visit</th>
<th>3rd Visit</th>
<th>5th Visit</th>
<th>7th/Final Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Difference:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1-2</td>
<td>0.220</td>
<td>0.087</td>
<td>0.247</td>
<td>0.093</td>
</tr>
<tr>
<td>Group 1-3</td>
<td>0.167</td>
<td>0.087</td>
<td>0.153</td>
<td>0.007</td>
</tr>
<tr>
<td>Group 2-3</td>
<td>-0.053</td>
<td>0.000</td>
<td>-0.093</td>
<td>-0.087</td>
</tr>
<tr>
<td>Normal Distribution: p&gt;0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>p=0.002</td>
<td>p=0.005</td>
<td>p=0.016</td>
<td>p=0.003</td>
</tr>
<tr>
<td>Group 2</td>
<td>p=0.000</td>
<td>p=0.001</td>
<td>p=0.000</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Group 3</td>
<td>p=0.000</td>
<td>p=0.004</td>
<td>p=0.000</td>
<td>p=0.001</td>
</tr>
<tr>
<td>Statistical Significance between Paired Groups: p&lt;0.05</td>
<td>p=0.181</td>
<td>p=0.740</td>
<td>p=0.097</td>
<td>p=0.463</td>
</tr>
</tbody>
</table>

Table 4.11 shows the inter-group comparison of the onset times of the Transverse Abdominus Muscle readings of visits 1, 3, 5 and 7.

There was no statistically significant (p<0.05) difference in the onset times of the Transverse Abdominus Muscle readings for the inter-group analysis.
a) Intra-group Analyses of the Onset Times of the Deltoid Muscle


<table>
<thead>
<tr>
<th>Factor</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1 mean</td>
<td>0.95</td>
<td>0.91</td>
<td>0.86</td>
</tr>
<tr>
<td>Visit 3 mean</td>
<td>0.83</td>
<td>0.77</td>
<td>0.74</td>
</tr>
<tr>
<td>Visit 5 mean</td>
<td>0.93</td>
<td>0.79</td>
<td>0.75</td>
</tr>
<tr>
<td>Visit 7 mean</td>
<td>0.68</td>
<td>0.89</td>
<td>0.75</td>
</tr>
<tr>
<td>Mean Change Visit 1-7</td>
<td>0.27</td>
<td>0.02</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Normal Distribution: (p>0.05)

<table>
<thead>
<tr>
<th>Visit</th>
<th>p</th>
<th>p</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1</td>
<td>p=0.875</td>
<td>p=0.198</td>
<td>p=0.208</td>
</tr>
<tr>
<td>Visit 3</td>
<td>p=0.004</td>
<td>p=0.037</td>
<td>p=0.397</td>
</tr>
<tr>
<td>Visit 5</td>
<td>p=0.014</td>
<td>p=0.000</td>
<td>p=0.049</td>
</tr>
<tr>
<td>Visit 7</td>
<td>p=0.324</td>
<td>p=0.001</td>
<td>p=0.032</td>
</tr>
</tbody>
</table>

Statistical Significance between Follow-Ups: (p<0.05)

<table>
<thead>
<tr>
<th>p</th>
<th>p</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>p=0.009</td>
<td>p=0.019</td>
<td>p=0.020</td>
</tr>
</tbody>
</table>

Multiple Comparison of Statistical Significance for Paired Groups: (p<0.05)

<table>
<thead>
<tr>
<th>p</th>
<th>p</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1-7</td>
<td>p=0.007</td>
<td>Visit 1-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visit 1-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visit 1-7</td>
</tr>
</tbody>
</table>

Table 4.12 shows the intra-group analysis of the Onset Times of the Deltoid Muscle for the three groups.

A decrease in mean onset times was seen for all groups.

There was a statistically significant (p<0.05) difference noted on intra-group analysis for all three groups. Specific significant (p<0.05) difference was noted in group one between visit 1 and 7. In group two a statistically significant (p<0.05) difference was noted between visit 1
and 3 and 1 and 5. In group three a statistically significant (p<0.05) difference was noted between visit 1 and 5, and visit 1 and 7.

b) Inter-group Analyses of the Onset Times of the Deltoid Muscle

**Table 4.13: Onset Times of the Deltoid Muscle: Inter-group Statistical Analyses.**

<table>
<thead>
<tr>
<th>Factor</th>
<th>1st Visit</th>
<th>3rd Visit</th>
<th>5th Visit</th>
<th>7th/Final Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Difference:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1-2</td>
<td>0.047</td>
<td>0.060</td>
<td>0.140</td>
<td>-0.213</td>
</tr>
<tr>
<td>Group 1-3</td>
<td>0.093</td>
<td>0.093</td>
<td>0.173</td>
<td>-0.067</td>
</tr>
<tr>
<td>Group 2-3</td>
<td>0.047</td>
<td>0.033</td>
<td>0.033</td>
<td>0.147</td>
</tr>
<tr>
<td>Normal Distribution: p&gt;0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>p=0.875</td>
<td>p=0.004</td>
<td>p=0.014</td>
<td>p=0.324</td>
</tr>
<tr>
<td>Group 2</td>
<td>p=0.198</td>
<td>p=0.037</td>
<td>p=0.000</td>
<td>p=0.001</td>
</tr>
<tr>
<td>Group 3</td>
<td>p=0.208</td>
<td>p=0.397</td>
<td>p=0.049</td>
<td>p=0.032</td>
</tr>
<tr>
<td>Statistical Significance between Paired Groups: p&lt;0.05</td>
<td>p=0.420</td>
<td>p=0.942</td>
<td>p=0.176</td>
<td>p=0.144</td>
</tr>
</tbody>
</table>

Table 4.13 shows the inter-group comparison of the onset times of the Deltoid Muscle readings of visits 1, 3, 5 and 7.

There was no statistically significant difference in the onset times of the Deltoid Muscle readings for the inter-group analysis.
a) Intra-group Analyses of the Onset Times of the Deltoid Muscle and Transverse Abdominus Muscle

Table 4.14: Onset Times of the Deltoid Muscle and Transverse Abdominus Muscle: Intra-group Analysis.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Group 1</th>
<th></th>
<th>Group 2</th>
<th></th>
<th>Group 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>T</td>
<td>D</td>
<td>T</td>
<td>D</td>
<td>T</td>
</tr>
<tr>
<td>Visit 1 mean</td>
<td>0.95</td>
<td>0.41</td>
<td>0.91</td>
<td>0.19</td>
<td>0.86</td>
<td>0.24</td>
</tr>
<tr>
<td>Visit 3 mean</td>
<td>0.83</td>
<td>0.35</td>
<td>0.77</td>
<td>0.26</td>
<td>0.74</td>
<td>0.26</td>
</tr>
<tr>
<td>Visit 5 mean</td>
<td>0.93</td>
<td>0.41</td>
<td>0.79</td>
<td>0.16</td>
<td>0.75</td>
<td>0.25</td>
</tr>
<tr>
<td>Visit 7 mean</td>
<td>0.68</td>
<td>0.32</td>
<td>0.89</td>
<td>0.23</td>
<td>0.75</td>
<td>0.31</td>
</tr>
<tr>
<td>Mean Change Visit 1- Visit 7</td>
<td>0.27</td>
<td>0.09</td>
<td>0.02</td>
<td>-0.04</td>
<td>0.11</td>
<td>-0.07</td>
</tr>
<tr>
<td>Normal Distribution: (p&gt;0.05)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visit 1</td>
<td>p=0.875</td>
<td>p=0.002</td>
<td>p=0.198</td>
<td>p=0.000</td>
<td>p=0.208</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Visit 3</td>
<td>p=0.004</td>
<td>p=0.005</td>
<td>p=0.037</td>
<td>p=0.001</td>
<td>p=0.397</td>
<td>p=0.004</td>
</tr>
<tr>
<td>Visit 5</td>
<td>p=0.014</td>
<td>p=0.016</td>
<td>p=0.000</td>
<td>p=0.000</td>
<td>p=0.049</td>
<td>p=0.000</td>
</tr>
<tr>
<td>Visit 7</td>
<td>p=0.324</td>
<td>p=0.003</td>
<td>p=0.001</td>
<td>p=0.000</td>
<td>p=0.032</td>
<td>p=0.001</td>
</tr>
<tr>
<td>Statistical Significance between Follow-Ups : (p&lt;0.05)</td>
<td>p=0.009</td>
<td>p=0.426</td>
<td>p=0.019</td>
<td>p=0.642</td>
<td>p=0.020</td>
<td>p=0.856</td>
</tr>
<tr>
<td>Multiple Comparison of Statistical Significance for Paired Groups: (p&lt;0.05)</td>
<td>Visit 1: p=0.003</td>
<td>Visit 1: p=0.001</td>
<td>Visit 1: p=0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Visit 3: p=0.005</td>
<td>Visit 3: p=0.001</td>
<td>Visit 3: p=0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Visit 5: p=0.002</td>
<td>Visit 5: p=0.001</td>
<td>Visit 5: p=0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Visit 7: p=0.002</td>
<td>Visit 7: p=0.001</td>
<td>Visit 7: p=0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.14 shows the intra-group comparisons between the onset times of the deltoid muscle and the transverse abdominus muscle.
There is a significant statistical (p<0.05) difference in these onset times in all three groups for every visit.

**Figure 4.6: Line Graph Representing the Mean Onset Times for the Deltoid and Transverse Abdominus Muscles**

Figure 4.6 shows the graphical representation of the onset times of the deltoid muscle together with the onset times of the transverse abdominus muscle.

Both onset times appear to fluctuate from visit to visit.
Figure 4.7 shows the graphical representation of the difference in onset times of the deltoid and transverse abdominus muscles.

There is a decrease in difference between visit 1 and visit 7. The decrease however is not consistent throughout the trial.
CHAPTER FIVE: DISCUSSION
CHAPTER 5: DISCUSSION

5.1 Introduction

This chapter entails the discussion of the subjective and objective results obtained in chapter three and statistically analysed in chapter four.

The results will be discussed with the following aims in mind: The effect that the chosen interventions had on the participants’ low back pain; The effect that the chosen interventions had on the surface EMG readings of the transverse abdominus muscle.

Any variations in the results will be explored in this chapter.

5.2 Demographics

The sample of participants was 80% female and 20% male. This uneven distribution did not necessarily have an effect on the results as each participant fitted the criteria for this study. Research studies by Cassidy, Carroll and Cote (1998), and Leboeuf and Kyvik (1998), show that females have a higher incidence when reporting low back pain. At least one episode of low back pain was reported as early as 12 years of age. This incidence had increased considerably by the age of 41 years (Leboeuf and Kyvik 1998). The sample group in this research was similar in its gender distribution.

The mean age of the participants was 25.29 years. This may have caused the Oswestry Disability scores to be lower than the required 20% for treatment according to the guidelines of disability referred to in chapter three. Older participants, with a longer history of chronic mechanical low back pain, may have had a greater Oswestry score. Andersson (1997) showed that the prevalence of low back pain increases up to 65 years and again after 80 years. This trend was demonstrated in this study with group one showing the lowest mean Oswestry score at visit 1 and the lowest mean age, while group three showed the highest mean Oswestry score at visit 1 and the highest mean age. However, as can be seen from the results, a 20% or lower disability score can be altered by treatment, regardless of age or gender.
5.3 Subjective Data

5.3.1 Oswestry Disability Questionnaire

A statistically significant ($p<0.05$) decrease in scores was seen in all three groups. Groups two and three experienced a statistically significant decrease at each visit. A statistically significant difference was only seen in group one from visit 5 and 7 (refer to table 4.3).

Clinically it can be seen that there was a decrease in the Oswestry scores for all the groups at every visit. Group one shows a slow but steady decrease, while groups two and three decrease more rapidly (refer to Figure 4.4). This indicates that all three forms of treatment were effective in decreasing the participants' perception of their pain and disability.

A mean decrease of 9.73% was seen in group one, group two showed a mean decrease of 13.96%, while group three showed a mean decrease of 20.64%. Group two showed a 31.43% greater improvement when compared to group one. Group three showed a 52.85% greater improvement when compared to group one. This indicates that chiropractic manipulative treatment alone provides more than 50% greater relief than the chosen abdominal exercises over 6 treatments. Chiropractic manipulative treatment alone is also more effective when compared to the combination of chiropractic manipulative treatment and abdominal exercises, with the former showing 32.36% greater improvement when compared to the latter.

A trial conducted comparing combined manipulation and stabilising exercises to consultation with a physician alone found that the combined group improved more than the consultation group (Niemistö, Lahtinen-Suopanki, Rissanen, Lindgren, Sarna and Hurri, 2003). Chiropractic treatment compared to hospital outpatient treatment showed that chiropractic treatment was more effective specifically for chronic low back pain (Meade, Dyer, Browne, Townsend and Frank, 1990). A systematic review of randomized controlled trials concluded that exercise therapy may be helpful in chronic low back pain, but not in acute low back pain (van Tulder, Malmivaara, Esmail and Koes, 2000). Few studies compare combined manipulation and stabilising exercises to manipulation alone. These studies confirm the positive results obtained in this study.
5.3.2 Numerical Pain Rating Scale

A statistically significant decrease in scores was seen in all three groups. Groups two and three experienced a statistically significant decrease at each visit. Statistical difference was only seen in group one from visit 5 and 7 (refer to table 4.3).

Clinically it can be seen, as with the Oswestry Disability scores, that the treatment was effective for all three groups. A study conducted by Farrar, Young, LaMoreaux, Werth and Poole (2001), concluded that a reduction of two points or 30% on the Numerical Pain Rating Scale is clinically significant.

Group one showed a mean decrease of 2. Group one seems to be more effective over a longer period of time; it took longer to show a significant result but continues to steadily decrease as the trial continued. It would then appear that abdominal strengthening exercises are effective as a long term solution for low back pain. Hayden, van Tulder, Malmivaara, and Koes (2005), reviewed 61 studies of exercise as a treatment for low back pain. They found that exercise was more effective than non-intervention in chronic low back pain only.

Groups two and three each incorporated a chiropractic manipulative component. These groups showed a mean decrease of 1.93 and 2.94 respectively. These two groups showed a much faster response to treatment when compared to group one, showing that significant relief from chronic mechanical low back pain can be obtained almost immediately.

In a study that compared chiropractic care only, which included manipulation and education on proper back care, strengthening and flexibility exercises, with medical care only, medical care with physiotherapy and chiropractic care with physical modalities, researchers showed that on the numerical pain rating scale, chiropractic care alone was, as in this study, the most effective in reducing patients pain in a shorter space of time (Hurwitz, Morgenstern, Harber, Kominski, Belin and Adams, 2002).

It must be noted that the Numerical Pain Rating Scale indicates the participants’ pain at that moment. This means that the results can vary quite significantly depending on the demands being placed on the body at the time. It is interesting to note however, that in this trial the majority of the scores showed a decline at each visit (refer to Figure 4.6).
Chiropractic manipulative treatment had this positive effect on the participants’ Oswestry Pain and Disability scores and Numerical Pain Rating Scale because manipulation of the restricted joint restores normal biomechanical function to the segment and activating superficial and deep somatic mechanoreceptors, proprioceptors and nociceptors, which induces a stimulus-produced analgesia (Bergman and Peterson, 2002). Improved nervous function would also allow the transverse abdominus muscle to function correctly as a stabiliser (Richardson, Snijders, Hides, Damen, Pas and Storm, 2002).

The exercises given were designed to provide support to the lumbar spine. Activating the transverse abdominals also stabilises the sacroiliac joints and decreases the lumbar lordosis (Taylor and Twomey, 2004). Providing this support to the lumbar spine would produce the favourable results obtained in the Oswestry Pain and Disability scores and the Numerical Pain Rating Scale.

5.4 Objective Data

5.4.1 Minimum EMG Activity of the Transverse Abdominus Muscle

The minimum EMG activity of the transverse abdominus muscle was measured in the resting phase of the measurement cycle.

As can be seen in chapter four, the statistical results show no significant change. Clinically however, changes can be seen.

In general the minimum EMG reading decreased at each visit except for group three which showed a mean increase of 0.51uV (refer to Figure 4.7). Interestingly group three also showed the greatest decrease in Numerical Pain Rating Scale scores and Oswestry Disability scores. This indicates a link between the resting activity level of the transverse abdominus and chronic mechanical low back pain. This reaction may be explained by acknowledging that spinal manipulation affects neurons differently (Pickar, 2002). Also, Pickar (2002), reports that spinal manipulation may be inhibitory and excitatory to motor function. The H-reflex inhibition seen immediately after manipulation is transient (Dishman and Burke, 2003), and therefore not a valid explanation for the changes seen.
Group three received chiropractic manipulation only. The increase in resting EMG activity suggests that the fixation of the vertebral joint complex could cause a compression of the part of the spinal nerves which innervate the transverse abdominus muscle (Gatterman, 2004). Therefore by reducing that fixation the activity of this muscle is improved. Other studies have found that following a manipulation the resting EMG readings decrease immediately. DeVocht, Pickar and Wilder (2005), found that some participants paraspinal resting EMG readings increased following manipulation.

Groups one and two did not show an overall improvement, suggesting that while the abdominal strengthening exercises played a role in decreasing the pain and disability of the participants, it does not positively affect the resting neurological functioning of the muscle.

Group two shows an initial increase in resting EMG activity at visit 3. This could be explained by looking at the subjective readings and deducing that the abdominal exercises took longer to take effect. It can therefore be surmised that at the 3rd visit the results obtained are produced by the chiropractic manipulation.

Manipulation of the lumbar spine could have an affect on the function of the transverse abdominus muscle directly via its nerve supply from the upper lumbar spinal nerves (Moore and Dalley, 2006). Manipulation also results in an immediate relaxation of paraspinal musculature (H-reflex) allowing the transverse abdominus muscle to then function optimally. Exercise does not have this effect. Long-term abdominal stabilising will merely strengthen the muscle while not alleviating any abnormal neurological stimuli to the muscle.

5.4.2 Maximum EMG Activity of the Transverse Abdominus Muscle

The results for the maximum EMG activity of the transverse abdominus muscle were not statistically significant.

The readings follow those of the minimum EMG activity of the transverse abdominus.

Group three shows an overall increase in the maximum EMG readings, while groups one and two show an overall decrease.
At some point each group shows an increase before decreasing again. Group one shows a slight increase at visit 5 before decreasing again. Group two shows and increase at visit 3 before decreasing slowly.

According to the reflexogenic theory the transverse abdominus should show a decrease in resting EMG activity but an increase in maximum contraction. This does not seem to be the case when not voluntarily contracting the muscle. This study tested the involuntary postural reaction of the transverse abdominus. It therefore appears that manipulation alone has an effect which supports previous literature. The manipulation allows optimal functioning of the muscle (Schafer and Faye, 1994). Dishman and Burke (2003), showed that manipulation using the diversified technique had a greater effect on the maximal contraction of paraspinal muscle that manipulation using an activator. Conversely it appears that conscious activation training of the transverse abdominus has the opposite effect over a short period of time.

Van Vliet and Heneghan (2006) state that feed-forward systems are changed in otherwise neurologically intact individuals with chronic low back and/or chronic cervical spine pain. Cortical mapping studies have shown that neural pathways adapt according to what and how much is practised. This suggests that when retraining the transverse abdominus muscle quality and quantity of training is important.

As discussed previously in the chapter and in the literature review, chiropractic manipulation has a positive effect on the maximum muscle contraction of both a muscle directly innervated by the nerve on the level manipulated and indirectly through somatic mechanical regulation of impulses to surrounding musculature. It can therefore be proposed in this study that manipulation alone produces favourable results due to increased activity of golgi tendon bodies in the thoracolumbar fascia following a manipulation. Increased activity can also be attributed to sudden stretching of the transverse abdominus muscle during the side-posture manipulation. It can be proposed that this causes relaxation of hypertonic muscle, therefore allowing it to contract optimally following the manipulation (Evans and Breen, 2006).
5.4.3 Onset Times of the Deltoid and Transverse Abdominus Muscle

These two readings will be discussed together as they are directly linked in this study. The aim was to determine whether chronic mechanical low back pain sufferers had an impaired transverse abdominal reaction when performing rapid upper limb movement. According to literature the abdominal reaction should be 30-100ms before the prime mover of the limb, in this case the deltoid muscle (Jull and Richardson, 2000).

The direct link between these two onset times can be seen in figure 4.9 and table 4.13. As the onset time of the deltoid muscle increased or decreased so did the onset time for the transverse abdominus muscle. It is important to note that in every instance the mean onset time for the transverse abdominus was the same or shorter than that of the deltoid, thus confirming the theory that the transverse abdominus plays an involuntary postural role in supporting the trunk during limb movement.

In almost every case in this study the transverse abdominus showed activation more than the suggested 30-100ms before the deltoid.

At visit 1, four participants did not show any pre-activation of the transverse abdominus muscle. Three of the participants were in group one and one in group three. One would then expect these participants to have the highest pain and disability ratings. This however, is not the case. The Oswestry scores for these participants were at or above the 20% disability mark (indicating a need for intervention). They were however not the highest Oswestry scores nor did they have the highest Numerical Pain Rating Scale scores. Considering also that these four participants represented only 8.89% of the sample, this indicates that a lack of pre-activation is not a primary factor in chronic mechanical low back pain as suggested by Marshall and Murphy (2006).

All three groups show an average decrease in the difference of onset times (figure 4.10). When considering the onset times with respect to the prescribed 30-100ms pre-activation, the findings in this study suggest that a much longer pre-activation time is possibly the norm.

When considering these results with the subjective findings it certainly appears that a decrease in activation times correlates with a decrease in pain and disability. Groups one
and three showed the greatest change in onset times, however, groups two and three showed the greatest improvement in subjective findings. This result is incongruous as group two theoretically should have shown a greater decrease in pre-activation as it was a combination of the interventions of group one and three. The positive results of each intervention would have been expected to combine to produce a greater positive. There is no other research with which to correlate these findings. It suggests that the two interventions do not have a synergistic effect as was expected, or there was interference from surrounding abdominal musculature.

Interference from other musculature could be quite a large problem in this kind of study, as the site for accurate measurement of the transverse abdominus is very specific and a deviation from this site causes the signal from the transverse abdominus to be over-ridden by that of the rectus abdominus and external obliques. It is therefore quite easy to have interference from other musculature.

Overall chiropractic manipulation has been shown to have a restorative and modulatory effect on the function of the musculature through reflex effects on mechanoreceptors within paraspinal tissues. This is obtained by mechanically stimulating receptors in the facet joint capsules, ligaments and muscles in the immediate vicinity of the joint.
CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The aim of this study was to determine the short-term effects of chiropractic manipulative treatment on the feed-forward activation of the deep abdominal muscles in patients with chronic low back pain.

This study has shown that chiropractic manipulation reduces the pre-activation time of the transverse abdominus muscle and significantly improves the participants’ perception of pain and disability. This is an important as it aids in the understanding the effects of chiropractic manipulation.

All forms of intervention used in this study had an effect on the feed-forward activation of the transverse abdominus muscle. Significant reductions in pain and disability have also been shown. Chiropractic manipulation had the greatest and most immediate effect. This suggests that chiropractic manipulation alone is more effective in reducing pain and disability even when combined with another effective intervention such as abdominal stabilising exercises. It was also more effective in restoring optimal function of the deep abdominal musculature. This affirms the popular theory that chiropractic manipulation is an effective intervention for chronic mechanical low back pain.

This study has also shown that chiropractic manipulation not only has an effect on paraspinal muscle tissue, but that this effect is carried through to muscle tissue somewhat distant from the directly affected segment. This too affirms popular theory that chiropractic manipulation has a positive effect on tissues distant to the fixation site.

6.2 Recommendations

Favourable results were obtained in this study, however there are several factors which could improve or change the results. The following recommendations can be made:

The smallest available electrodes were used in this study, however smaller electrodes would also allow greater accuracy of placement and reduce signal interference.
Greater restriction when selecting the inclusion and exclusion criteria would also eliminate outside variables. In this study the participants’ current level of pain, posture and activity levels were not considered when selecting participants. Therefore groups would be more similar.

Although the age limits were fairly small, the sample consisted of a large amount of participants below the age of 30 years. An older sample group could result in higher levels of pain and disability and therefore possibly show a greater change during treatment.

In conjunction to above, participants with more severe pain could be chosen in order to more accurately assess a reduced feed-forward reaction. The participants in this study had pain scores varying from slight pain to moderately severe. A sample with a smaller range of pain scores would produce more easily interpreted results.

During the study a number of participants fell ill. Part of their symptoms included increased sensitivity and body aches. In future these participants should be eliminated due to the potential of their illness to produce inaccurate results.

Similarly a larger sample size would cause small inaccuracies to be eliminated or have little effect on results. The smaller the sample size, the greater effect any incongruencies have on results.

Further studies should investigate the role of core stabilization more closely. Kibler, Press and Sciascia (2006), stated that core stabilisation should avoid emphasising the use of single planar exercises that isolate specific muscles or specific joints, as was investigated in this study. Kibler, Press and Sciascia (2006) go on to state that emphasis should be on early progression to functional positions, motions and muscle activation sequences. In this way, the normal physiological activations can be restored, which will lead to the restoration of normal biomechanical motions.
REFERENCES


Dishman, D. J. and Burke, J. (2003). Spinal reflex excitability changes after cervical and lumbar spinal manipulation; A Comparative Study. The Spine Journal: 3(3); 204-212


APPENDICES

APPENDIX A: OSWESTRY LOW BACK PAIN AND DISABILITY QUESTIONNAIRE

<table>
<thead>
<tr>
<th>BACK PAIN AND DISABILITY QUESTIONNAIRE (REVISED OSWESTRY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
</tr>
</tbody>
</table>

This questionnaire has been designed to give your health care provider information as to how your back pain has affected your ability to manage everyday life. Please answer every section and mark in each section only the ONE box which applies to you. I realize you may consider that two of the statements in any one section relate to you, but please just mark the box which most closely describes your problem today.

<table>
<thead>
<tr>
<th>Section 1 – Pain Intensity</th>
<th>Section 6 – Standing</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ The pain comes and goes and is very mild.</td>
<td>□ I can stand as long as I want without pain.</td>
</tr>
<tr>
<td>□ The pain is mild and does not vary much.</td>
<td>□ I have some pain on standing but it does not increase with time.</td>
</tr>
<tr>
<td>□ The pain comes and goes and is moderate.</td>
<td>□ I cannot stand for longer than one hour without increasing pain.</td>
</tr>
<tr>
<td>□ The pain is moderate and does not vary much.</td>
<td>□ I cannot stand for longer than ½ hour without increasing pain.</td>
</tr>
<tr>
<td>□ The pain comes and goes and is severe.</td>
<td>□ I cannot stand for longer than 10 minutes without increasing pain.</td>
</tr>
<tr>
<td>□ The pain is severe and does not vary much.</td>
<td>□ I avoid standing because it increases the pain straight away.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section 2 – Personal Care</th>
<th>Section 7 – Sleeping</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ I would not have to change my way of washing or dressing in order to avoid pain.</td>
<td>□ I get no pain in bed.</td>
</tr>
<tr>
<td>□ I do not normally change my way of washing and dressing even though it causes some pain.</td>
<td>□ I get pain in bed but it does not prevent me from sleeping well.</td>
</tr>
<tr>
<td></td>
<td>□ Because of pain my normal night’s sleep is reduced by less than ¼.</td>
</tr>
<tr>
<td></td>
<td>□ Because of pain my normal night’s sleep is reduced by less than ¼.</td>
</tr>
<tr>
<td>Section 3 – Lifting</td>
<td>Section 8 – Social Life</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>□ I can lift heavy weights without extra pain.</td>
<td>□ My social life is normal and gives me no pain.</td>
</tr>
<tr>
<td>□ I can lift heavy weights but it causes extra pain.</td>
<td>□ My social life is normal but increases the degree of pain.</td>
</tr>
<tr>
<td>□ Pain prevents me from lifting heavy weights off the floor.</td>
<td>□ Pain has no significant effect on my social life apart from limiting my more energetic interests, e.g. dancing, etc.</td>
</tr>
<tr>
<td>Pain prevents me from lifting heavy weights off the floor, but I manage if they are conveniently positioned (e.g. on a table).</td>
<td>□ Pain has restricted my social life and I do not go out very often.</td>
</tr>
<tr>
<td>□ Pain prevents me from lifting heavy weights but I can manage light to medium weights if they are conveniently positioned.</td>
<td>□ Pain has restricted my social life to my home.</td>
</tr>
<tr>
<td>I can only lift very light weights at the most.</td>
<td>□ I have hardly any social life because of the pain.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section 4 – Walking</th>
<th>Section 9 – Traveling</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ I have no pain on walking.</td>
<td>□ I have no pain while traveling.</td>
</tr>
<tr>
<td>□ I have some pain on walking but it does not increase with distance.</td>
<td>□ I have some pain while traveling but none of my usual forms of travel make it any worse.</td>
</tr>
<tr>
<td>□ I cannot walk more than 1 mile without sleep is reduced by less than ½.</td>
<td>□ Because of pain my normal night’s sleep is reduced by less than ¼.</td>
</tr>
<tr>
<td>□ Because of the pain I am unable to do some washing and dressing.</td>
<td>□ Pain prevents me from sleeping at all.</td>
</tr>
<tr>
<td>□ Because of the pain I am unable to do any washing and dressing without help.</td>
<td></td>
</tr>
</tbody>
</table>
increasing pain.
- I cannot walk more than ½ mile without increasing pain.
- I cannot walk more than ¼ mile without increasing pain.
- I cannot walk at all without increasing pain.

- I have extra pain while traveling but it does not compel me to seek alternate forms of travel.
- I have extra pain while traveling that compels me to seek alternative forms of travel.
- Pain restricts all forms of travel.
  Pain prevents all forms of travel except that done lying down.

<table>
<thead>
<tr>
<th>Section 5 – Sitting</th>
<th>Section 10 – Changing Degree of Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can sit in any chair as long as I like.</td>
<td>My pain is rapidly getting better.</td>
</tr>
<tr>
<td>I can only sit in my favorite chair as long as I like.</td>
<td>My pain fluctuates but overall is definitely getting better.</td>
</tr>
<tr>
<td>Pain prevents me from sitting more than 1 hour.</td>
<td>My pain seems to be getting better but improvement is slow at present.</td>
</tr>
<tr>
<td>Pain prevents me from sitting more than ½ hour.</td>
<td>My pain is neither getting better nor worse.</td>
</tr>
<tr>
<td>Pain prevents me from sitting more than 10 minutes.</td>
<td>My pain is gradually worsening.</td>
</tr>
<tr>
<td>I avoid sitting because it increases my pain right away.</td>
<td>My pain is rapidly worsening.</td>
</tr>
</tbody>
</table>

APPENDIX B: NUMERICAL PAIN RATING SCALE

Rate the severity of your pain by ticking one box on the following scale:

<table>
<thead>
<tr>
<th>No pain</th>
<th>Excruciating pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
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<tr>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>
APPENDIX C: ADVERTISEMENT

Are you experiencing persistent Low Back Pain?

If you are between 18 and 35yrs old, You might qualify for a free Chiropractic research study.

*All treatment is conducted by a Chiropractic intern student under supervision at the University of Johannesburg Chiropractic Clinic*

If you are interested please do not hesitate to call:

Celia Meldrum  084 447 5991

| Celia Meldrum | 084 447 5991 | Celia Meldrum | 084 447 5991 | Celia Meldrum | 084 447 5991 | Celia Meldrum | 084 447 5991 | Celia Meldrum | 084 447 5991 | Celia Meldrum | 084 447 5991 |
APPENDIX D: CASE HISTORY

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

CASE HISTORY

Date: ________________

Patient: ___________________________ File No: __________

Age: _______ Sex: _______ Occupation: ___________________

Student: ___________________________ Signature: ________________

FOR CLINICIAN’S USE ONLY

Initial visit clinician: ________________ Signature: ________________

Case History: __________________________________________________

Examination:
Previous: UJ Current: UJ
Other Other

X-ray Studies:
Previous: UJ Current: UJ
Other Other

Clinical Path. Lab:
Previous: UJ Current: UJ
Case status:
PTT: Conditional: Signed off: Final sign out:

Recommendations:

Students case history

1. Source of history:

2. Chief complaint: (patient’s own words)

3. Present illness:
   
   Location

   Onset

   Duration

   Frequency

   Pain (character)

   Progression

   Aggravating factors

   Relieving factors

   Associated Sx’s and Sg’s
Previous occurrences

Past treatment and outcome

4. Other complaints:

5. Past history
   General health status
   Childhood illnesses
   Adult illnesses
   Psychiatric illnesses
   Accidents/injuries
   Surgery
   Hospitalisation

6. Current health status and lifestyle
   Allergies
   Immunizations
   Screening tests
   Environmental hazards
   Safety measures
   Exercise and leisure
   Sleep patterns
   Diet
   Current medication
   Tobacco
7. **Family history:**
   - **Immediate family:**
     - Cause of death
     - DM
     - Heart disease
     - TB
     - HBP
     - Stroke
     - Kidney disease
     - CA
     - Arthritis
     - Anaemia
     - Headaches
     - Thyroid disease
     - Epilepsy
     - Mental illness
     - Alcoholism
     - Drug addiction
     - Other

8. **Psychosocial history:**
   - Home situation
   - Daily life
   - Important experiences
   - Religious beliefs
9. Review of systems:

General
Skin
Head
Eyes
Ears
Nose/sinuses
Mouth/throat
Neck
Breasts
Respiratory
Cardiac
Gastro-intestinal
Urinary
Genital
Vascular
Musculoskeletal
Neurologic
Haematologic
Endocrine
Psychiatric
APPENDIX E: PHYSICAL EXAMINATION

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

PHYSICAL EXAMINATION

Underline abnormal findings in RED.  Date: ________________

Patient: ___________________  File No: _______________

Clinician: ___________________  Signature: _______________

Student: ___________________  Signature: _______________

Height: ______  Weight: ______  Temp: ______

Rates: Heart: ______  Pulse: ______  Respiration: ______

<table>
<thead>
<tr>
<th>Blood pressure:</th>
<th>Arms:</th>
<th>L</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Legs:</td>
<td>L</td>
<td>R</td>
</tr>
</tbody>
</table>

General Appearance:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
STANDING EXAMINATION

1. Minor’s sign
2. Skin changes
3. Posture: Erect
   - Adam’s
4. Ranges of motion (Thoracolumbar Spine)
   - T/L spine:
     - Flexion: 90° (fingers to floor)
     - Extension: 50°
     - R. lat. flex: 30° (fingers down leg)
     - L. lat. flex: 30° (fingers down leg)
     - Rot. to R: 35°
     - Rot. to L: 35°

5. Romberg’s sign
6. Pronator drift
7. Trendelenburg’s sign
8. Gait:
   - rhythm
   - balance
   - pendulousness
   - on toes
   - on heels
   - tandem

9. Half squat
10. Scapular winging
11. Muscle tone
12. Spasticity/Rigidity
13. Shoulder:
    - skin symmetry
    - ROM - glenohumeral
14. Chest measurement:
   - inspiration cm
   - expiration cm

15. Visual acuity

16. Breast examination:
   Inspection: - skin
   - size
   - contour
   - nipples
   - arms overhead
   - hands against hips
   - leaning forward
   Palpation - axillary lymph nodes
   - breast incl. tail

SEATED EXAMINATION

1. Spinal posture
2. Head
   - hair
   - scalp
   - skull
   - face
   - skin
3. Eyes:
   Observation - conjunctiva
   - sclera
   - eyebrows
   - eyelids
   - lacrimal glands
   - nasolacrimal duct
   - position and alignment
   - corneas and lenses
   - corneal reflex
   - ocular movement
     | L  | R |
     | III | IV | VI | III | IV | VI |
   - visual fields
   - accommodation
4. **Ears:**
   - auricle
   - ear canal
   - drum
   - auditory acuity
   - Weber test
   - Rinne test

5. **Nose:**
   - External
   - Internal - septum
   - turbinates
   - olfaction

6. **Sinuses (frontal & maxillary):**
   - tenderness
   - transillumination

7. **Mouth and pharynx:**
   - lips
   - buccal mucosa
   - gums and teeth
   - roof
   - tongue - inspection
   - movement
   - taste
   - palpation
   - pharynx - CN X
   - inspection
9. Neck

- posture
- size
- swelling
- scars
- discolouration
- hair line

Ranges of motion (cervical spine)

The following are normal ranges of motion

- Forward flexion = 45 ° chin to larynx or sternum
- Extension = 55 ° forehead parallel to ground
- L/R Rotation = 70 °
- L/R Lat Flexion = 40 °

<table>
<thead>
<tr>
<th>L. Rot</th>
<th>Flex.</th>
<th>R. Rot</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. Lat Flex</td>
<td></td>
<td>R. Lat Flex</td>
</tr>
</tbody>
</table>

- lymph nodes
- trachea
- thyroid
- carotid arteries (thrills, bruit)
- Cranial Nerves
  - CN V
  - CN VII
  - CN VIII (nystagmus)
  - CN IX
  - CN XI
  - CN X11

9. NEUROLOGICAL EXAMINATION (CERVICAL SPINE)

<table>
<thead>
<tr>
<th>DERMATOMES</th>
<th>Left</th>
<th>Right</th>
<th>MYOTOMES</th>
<th>Left</th>
<th>Right</th>
<th>REFLEXES</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td></td>
<td></td>
<td>Neck</td>
<td></td>
<td></td>
<td>Biceps</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flexion</td>
<td></td>
<td></td>
<td>C5</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>C1/2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td></td>
<td></td>
<td>Lat. Neck</td>
<td></td>
<td></td>
<td>Brachio</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>–</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
9. **Peripheral vasculature:**
   - **Inspection**
     - skin
     - nail beds
     - pigmentation
     - hair loss
   - **Palpation**
     - pulses: femoral, dorsalis pedis, popliteal, radial, post. Tibial, brachial
     - lymph nodes: epitrochlear
     - temperature (feet and legs)
- Manual compression test
- Retrograde filling (Tredelenburg) test
- Arterial insufficiency test

10. Musculoskeletal:
   (i) ROM
   - hip
<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>flex.</td>
<td>90</td>
<td>120</td>
</tr>
<tr>
<td>ext.</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>abd.</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>add.</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>int rot</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>ext rot</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>flex.</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>ext.</td>
<td>0 /15</td>
<td></td>
</tr>
<tr>
<td>plantar Flex</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>dorsiflex</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>inversion</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>eversion</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>
   - Apparent
   - Actual
   (ii) leg length
   - Co-ordination - point to point
   - dysdiachokinesia

10. TMJ
   - Inspection - ROM
   - deviation
   - crepitus
   - tenderness

11. Thorax
   - Inspection
   - skin
   - shape
   - respiratory distress
   - rhythm (respiratory)
- depth (respiratory)
- effort (respiratory)
- intercostals supraclavicular retraction

- Palpation
  - tenderness
  - masses
  - respiratory expansion
  - tactile fremitus

- Percussion
  - lungs (posterior)
  - diaphragmatic excursion
  - kidney punch

- Auscultation
  (i) breath sounds
  - vesicular
  - bronchial
  (ii) adventitious sounds
  - crackles (rales)
  - wheezes (rhonchi)
  - rubs
  (iii) voice sounds
  - broncophony
  - whispered pectoriloquy
  - egophony

- Cardiovascular
  - auscultation (aortic murmurs)
  - Allen’s test

SUPINE EXAMINATION

1. JVP
2. PMI
3. Auscultation heart (L. lat. Recumbent)
4. respiratory excursion
5. percussion chest (anterior)
6. breast palpation
7. Abdominal Examination
   - Inspection
     - skin
     - umbilicus
     - contour
     - peristalsis
     - pulsations
     - hernias (umbilical/incisional)

   - Auscultation
     - bowel sound
     - bruit
• Percussion  
  - general  
  - liver  
  - spleen  

• Palpation  
  - superficial reflexes  
  - cough  
  - light  
  - rebound tenderness  
  - deep  
  - liver  
  - spleen  
  - kidneys  
  - aorta  
  - intra-/retro-abdominal wall mass  
  - shifting dullness  
  - fluid wave  

• Acute abdomen  
  - where pain began and now  
  - cough  
  - tenderness  
  - guarding/rigidity  
  - rebound tenderness  
  - rovsing’s sign  
  - psoas sign  
  - obturator sign  
  - cutaneous hyperaesthesia  
  - rectal exam  
  - Murphy’s sign

MENTAL STATUS

(i) Appearance and behaviour  
  - level of consciousness  
  - posture and motor behaviour  
  - dress, grooming, personal hygiene  
  - facial expression  
  - affect

(ii) Speed and language  
  - quantity  
  - rate  
  - volume  
  - fluency  
  - aphasia (pm)

(ii) Mood

(v) Memory and attention  
  • orientation (time, place, person)
• remote memory
• recent memory
• new learning ability

(vi) Higher cognitive functions

• information and vocabulary
• (general and specialised knowledge)
• abstract thinking

### NEUROLOGICAL EXAMINATION (LUMBAR SPINE)

<table>
<thead>
<tr>
<th>DERMATOMES</th>
<th>Left</th>
<th>Right</th>
<th>MYOTOMES</th>
<th>Left</th>
<th>Right</th>
<th>REFLEXES</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>T12</td>
<td></td>
<td></td>
<td>Hip Flexion</td>
<td></td>
<td></td>
<td>Patellar</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(L1/L2)</td>
<td></td>
<td></td>
<td>(L3, 4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1</td>
<td></td>
<td></td>
<td>Knee Extension</td>
<td></td>
<td></td>
<td>Medial Hamstring</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(L2, 3, 4)</td>
<td></td>
<td></td>
<td>(L5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L2</td>
<td></td>
<td></td>
<td>Knee Flexion</td>
<td></td>
<td></td>
<td>Lateral Hamstring</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(L5/S1)</td>
<td></td>
<td></td>
<td>(S1)</td>
<td></td>
<td></td>
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<tr>
<td>L3</td>
<td></td>
<td></td>
<td>Hip Int. Rot</td>
<td></td>
<td></td>
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<td>(L4/L5)</td>
<td></td>
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<tr>
<td>L4</td>
<td></td>
<td></td>
<td>Hip Ext. Rot</td>
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<td></td>
<td>(L5/S1)</td>
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<tr>
<td>L5</td>
<td></td>
<td></td>
<td>Hip Adduction</td>
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<td></td>
<td></td>
<td></td>
<td>(L2, 3, 4)</td>
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<tr>
<td>S1</td>
<td></td>
<td></td>
<td>Hip Abduction</td>
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<td></td>
<td></td>
<td>(L4/5)</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>S2</td>
<td></td>
<td></td>
<td>Ankle Dorsiflexion</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>(L4/L5)</td>
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</tr>
<tr>
<td>S3</td>
<td></td>
<td></td>
<td>Hallux Extension</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>(L5)</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Ankle Plantar Flexion</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>(S1/S2)</td>
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<td></td>
<td></td>
<td>Eversion</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>(S1)</td>
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<td>Inversion</td>
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<td></td>
<td></td>
<td>(L4)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Hip Extension</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(L5/S1)</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
STANDING

BODY TYPE
POSTURE
OBSERVATION: -

Muscle Tone
Bony + Soft Tissue Contours
Skin
Scars
Discolouration
Step deformity

SPECIAL TESTS

Schober’s Test
Spinous Percussion
Treadmill
Minor’s Sign
Quick Test
Trendelenburg Test
**RANGE OF MOTION**

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

-match diagram.png

/ = Pain free limitation
// = Painful limitation

6. GAIT

- Rhythm, pendulousness
- On Toes (S1)
- On Heels (L4, 5)
- Halt Squat on one leg (L2, 3, 4)
- Tandem Walking

7. **MOTION PALPATION** – sacroiliac joints

B. SITTING

01. **SPECIAL TESTS**

- Tripod Test
- Kemp’s Test
- Valsalva Manoeuvre
### MOTION PALPATION

<table>
<thead>
<tr>
<th>Jt. Play</th>
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### C. SUPINE

#### 01. OBSERVATION

- Hair, Skin, Nails
- Fasciculations

#### 2. PULSES

- Femoral
- Popliteal
- Dorsalis Pedis
- Posterior Tibial

#### 3. MUSCLE CIRCUMFERENCE

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5. **ABDOMINAL EXAMINATION**

- Observation
- Abdominal Reflexes
- Auscultation Abdomen and Groin
- Palpation Abdomen and Groin

Comments: _____________________________________________________

______________________________________________________________

______________________________________________________________

NEUROLOGICAL EXAMINATION

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7. **SPECIAL TESTS**

- SLR
- WLR
- Braggard's
- Bowstring
- Sciatic Notch Pressure
- Sign of the Buttock
- Bilateral SLR
- Patrick Faber
- Gaenslen's Test
- Gapping Test
- “Squish” Test
- Gluteus Maximus Stretch
- Thomas' Test
- Rectus Femoris Contracture Test
- Hip Medial Rotation
- Psoas Test

**LATERAL RECUMBENT**

- Sacroiliac Compression
- Ober's Test
- Femoral Nerve Stretch Test
- Myotomes:  - Quadratus Lumborum Strength
  - Gluteus Medius Strength
PRONE

- Facet joint challenge
- Myofascial Trigger points:
  - Quadratus Lumborum
  - Gluteus Medius
  - Gluteus Maximus
  - Piriformis
  - Tensor Fascia Lata
  - Hamstrings
- Skin Rolling
- Erichsen's Test
- Sacroiliac Tenderness
- Pheasant's Test
- Gluteal Skyline
- Myotomes:
  - Gluteus Maximus strength

NON-ORGANIC SIGNS

- Pin-point pain
- Axial Compression
- Trunk Rotation
- Burn's Bench Test
- Flip Test
- Hoover's Test
- Ankle Dorsiflexion Test
- Pin-point pain
# APPENDIX G: S.O.A.P. NOTE

## CHIROPRACTIC DAY CLINIC

**SOAP NOTE:**

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| A:       | P:        |

**Comments:**

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| A:       | P:        |

**Comments:**
APPENDIX H: INFORMATION AND CONSENT FORM

I, Celia Meldrum, invite you to participate in my research study. I am currently a Chiropractic student, completing a Masters degree at the University of Johannesburg.

The aim of this study is to determine the effect of a sacroiliac adjustment on the feed-forward activation of the deep abdominal muscles and its effect on low back pain.

There are three treatment groups. Group one: exercise only. Group two: both chiropractic adjustment and exercise. Group three: chiropractic treatment only.

You will receive seven treatments. Each treatment will involve evaluation and feedback on any changes you are experiencing, surface EMG readings and a lumbar adjustments. The surface EMG readings will be taken before the adjustment is performed on the first, third and fifth visits. On the seventh visit only readings will be taken.

The research study will take place at the University of Johannesburg Chiropractic Day Clinic. Your privacy will be protected at all times by ensuring total anonymity.

Your participation is of an entirely voluntary nature; you are free to withdraw from this study at any time. The potential benefits are relief of back pain and a better understanding of the role that the transverse abdominus together with lumbar adjustments plays in low back pain. Chiropractic adjustment is a safe, non-painful form of treatment, though some discomfort may be expected post adjustment.

After this study is complete I will provide you feedback regarding outcomes if you wish.
I have fully explained the procedures and their purpose. I have asked whether or not any questions have arisen regarding the procedures and have answered them to the best of my ability.

Date:____________________   Researcher:____________________

I have been fully informed as to the procedures to be followed and have been given a description of the discomfort, risks and benefits expected from treatment. In signing this consent form I agree to this form of treatment and understand my rights and that I am free to withdraw at any time.

Date:____________________   Participant:____________________
APPENDIX I: ABDOMINAL EXERCISES

Lumbopelvic stabilising exercises (Hall and Brody 1999)

1. Abdominal hollowing and bracing
   
   - Patient lies on his/her back with knees bent and feet flat on floor.
   - Patient breathes in deeply. While exhaling the patient draws the navel to the spine simultaneously contracting the deep abdominal muscles.
   - The patient maintains a light contraction of the abdominals while repeating the exercise ten times.

2. Four point kneeling with variations
   
   - Patient kneels on hands and knees with the spine in a neutral position.
   - Patient then lifts right arm and left leg while maintaining a neutral spine.
   - Hold position for ten seconds while maintaining a stable trunk.
   - Repeat ten times on alternating sides.

3. Bent-Knee Fall-out
   
   - Patient lies on back with one knee bent.
   - Keeping the lumbar spine in a neutral position contract the abdominals.
   - Keep the hips and trunk still and let the bent knee abduct to the floor.
   - Also keeping the hips and trunk still return the knee to its’ starting position.
   - Repeat exercise ten times on each leg.