

**TO DETERMINE THE IMMEDIATE EFFECT OF
SACROILIAC AND LUMBAR MANIPULATION ON
QUADRICEPS FEMORIS AND HAMSTRING
TORQUE RATIOS IN THE CONTRALATERAL
LIMB IN PATIENTS SUFFERING FROM
MECHANICAL LOW BACK PAIN**

A dissertation submitted in partial compliance with the requirements for a Masters Degree in Technology, in the Department of Chiropractic at the Durban Institute of Technology

By

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DEDICATION

To my parents, Barrie and Jean, who have, through their lives and their love, shown me the greatest gift of all, the love of the Father.

ACKNOWLEDGEMENTS

Commit your work to the Lord, and then your plans will succeed (Proverbs 16:3). To my Heavenly Father, who through Him, all is possible.

To my parents, Barrie and Jean, who have supported me through the good times and the bad and especially to my dad who has instilled in me a love for Chiropractic and shown me what a privilege it is to help others.

To Michelle, who has been the best friend and sister in Christ that anyone could ever ask for.

To Dr Charmaine Korporaal, my supervisor, for without her I would never have got through Chiropractic and this research.

To all the staff at the DIT Chiropractic Department, for making sure everything runs smoothly and to all our clinicians for their pearls of wisdom.

To all my colleagues and classmates, for their support through the tough times and all the many laughs we've shared.

Most importantly I would like to thank all my subjects who so willingly commissioned their bodies for the sake of science.

ABSTRACT

Low back pain has been shown to be associated with inhibition of the lower limb musculature. This inhibition is called arthrogenic muscle inhibition (AMI). Sacroiliac joint dysfunction has been linked with AMI of the ipsilateral and contralateral quadriceps and hamstring muscles. Sacroiliac manipulation has been shown to significantly reduce ipsilateral AMI, however no studies have been conducted to illustrate the effect of sacroiliac manipulation on contralateral AMI. Neither have there been studies to show the presence or extent of spinal dysfunction between the levels of L2-L5 and its significance on muscle inhibition in the quadriceps and hamstring muscles, nor the effect of manipulation of these levels on AMI of the quadriceps and hamstring muscles.

The purpose of this study was therefore to determine whether spinal manipulation has an effect on AMI of the contralateral limb as well as that of the ipsilateral limb.

This study was a placebo controlled pre – post quasi-experimental trial.

Fifty nine patients with mechanical low back pain were randomly assigned to either a treatment or control group. After a full case history, physical examination and lumbar and pelvis regional assessment, the treatment group received spinal manipulation and the control group, detuned ultrasound. Both groups' bilateral quadriceps and hamstring torque ratios were assessed using the Cybex Orthotron II Isokinetic Rehabilitation System (Cybex Norm, Testing and Rehabilitation System; Lumex Inc, New York, NY) before and after treatment.

The first objective of this study was to evaluate the immediate effect of manipulation on contralateral quadriceps and hamstring torque ratios utilising the Cybex Orthotron II Isokinetic Rehabilitation System.

The second objective was to evaluate the immediate effect of manipulation on ipsilateral quadriceps and hamstring torque ratios utilising the Cybex Orthotron II Isokinetic Rehabilitation System.

The third objective was to evaluate the immediate effect of manipulation on ipsilateral quadriceps and hamstring torque ratios versus immediate effect of manipulation on contralateral quadriceps and hamstring torque ratios utilising the Cybex Orthotron II Isokinetic Rehabilitation System.

The fourth objective was to evaluate the presence or absence of spinal dysfunction between the levels of L2-L5 and the sacroiliac joint and the significance of spinal dysfunction on muscle inhibition in the quadriceps and hamstring muscles.

While the original purpose of this study did not involve investigation of work and power of the quadriceps and hamstring and the effect of manipulation on these values, testing made gathering of the data possible and it was thus included.

Data were captured in MS Excel and exported into SPSS version 11.5 (SPSS Inc, Chicago, Ill, USA) for analysis. A significance level of 0.05 was used.

Pearson's chi square tests were used to compare independent proportions. Student's t-tests were used to compare means of two independent groups.

Longitudinal analysis:

Repeated measures ANOVA was used to simultaneously test the six null hypotheses:

1. There is no change over time (regardless of group) (time main effect)
2. There is no difference between the groups (regardless of time) (group main effect)
3. There was no difference between the ipsilateral or contralateral side (side main effect)

4. There was no difference over time between the side (time*side interaction)
5. There is no effect of the intervention (time*group interaction)
6. The intervention effect was not dependant on side (time*group*side interaction)

The results of the study showed significant improvements of the contralateral and ipsilateral hamstring torque ratios, however, the study failed to show a statistically significant improvement in both the contralateral and ipsilateral quadriceps torque ratios. There was no significant difference between contralateral and ipsilateral peak torque ratios.

The observation of increased hamstring torque ratios and the reduction in AMI ipsilaterally and contralaterally post-manipulation is intriguing, although the possible mechanisms leading to the reduction in AMI post-manipulation can only be speculated on. The results of this study do indicate a central mechanism affecting both the ipsilateral as well as the contralateral limbs. Due to this study only investigating the immediate effect, no deductions can be made concerning the duration of the treatment effect. The results of this study point to the possible usefulness of spinal manipulation for the treatment of AMI in both the ipsilateral and contralateral limbs and the possibility of the involvement of a central mechanism in AMI.

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DEFINITION OF TERMS

Adjustments

The Chiropractic adjustment is a specific form of direct articular manipulation using either long or short lever techniques with specific contacts and is characterised by a dynamic thrust of controlled velocity, amplitude and direction (Haldeman, 1992: 621).

Angle of peak torque

This is defined as the point in the range of motion where peak torque is produced. It usually occurs at the same range in the range of motion for similar movements and speeds and typically occurs in the mid range of a motion. This should be at the point in the ROM where the length-tension relationship is maximal (Marrule, 1996: 110-114).

Joint Restriction

A state whereby an articulation has become temporarily immobilised in a position that it may normally occupy during any phase of physiological spinal movement (Haldeman, 1992: 623). Fixations are caused by muscular spasm, a shortened ligament or by intra-articular blocking (Gatterman, 1990: 408).

Lumbar Facet Syndrome

Refers to low back pain in which the primary lesion is identified to originate in the lumbar facet joints of the lumbar spine (Kirkaldy-Willis, 1988: 135-137).

Manipulation

A passive therapeutic procedure in which specifically directed manual forces are applied to the vertebral and extra-vertebral articulations of the body, with the object of restoring mobility to the restricted areas. (Gatterman, 1990: 410).

Mechanical Low Back Pain

For the purpose of this study it is pain caused by posterior facet syndrome and sacroiliac syndrome (Schafer and Faye, 1989).

Peak torque

This is the highest muscular torque produced by the muscle at a given rate of angular motion. It indicates the muscle's maximum output capability. Torque can be evaluated specific to time or to degree of range of motion. When used alone it is difficult to evaluate the specific strength of a person (Marrule, 1996: 110-114).

Posterior Facet Syndrome

This is pain originating primarily from the posterior facet joints of the lumbar spine (Kirkaldy-Willis, 1988: 133-135, Plaugher, 1993: 216–217 and Schafer and Faye, 1989: 217)

Sacroiliac Syndrome

Refers to low back pain in which the primary lesion is identified to originate in the sacroiliac joint or joints of the pelvis (Kirkaldy-Willis, 1988: 135-137).

Subluxation

A motion segment in which alignment, movement integrity and/or physiologic function are altered although contact between the joint surfaces remains intact (Gatterman, 1995: 6).

Twitch-interpolation technique

A method of measurement of arthrogenic muscle inhibition (AMI) in which a combination of a mean voluntary muscle contraction with an added supramaximal external stimulus is utilised (Hopkins and Ingersoll, 2000). The quantification of the maximal voluntary muscle activation is based on the principle that if all the muscle fibres are activated voluntarily, a superimposed external muscle stimulation will not produce any additional muscle force. However, if the muscle cannot be fully contracted voluntarily, additional force is generated by superimposed muscle stimulation (Urbach et al., 1999). It represents the extent of motor units that are activated during the contraction (Suter et al., 1998).

CHAPTER 1

INTRODUCTION

1.1 THE PROBLEM

Sacroiliac dysfunction is commonly associated with arthrogenic muscle inhibition (AMI) especially of the quadriceps (Suter et al., 1999; Suter et al., 2000) and hamstring muscles (Hillermann, 2003). AMI is clinically important because it limits the functional recovery of muscles after injury and thus delays return to play in athletes (Hopkins and Ingersoll, 2000). Wyke (1985: 72-77) observed that articular mechanoreceptor afferent nerve fibres give off collateral branches that are distributed both intersegmentally and intrasegmentally. Therefore manipulation of an individual joint not only affects the motor unit activity in the muscles operating over the joint being manipulated, but also in more remote muscles. The effect of manipulation of the SI joint on ipsilateral AMI of the quadriceps and hamstring has been well investigated and manipulation has been shown to reduce AMI (Suter et al., 1998 and 1999), however, no studies have yet been done to investigate the effect of manipulation of the SI or Lumbar facet joints on AMI in the contralateral limb despite studies which postulate the presence of this contralateral AMI (Suter et al., 1998 and 1999; Hurley et al., 1994).

1.2 OBJECTIVES OF THIS RESEARCH

Thus this study was formulated to determine the immediate effect of sacroiliac and lumbar manipulation on quadriceps femoris and hamstring torque ratios in the contralateral limb in patients suffering from mechanical low back pain

Objective 1

To evaluate the immediate effect of manipulation on contralateral quadriceps and hamstring torque ratios utilising the Cybex Orthotron II Isokinetic Rehabilitation System

The **first hypothesis** was that spinal manipulation would have a significant immediate effect on contralateral quadriceps and hamstring ratios.

Objective 2

To evaluate the immediate effect of manipulation on ipsilateral quadriceps and hamstring torque ratios utilising the Cybex Orthotron II Isokinetic Rehabilitation System

The **second hypothesis** was that spinal manipulation would have a significant immediate effect on ipsilateral quadriceps and hamstring ratios, as suggested in the literature.

Objective 3

To evaluate the immediate effect of manipulation on ipsilateral quadriceps and hamstring torque ratios versus immediate effect of manipulation on contralateral quadriceps and hamstring torque ratios utilising the Cybex Orthotron II Isokinetic Rehabilitation System.

The **third hypothesis** was that spinal manipulation would have a significant immediate effect on contralateral quadriceps and hamstring ratios, possibly as significant an effect as that on ipsilateral quadriceps and hamstring torque ratios.

Objective 4

To evaluate the presence or absence of spinal dysfunction between the levels of L2-L5 and the sacroiliac joint and the significance of spinal dysfunction on muscle inhibition in the quadriceps and hamstring muscles.

The **fourth hypothesis** was that spinal dysfunction is related to changes in muscle inhibition in the quadriceps and hamstring muscles.

1.3 ASSUMPTIONS OF THIS STUDY

The following assumptions were made in the study:

1. Suter et al (2000) stated that arthrogenic muscle inhibition is the inability of a muscle to recruit all motor units of a muscle group during a maximal effort

voluntary muscle contraction. Therefore, recruitment of an inhibited muscle group does not occur to its full extent.

2. Mechanoreceptor activity plays the primary role in arthrogenic muscle inhibition (Hopkins and Ingersoll, 2000). Manipulation of a joint has been proposed to activate mechanoreceptors from structures in and around the manipulated joint. The altered afferent input arising from the stimulation of these receptors is thought to cause changes in the motor neuron excitability, with a subsequent decrease in AMI (William, 1997: 144; Suter et al., 2000).

1.4 POTENTIAL BENEFITS OF THIS STUDY

AMI is known to limit the functional recovery of muscles and joints after injury (Suter et al., 2000) by hindering early active exercise in the joint rehabilitation process. This early active exercise is essential for decreased healing time, increased vascular growth, quicker regeneration of scar tissue, and stronger ligament and tendon healing. Thus one of the early goals in the rehabilitation process should be to reduce or eliminate muscle inhibition in order to regain full recovery of the affected structures (Hurley et al., 1994). A therapeutic intervention that could block or slow arthrogenic muscle inhibition would allow clinicians to return an athlete to participation with less strength or kinesthetic limitations once healing has occurred (Hopkins and Ingersoll, 2000). Also with the high amount of competition in the sporting world in this day in age, it is becoming of paramount importance for the athlete to return to training as soon after the injury as possible and so this research aims to add to the body of knowledge on rehabilitation protocols, thus aiding health care practitioners.

CHAPTER TWO

LITERATURE REVIEW

This chapter discusses the literature behind my study. The following aspects are discussed: -

- Mechanical low back pain
- Arthrogenic muscle inhibition and relevant neuroanatomy

2.1 MECHANICAL LOW BACK PAIN

Low back pain (LBP) afflicts at least 70% of the population at some time during their lives and poses a major socioeconomic burden, accounting for 13% of sickness absences in the United Kingdom (Speed, 2005). Hendler et al. (1995) found that up to as much as 80% of the adult population has sought, or at one time will seek, treatment for their LBP. Of that, most symptoms have biomechanical causes (Rives and Douglass, 2004).

2.1.1 Aetiology of Mechanical Low Back Pain

Schafer and Faye (1989:195) describe the three most common types of low back pain as lumbar facet syndrome, sacroiliac syndrome and lumbar radicular syndrome (discogenic or mechanical in origin)

The cause of these syndromes may be due to (Schafer and Faye, 1989:195):

1. Sprain / strain
2. Overuse
3. Poor posture
4. Disuse
5. Joint dysfunction (fixation or hyper mobility)
6. Developmental abnormalities
7. Degenerative changes and
8. Combination of any of the above

2.1.2 Sacroiliac Syndrome

In this respect sacroiliac syndrome (SI syndrome) is a collection of symptoms and signs that result from mechanical irritation of the sacroiliac joint (SI joint) (Kirkaldy-Willis and Hill, 1979). This is a common source of low back pain, with some studies reporting the sacroiliac joint to be the main problem in as many as 50 to 70% of adults suffering with low back pain (Bernard and Kirkaldy-Willis, 1987). Others estimate it to be between 55% and 61.5% (Cibulka et al., 1998), but all agree that the SI joint is a noteworthy source of pain in patients with low back pain (Sakamoto et al., 2001; Murata et al., 2000 and 2001; Cibulka et al., 1998; Daum, 1995; Schwarzer, Aprill and Bogduk, 1995; Bernard and Kirkaldy-Willis, 1987). Altered mobility or dysfunction of the sacroiliac joint has thus been implicated as the main pathology in sacroiliac syndrome (Cassidy and Mierau, 1992) and Toussaint et al. (1999) estimates the prevalence of sacroiliac joint dysfunction to be between 19.3% and 47.9%, depending on variables such as age, sex, level of physical fitness, employment and degree of education in the study group.

According to Cassidy and Mierau (1992), the pain of sacroiliac syndrome is located most often over the posterior superior iliac spine and buttock. It may be referred into the groin and lower extremity in a non-dermatomal pattern and is rarely associated with lower quadrant abdominal pain. McCullagh et al (1997:180-181) agree that this presentation is a "classic presentation". The symptoms of SI dysfunction are generally exacerbated by activities of daily living that tend to load the pelvis asymmetrically and patients frequently favor the uninvolved side whilst seated (Daum, 1995). In addition weight bearing and laying on the affected side is found to increase the pain (Hendler et al., 1995). A diagnosis of SI syndrome can be made when pain and motion restriction of the SI joint are present in the absence of neurological signs (Walters, 1993:155+161 and Cassidy and Mierau, 1992: 216-218). Clinical tests that are used in the diagnosis of this syndrome are pain provocation tests such as Gaenslen's and Patrick Faber tests and extension tests (Riggien, 2003; Reider, 1999:195 and McCullach et al., 1997: 180-181) and Posterior shear test (Laslett and Williams, 1994). Cibulka (2002) suggests that at least three out of these four tests should be positive in order to make a diagnosis of sacroiliac syndrome. Laslett et al. (2005) found in their study that SI joint pain provocation tests have significant diagnostic ability.

In addition restrictions may be found in both the upper and lower part of this joint, in flexion and extension (Cassidy and Mierau, 1992). The standing-leg-raising test or Gillet Method (Gatterman, 1995:460-465) is the most commonly used test to identify restrictions. This test is reported to be reliable; however its validity remains to be proven (Cassidy and Mierau, 1992).

Nevertheless treatment employed to restore motion to these joints has been indicated to be successful (Cassidy and Mierau, 1992). In this regard manipulation of the sacroiliac joint has been shown to be a successful treatment for sacroiliac syndrome (Cassidy and Mierau, 1992), especially the side posture method.

It is thought that treatment such as manipulation, applied in the form of a low-amplitude, high velocity thrust, results in the restoration of motion, as well as also the activation of mechanoreceptors and proprioceptors in and around the joint that is being manipulated (Suter et al., 2000 and Colloca in Fuhr et al., 1997:42). SI manipulation may therefore alter the sensory input that affects the afferent pathways of the spine (Suter et al., 2000) and thus result in a change in motor neuron excitability (Suter et al., 2000 and Harrison et al., 1997) and increase motor unit recruitment (Suter et al., 2000 and William, 1997:144).

Hence this study aimed to assess the neurophysiological effect of manipulation, as it is this effect that acts in the reduction of AMI.

2.1.3 Lumbar Facet Syndrome

Like sacroiliac syndrome, in lumbar facet syndrome altered mobility or dysfunction of the posterior facet joints of the lumbar spine has been implicated as the main pathology (Manchikanti et al., 2004; Bergmann et al., 1993 and Schafer and Faye, 1989). The pain of lumbar facet syndrome is usually in the midline, presenting with an achy (sometimes sharp) pain that improves in the morning after rest and becomes worse in the evening after prolonged weight bearing (Schwarzer et al., 1994; Bergmann et al., 1993 and Schafer and Faye, 1989). The pain is aggravated by any manoeuvre causing extension of the lumbar spine, such as Kemp's test, and often relieved by forward flexion (Cassidy and Mierau, 1992). Associated referred pain can refer to the ipsilateral iliac crest, buttock, groin, scrotum, labium or leg (usually above the knee). There are no conclusive neurologic signs and no pain on

coughing or sneezing (Bergmann et al., 1993 and Schafer and Faye, 1989), associated with this syndrome.

Restrictions can occur in flexion, extension, lateral flexion and rotation. Motion palpation of the lumbar spine is used to detect these restrictions (Bergmann et al., 1993 and Schafer and Faye, 1989). Motion palpation has been shown to be a reliable tool to detect restrictions in the lumbar spine (French et al., 2000; Hawk et al., 1999 and Boline et al., 1993).

In order to eliminate these joint restrictions manipulation of the lumbar facet joint has been shown to be a successful treatment in those suffering with lumbar facet syndrome and the side posture manoeuvre is most commonly used to manipulate this joint (Bergmann et al., 1993 and Schafer and Faye, 1989).



Figure 1: Side posture sacroiliac manipulation



Figure 2: Lumbar Roll used for manipulation of lumbar facet joint

In the same way that manipulation of the SI joint results in a reduction of AMI, manipulation of the lumbar facet joint results in a reduction in AMI by the stimulation of mechanoreceptors and proprioceptors (Herzog, 1995).

As a result of the presence of these restrictions within the lumbar facet and sacroiliac joints, it has been hypothesised that there is an adverse effect on the ability of muscles overlying the joint as well as those within the motor neuron pool to perform maximally. The following section therefore describes this phenomenon – arthrogenic muscle inhibition – in more detail.

2.2 ARTHROGENIC MUSCLE INHIBITION

Arthrogenic muscle inhibition (AMI) is defined as a presynaptic, ongoing reflex inhibition of musculature surrounding a joint, following dysfunction within that joint (Hopkins and Ingersoll, 2000). The muscle is thus unable to recruit all motor units of the muscle group to their full extent during a maximal effort voluntary muscle contraction and is a natural response designed to protect the joint from further damage (Suter et al., 2000).

During joint injury descending tonic spinal inhibition of inhibition is reduced allowing for an increase in AMI (Cervero et al., 1991). Therefore it is hypothesised that mechanoreceptor activity plays the primary role in AMI (Hopkins and Ingersoll, 2000), which supports the theory in respect of the effect of manipulation on AMI, as it stimulates the mechanoreceptors of the joint and surrounding structures (Suter et al., 2000 and William, 1997:144).

In addition AMI is clinically important because it limits the functional recovery of muscles and joints after injury (Suter et al., 2000). Hurley et al (1994) suggest that one of the early goals in the rehabilitation process should be to reduce or eliminate muscle inhibition in order to regain full recovery of the affected structures.

In order to understand AMI it is important to understand the basic principles of the neurological system, which will be covered in the following sections before the effect of manipulation on AMI will be introduced in the context of SI and lumbar facet syndrome.

2.2.1 Relevant neuroanatomy and neurophysiology

The spinal cord consists of a complex system of channels relaying information in electronic form to and from various parts of the body (Hopkins and Ingersoll, 2000). The central and peripheral nervous systems work together to gather transmit and process information from many different neuropsychological systems in order to coordinate movement (Hopkins and Ingersoll, 2000). Almost all sensory information from the somatic segments of the body enters the spinal cord through the dorsal roots of the spinal nerves and is then carried to the brain via two sensory pathways, the dorsal column-medial lemniscal and the anterolateral system (Guyton and Hall, 1997). The joint constantly transmits information regarding environment, position and

movement to the supraspinal centres (Hopkins and Ingersoll, 2000). Change in afferent input to the spinal cord from the joint appears to be the most influential factor associated with AMI (Hopkins and Ingersoll, 2000) and how this change occurs and the neuroanatomy involved in this change will be discussed next.

2.2.1.1 Joint Receptors

Mechanoreceptors are receptors that act to transduce energy from one form into a specific nerve signal (Zimny, 1988) and proprioceptors act to transduce information about the relationship between body segments (Latash, 1998). As such joint receptors are mechanoreceptors which can also act as proprioceptors, thus providing information about the relative position of body segments as well as initiating protective reflex mechanisms that help to protect and stabilise the joint (Hopkins and Ingersoll, 2000).

Arthrogenic muscle inhibition is mainly caused by the stimulation of mechanoreceptors and to a lesser degree by free nerve endings and specialised nociceptors from within the joint (Ingersoll et al., 2003). Joint receptors are located in joint capsules, ligaments and tendons (Levangie and Norkin, 2001:71).

Relative to the low back (lumbar facet joints and the sacroiliac joint), most synovial joints are said to contain four types of receptors that are classified according to Wyke's classification system (Wyke, 1985, as cited by Leach, 1995).

For purposes of clarity, the receptors are divided into four groups according to their neurological properties, which include three corpuscular mechanoreceptors and one nociceptor - these are Type I, Type II, Type III and Type IV mechanoreceptors respectively (Wyke, 1985, as cited by Leach, 1995 and Bergmann et al in Bergmann et al., 1993 and Schafer in Schafer 1987) and described as follows:

- Type I receptors are confined to the outer layers of the joint capsule and are stimulated by active or passive joint motions. They have a low threshold, making them very sensitive to movement and they are slow adapting, making the effects of movement long lasting.
- Type II receptors are found within the deeper layers of the joint capsule. They are also low threshold and are stimulated even with minor changes in tension.

Unlike Type I receptors, however, type II receptors are very rapidly acting and cease firing when the joint stops moving.

- Type III receptors are absent from all the synovial spinal joints but are found in the intrinsic and extrinsic ligaments of the peripheral joints.
- Type IV receptors are composed of a network of free nerve endings as well as unmyelinated fibres. They are associated with pain perception and include many different varieties and wide ranges of sensations. They are present throughout the fibrous portions of the joint capsule and ligaments.

In this respect, the lumbar facet joints of the spine contain three of the four types of sensory mechanoreceptors that are stimulated by tissue tension (Bergmann et al., 1993). Most of the mechanoreceptors in the SI joint are thought to be nociceptors, with few proprioceptors. This may be due to the lesser mobility of the SI joint (Sakamoto et al., 2001)

The presence of mechanoreceptive and nociceptive nerve endings in the lumbar facet joints implies that neural input from the facets is important to proprioception and pain sensation in the lumbar spine.

Wyke (1985, as cited by Leach, 1995 and Bergmann et al in Bergmann et al., 1993 and Schafer in Schafer 1987) classifies receptors according to their neurological properties however; there are other classification systems such as that described by Jones (Jones in Cohen, 1999:119), where receptors are classified according to histological make-up rather than their neurological properties. However, Ruffini endings described by Jones (Jones in Cohen, 1999:119, appear to be similar to Type I receptors described by Wyke (Wyke, 1985, as cited by Leach, 1995 and Bergmann et al in Bergmann et al., 1993 and Schafer in Schafer 1987) and Golgi like endings similar to Type III receptors. According to Jones classification of joint receptors, joints contain three specific types of mechanoreceptors (Hopkins and Ingersoll, 2000 and Jones in Cohen, 1999:119)

1. Ruffini endings

These are slowly adapting receptors and therefore are capable of a prolonged period of discharge. These receptors also have a very low threshold, thereby responding to very slight changes in ligament tension and capsular pressure. These receptors play a role in signalling proximity of the joint to its range of

motion limitations as well as being active during capsular pressure from joint effusion. They are mostly found in the joint capsule and ligaments (Hopkins and Ingersoll, 2000)

2. Golgi like endings

These receptors fire rapidly upon first movement of a joint and then slow to a steady discharge. They help provide information about joint position (Hopkins and Ingersoll, 2000). Golgi like endings are commonly found in ligaments around the joint (Jones, 1999:119).

3. Pacinian corpuscles

These receptors are different from the other two in that it adapts quickly to a stimulus. Their brief, high velocity impulses indicate joint acceleration and deceleration. Pacinian corpuscles are found mainly in the fibrous periosteum near articular attachments (Jones, 1999:119).

In addition to this the free nerve endings are non-specialised, non-encapsulated, unmyelinated receptors and function mostly as pain receptors as well as providing a crude awareness of initial joint movement (Hopkins and Ingersoll, 2000). According to Darby and Daley in Cramer and Darby (1995:253), all nociceptors are free nerve endings and may be viewed as Type IV receptors.

2.2.1.2 Neural Pathways

2.2.1.2.1 Afferent pathway to the spinal cord

The previously discussed receptors are specialised endings to sensory nerve fibres. When the receptor is stimulated, there is a change in membrane potential, which depolarises the membrane and produces an action potential. The action potential travels along the dendrite of the sensory neuron until it reaches the cell body, located in a dorsal root ganglion very close to the spinal cord. The cell body projects through the dorsal horn of the spinal cord where it makes connections with several different types of neurons (Latash, 1998 as cited in Hopkins and Ingersoll, 2000).

After entering the cord and synapsing with the neurons in the dorsal horn, every sensory signal travels to two separate destinations, one terminates in the gray matter of the spinal cord and elicits local reflexes and the other transmits signals to higher levels in the spinal cord, to the brain stem and to a lesser degree, the cortex, where integration of signals takes place (Guyton and Hall, 1997:441).

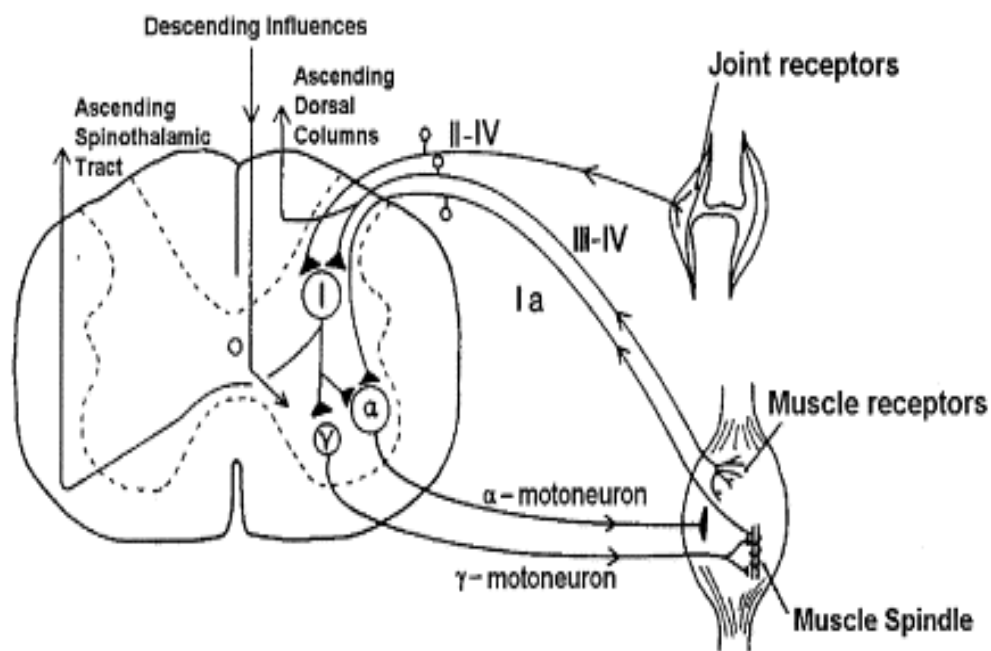


Figure 3: Diagram illustrating afferent pathways from joint receptors to the spinal cord as adapted from Pickar (2002)

To achieve the aim of slowing or modifying AMI, afferent nerve activity needs to be modified (Hopkins and Ingersoll, 2000).

2.2.1.2.2 The Interneuron

An interneuron can be described as a neuron receiving information from a neuron and transmitting this information to other neurons (e.g. a sensory neuron transmitting impulses to the interneuron which then disperses the incoming information). These cells are numerous and are present in all areas of the cord gray matter. They are small and highly excitable and are responsible for most of the integrative functions of the spinal cord (Guyton and Hall, 1997). Once the sensory fibre enters the dorsal horn of the spinal cord, it usually branches to synapse on several interneurons. Interneurons are the intermediates of pathways to alpha and gamma motor neurons, to automatic efferent neurons which are responsible for the local reflexes and to ascending pathways. They receive projections from sensory afferent fibres, descending fibres and other interneurons. Interneurons thus play an important

integrative function and the net effect of all information arriving at the interneuron is expressed in the inhibitory and excitatory response of the motor neuron pool (Hopkins and Ingersoll, 2000).

There are different types of interneurons and several interneuronal systems. Of these systems, the joints' receptors appear to stimulate the Ib inhibitory interneuron system (Hopkins and Ingersoll, 2000) within the spinal cord.

The interneuron is one of the places where integration takes place, and this integration in turn affects MN excitability. Since the integration is taking place in an interneuron instead of all factors coming together at the MN, the net effect of the interneuron could affect AMI.

2.2.1.2.3 Ascending and Descending Information

Sensory information ascends in the spinal cord via the dorsal column pathway. The ascending fibres terminate in the medulla, continuing via the medial lemniscus to the ventroposterior-lateral nucleus of the thalamus and on to the cerebral cortex (Hopkins and Ingersoll, 2000 and Guyton and Hall, 1997). The net effect achieved by this system is the receiving of information from the lower spinal centres and integrating this information in order to form a response.

Descending pathways are arranged into spinal tracts that carry specific information from a supraspinal centre. The most important pathways involved in the modification of AMI are the corticospinal tract, vestibulospinal tract and rubrospinal tracts (Hopkins and Ingersoll, 2000 and Guyton and Hall, 1997). Discussion of these tracts and how they play a role in the development of AMI follows.

- The cortical neurons of the **corticospinal tract** synapse on alpha MN's, gamma MN's and interneurons, thereby carrying motor information to the MN. This tract is the most direct pathway for information received and processed by the motor cortex to reach the musculature to produce movement (Porter, 1999 in Cohen, 1999:248). One of the functions of the corticospinal tract is the production of signals that govern the force of muscle contraction (Porter, 1999 in Cohen, 1999:250). Most of the cortical neurons facilitate, however some are inhibitory neurons that inhibit normal afferent activity from causing a motor

response (Hopkins and Ingersoll, 2000 and Guyton and Hall, 1997). Consequently, force of muscle contraction might be reduced.

- The **vestibulospinal tract** neurons play a major role in the regulation of postural reflexes, especially in helping to maintain an upright posture (Hopkins and Ingersoll, 2000), regulation of balance (Colloca, 1997 in Fuhr et al., 1997:158) and proprioception (Snell, 1997:365). Prior to voluntary movement, postural reflexes change and these changes are mediated at the interneuron by the vestibular system and the cerebral cortex (Hopkins and Ingersoll, 2000), thus the afferent information of the MN pool might be altered as a result. Iles (1996) and Iles and Pacini (1992) concluded that corticospinal and vestibulospinal neurons converge on inhibitory neurons to inhibit the inhibitory mechanism resulting from the stimulation of cutaneous receptors. This is further supported by Cervero et al. (1991) who reported a constant tonic inhibition from supraspinal centres that inhibits normal afferent activity from causing a motor response. Cervero et al (1991) reported that during joint injury descending tonic spinal inhibition is reduced, thus allowing for an increase in AML.
- The **rubrospinal tract** works in close association with the corticospinal tract in the control of distal musculature (Porter, 1999 in Cohen, 1999:270). It also has been concerned in the inhibitory actions by affecting interneurons that inhibit normal afferent activity from causing a motor response (Hopkins and Ingersoll, 2000). Muscle strength might be reduced as a result of the altered afferent innervation of the MN pool through inhibition of the MN pool (Terblanche, 2004).
- The **spinal motor neuron** and the muscle fibres it innervates, work together as a unit known as a motor unit (Darby and Daley in Cramer and Darby, 1995:284). The greater the force required during muscle contraction, the greater the number of motor units recruited. Thus the number of motor units recruited governs the strength of muscle contraction (Iyer et al. 1999 in Cohen, 1999:221). The inhibitory interneurons mediate the afferent innervation of the MN pool, resulting in a decrease in recruitment ability within the MN pool (Hopkins and Ingersoll, 2000). As a result, the efferent response of the muscles that are innervated by the MN pool is also altered, resulting in fewer motor units being recruited and a lesser percentage of the MN pool being activated (Iyer et al. 1999 in Cohen, 1999:221). The force of muscle contraction of those muscles governed by that MN pool is reduced and

consequently, AMI is clinically manifested as a reduction in muscle strength (Suter et al., 1999).

2.2.1.3 Innervation

In order for manipulation to have an effect through a hypothesised neurological mechanism, it stands to reason that the innervation of the joint and the related muscles must stem from a similar MN pool.

The motor nerve supply of the quadriceps and hamstring muscles fall into the same MN pool as that of the sensory nerve supply of the sacroiliac joint and lumbar facet joints of L2-5. Previous studies (Hillerman, 2003 and Suter et al., 1999 and 2000) have illustrated the presence of AMI in the quadriceps and hamstring muscle in patients with anterior knee pain which has been attributed to the nerve supply of the knee falling into the same MN pool as the quadriceps and hamstring muscle. Thus it stands to reason that injury of the sacroiliac joint and lumbar facet joints (L2-5) will also cause AMI of the quadriceps and hamstring muscle as they fall within the same MN pool.

In this respect there are four muscles that make up the quadriceps femoris muscle. These are: -

- rectus femoris,
- vastus lateralis,
- vastus medialis and
- vastus intermedius.

They all receive supply from the posterior divisions of L2, 3, 4 via the femoral nerve (Moore, 1999 and Williams et al., 1980: 870-879).

The antagonists to the quadriceps femoris muscle are the three muscles collectively known as the hamstring muscle: -

- semimembranosus,
- semitendinosus and
- biceps femoris.

Semitendinosus and semimembranosus get their supply from the tibial division of the sciatic nerve (L5, S1, 2). The biceps femoris has 2 heads, the long and short head. The long head is supplied by the tibial division of the sciatic nerve L5-S2 and the

short head by the peroneal division of the sciatic nerve L5-S2 (Moore, 1999 and Williams et al., 1980: 870-879).

In comparison to the above, the segmental supply of the SI joint can range from L2-S4 (Cassidy and Mierau, 1992: 211-212). The L4 and L5 levels most frequently innervate the anterior aspect of the joint, whilst the posterior aspect more commonly receives innervation from S1 and S2 levels (Cassidy and Mierau, 1992: 211-212). Thus plexiform networks from the posterior primary rami of the L5-S4 segments innervate the anterior and posterior aspects of the SI joint. In addition the accessory ligaments of the SI joint receive fibres from L1-S2 (Walters, 1993: 152-153).

The facet joints of the lumbar spine are innervated by nerves that arise from medial branches of dorsal primary rami of the spinal nerve of that level. Each articular branch supplies the joint nearby and may send to the subjacent joints (one above and one below) as well via ascending and descending primary afferents (Moore, 1999). All parent neurons, which vary in diameter and conduction velocity, are derived from the dorsal and ventral rami, as well as the recurrent meningeal nerve of each segmental spinal nerve (Bergmann et al., 1993).

The following discuss inhibition and how this inhibition can affect the quadriceps and hamstring musculature in patients with injury to the sacroiliac joint and lumbar facet joints (L2-5).

2.2.2 Types of Inhibition

Inhibition is a very common regulatory process in the neuromuscular system. AMI is one of many inhibitory mechanisms that help regulate musculoskeletal movement and in this respect inhibition in the nervous system is either postsynaptic or presynaptic in addition to which synapses between neurons and between neuron and membrane may be either excitatory or inhibitory in nature (Hopkins and Ingersoll, 2000).

In ***postsynaptic inhibition***, both excitatory and inhibitory processes result in the release of a neurotransmitter at the terminal end plate. The neurotransmitter then traverses the synaptic cleft to bind to a specific receptor on the postsynaptic membrane, causing an excitatory or inhibitory potential at the postsynaptic

membrane. If the neurotransmitter is an inhibitory transmitter, then the binding to the specific site will cause ion channels to open that will hyperpolarize the membrane, thus making it more difficult for the combined action of all synapses to generate an action potential and thereby inhibition takes place. The neurotransmitter most involved in postsynaptic inhibition is gamma-aminobutyrate (GABA) (Hopkins and Ingersoll, 2000).

According to Hopkins and Ingersoll (2000), the purpose of **presynaptic inhibition** is to decrease the effectiveness of just one type of neuron synapsing on the membrane. Presynaptic inhibition may be more specific than postsynaptic inhibition, which acts on the entire membrane. Presynaptic inhibition is generally caused by a decrease in neurotransmitter release from the terminal presynaptic membrane and is thought to involve interference with calcium influx at the terminal synapse (Leonard, 1998 and Hopkins and Ingersoll, 2000).

Thus presynaptic inhibition occurs in the presynaptic terminals before the signal ever reaches the synapse, whereas postsynaptic inhibition is caused by inhibitory synapses operating at the neuronal membrane (Guyton and Hall, 1997).

AMI is thought to be a combination of presynaptic and postsynaptic inhibition. All afferent and supraspinal fibres synapsing on the interneuron conduct their excitatory or inhibitory information. Other fibres synapse on the presynaptic membrane, resulting in presynaptic inhibition or excitation. The result of presynaptic factors on the neuron is then transmitted to the interneuron in either an excitatory or inhibitory form. The net effect of the neurons synapsing on the interneuron is then mediated by postsynaptic neurotransmitters. The summation of all involved factors results in excitation or inhibition of the impulses to the musculature (Hopkins and Ingersoll, 2000). Other inhibitory mechanisms may also play a role in AMI such as **recurrent inhibition** and **reciprocal inhibition**.

Reciprocal inhibition is the inhibition which occurs in the antagonist muscles when there is excitation of the agonist muscles e.g. When a stretch reflex excites one muscle, it often at the same time inhibits the antagonist muscles (Guyton and Hall, 1997). Reciprocal inhibition is caused by Ia inhibitory interneuron activity (Hopkins and Ingersoll, 2000).

Recurrent inhibition is inhibition mediated by Renshaw cells found on the efferent loop near the alpha MN. The net result of recurrent inhibition is inhibition of the affected MN pool and its synergists and disinhibition of the antagonists (Hopkins and Ingersoll, 2000). It is caused by inhibition of Ia interneuron activity (Hopkins and Ingersoll, 2000).

2.2.3 Mechanism of development of ipsilateral AMI

Joint injury is thought to result in the stimulation of receptors of the affected joint which results in conduction of afferent information via primary afferents toward the CNS (Young et al., 1993). At the dorsal horn of the spinal cord, these primary afferents synapse on numerous inhibitory interneurons (Hopkins and Ingersoll, 2000). From here the information ascends via the ascending pathways (dorsal column – medial lemniscal system and the anterolateral system) to the postcentral gyrus of the cerebral cortex where the information is interpreted. Thereafter, efferent information is conducted towards the spinal motor neurons via the descending pathways (corticospinal, vestibulospinal and rubrospinal) (Hopkins and Ingersoll, 2000 and Guyton and Hall, 1997). The efferent information may be further inhibited through synapses with additional inhibitory interneurons in the spinal cord. Thus, the efferent information arriving at the spinal motor neurons is altered as well as the efferent responses of those muscles supplied by them.

Thus when one considers that the spinal motor neurons are arranged into groups called motor neuron pools^a and it is these motor neuron pools that are responsible for the force of muscle contraction of the group of muscles they supply (Hopkins and Ingersoll, 2000), then it follows that AMI is the inability to recruit all motor units of the muscle group to their full extent (Suter et al., 2000).

2.2.4 AMI of the contralateral limb

Suter et al (1999 and 1998) and Hurley, Jones and Newham (1994) in their studies on AMI demonstrated a considerable amount of muscle inhibition in the contralateral, uninjured leg. Suter et al (1998) suggested two potential explanations for the appearance of AMI in the contralateral leg:

^a The spinal motor neuron and the muscle fibres it innervates are called a motor unit and thus due to the generalised inhibitory effect of interneuronal activity, there is a reduction in motor unit recruitment and a reduction in force of muscle contraction

Firstly, as a result of joint dysfunction there is a change in gait pattern and / or physical activity, which in turn may modify the neuromuscular control of the involved muscles.

Secondly, Suter et al (1998) proposed the concept of the transfer of unilateral inflammation towards the contralateral side by means of neural connections in the spinal cord, what they term reflex neurogenic inflammation.

Thirdly and in addition to Suter et al (1998), there is a suggestion from the above literature that a central neural mechanism of neural control may be possible in perpetuating the muscle inhibition (cortical in origin). In this respect Young (1993) suggests that there may be convergent input from the contralateral limb, as unilateral inflammation can cause increased responsiveness of some ascending tract cells affecting their formulated responses bilaterally.

And lastly the possibility of local neurological cross over effects at the level of the interneuron's which affects both the ipsilateral and the contralateral limbs. This is supported by Koceja et al (1991) who postulated that crossed spinal pathways transmit information to the contralateral leg and thus this may result in arthrogenic muscle inhibition of the contralateral leg. Urbach et al (1999) confirmed this theory in his study of the bilateral deficit of voluntary quadriceps muscle activation in patients with a unilateral ACL tear, using a highly sensitive and established twitch-interpolation technique (see glossary for definition).

Thus Urbach et al (1999) state that the inability to fully activate the quadriceps muscle voluntarily affects the injured and the uninjured side to the same extent. It has been shown that unilateral acute inflammation increases the effectiveness of tonic descending inhibition, resulting in decreased hyperexcitability for the afferent input from the inflamed knee as well as for the input from regions of the contralateral leg.

As a result of these findings, hypotheses tend to point toward central mechanisms causing voluntary muscle activation deficiencies in cases of joint pathology (Urbach et al., 1999). Urbach et al (1999) goes on to say that the contralateral inhibition may

be regarded as a tool to maintain a bilateral balance of motor output in order to protect the joint and soft tissue from further damage.

Further to this Hurley et al (1994) also tried to explain the presence of AMI in the contralateral quadriceps by indicating that damage to articular mechanoreceptors elicits abnormal joint afferent signals that decreases excitability of the spinal neurons controlling quadriceps activity. As these spinal neurons receive bilateral convergent input, a unilateral joint injury which produces abnormal afference, may be perceived as having arisen bilaterally (by the interneuronal pool or central nervous systems), and result in bilateral reduction of quadriceps activation.

This supported the 1991 study by Koceja et al (1991) on the quantitative assessment of human crossed-spinal reflex pathways, where it was determined that crossed spinal pathways transmit information to the contralateral leg. Hopkins and Ingersoll (2000) confirms Hurley et al (1994) and Urbach et al (1991) proposal that it is these crossed spinal pathways that inhibit the joint musculature of the contralateral leg.

Spinal manipulation is used as a therapeutic approach and has been shown to successfully restore joint motion and reduce restriction in a symptomatic joint. Numerous treatment modalities such as pharmacological agents, cryotherapy and TENS (discussed next under 2.2.5) are used in the treatment of AMI and in attempt to restore a normal neurological reflex circuit. Spinal manipulation is possibly a treatment that can be used to treat both entities and therefore treat the major clinical condition.

2.2.5 Treatment

AMI is a limiting factor in rehabilitation of joint injury (Hopkins and Ingersoll, 2000). It results in strength deficits, often long after healing has occurred, as well as muscle atrophy. It is often the cause of re-injury with return to competition and it prevents the athlete from performing early active exercise necessary to help increase healing (Hopkins and Ingersoll, 2000). Thus it follows that a reduction in AMI would allow the athlete to perform early active exercise, which would facilitate healing and prevent decreases in strength and muscle mass, allowing the athlete to return to competition stronger and less susceptible for further injury (Hopkins and Ingersoll, 2000).

Some of the therapeutic interventions of AMI are listed below: -

- Pharmacological agents (e.g. injection of lidocaine into the effused joint capsule), which are principally aimed at performing a gross nerve block and thereby negating the inhibitory process, resulting in a “switching off” of AMI. However, all perceived pain is also turned off, preventing essential feedback and without pain, further damage is inevitable (Hopkins and Ingersoll, 2000).
- Cryotherapy which is principally aimed at slowing and eventual blocking of sensory nerve fibres (Hopkins and Ingersoll, 2000). The cooler the nerve becomes, the slower the impulse is carried (Knight, 1995:301). The resultant increase in action potential time might cause a decrease in peak-to-peak amplitude of depolarisation at the interneuron (Hopkins and Ingersoll, 2000). This could result in a decrease in firing of the inhibitory interneuron and a successive increase in voluntary activation of the MN pool (Ingersoll et al., 2003).
- Transcutaneous electrical nerve stimulation (TENS) is principally aimed at stimulating cutaneous type I nerve endings which compete for the same type I afferent fibres that carry information from joint receptors to the spinal cord, thereby reducing AMI, resulting in increased muscle performance. (Hopkins and Ingersoll, 2000).

Lidocaine injection, cryotherapy and TENS are mostly aimed at reduction of joint pain and muscle atrophy. As has been already stated these techniques do cause a reduction in AMI to varying degrees, but are considered inadequate in causing a significant reduction in AMI (Hopkins and Ingersoll, 2000). In this respect, Ingersoll et al (2003) state that additional therapy techniques and modalities be investigated for their usefulness in eliminating or reducing AMI. Also, these techniques address the AMI and accompanied pain with joint injury; however, it does not address the reduced mobility of the joint that is found in syndromes such as SI syndrome and lumbar facet syndrome. It follows that the therapy should also be applicable to SI / facet joint syndrome and to the restoration of joint motion.

- Spinal manipulation – Suter et al (2000) concluded in a randomised, double-blinded, controlled clinical trial that spinal manipulation may possibly be an effective treatment of AMI in the knee extensors based on their findings, although the validity of their study has been questioned due to a poorly controlled study sample (Terblanche, 2004). Hillerman (2003) found a significant improvement in the quadriceps and hamstring muscle torque ratios following manipulation of the SI joint in patients suffering from patellofemoral pain syndrome (PFPS). Matkovich (2004) also found that spinal manipulation had a significant effect on the ipsilateral torque ratios of the hip musculature in patients suffering from low back pain. These three studies point to the use of spinal manipulation as a therapeutic modality in the treatment of AMI.

Thus the theory behind how manipulation causes a reduction in AMI, is thought to be related to altered afferent input arising from the stimulation of mechanoreceptors during manipulation. There are thus changes in the MN pool excitability of the musculature whose innervation is the same as the innervation of the joint being manipulated, resulting in a subsequent reduction in AMI (Suter et al., 2000 and William, 1997:144).

Therefore in this study, manipulation was performed on all joints linked to the motor neuron pool of the hamstring and quadriceps muscles, which were the sacroiliac joint and the lumbar facet joints from L2 - L5.

It would stand to reason that manipulation of the symptomatic joint would have an effect on AMI in the ipsilateral limb as well as the contralateral, asymptomatic limb as a result of the crossed spinal pathways discussed previously.

The following discussion addresses the measurement of this change of AMI in the clinical context.

2.2.6 Measuring arthrogenic muscle inhibition

The effect of AMI is a reduction in MN pool recruitment and there are many different ways of measuring AMI. It may be measured using:

- Voluntary motor unit recruitment or voluntary force output as measured by a dynamometer or through electromyography.
- Involuntary measures of MN recruitment through controlled stimulation of sensory fibres and evaluation of the reflexive twitch contraction using the Hoffmann reflex (H-reflex).
- A combination of a voluntary contraction with a superimposed electrical impulse (e.g., interpolated twitch techniques).

Each method has advantages and disadvantages (Ingersoll et al., 2003).

Decreased **maximum voluntary contraction (MVC)** is one of the final outcomes of AMI. The difference in a baseline MVC and an MVC following injury is essentially inhibition (Hopkins and Ingersoll, 2000). AMI is evident using this method; however there are some drawbacks (Ingersoll et al., 2003):

In order to effectively measure differences in voluntary force production, the subject must be willing and able to perform a maximum voluntary contraction. The MVC must also be accurate and reproducible. If a subject is asked to perform an MVC post injury, there are psychological factors such as perceived pain and lack of confidence, as well as actual pain, which could hinder their ability to perform an MVC (Ingersoll et al., 2003).

With the **Hoffmann reflex (H-reflex)**, the measurement method also uses an entire group of muscles with aid from synergists that may or may not be inhibited (Ingersoll et al., 2003). As it is impossible to measure independent muscles separately and as we have already discussed the contralateral leg comparison is not valid in establishing a baseline measurement as the contralateral leg has also shown evidence of AMI, the interpolated twitch technique may be used as a better comparison to the pathological measurement (Hopkins and Ingersoll, 2000).

The **interpolated twitch technique** is a combination of an MVC and an additional supramaximal external stimulus to make up for the inhibited portion of the MN pool. This technique allows for a measurement of AMI without a baseline torque measurement. However the validity of this measurement is questionable as the

magnitude of the force generated during a twitch is very small compared with the background force, and it can easily go undetected (Hopkins and Ingersoll, 2000).

It has therefore been suggested that using the *Hoffman's reflex* to study AMI in a pathological population, would perhaps be more useful than using *dynamometry*, as the subject requires no physical effort during testing (Hopkins and Ingersoll, 2000), and would therefore prevent an aggravation in their pain as a result of the testing. However, the H-reflex does not take into account supraspinal inputs that may affect the MN pool during voluntary exercise (Ingersoll et al., 2003), thus making this method of measurement less useful for the purposes of this study.

As a result Pincivero et al (1997) state that due to the ability to quantify reliably and relatively precisely the values for maximal strength and endurance, as measured by the three methods discussed above, they recommend *isokinetic dynamometry*, as a valuable tool for the evaluation of muscular capability and injury assessment.

Thus for the purpose of this study isokinetic dynamometry was utilised as the tool of choice.

2.3 SUMMARY

A review of the literature shows the need to further investigate any treatments aimed at the reduction or elimination of AMI (Ingersoll, Palmieri and Hopkins, 2003).

The stimulation of nociceptors, as in the case of symptomatic sacroiliac or lumbar facet syndrome, can lead to AMI of the muscles within the joint's motor neuron pool (Hopkins and Ingersoll, 2000). In support of this the sacroiliac joint and lumbar facet joints have been linked to ipsilateral AMI of the quadriceps and hamstring group (Matkovich, 2004; Hillermann, 2003; Hopkins and Ingersoll, 2000; Suter et al., 2000 and Suter et al., 1999).

Furthermore Suter et al (1998 and 1999) and Hurley, Jones and Newham (1994) in their studies on AMI demonstrated a considerable amount of muscle inhibition in the contralateral, uninjured leg. In congruence with Urbach et al (1999) who stated that

the inability to fully activate the quadriceps muscle voluntarily affects the injured and the uninjured side to the same extent. Thus many authors have developed proposals to explain the presence of this contralateral AMI (Hopkins and Ingersoll 2000; Suter et al., 1999 and 1998, Hurley et al., 1994 and Urbach et al., 1991), however little has been done to investigate the effect of treatment thereon.

According to Hopkins and Ingersoll (2000), one of the final outcomes of AMI is the reduction in voluntary contraction of the affected muscles. Assessing the voluntary force output (peak torque), by using isokinetic dynamometry for example, is an effective and simple measure of voluntary contraction (Hopkins and Ingersoll, 2000 and Pincivero et al., 1997).

Suter et al (2000 and 1999) state that spinal manipulation may possibly be an effective treatment of AMI in the lower limb musculature due to stimulation of the mechanoreceptors of the adjusted joint, which alters the afferent innervation to the spinal cord.

Thus the aim of this research was to determine whether or not there is an immediate effect of sacroiliac and lumbar manipulation on quadriceps femoris and hamstring torque ratios in the contralateral limb of patients who suffer from mechanical low back pain.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This chapter gives a detailed report of how the study was carried out, including study design, how the data was collected and assessed and the interventions used in the study.

3.2 STUDY DESIGN

3.2.1 Study type

This study was a placebo controlled pre – post quasi-experimental trial.

3.2.2 Sampling Procedure

Randomised non-probability based sampling procedures were used on subjects who responded to advertisements placed in and around the Durban Institute of Technology Chiropractic Day Clinic, sports centres and medical clinics.

Subjects then underwent a telephonic interview in which they were asked their age, gender, duration of pain, any previous surgery or trauma to their lower back and whether they were currently on any medication for their back pain. Provided they were deemed suitable to be included into this study, an initial consultation was scheduled at the Durban Institute of Technology Chiropractic Day Clinic in order to assess the suitability of the respondents to be included in the study.

3.2.3 Sample allocation

The sample consisted of the first 60 subjects that met the inclusion and exclusion criteria. There were two groups, Group A and Group B, where subjects received either manipulation or detuned ultrasound. Randomised non-probability based sampling procedures were used. The inclusion and exclusion criteria were as follows:

Inclusion Criteria –

1. Subjects were between the ages of 18-45 years. Brandt (2002) found that little radiographic evidence of osteoarthritis existed in people below the age of 45 years.
2. Subjects must have had a chief complaint of low back pain that was locally tender to palpation (Riggien, 2003 and McCullach et al. 1997: 180-181).
3. The pain was aggravated by provocation tests, like Gaenslens and Patrick Faber tests for Sacroiliac syndrome (Riggien, 2003 and McCullach et al. 1997: 180-181) and Kemps test (Corrigan and Maitland, 1998:35), facet joint challenge (Gatterman, 1990:84), hyperextension in a prone position (Gatterman, 1990: 162) and well localised paraspinal tenderness (Helbig and Lee, 1988:62) for lumbar facet syndrome.
4. There was clinical evidence of decreased movement or asymmetry of the sacroiliac joint or lumbar facet joints from L2-L5 (Riggien, 2003 and McCullach, 1997: 180-181).
5. There was no other apparent cause of the subject's sacroiliac joint or lumbar facet joint pain localization i.e. infection (Riggien, 2003 and McCullach, 1997: 180-181).
6. Subjects were only accepted if they had given informed consent, had undergone a detailed case history (appendix A), revised physical (appendix B) and lumbar spine and pelvis regional examination (appendix C).

Exclusion Criteria

1. Subjects exhibiting any of the following contra-indications to manipulation were not considered for this study: (Gatterman, 1990)
 - Examples included : Disc herniations with increasing signs and symptoms of neurological deficit, Abdominal aortic aneurysm, Lumbar spine tumours, Lumbar spine infections and any lumbar spine traumatic injuries.
2. Subjects were excluded from the study if they were currently on medication or receiving treatment for their low back pain (Haldeman, 1992:641).
3. Subjects who had had previous surgery / trauma to their lower back were also excluded.
4. Subjects who had any of the above exclusion criteria were excluded.
5. Need for further clinical or special investigations (e.g. x-rays). Subjects were not x-rayed as the budget for this study did not allow it.
6. Subjects were excluded if they showed any contraindications to isokinetic testing procedures, as outlined by www.isokinetics.net (2003) and Davies (1992).
7. Informed consent was not signed or the patient was not able to give consent.

3.2.4 First Consultation

Subjects were given a covering letter (Appendix E), explaining the study to them. They were required to complete and sign an informed consent form (Appendix D). Subjects were then assessed by means of a case history (appendix A), physical examination (appendix B) and lumbar spine and pelvis regional examination (appendix C) in order to see whether they were suitable for the study.

A second consultation was arranged at a time suitable for the subject and the biokineticist.

3.2.5 Second Consultation

This second consultation took place at the Kingspark Sharks Medical Centre. Testing of Quadriceps and Hamstring muscle torque was performed using the Cybex Orthotron II Isokinetic Rehabilitation System in the actions of flexion and extension of the knee.

Subjects completed a 5 minute warm-up cycle, followed by 3 sets of a 20 second hamstring and quadriceps muscle stretch. The subject then underwent concentric-concentric testing of the thigh.

Immediately after testing the subjects received manipulation of the involved side (most symptomatic side). Immediately after the manipulation subjects re-performed the isokinetic testing. This was to check if the manipulation would cause an increase in objective peak torque values.

3.3 METHODS OF MEASUREMENT

3.3.1 Data

3.3.1.1 Primary Data

Measurement of the subjects quadriceps and hamstring torque ratios were obtained pre and post manipulation using a Cybex Orthotron II Isokinetic Rehabilitation System.

3.3.1.2 Secondary Data

Secondary data were obtained from a search of the related literature. This included journals, web sites, textbooks and published reports containing information relevant to the research being conducted.

3.3.2 Measurement of Data: concentric-concentric isokinetic

Testing

Data was measured using the Cybex Orthotron II Isokinetic Rehabilitation System. Several authors have agreed upon the reliability and validity of this instrument (Davies, 1992: 35; Chan and Mafulli, 1996: 22-3; Callaghan et al., 2000).

There are 3 primary types of exercises commonly used in rehabilitation viz Isometric, Isotonic and Isokinetic (Davies, 1992). Isometric exercises are performed at fixed speed and fixed resistance, Isotonic exercises at variable speed and fixed resistance and Isokinetic exercises at fixed speed with accommodating resistance (Davies, 1992).

There are many purposes of Isokinetic testing, such as (Davies, 1992):

- Objective record
- Athletic screening
- Industrial screening
- Testing to establish a data base
- Quantifying objective information
- Identifying malingerers.

Clinical testing is one of the most important aspects of dynamometry. The isokinetic dynamometer provides a quantitative measurement of muscular force generated by a limb at any given moment or any position. Isokinetic testing provides an effective method of attaining objective measures (Deans, 2001).

3.3.2.1 Variables affecting validity and reliability

There are numerous variables that may affect the reproducibility of results and thus the following parameters were used to ensure validity and reliability (Davies, 1992):

- Calibration - the isokinetic equipment was calibrated regularly.
- Stabilisation - Straps were applied to provide stabilisation for other body parts to isolate on the area being tested.

- Educate subject - the subject was informed and educated about isokinetics, the feeling of isokinetics, purpose of the test, and the requirements of the subject.
- Warm-ups - the subject performed several submaximal and at least one maximal warm up practice repetition prior to the test. The submaximal warm-ups prepared the extremity for the test and allowed the subject to get a feel of what the test would be like and the maximal repetitions create a positive transfer of learning from a submaximal test effort to a maximal test effort.
- Verbal commands – should be consistent from one test to the next. Verbal encouragement during the test has been shown to increase the maximum voluntary force output (Campenella, Mattacola and Kimura, 2000). However this was kept standardized and consistent.
- Subject positioning – Evidence indicates the importance of postural specificity when conducting clinical testing. Due to the elastic characteristics of muscles, any change in the length of the muscle as a result of active or passive joint motion, will result in an associated change in the tensile strength of that muscle. Keeping the hip angle constant is very important during testing of the lower limb in order to prevent this change (Deans, 2001).
- Gravity Correction of the limb being tested – allows for the measurement of the peak torque of the limb being tested only (Davies, 1992).

3.3.2.2 Contraindications to Isokinetic testing (Davies, 1992)

Relative Contraindications

- Pain
- Limited ROM
- Effusion or synovitis
- Chronic third degree sprain
- Subacute sprain (musculotendinous unit)

Absolute Contraindications

- Soft tissue healing constraints
- Severe pain

- Extremely limited ROM
- Severe effusion
- Unstable joint or bone
- Acute strain (musculotendinous unit)
- Acute sprain

3.3.2.3 Method of use

Before the isokinetic testing was performed subjects completed a 5 minute warm-up cycle on a stationary bike, followed by 3 sets of a 20 second stretching of the quadriceps and hamstrings bilaterally. Subjects were placed in a comfortable upright-seated position, backrest at 85°. Thigh, pelvic and torso straps were used in all positions in order to minimise body movements. The knee rested at an angle of 90° from full extension. The lateral femoral condyle was used as the bony landmark for matching the axis of rotation of the knee joint with the axis of rotation of the dynamometer resistance adaptor. Subjects were given verbal encouragement whilst performing the test to ensure maximal effort.

The concentric-concentric testing procedure was used:

- 6 sub-maximal warm-up repetitions at 90°/sec
- 1 minute rest
- 3 repetitions of maximal effort at 60°/sec
- 5 minute warm-down cycle
- Manipulative intervention/s applied
- 3 repetitions of maximal effort at 60° /sec

(Davies, 1992:43-4; Perrin, 1993:48; Chan and Muffilli, 1996:10; Pincivero, Lephart and Karunakara, 1997; Suter et al., 2000; Clifton, 2003).

An average of 3 readings was taken before and after manipulation in order to improve accuracy of measurement (Ringdahl, 1993:132).

3.4 INTERVENTIONS

3.4.1 Manipulative Therapy

The sacroiliac joint and lumbar facet joint were manipulated according to the restriction found on the symptomatic or most symptomatic side.

To detect restrictions in the Sacroiliac joint the standing flexed-knee-raising test was used (Schafer and Faye, 1990: 260). Restrictions were palpated in either the upper or lower joint and in either flexion or extension.

Motion palpation of the Lumbar Spine according to Schafer and Faye (1990) was used to detect restrictions in flexion, extension, lateral flexion and rotation. A lack of springy end feel at the end of ranges of motion indicated that a motion unit was restricted or fixated (Schafer and Faye, 1990: 213)

The manipulation techniques employed were all diversified manipulations according to Szaraz (1990: 139-141) and Schafer and Faye (1990: 393), which are outlined below.

3.4.1.1 The SI Joint manipulation

The SI joint was manipulated according to the restriction that was palpated (i.e. in Upper Extension and Flexion and Lower Extension and Flexion).

Positioning of the subject was dependent on the restriction present:

Flexion fixation – subject in side lying position with lesion side up

Extension fixation – subject in side lying position with lesion side down

With the subject in the side lying position, the subject's lower arm was pulled toward the researcher, and folded over the top of the shoulder and stabilised with the researcher's cephalad hand. The subject's lower leg was only slightly bent at the knee and the upper leg was flexed at the hip and knee. The foot of the upper leg was placed into the popliteal fossa of the lower leg. The pelvis was at 90° to the table.

The researcher stood alongside the subject in a fencer stance. The subject's upper leg was supported between the researcher's upper thighs. The researcher took a pisiform contact with the caudal hand over the involved area (i.e. superior or inferior)

of the SI joint. Researcher then removed slack by applying a cephalad traction force with the indifferent hand and an anterior rotation of the pelvis with the contact hand. Once slack had been fully removed, a body drop was performed whilst a high velocity, low amplitude thrust was applied in an inferior line of drive.

[Adapted from: Szaraz (1990): 137-141; Schafer and Faye (1990): 260-283; Suter et al. (2000)]

3.4.1.2 Lumbar Roll (Pisiform – Mamillary)

This was indicated for rotary type fixations of L1 – L5. With the subject in the lateral recumbent or side lying position as with the SI manipulation, the subject's lower arm was pulled toward the researcher, and folded over the top of the shoulder and stabilised with the researcher's cephalad hand. The subject's lower leg was only slightly bent at the knee and the upper leg was flexed at the hip and knee. The foot of the upper leg was placed into the popliteal space of the lower leg. The pelvis was at 90 degrees to the table.

The researcher stood alongside the subject in a fencer stance. The subject's upper leg was supported between the researcher's upper thighs. The researcher's pelvis was at the level of the lesion. The subject's upper leg was flexed while the researcher monitored the interspinous movement of the segments above and below the lesion. The pelvis and thigh were stabilised at the point of the start of any movement of the involved spinous process by downward transfer of the researcher's weight towards the floor. The researcher's forward leg carried the majority of his/her weight. Researcher then removed slack by applying a cephalad traction force with the indifferent hand while a pisiform contact was made with the caudad hand on the mamillary process of the superior segment. The fingers were spread, facing cephalad and with fifth digit parallel to the spinal column. The cephalad hand was placed on the subject's upper shoulder and used to stabilise the torso and prevent excessive torsion. Once slack had been fully removed, a body drop was performed whilst a high velocity, low amplitude thrust was applied.

[Adapted from: Szaraz (1990): 9.1]

From the most symptomatic side :

- 1) Only the ipsilateral sacroiliac (SI) joint or lumbar facet joint was manipulated.

- 2) Only L2 – L5 were manipulated as the motor neuron pool of the quadriceps and hamstring muscles is derived from the spinal levels between L2 – L4 and L5 – S2 respectively (Hillermann, 2003)
- 3) If the subjects have bilateral low back pain, they were asked to make a subjective judgement as to which side was worse. Only that side was manipulated.
- 4) An audible cavitation was not required to indicate a successful manipulation (Suter et al. 1994)

3.4.2 Detuned Ultrasound

In order to improve the validity of this study, a control group was given one treatment with a detuned ultrasound machine for a period of five minutes. This method of intervention was used so as to eliminate any possible direct mechanical changes to the area being treated.

Using a control group allows the researcher to detect any effects of the experiment itself. The need for control groups in experimentation has been nowhere more evident than in medical research as subjects tend to improve no matter what they are given, and it is unclear how much of the improvement is due to the experimental treatment or due to the attention they are given as a result of the experiment (Babbie, 1999). With the use of a placebo control group however, one can tell if the treatment is effective by measuring if the treatment group improves more than the placebo group.

3.5 STATISTICAL ANALYSIS

Data were captured in MS Excel and exported into SPSS version 11.5 (SPSS Inc, Chicago, Ill, USA) for analysis. A significance level of 0.05 was used.

Pearson's chi square tests were used to compare independent proportions. T-tests were used to compare means of two independent groups. Fisher's exact test was also used.

Longitudinal analysis:

Repeated measures ANOVA was used to simultaneously test six null hypotheses:

1. There is no change over time (regardless of group) (time main effect)
2. There is no difference between the groups (regardless of time) (group main effect)
3. There was no difference between the ipsilateral or contralateral side (side main effect)
4. There was no difference over time between the side (time*side interaction)
5. There is no effect of the intervention (time*group interaction)
6. The intervention effect was not dependant on side (time*group*side interaction)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter deals with the results obtained from the data collected in this study and the discussion of those results.

The primary data

The measurements included:

- Peak torque for quadriceps - measured in Newton meters (NM).
- Peak torque for hamstrings - measured in Newton meters (NM).
- The quadriceps ratio - expressed as a percentage of flexors/extensors
- The hamstring ratio - expressed as a percentage of flexors/extensors
- Total quadriceps work - measured in Joules (J)
- Total hamstring work - measured in Joules (J)
- Total work ratio - expressed as a percentage of flexors/extensors
- Average quadriceps power - measured in Watts (W)
- Average hamstring power - measured in Watts (W)
- Average power ratio - expressed as a percentage of flexors/extensors

The secondary data

This consisted of information drawn for the literature as available from books, journal articles and the internet as appropriate.

4.2 DEMOGRAPHICS

Sixty subjects were enrolled into the study, however one subject was excluded as she experienced pain during testing and as a result her results were inconclusive and could not be utilized. No further subjects were excluded and none withdrew once they were accepted into the study.

4.2.1 Gender

The subjects consisted of 47.5% females (n=28) and 52.5% (n=31) males. Low back pain is found equally amongst males and females (Goubert et al., 2004 and Krause et al., 2004) and the ratio of males to females in this study closely represents that, with only a slightly higher percentage of males to females. However, with reference to the isokinetic testing, the females were generally weaker than the males, and future studies should just include males or females as this could be skewing the results, as this would assist with the interpretation and generalization of the results.

4.2.2 Age and Weight

Table 1: Descriptive statistics for age and weight of sample (n=59)

| | | AGE | WEIGHT |
|----------------|---------|-------|--------|
| N | Valid | 59 | 59 |
| | Missing | 0 | 0 |
| Mean | | 25.90 | 74.95 |
| Std. Deviation | | 6.538 | 16.389 |
| Minimum | | 18 | 48 |
| Maximum | | 45 | 126 |

Their **ages** ranged from 18 to 45, with a mean of 25.9 (SD 6.5) (See Table 1).

Methodologically subjects between the ages of 18 and 45 were selected for this study as Brandt (2002) shows there is little radiographic evidence of osteoarthritis in patients less than 45 years of age, thus allowing this study to not have confounding variables due to degenerative changes within the extremity of spinal joints, although without x-ray confirmation to exclude degenerative changes, one cannot be

absolutely certain. The budget for this study did not allow for x-rays to be taken of subjects. The sample included subjects in this entire range (18-45 years), with the mean age of 25, 9 years of age. This representation was therefore lower than the range of 30 to 50 years of age, the range that low back pain is most commonly found in (Deyo et al., 2001).

Another factor influencing these results may have been the large proportion of students responding to and participating in this study. This large response by students could be attributed to the fact that the study took place in a teaching institution.

It is therefore suggested that future studies should consider restricting the age limit to an older population (30 to 50 years of age) which more accurately represents the age group most affected by low back pain or have a stratification table in order to prevent age group clusters and thereby potentially skewing the data (Mouton, 1996).

In the context of this pre-post evaluation study, the effect of a wide age range would not adversely affect the data as the study looked for trends in change between the reading taken at the outset to the follow up reading for each subject and then compared the trends between patients.

It is however noted that the research would be strengthened should the age variance have been controlled for at the outset of the study. In addition the data would have been more readily transferable to a specific age group had the patients been limited to a smaller age range or been stratified.

Weights ranged from 48 to 126 kg with a mean of 75 kg (SD 16.4) (See Table 1).

The weight distribution of this sample was wide, being between 48 and 126 kg. When one assesses the mean weight of 75 kg (in this study) it does not depict a sample of subjects that are overweight. However, Celan and Turk (2005) in their study on the impact of anthropometric parameters on the incidence of low back pain showed that nutritional status, body build, constitution and muscular development are not associated with the incidence of low back pain.

Nonetheless it is noted that weight strength ratios have been implicated in previous research to affect the results on the isokinetic dynamometer as a result of increased ability to utilize gravitational advantage in those planes in which gravity is able to assist, thereby skewing the results of peak torque (Davies, 1992).

Muscle mass rises proportionately with body weight. Hence heavier subjects produce higher isokinetic moments. However, this relationship is not linear and is one of the reasons for normalizing strength to body weight using Newton meter per kilogram body weight (www.isokinetics.net and De Ste Croix et al., 2003).

Davies (1992:395) advocates that gravity compensation should be performed prior to each test on every subject, however, the researcher was unable to do this and so this may have had an effect on the result.

As this study compared the pre and post isokinetic testing values in each subject, and not comparing subjects to one another, it is unlikely that this would have affected the results greatly. It is however recommended for future research that the subjects be kept to a narrow weight range or alternatively to be stratified according to weight.

4.2.3 Ethnicity

The ethnicity of the majority of the sample was Caucasian (n=47). There were 5 Africans and 5 Indians, and only one Asian and one Coloured participant. The racial distribution in percentage is shown in Figure 1.

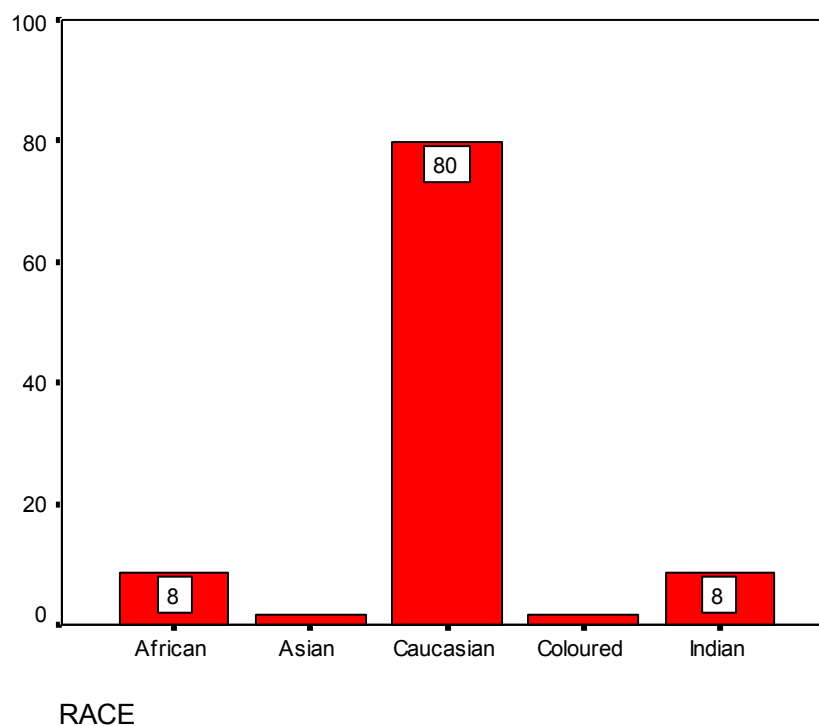


Figure 1: Racial distribution of study participants (n=59)

There is no evidence of ethnicity having an effect on the presentation of low back pain as Docrat (1999) determined the lifetime incidence of low back pain in a small sample of Indian and Colored communities in South Africa to be 78.2% and 76.6%, respectively, whilst van der Meulen (1997) found that the lifetime incidence of LBP amongst a small sample of indigenous Africans in South Africa to be 57.6%. Prevalence of LBP in the developed world vary according to different studies and no data could be found concerning the prevalence of LBP in a South African Caucasian population, however, Walker (2004) found the lifetime incidence of LBP in a sample of 3000 Australian adults to be 79.2%. Incidence among different ethnicities appears to be mostly similar. However, Chibnall et al (2005) found that race is a factor influencing occupational low back injury outcomes, finding that the Caucasian population respond better to treatment than their African American counterparts.

Nonetheless it is noted that ethnicity could have influenced the outcomes of this study due to misunderstanding in the verbal cues that the patient received before and / or during testing. There could have also been misunderstanding due to insufficient explanation on the part of the researcher (being only English speaking), or a combination of the two.

The ethnicity should not have influenced the perception of treatment, but rather the understanding of the subject of the study, which differed according to level of education, not according to ethnicity.

These two assertions stem from research in the languages and translation where even if words are translated accurately, the meaning of a phrase or combination of words may be unclear, as meaning is not only determined by words or phrases, but also in their interpretation by others (Scollen and Scollen, 1995). This is because when words are taken out of context they will lose their meaning (Baynham, 1995). Thus meaning will differ between cultures, even if the same words are used. Consequently, with translation some validity will be lost as the instructions may not be understood and error will be introduced in the results of the questionnaire (Baynham, 1995; Scollen and Scollen, 1995). Thus the interpretation of the patient by the researcher's instructions may have resulted in incorrect or submaximal effort during the testing procedures.

4.2.4 Occupation

There were a variety of different occupations in the sample, with the most common being student (n=20). The occupations are shown in Table 2 in order of frequency.

Table 2: Occupation of study subjects (n=59)

| | Frequency | Percent |
|-------------------------|-----------|---------|
| Student | 20 | 33.9 |
| Self Employed | 3 | 5.1 |
| Banker | 2 | 3.4 |
| Manager | 2 | 3.4 |
| Sales Executive | 2 | 3.4 |
| Somatologist | 2 | 3.4 |
| Teacher | 2 | 3.4 |
| Computer Programmer | 1 | 1.7 |
| School Deputy Principal | 1 | 1.7 |
| Economist | 1 | 1.7 |
| Graphic Designer | 1 | 1.7 |
| Tennis Coach | 1 | 1.7 |
| Production Manager | 1 | 1.7 |
| Nursing Sister | 1 | 1.7 |
| Dietician | 1 | 1.7 |
| Business Owner | 1 | 1.7 |
| House Executive | 1 | 1.7 |
| IT | 1 | 1.7 |
| Domestic Worker | 1 | 1.7 |
| Food Safety Officer | 1 | 1.7 |
| Pilot | 1 | 1.7 |
| Commercial Diver | 1 | 1.7 |
| Occupational Therapist | 1 | 1.7 |
| Estate Agent | 1 | 1.7 |
| Waitress | 1 | 1.7 |
| Storeman | 1 | 1.7 |
| Researcher | 1 | 1.7 |
| Electrical Consultant | 1 | 1.7 |
| Policeman | 1 | 1.7 |
| Dancer | 1 | 1.7 |
| Building Contractor | 1 | 1.7 |
| Site Manager | 1 | 1.7 |
| Security Manager | 1 | 1.7 |
| Total | 59 | 100.0 |

Occupation has been found to have a great effect on low back pain, with those involved in more intensive and prolonged hours of manual labour more likely to suffer from low back pain than those involved in non manual labour (Krause et al.,

2004). Therefore it should be expected that a large proportion of the presenting subjects should be from occupations that involve manual labour.

It must be re-iterated here again, that the reason for the large number of students is due to the study taking place in a teaching institution, yet there was a fair spread of manual and non manual labour occupations in each treatment group.

However, there were considerably more subjects involved in non-manual occupations than in manual occupations (13:46), which could be due to the fact that

- ❖ manual labourers were unable to come in for consultations during working hours, whereas those involved in non-manual labour were far more able.
- ❖ there were also a large proportion of students involved in the study. Although it must be noted that manual labour as found in occupational therapy, somatology, chiropractic and nursing, were excluded as students of these disciplines was classified as students and not manual labourers. Thus the possibility exists that although they partake in manual activities as part of the learning process, this has not been documented as students are generally classified as non-manual persons.

Therefore the demographics as related to occupation seems to approximate the norm, even though it is noted that the type of descriptions utilized in this study does detract from the comparability with other studies in respect of the manual / non-manual occupational norm.

4.2.5 Comparison of demographics between treatment groups

The subjects were randomized into two treatment groups, with 30 (50.8%) in the active manipulation group and 29 (49.2%) in the placebo ultrasound group. There was a non-significant difference in proportions of males in each group, with a slightly higher percentage in the ultrasound group ($p = 0.195$, Table 3). The racial groups were distributed approximately equally between the two treatment groups ($p = 0.405$, Table 4). Table 5 shows that there was no significant difference in mean age ($p = 0.177$) or weight ($p = 0.122$) between the treatment groups. Thus, as expected, demographics were similar between the treatment groups irrespective of the randomization process where the demographics of the groups could not be controlled for. Thus there was no need to control for any demographics in further

analysis and the concerns noted earlier in terms of the potential skewing of the data where eliminated.

Table 3:
Cross-tabulation of gender and treatment group

| | | | GENDER | | Total |
|-----------------|--------------|--------------------------|--------|-------|--------|
| | | | Female | Male | |
| Treatment group | Manipulation | Count | 17 | 13 | 30 |
| | | % within Treatment group | 56.7% | 43.3% | 100.0% |
| | Ultrasound | Count | 11 | 18 | 29 |
| | | % within Treatment group | 37.9% | 62.1% | 100.0% |
| Total | | Count | 28 | 31 | 59 |
| | | % within Treatment group | 47.5% | 52.5% | 100.0% |

Fisher's exact p value =0.195

Table 4:
Cross-tabulation of race and treatment group

| | | | RACE | | | | | Total |
|-----------------|--------------|--------------------------|---------|-------|-----------|----------|--------|--------|
| | | | African | Asian | Caucasian | Coloured | Indian | |
| Treatment group | manipulation | Count | 2 | 1 | 23 | 0 | 4 | 30 |
| | | % within Treatment group | 6.7% | 3.3% | 76.7% | .0% | 13.3% | 100.0% |
| | ultrasound | Count | 3 | 0 | 24 | 1 | 1 | 29 |
| | | % within Treatment group | 10.3% | .0% | 82.8% | 3.4% | 3.4% | 100.0% |
| Total | | Count | 5 | 1 | 47 | 1 | 5 | 59 |
| | | % within Treatment group | 8.5% | 1.7% | 79.7% | 1.7% | 8.5% | 100.0% |

Pearson's chi square 4.005, p = 0.405

1

Table 5:

Comparison of mean age and weight between the treatment groups

| | Treatment group | N | Mean | Std. Deviation | Std. Error Mean | p value |
|--------|-----------------|----|-------|----------------|-----------------|---------|
| AGE | manipulation | 30 | 27.03 | 7.379 | 1.347 | 0.177 |
| | ultrasound | 29 | 24.72 | 5.418 | 1.006 | |
| WEIGHT | manipulation | 30 | 71.70 | 18.598 | 3.395 | 0.122 |
| | ultrasound | 29 | 78.31 | 13.234 | 2.458 | |

Mouton (1996) suggested that in order to ensure that the experimental and control groups are comparable, randomization and matching of subjects in the two groups must be used to enable the researcher to draw causal inferences with a high degree of validity. This was achieved in this study even in the face of the randomization process (random allocation as per subject selection) used in this study; and the fact that there is no significant difference between the treatment and the placebo groups indicate that the research results have a higher degree of validity and generalization is possible (Mouton, 1996).

4.3 LONGITUDINAL DATA ANALYSIS

4.3.1 Effect of the intervention and comparison between ipsilateral and contralateral sides

4.3.1.1 Peak torque

4.3.1.1.1 Flexors

Table 6 shows that there was a significant treatment effect for peak torque of flexors ($p=0.010$). Figure 2 shows parallel profiles of the two sides over time. Figure 3 shows that the manipulation group experienced a mean increase in peak torque over time, while the ultrasound group showed a decrease. There was no significant difference between the ipsilateral and contralateral sides ($p=0.155$), and the treatment effect was not influenced by side ($p = 0.909$).

Table 6: Within and between subject's effects for Peak Torque of flexors

| Effect | Statistic | p value |
|------------------|---------------------|---------|
| Time | Wilk's Lambda 0.991 | 0.485 |
| Group | F=0.235 | 0.630 |
| Side | Wilk's Lambda 0.965 | 0.155 |
| Time*side | Wilk's Lambda 0.997 | 0.685 |
| Time*group | Wilk's Lambda 0.889 | 0.010 |
| Time* group*side | Wilk's Lambda 1.000 | 0.909 |

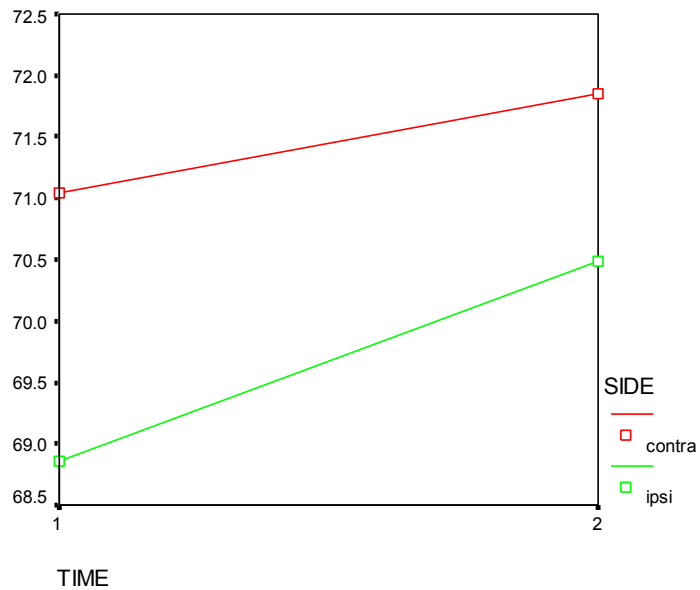


Figure 2: Profile plot of mean peak torque of flexors over time by side

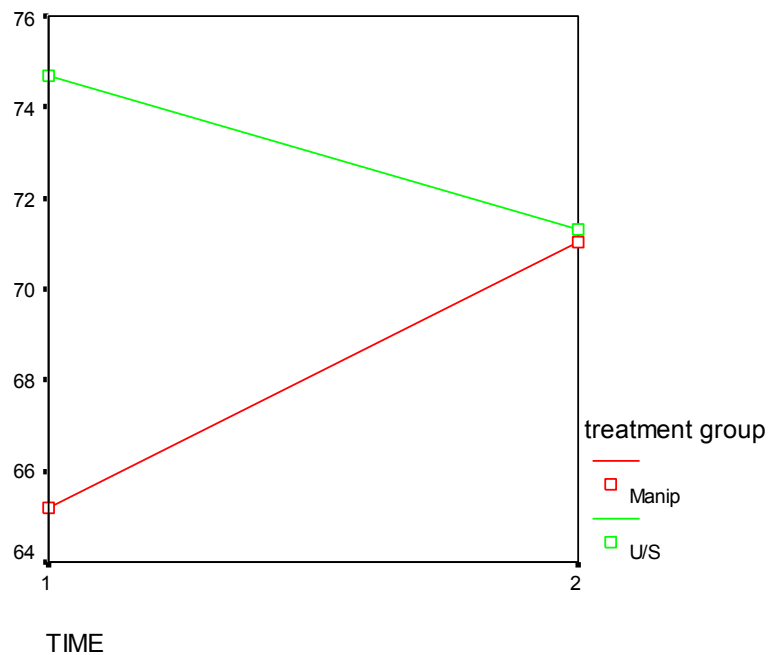


Figure 3: Profile plot of mean peak torque of flexors by treatment group over time

There is no statistically significant difference between the ipsilateral and contralateral limbs, which implies that the suggestion of a central mechanism is supported by the outcomes of this variable, or at least in part, that the reduction of AMI seen ipsilaterally as a result of manipulation is also seen contralaterally (but to a lesser degree). Therefore we could conclude for flexion at least that we have support for a central neural mechanism related to AMI.

These results are congruent with those of Hillerman (2003) who found a significant improvement in the flexor torque ratios following manipulation of the SI joint in subjects suffering from patellofemoral pain syndrome.

The results of this study showed that manipulation of both the SI joint as well as the lumbar facet joints in patients suffering from low back pain has a significant effect on the flexor peak torque ratios in both the ipsilateral and contralateral limbs.

However, the trends seem to be stronger on the ipsilateral side as compared to the contralateral side. A possible explanation for this could be that as a result of position in which the manipulation is administered:

- ❖ Where there is an increased **degree of stretch** being imparted to the hamstrings than the quadriceps during side posture manipulation (on the ipsilateral side to manipulation),
- ❖ A **biomechanical change in the alignment** of the SI joint surfaces (on the ipsilateral side to manipulation)

Thus it would seem that the combined effects of a biomechanical change as well as a **2 fold neurological stimulation** (through the muscle stretch and the articular changes), could result in the flexors improving more on the ipsilateral side as opposed to the contralateral side (as there is a lack on muscle stimulation on the contralateral side).

In addition it could also be argued that the relationship between the flexors and extensors would account for agonist and antagonist relationship where activation and relaxation are reciprocal, where if one is stretched the other will also relax

(Hopkins and Ingersoll, 2000) when the subject is brought back to the neutral position for the joint under study.

Therefore the sudden muscle stretch imparted during manipulation could be playing a greater role than expected and must be accounted for. According to Korr (1965 as cited in Leach, 1994), stretch of the intrafusal fibers by forcefully stretching the muscle against its spindle maintained resistance, would produce a barrage of afferent impulses of sufficient intensity so as to signal the CNS to reduce the gamma motor neuron discharge and, stimulation of the Golgi tendon organs by forced stretch would cause gamma as well as alpha motor neuron inhibition (Leach, 1994). Muscle spindle primary fibers respond to stretch, resulting in afferent activity that synapses on interneurons, such as the Ia inhibitory interneuron. Stimulation of this neuron results in inhibition of the antagonist muscle (Hopkins and Ingersoll, 2000). Therefore reciprocal inhibition that is caused by Ia inhibitory interneuron activity playing a role in producing AMI is in some manner reduced though the neural activity related to the muscle stretch produced in addition to the effects of the manipulation.

Also, in some subjects, there was a lumbar facet syndrome as well as a sacroiliac syndrome with the lesion on the same side. In this case the most symptomatic restriction was chosen as that which was manipulated. However the possibility exists that one side was stretched twice – with the application of a manipulation to the SI and lumbar spine with the patient in exactly the same position. This may have magnified the results on the side manipulated therefore enhancing the increases on the ipsilateral side or decreasing the significance of the effects on the contralateral side.

4.3.1.1.2 Extensors

There was no significant difference between the ipsilateral and contralateral sides for peak torque of extensors ($p = 0.824$), nor side by time interaction ($p = 0.247$), although the profile plot in Figure 4 shows that the contralateral side decreased over time while the ipsilateral side increased over time. Neither was there a significant treatment effect ($p=0.722$). Figure 5 shows that both groups remained relatively constant over time.

Table 7: Within and between subject's effects for Peak Torque of extensors

| Effect | Statistic | p value |
|------------------|---------------------|---------|
| Time | Wilk's Lambda 0.998 | 0.750 |
| Group | F=2.008 | 0.162 |
| Side | Wilk's Lambda 0.999 | 0.824 |
| Time*side | Wilk's Lambda 0.977 | 0.247 |
| Time*group | Wilk's Lambda 0.998 | 0.722 |
| Time* group*side | Wilk's Lambda 1.000 | 0.874 |

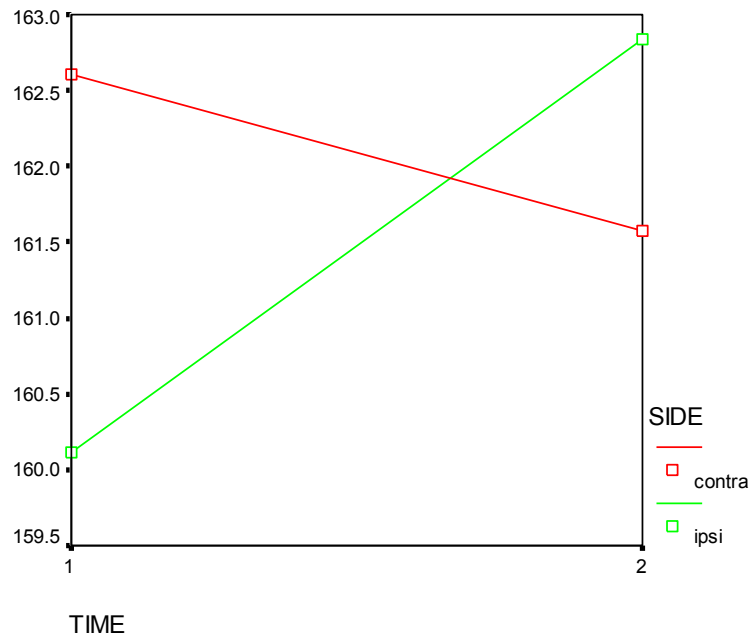


Figure 4: Profile plot of mean peak torque of extensors over time by side

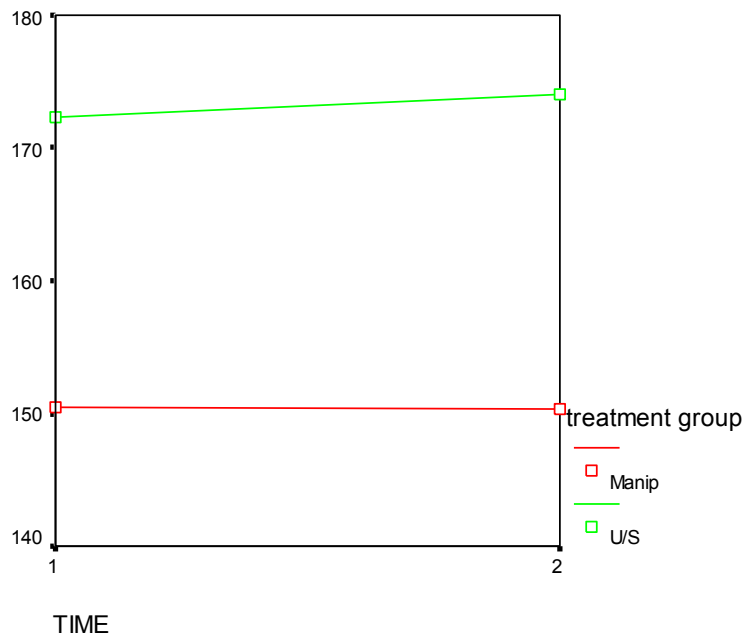


Figure 5: Profile plot of mean peak torque of extensors by treatment group over time

These figures indicate that there was no change in the treatment groups, other than a slight trend of increase in the Ultrasound group, which could possibly be as a result of stimulation due to mechanical stimuli associated with the action of applying the ultrasound head in the placebo group. Even though the ultrasound was detuned, there could have possibly been a treatment effect due to the mechanical stimuli. According to Melzack and Wall (1965), mechanical stimuli can cause increased mechanoreceptor input, leading to a precedence of impulses along the large myelinated A β in comparison to those of the smaller diameter nociceptive A α and C fibers, which results in inhibition of the nociceptive activity. Since the increased presence of AMI has been associated with an increase in pain perception (Suter et al., 1998), the decrease in pain suggested by Melzack and Wall (1965), could have had an effect on the results.

This is supported by the studies conducted by Hillerman (2003) and Suter et al (2000) who found that manipulation of the SI joint had an effect on the extensors (quadriceps) of the knee, as a result of knee pain reduction. This is further supported by Davies (1992) who states that Mangine (personal communication, unpublished data) in his study on the evaluation of the quadriceps and hamstrings to joint effusion found that the hamstrings proportionally demonstrated a greater functional decrease in function as a result of joint effusion than the quadriceps.

These suggestions could however be overshadowed by gravity which may have assisted the flexors and inhibited the extensors, and thus could have skewed the results, with better results for flexion than extension. This suggestion is however negated when one compares the ipsilateral and contralateral sides, where the one increases and the other decreases respectively. Should gravity have played a part the / trend should have been in the same direction for both sides. Nevertheless future studies should perhaps try doing testing in the side posture (side lying) position where the effect of gravity would be negated.

In summary for the peak torque of the flexors and extensors

There seems to be a suggestion that the neurological effects achieved in respect of reducing AMI are 2 fold:

- ❖ Through the muscle stretch (hamstring / knee flexor only) on the side manipulated and
- ❖ Through the restoration of motion within the joint manipulated.

This study was structured to include manipulation of facet joints of levels L2-L5 as well as the SI joint, depending on where the joint dysfunction occurred. Thus with the hamstrings receiving its innervation from L5-S2 and the quadriceps receiving their innervation from L2-L4, there could have been a manipulation specific effect on one or both of the muscles dependent on the level(s) affected by the manipulation employed. This could therefore have biased the study inadvertently to favour either the knee flexors or extensors.

It is suggested that further studies specify as to how many subjects with sacroiliac or lumbar fixations were in one treatment group compared with the other and what levels were manipulated in order to determine whether this factor introduces a treatment bias.

Furthermore even though the graphs show little or no improvement, it is noted that the Fig 4 indicates that the ipsilateral side nevertheless benefited from the intervention as compared to the contralateral side. These effects could be related to those mentioned above under flexors (4.3.1.1.1).

4.3.1.1.3 Peak torque ratio

There was a significant treatment effect for peak torque ratio ($p = 0.006$).

There was no difference between the sides ($p = 0.343$) and there was no time * side interaction ($p = 0.511$). Side did not influence the treatment effect ($p = 0.893$). Figure 6 shows that the contra-lateral side showed an increase over time, while the ipsilateral side decreased slightly, however this interaction was not statistically significant. Figure 7 shows that the two treatment groups reacted differently over time. The manipulation group increased in mean peak torque over time while the placebo group decreased.

Table 8: Within and between subject's effects for Peak Torque ratio

| Effect | Statistic | p value |
|------------------|---------------------|---------|
| Time | Wilk's Lambda 0.998 | 0.727 |
| Group | F=1.398 | 0.242 |
| Side | Wilk's Lambda 0.984 | 0.343 |
| Time*side | Wilk's Lambda 0.992 | 0.511 |
| Time*group | Wilk's Lambda 0.876 | 0.006 |
| Time* group*side | Wilk's Lambda 1.000 | 0.893 |

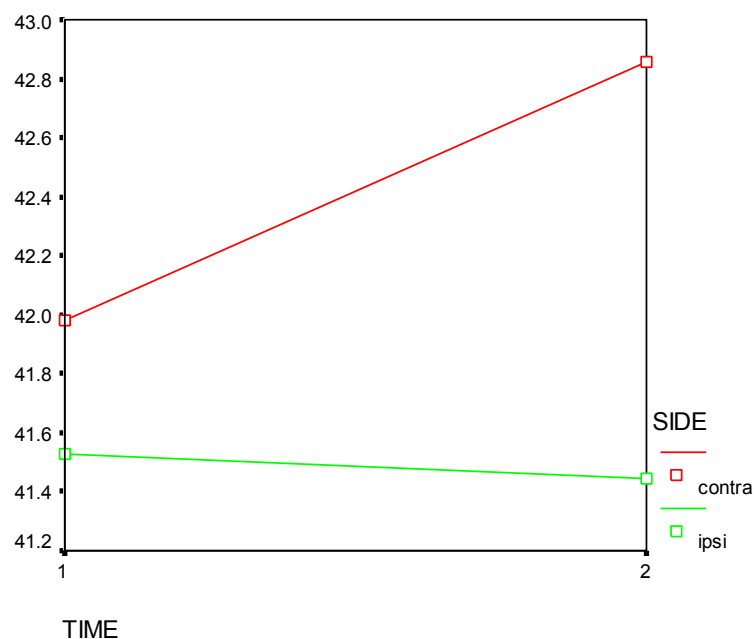


Figure 6: Profile plot of mean peak torque ratio over time by side

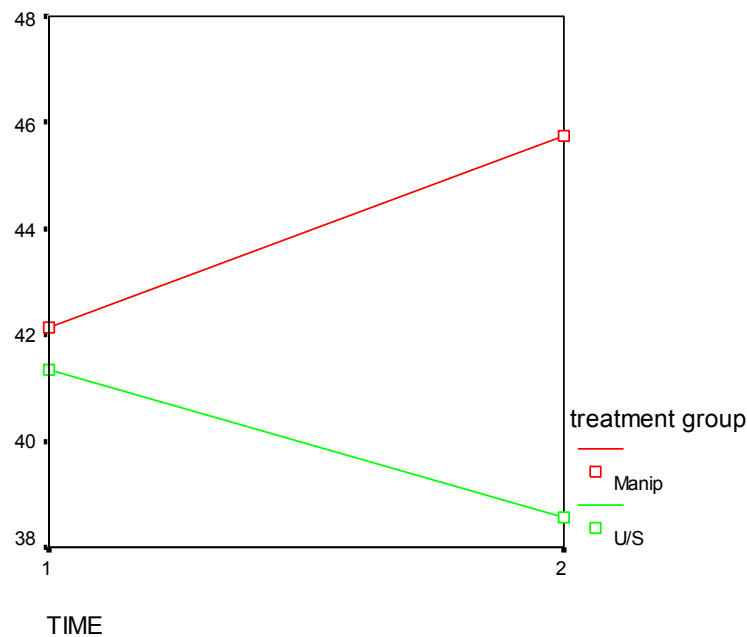


Figure 7: Profile plot of mean peak torque ratio over time by group

Calculation of unilateral ratios of muscles (agonist /antagonist) permits better symmetry of performance and without a significant muscle imbalance, there is less likelihood of muscle strains (Davies, 1992). Thus an improvement in muscle torque ratio of flexor/extensor indicates a decrease in muscle imbalance.

In this study there was no statistical difference between the contralateral and ipsilateral limbs, although the contralateral does appear to have more of an increase over time. This could be due to the ipsilateral limb showing a marginally (although not significant) greater increase in the flexor peak torque values, but not in the extensors, which compares with the contralateral limb where the extensor peak torque decreased and the flexors peak torque increased resulting in an increase in the resultantly calculated ratio.

When assessing the manipulated versus the placebo groups one notices that when individually assessed the manipulation group showed an increase in flexor peak torque with no change in the extensor peak torque therefore resulting in an increased ratio; as compared to the placebo group where there was a decrease in the flexor peak torque and a mild increase in the extensor peak torque resulting in a decrease in the peak torque ratio. This correlates well with the peak torque ratios depicted in figure 7. It further supports the theories suggested prior to this point where the effects are greatest on the flexor group, possibly due to the 2 fold stimulation on the ipsilateral or manipulated side.

4.3.1.2 Work

4.3.1.2.1 Flexors

For work of flexors, there was a significant treatment effect ($p = 0.007$). Figure 8 showed that the ipsilateral side showed a slight increase over time while the contralateral side remained constant, but this slight interaction was not statistically significant. The manipulation group showed an increase over time while the ultrasound group showed a decrease over time (Figure 9). This treatment effect was not influenced by side ($p = 0.927$), and the ipsilateral and contralateral sides were not significantly different from each other overall ($p = 0.214$) or over time ($p = 0.501$).

Table 9: Within and between subject's effects for Work of flexors

| Effect | Statistic | p value |
|------------------|---------------------|---------|
| Time | Wilk's Lambda 0.998 | 0.714 |
| Group | F=0.221 | 0.640 |
| Side | Wilk's Lambda 0.973 | 0.214 |
| Time*side | Wilk's Lambda 0.992 | 0.501 |
| Time*group | Wilk's Lambda 0.880 | 0.007 |
| Time* group*side | Wilk's Lambda 1.000 | 0.927 |

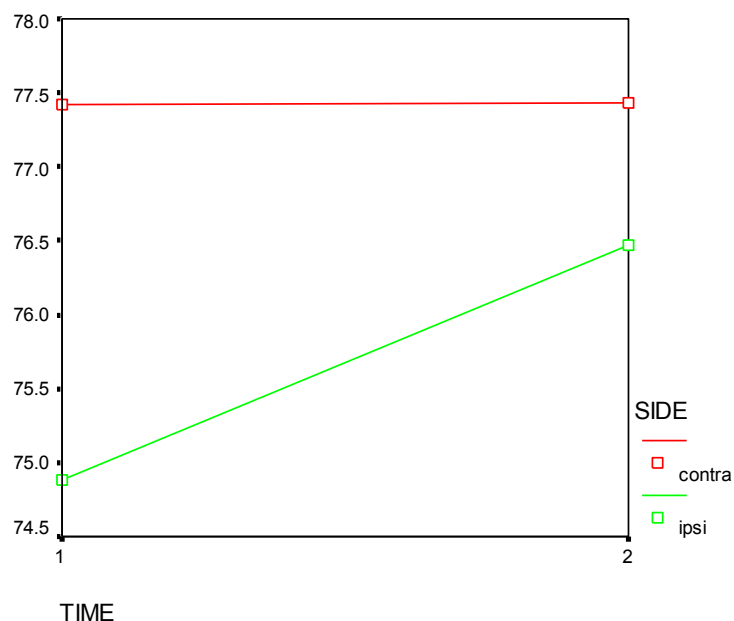


Figure 8: Profile plot of mean work of flexors over time by side

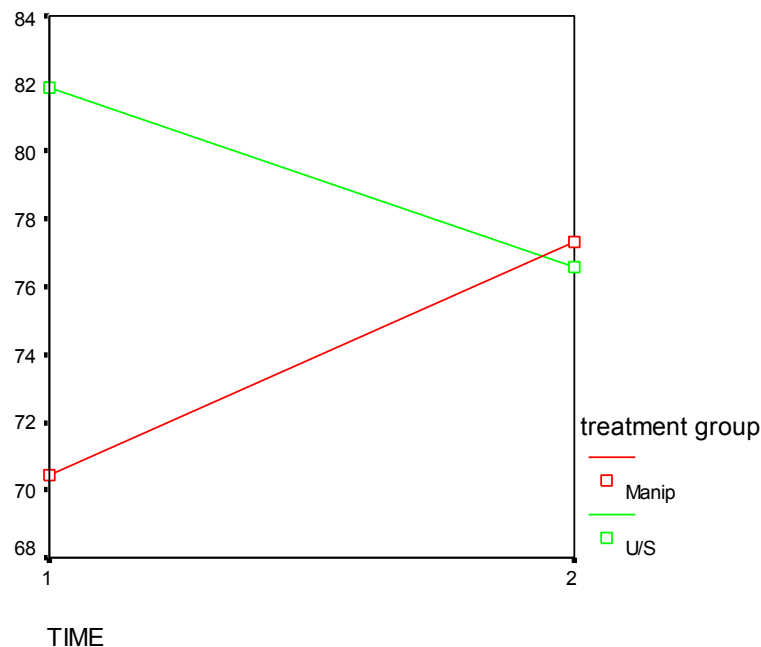


Figure 9: Profile plot of work of flexors over time by group

Work is the total area under the torque curve with each repetition, regardless of speed, ROM or time. It is a function of force and distance and because the distance is constant during isokinetic testing, work is directly related to force. Work, to a great extent, depends on the nutritive supply of the muscle, mostly on the glycogen stores. Work output, oxygen consumption and cardiac output during exercise are all directly related to each other, because the muscle work output increases oxygen consumption, which in turn dilates the muscle blood vessels, thus increasing venous return and cardiac output. This is all co-ordinated by the sympathetic nervous system. The normal untrained athlete can increase cardiac output a little over fourfold, and the well trained athlete can increase output about sixfold (Guyton and Hall, 1997:696). Thus, there are many confounding factors affecting the work output readings, which will vary according to each individual.

Nonetheless work showed a significant treatment effect for flexors which further supports the proposed two fold theory whereby the effect on the flexors is through 2 mechanisms:

- ❖ The stretch of the flexor as well as the
- ❖ Biomechanical effect on the restarted joint on that side,

allowing the muscle to achieve optimum length as well as function as more motor end plates are stimulated in order to activate a greater area of the muscle, thus potentially increasing the work capacity of the muscle.

This is supported by the fact that the ipsilateral limb showed more of an increase than the contralateral side, although this was not significant.

The results can however not be seen in isolation as we know there are more than these 2 factors that affect work. This is principally because work cannot be derived from the peak torque readings alone and the mechanism for work is also related to factors beyond the neurological effect namely the physiological effects (as described above). The neurological stimulus may stimulate these physiological effects, but these may only change after the physiological processes have been completed and a change manifests in the results. Therefore without follow up readings at intervals after 48 hours, it is difficult to isolate the effects of the neurological stimuli.

4.3.1.2.2 Extensors

There was no significant treatment effect for work of extensors ($p = 0.257$). Figure 10 showed that the ipsilateral side increased over time while the contralateral side decreased slightly. There was no significant difference between the two sides overall ($p = 0.894$). Figure 11 showed that both groups remained relatively constant over time. There was a non-significant trend towards an interaction between side and time ($p = 0.172$).

Table 10: Within and between subject's effects for Work of extensors

| Effect | Statistic | p value |
|------------------|---------------------|---------|
| Time | Wilk's Lambda 0.992 | 0.497 |
| Group | F=1.711 | 0.196 |
| Side | Wilk's Lambda 1.000 | 0.894 |
| Time*side | Wilk's Lambda 0.968 | 0.172 |
| Time*group | Wilk's Lambda 0.978 | 0.257 |
| Time* group*side | Wilk's Lambda 0.993 | 0.518 |

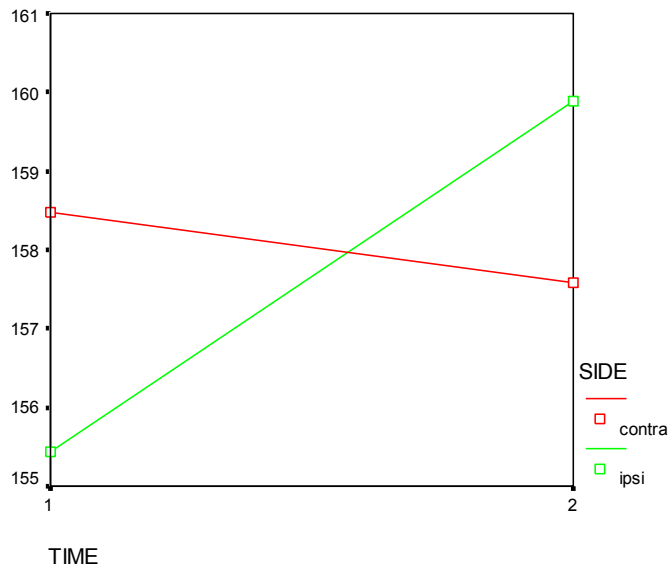


Figure 10: Profile plot of mean work of extensors over time by side

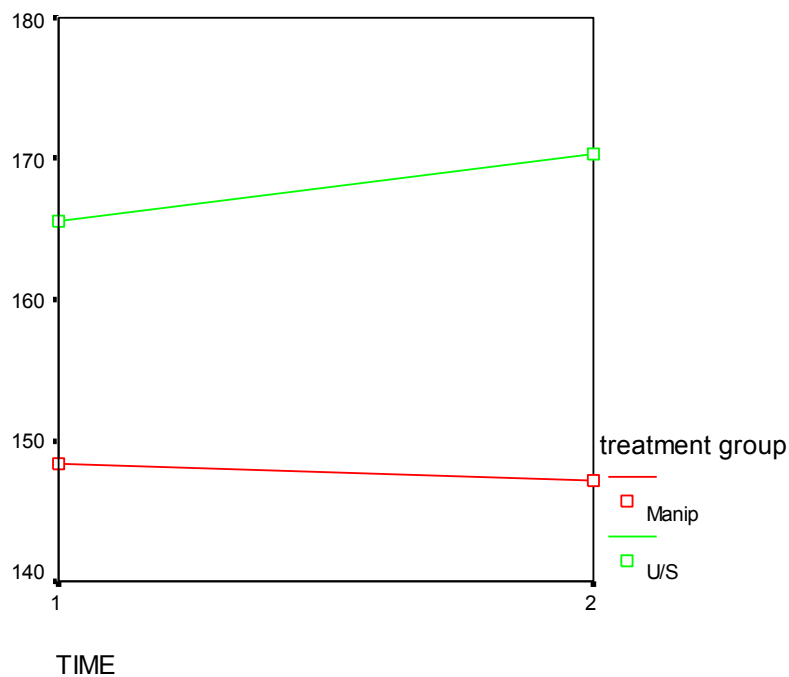


Figure 11: Profile plot of work of extensors over time by group

The above trends for work of extensors seem to mirror the results in the work especially when one assess the ipsilateral versus the contralateral sides.

However with the analysis by group over time (manipulation versus placebo), manipulation decreases the work done by the extensors of the knee, whereas in the ultrasound group, work increases over time (although only in trend) as these figures indicate no statistically significant change. This supports the theory that the muscle stretch has a great effect on work, as it only applies to the flexor groups as opposed to the extensor group of knee muscles. These results would thus imply that this

proposed mechanism of action plays a large role in the reduction of AMI especially when one combines this with the figure 10, where we see that the ipsilateral side improves possibly as a result of reciprocal relaxation of the agonist – antagonist relationship after the sudden stretch of the hamstrings during the manipulation.

However the above are only conjectures and hypotheses as there was no significant difference between sides and because it is noted that there is a baseline difference between the starting points of the two sides. In addition these data could also be affected by those physiological factors that were addressed in the discussion with the flexors.

4.3.1.2.3 Ratio

Figure 12 suggests that the two sides behaved differently over time, with the ipsilateral side decreasing over time and the contralateral side increasing over time. The treatment effect was not influenced by side ($p = 0.674$). There was a significant treatment effect ($p = 0.002$) for work ratio (Figure 13), but no difference between the sides ($p=0.397$), nor time*side interaction ($p = 0.336$).

Table 11: Within and between subject’s effects for Work ratio

| Effect | Statistic | p value |
|------------------|---------------------|---------|
| Time | Wilk’s Lambda 1.000 | 0.981 |
| Group | F= 0.602 | 0.441 |
| Side | Wilk’s Lambda 0.987 | 0.397 |
| Time*side | Wilk’s Lambda 0.984 | 0.336 |
| Time*group | Wilk’s Lambda 0.838 | 0.002 |
| Time* group*side | Wilk’s Lambda 0.997 | 0.674 |

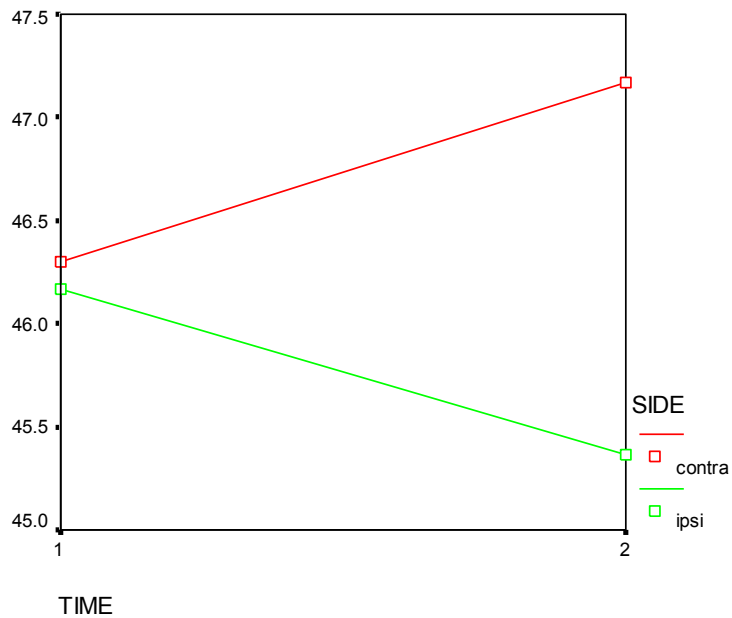


Figure 12: Profile plot of mean work ratio over time by side

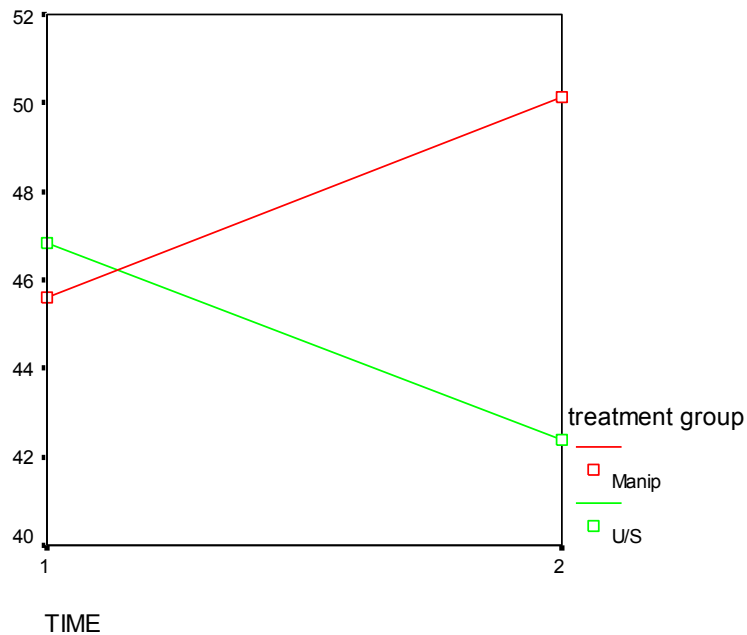


Figure 13: Profile plot of mean work ratio over time by group

Calculation of unilateral ratios of muscles (agonist /antagonist) permits better symmetry of performance and without a significant muscle imbalance, there is less likelihood of muscle strains (Davies, 1992). Thus an improvement in work ratio of flexor/extensor indicates a decrease in muscle imbalance.

When assessing the ratios it is noted that the baseline points of reference are more comparable than those for work of extensors and work of flexors implying that the

comparability between groups is best here. Again the results are accurate when compared to the results of each of the units individually.

The contralateral side does appear to have more of an increase over time, which implies that there could be a lag in the ipsilateral side attaining physiological normalcy prior to attaining the same results as the contralateral side, where muscle length and pliability were not affected by the presence of restricted joint movement within the SI joint (as found on the ipsilateral side). This hypothesis can only be tested with further readings and ratio calculations beyond the pre-post measurements taken in this study therefore it is suggested that future studies take this into account.

4.3.1.3 Power

4.3.1.3.1 Flexors

Figure 14 shows a trend towards an interaction between time and side, with the power output of the contralateral side increasing over time and the ipsilateral side decreasing over time. However, this interaction trend was not statistically significant ($p = 0.122$, Table 11). There was a borderline significant treatment effect ($p = 0.072$). Figure 15 shows that the manipulation group increased over time while the ultrasound group decreased.

Table 12: Within and between subject's effects for Power of flexors

| Effect | Statistic | p value |
|------------------|---------------------|---------|
| Time | Wilk's Lambda 0.995 | 0.578 |
| Group | F=0.214 | 0.645 |
| Side | Wilk's Lambda 1.000 | 0.964 |
| Time*side | Wilk's Lambda 0.959 | 0.122 |
| Time*group | Wilk's Lambda 0.944 | 0.072 |
| Time* group*side | Wilk's Lambda 0.996 | 0.643 |

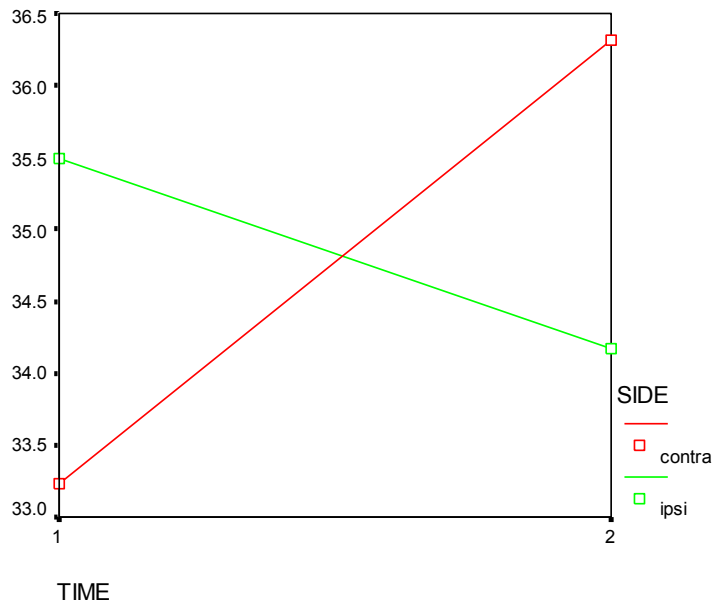


Figure 14: Profile plot of mean power of flexors over time by side

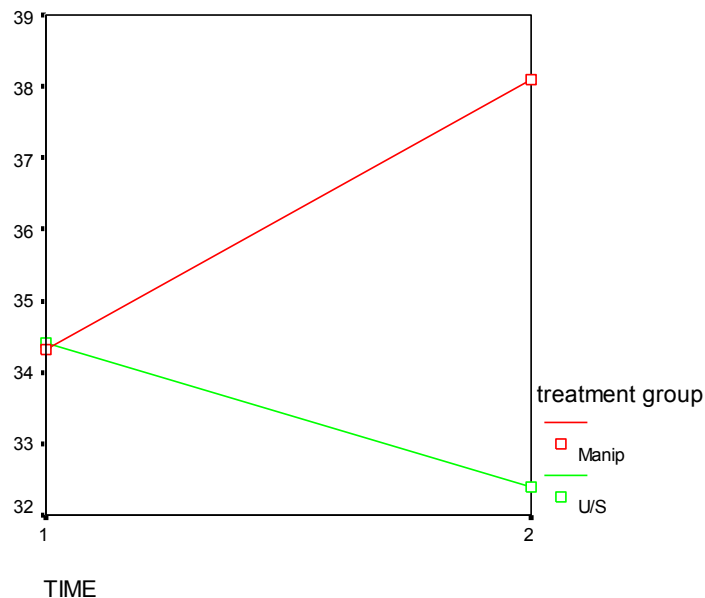


Figure 15: Profile plot of mean power of flexors over time by group

Power is the total work divided by the time it takes to perform the work and is measured in Watts. Average power determines the speed of the greatest metabolic expenditure (Davies, 1992). Power is determined not only by the strength of contraction but also by the distance of contraction and the number of times that it contracts each minute (Guyton and Hall, 1997:688).

As the distance of contraction and number of times of contraction each minute were constant for each subject, these variables should not affect the power readings.

The trends show that there is an increase in power in the contralateral limb and a decrease in the ipsilateral limb. This could be related to the fact that in order to obtain optimal power one first needs to have normalized peak torque ratios. In the contralateral limb, the ratios were already intact before the manipulation as opposed to the ipsilateral limb where joint restriction would have biomechanically impeded the normalization of the peak torque until after the manipulation procedure and then also not necessarily within the time period before re-evaluation. Therefore the ipsilateral limb was at a biomechanical disadvantage in addition to the neurological disadvantage present in both limbs as hypothesized before.

When we remove the neurological disadvantage, we may not have given enough time for the ipsilateral biomechanical disadvantage to normalize whereas the contralateral limb which already had optimum ratio, also had an additional neurological input, thereby stimulating that side and giving more power.

4.3.1.3.2 Extensors

There was no significant treatment effect for extensors for power ($p = 0.334$). Figure 16 shows that the ipsilateral side decreased over time, while the contra-lateral side increased over time. Thus, although it was not statistically significant, there was a trend towards a greater improvement in the contra-lateral side. Figure 17 shows that the profiles of both groups were approximately parallel over time, thus the intervention had no effect in this instance. There was no significant time*side interaction ($p = 0.301$).

Table 13: Within and between subject's effects for Power of extensors

| Effect | Statistic | p value |
|------------------|---------------------|---------|
| Time | Wilk's Lambda 1.000 | 0.985 |
| Group | F=2.151 | 0.148 |
| Side | Wilk's Lambda 0.995 | 0.603 |
| Time*side | Wilk's Lambda 0.981 | 0.301 |
| Time*group | Wilk's Lambda 0.984 | 0.334 |
| Time* group*side | Wilk's Lambda 0.986 | 0.336 |

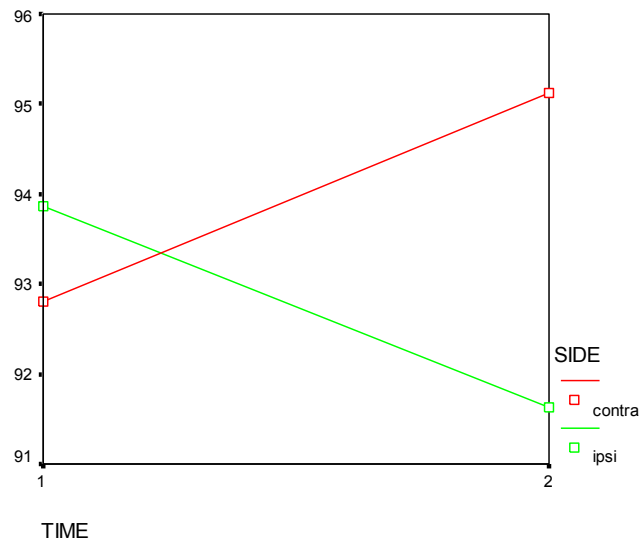


Figure 16: Profile plot of mean power of extensors over time by side

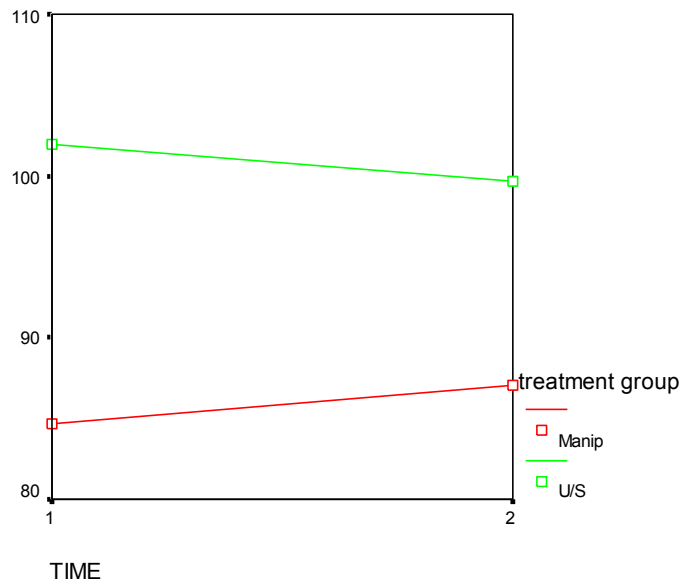


Figure 17: Profile plot of mean power of extensors over time by group

The trends here again show that there is an increase in power in the contralateral limb and a decrease in the ipsilateral limb, although it was not statistically significant. This could be related to the fact that in order to obtain optimal power one first needs to have normalized peak torque ratios. In the contralateral limb, the ratios were already intact before the manipulation as opposed to the ipsilateral limb. Therefore the same analogies as applicable to the flexors seem to be apparent with the extensors.

4.3.1.3.3 Ratio

There was no significant difference between the two sides over time ($p = 0.300$), however, Figure 18 shows that the ipsilateral side showed a steeper increase over time than the contra-lateral side. There was also no treatment effect for this outcome ($p = 0.971$). Figure 19 shows parallel profiles of the two groups.

Table 14: Within and between subjects effects for Power ratio

| Effect | Statistic | p value |
|------------------|---------------------|---------|
| Time | Wilk's Lambda 0.965 | 0.155 |
| Group | F=0.846 | 0.362 |
| Side | Wilk's Lambda 0.974 | 0.222 |
| Time*side | Wilk's Lambda 0.981 | 0.300 |
| Time*group | Wilk's Lambda 1.000 | 0.971 |
| Time* group*side | Wilk's Lambda 0.996 | 0.649 |

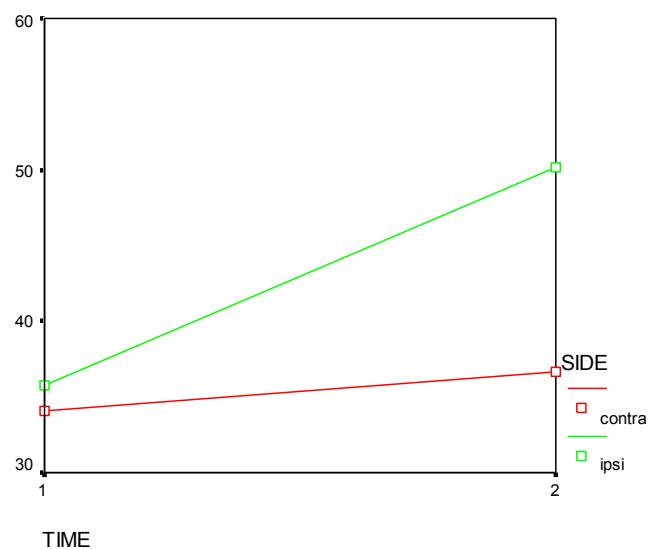


Figure 18: Profile plot of mean power ratio over time by side

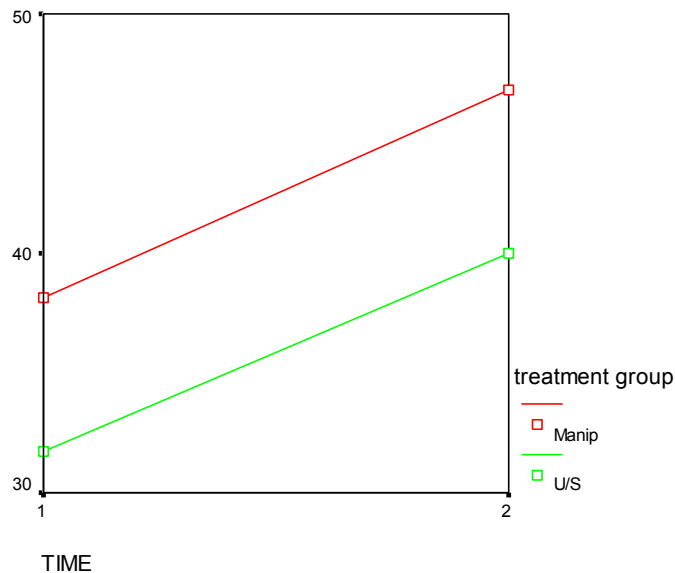


Figure 19: Profile plot of mean power ratio over time by group

In ratio terms the ipsilateral limb improved to a greater extent than the contralateral limb and the ultrasound and manipulation groups improved to the same degree.

The trend of increase in the U/S group could possibly be as a result of irritation due to mechanical stimuli as a result of the action of the ultrasound head. Even though the ultrasound was detuned, there could have possibly been a treatment effect due to the mechanical stimuli. According to Melzack and Wall (1965), the mechanical stimuli causes increased mechanoreceptor input, leading to a precedence of impulses along the large myelinated A β to those of the smaller diameter nociceptive A α and C fibers, which results in inhibition of the nociceptive activity.

The contralateral ratio may have shown less of an improvement (however not statistically significant) in power ratio as a result of a greater improvement in the flexors than the extensors, thereby allowing the ratio to negate the improvements seen individually in the flexors and extensors respectively. However on the converse the ratio may reflect a more comparable norm as the baseline starting points for the groups compared in terms of ipsilateral and contralateral are more aligned.

Therefore it would seem again that the 2 fold biomechanical and stretch reflexes initiating the neurological changes are indeed greater on the side of the joint restriction and therefore affect that side (ipsilateral) to a greater degree.

4.4 SUMMARY

- ∞ Peak torque of flexors and extensors
Peak torque showed **significant treatment effects for flexors**. There was no treatment effect, nor trend towards a treatment effect in any measurement for extensors.

- ∞ Peak torque ratio over time
Peak torque showed **significant treatment** effects for ratio.

- ∞ Work over time of flexors and extensors
Work showed **significant treatment effects for flexors**. There was no treatment effect, nor trend towards a treatment effect in any measurement for extensors.

- ∞ Work ratio over time
Work showed **significant treatment effects** for ratio.

- ∞ Power of flexors and extensors
Power showed a **non-significant trend towards a treatment effect for flexors** but no trend in any other muscle type.

- ∞ Ratio of power over time
Ratio showed a faster increase in **the ipsilateral side**.

In no instance did side influence the treatment effect to a significant degree, other than power.

There were no statistically significant **time*side interactions** for any outcome, however, non-significant trends were demonstrated for all outcomes except peak torque flexors. For peak torque and work, the ipsilateral side showed more of an increase than the contralateral side for flexors and extensors, but for ratio the contralateral side seemed to increase at a faster rate. For power, the reverse was shown: flexors and extensors showed a greater increase in the contralateral side but ratio showed a faster increase in the ipsilateral side.

It would therefore seem that

- ❖ Peak torque and work which are more intimately related to:
 - Normal muscle function (motor unit recruitment and biomechanical restriction (as in joint dysfunction)) and
 - Neurological control (by local reflex circuits and resultant inhibition)

Which implies that the side being treated (ipsilateral) would respond to a greater degree sooner than the side that has no marked changes (contralateral). As opposed to power which requires both neurological and physiological normalcy in the muscle being tested. This would not have been achieved in this pre- post intervention study as the measurement taken directly after the intervention would not have been able to measure any changes due to physiological effects that may only have become apparent after time (Pickar, 2002).

Peak torque and work showed significant **treatment effects** for flexors and ratio.

There was no treatment effect, nor trend towards a treatment effect in any measurement for extensors. Power showed a non-significant trend towards a treatment effect for flexors but no trend in extensors. In no instance was the treatment effect influenced by side.

Therefore the treatment has a significant benefit for peak torque and work in flexors and the ratio, but not for extensors. There was a trend towards the ipsilateral side showing more benefit than the contralateral side in peak torque and work flexors and extensors, and the contralateral side showing increased benefit in power flexors and extensors. Ratio measurements increased to a greater extent in the contralateral side for peak torque and work, and in the ipsilateral side for power.

The effects as for **time*side interactions** would be applicable to the treatment effects however they would be modified by the following:

- ❖ The fact that the stimulus would be greater for the stretched flexors than the extensors of the knee, which would have been consistent throughout the peak torque, work and power as only one group would have received the intervention as opposed to the other (placebo ultrasound), even in the face of the hypothesized effects of the placebo.

These results indicate to practitioners in clinical practice that spinal manipulation is effective in the rehabilitation protocol for reducing AMI in the hamstrings and that it has an effect on the contralateral AMI as well as the ipsilateral AMI.

These recommendation must however be tempered with the understanding that this study was underpowered to detect significant differences if they existed between the sides. In almost all measurements there was a trend towards a time*side interaction visible from the profile plot, but this was never statistically significant. The scale of this interaction was always smaller than treatment effect, and thus never achieved statistical significance even if the treatment effect did. A larger study specifically powered to detect side interactions would be recommended to make definite conclusions about which side is affected to a greater extent.

4.5 HYPOTHESIS TESTING

4.5.1 Null Hypothesis

This is ordinarily the hypothesis that one rejects. In hypothesis testing, the null hypothesis is usually the result that one does not want and it is indicated by H_0

4.5.2 Alternative Hypothesis

This is usually the result that one wishes to accept, i.e. the required result and is indicated by H_a

The **first objective** was to evaluate the immediate effect of manipulation on contralateral quadriceps and hamstring torque ratios utilizing the Cybex Orthotron II Isokinetic Rehabilitation System.

The hypothesis was that manipulation has a significant immediate effect on contralateral quadriceps and hamstring torque ratios.

This is rejected for peak torque and work and accepted for power in respect of both the flexors and the extensors.

The **second objective** was to evaluate the immediate effect of manipulation on ipsilateral quadriceps and hamstring torque ratios utilizing the Cybex Orthotron II Isokinetic Rehabilitation System.

The hypothesis was that manipulation would have a significant immediate effect on ipsilateral quadriceps and hamstring torque ratios, as suggested in the literature.

This is accepted for peak torque and work and rejected for power in respect of both the flexors and the extensors.

The **third objective** was to evaluate the immediate effect of manipulation on ipsilateral quadriceps and hamstring torque ratios versus immediate effect of manipulation on contralateral quadriceps and hamstring torque ratios utilizing the Cybex Orthotron II Isokinetic Rehabilitation System.

The hypothesis was that spinal manipulation would have a significant immediate effect on contralateral quadriceps and hamstring ratios, possibly as significant an effect as that on ipsilateral quadriceps and hamstring torque ratios.

This is rejected for peak torque and work and accepted for power.

The **fourth objective** was to evaluate the presence or absence of spinal dysfunction between the levels of L2-L5 and the sacroiliac joint and the significance of spinal dysfunction on muscle inhibition in the quadriceps and hamstring muscles.

The hypothesis is that spinal dysfunction is related to changes in muscle inhibition in the quadriceps and hamstring muscles.

This is rejected for peak torque and work and accepted for power.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The purpose of this study was to investigate the immediate effect of sacroiliac and lumbar manipulation on quadriceps femoris and hamstring torque ratios in the contralateral limb in patients suffering from mechanical low back pain.

The first objective was to evaluate the immediate effect of manipulation on contralateral quadriceps and hamstring torque ratios utilising the Cybex Orthotron II Isokinetic Rehabilitation System. The second objective was to evaluate the immediate effect of manipulation on ipsilateral quadriceps and hamstring torque ratios utilising the Cybex Orthotron II Isokinetic Rehabilitation System. The third objective was to evaluate the immediate effect of manipulation on ipsilateral quadriceps and hamstring torque ratios versus immediate effect of manipulation on contralateral quadriceps and hamstring torque ratios utilising the Cybex Orthotron II Isokinetic Rehabilitation System. The fourth objective was to evaluate the presence or absence of spinal dysfunction between the levels of L2-L5 and the sacroiliac joint and the significance of spinal dysfunction on muscle inhibition in the quadriceps and hamstring muscles.

While the original purpose of this study did not involve investigation of work and power of the quadriceps and hamstring and the effect of manipulation on these values, testing made gathering of the data possible and it was thus included.

Significant improvements of the contralateral and ipsilateral hamstring torque ratios were noted, however the study failed to show a statistically significant improvement in both the contralateral and ipsilateral quadriceps torque ratios. There was no significant difference between contralateral and ipsilateral peak torque ratios.

Therefore manipulation can be recommended as a component of the rehabilitation protocol of the hamstrings in those suffering with mechanical low back pain. As this study involved largely a younger sample this can be applied to the younger

population, but further research will indicate whether it can be applied to both younger as well as older populations.

5.2 RECOMMENDATIONS

To improve the statistical significance, the following recommendations can be made

- A larger sample size would increase the validity of the study and minimize the possibility of incorrectly accepting the null hypothesis.
- Stricter inclusion and exclusion criteria should be applied in order to get a more uniform sample group.
- Future studies should consider restricting the age limit to an older population (30 to 50 years of age), which more accurately represents the age group most affected by low back pain.
- A sample group of just males or just females in order to get a more uniform sample group, especially with the use of isokinetic testing as both weight and strength vary significantly between male and female.
- Only those with Sacroiliac syndrome or with Lumbar facet syndrome should be studied in any one study.
- Those with bilateral dysfunction should be excluded.
- A pain questionnaire should be used in order to evaluate the effect that the reduction in pain post manipulation may have on the reduction in inhibition.
- This study only investigated the immediate effect of manipulation. Future studies should incorporate an investigation of the short and long term effects.
- It was noted during the study that after 5 minutes of cycling for a warm-up subjects were more comfortable during manipulation and far easier to manipulate. Possible study could be done to investigate if there is a difference between patients who are adjusted after mild exercise versus those who have had no exercise pre-manipulation.

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APPENDIX A

DURBAN INSTITUTE OF TECHNOLOGY
CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient:: _____ Date _____
File # : _____
Sex : _____ Occupation: _____
Intern : _____ Signature: _____

FOR CLINICIANS USE ONLY:

Initial visit

Clinician: _____

Signature : _____

Case History:

Examination:

Previous:

Current:

X-Ray Studies:

Previous:

Current:

Clinical Path. lab:

Previous:

Current:

CASE STATUS:

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

CONDITIONAL:

Reason for Conditional:

| | |
|------------|-------|
| | |
| | |
| Signature: | Date: |

Conditions met in Visit No:

Signed into PTT:

Date:

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

Intern's Case History:

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

3. Present Illness:

| | | |
|--|--------------------|--------------------|
| | Complaint 1 | Complaint 2 |
|--|--------------------|--------------------|

| | | |
|--|--|--|
| <ul style="list-style-type: none"> ▶ Location ▶ Onset : Initial: Recent: 1. Cause: ▶ Duration ▶ Frequency ▶ Pain (Character) ▶ Progression ▶ Aggravating Factors ▶ Relieving Factors ▶ Associated S & S ▶ Previous Occurrences ▶ Past Treatment ▶ Outcome: | | |
|--|--|--|

4. Other Complaints:

5. Past Medical History:

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

6. Current health status and life-style:

- ▶ Allergies
- ▶ Immunizations
- ▶ Screening Tests incl. xrays
- ▶ Environmental Hazards (Home, School, Work)

- ▶ Exercise and Leisure
- ▶ Sleep Patterns
- ▶ Diet
- ▶ Current Medication
- ▶ Analgesics/week:
- ▶ Tobacco
- ▶ Alcohol
- ▶ Social Drugs

7. Immediate Family Medical History:

- ▶ Age
- ▶ Health
- ▶ Cause of Death
- ▶ DM
- ▶ Heart Disease
- ▶ TB
- ▶ Stroke
- ▶ Kidney Disease
- ▶ CA
- ▶ Arthritis
- ▶ Anaemia
- ▶ Headaches
- ▶ Thyroid Disease
- ▶ Epilepsy
- ▶ Mental Illness
- ▶ Alcoholism
- ▶ Drug Addiction
- ▶ Other

8. Psychosocial history:

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

9. Review of Systems:

- ▶ General
- ▶ Skin

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

APPENDIX B

Durban Institute of Technology

PHYSICAL EXAMINATION: SENIOR

Patient Name : _____ **File no :** _____ **Date :** _____

Student : _____ **Signature :** _____

VITALS:

| | | | |
|-----------------|-----------------------------|----------------------------|-----------------------------|
| Pulse rate: | | Respiratory rate: | |
| Blood pressure: | R | L | Medication if hypertensive: |
| Temperature: | | Height: | |
| Weight: | Any recent change? Y / N | If Yes: How much gain/loss | Over what period |

GENERAL EXAMINATION:

| | |
|-------------------------------|---------------|
| General Impression | |
| Skin | |
| Jaundice | |
| Pallor | |
| Clubbing | |
| Cyanosis (Central/Peripheral) | |
| Oedema | |
| Lymph nodes | Head and neck |
| | Axillary |
| | Epitrochlear |
| | Inguinal |
| Pulses | |
| Urinalysis | |

SYSTEM SPECIFIC EXAMINATION:

CARDIOVASCULAR EXAMINATION

RESPIRATORY EXAMINATION

ABDOMINAL EXAMINATION

NEUROLOGICAL EXAMINATION

COMMENTS

Clinician: _____ **Signature :** _____

APPENDIX C

REGIONAL EXAMINATION - LUMBAR SPINE AND PELVIS

Patient: _____ **File#:** _____
Date: ___/___/___

Intern\Resident: _____ Clinician: _____

STANDING:

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

Minor's Sign
 Muscle Tone
 Spinous Percussion
 Scober's Test (6cm)
 Bony and Soft Tissue Contours

GAIT:

Normal walking
 Toe walking
 Heel walking
 Half squat

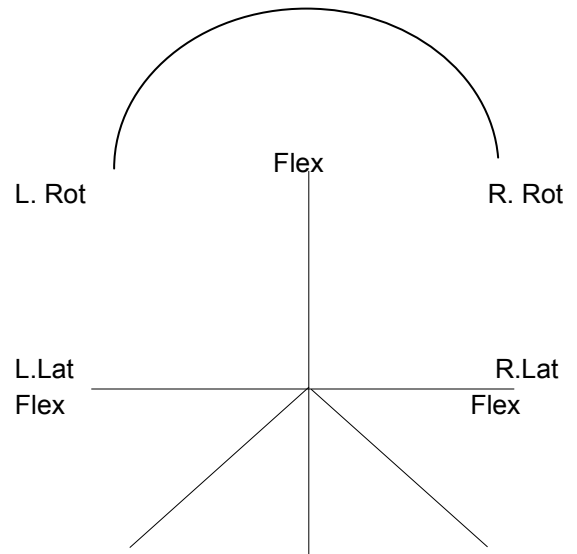
ROM:

Forward Flexion = 40-60° (15 cm from floor)

Extension = 20-35°

L/R Rotation = 3-18°

L/R Lateral Flexion = 15-20°



Which movt. reproduces the pain or is the worst?

- Location of pain
- Supported Adams: Relief? (S)
Aggravates? (disc, muscle strain)

SUPINE:

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

| | | Degr ee | LBP? | Location | Leg pain | Buttock | Thigh | Calf | Heel | Foot | Braggard |
|--|----------|------------|------|----------|----------|---------|-------|------|------|------|----------|
| | L | | | | | | | | | | |
| | R | | | | | | | | | | |

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

SITTING:

Spinous Percussion

Valsalva

Lhermitte

| Sl, +, ++ | R I P O D | Degree | LBP? | Location | Leg pain | Buttock | Thigh | Calf | Heel | Foot | Braggard | |
|-----------|-----------------------|--------|------|----------|----------|---------|-------|------|------|------|----------|--|
| | | L | | | | | | | | | | |
| | | R | | | | | | | | | | |

| | | | | | | | | | | | |
|--------------|---|--|--|--|--|--|--|--|--|--|--|
| Slump 7 test | L | | | | | | | | | | |
| | R | | | | | | | | | | |

LATERAL RECUMBENT:

| | L | R |
|--------------------|---|---|
| Ober's | | |
| Femoral n. stretch | | |
| SI Compression | | |

PRONE:

| | L | R |
|-------------------------|---|---|
| Gluteal skyline | | |
| Skin rolling | | |
| Iliac crest compression | | |
| Facet joint challenge | | |

| | | |
|----------------|--|--|
| SI tenderness | | |
| SI compression | | |
| Erichson's | | |
| Pheasant's | | |

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

NON ORGANIC SIGNS:

Pin point pain
 Axial compression
 Trunk rotation
 Burn's Bench test

Flip Test
 Hoover's test
 Ankle dorsiflexion test
 Repeat Pin point test

NEUROLOGICAL EXAMINATION

Fasciculations

Plantar reflex

| level | Tender? | Dermatomes | | DTR | L | R |
|-------|---------|------------|---|----------------|---|---|
| | | L | R | | | |
| T12 | | | | Patellar | | |
| L1 | | | | Achilles | | |
| L2 | | | | | | |
| L3 | | | | Proprioception | | |
| L4 | | | | | | |
| L5 | | | | | | |
| S1 | | | | | | |
| S2 | | | | | | |
| S3 | | | | | | |

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

BASIC THORACIC EXAM

History

Passive ROM

Orthopedic

BASIC HIP EXAM

History ROM: Active

Passive : Medial rotation : A) Supine (neutral) If reduced - hard \ soft end feel
 B) Supine (hip flexed): -

Trochanteric bursa

APPENDIX D



D U R B A N
INSTITUTE of
TECHNOLOGY
INFORMED CONSENT FORM
 (To be completed by patient / subject)

Date _____ :

Title of research project : To determine the immediate effect of lumbar and sacroiliac manipulation on quadriceps and hamstring torque ratios of the contralateral limb.

Name of supervisor : **Dr C Korporaal**
Tel : **2042611**

Name of research student : **Jane Lewis**
Tel : **2042205**

Please circle the appropriate answer

YES /NO

- | | | |
|---|-----|----|
| 1. Have you read the research information sheet? | Yes | No |
| 2. Have you had an opportunity to ask questions regarding this study? | Yes | No |
| 3. Have you received satisfactory answers to your questions? | Yes | No |
| 4. Have you had an opportunity to discuss this study? | Yes | No |
| 5. Have you received enough information about this study? | Yes | No |
| 6. Do you understand the implications of your involvement in this study? | Yes | No |
| 7. Do you understand that you are free to withdraw from this study? at any time without having to give any a reason for withdrawing, and without affecting your future health care. | Yes | No |
| 8. Do you agree to voluntarily participate in this study | Yes | No |
| 9. Who have you spoken to? _____ | | |

**Please ensure that the researcher completes each section with you
 If you have answered NO to any of the above, please obtain
 the necessary information before signing**

Please Print in block letters:

Patient /Subject Name: _____ Signature: _____

Witness Name: _____ Signature: _____

Research Student Name: _____ Signature: _____

APPENDIX E

LETTER OF INFORMATION

Dear patient, welcome to this study.

Title of Research project: To determine the immediate effect of lumbar and sacroiliac manipulation on quadriceps and hamstring torque ratios of the contralateral limb.

Name of supervisors: Dr C Korporaal
Mr Jimmy Wright

Name of research student: Jane Lewis

Name of institution: Durban Institute of
Technology

Introduction and purpose of this study:

This research study involves 60 patients and is to determine the immediate effect of lumbar and sacroiliac manipulation on quadriceps and hamstring torque ratios of the contralateral limb.

Procedures

The first consultation

This will take place at the Chiropractic Day Clinic at Durban Institute of Technology where you will be required to undergo an initial consultation which will include a history taking, relevant physical examination and low back regional examination. This will take approximately an hour and a half.

The second consultation

This will take place at the Kingspark Medical Centre (directions are provided). The date of the appointment will be made subject to the availability of Mr Wright. This testing session involves an initial strength test of you quadriceps and hamstring muscles using an isokinetic testing apparatus, followed by a treatment. After you treatment, your quadriceps and hamstring muscle strength will be retested. This visit will take approximately half and hour.

Directions

From the Chiropractic Day Clinic, turn right into Mansfield Rd. At the robots turn right into Botanic Gardens Rd and continue along Botanic Gardens Rd (becomes Cowey Rd) until you reach Argyle Rd. Turn right into Argyle Rd and at the corner of Argyle and Umgeni Rd, turn Left into Umgeni rd. Continue until you reach the intersection of Umgeni and Walter Gilbert Rd, and then turn right into Walter Gilbert Rd. Kingspark stadium will be on you r left hand side and Sharks Medical Centre is just next to Virgin Active.

Cost of the study

All treatments are free of charge and participation is completely on a voluntary basis.

Confidentiality

All patient information is confidential and the results will be used for research purposes only.

Withdrawal from the study without your consent

You are asked not to change any lifestyle habits, medication or supplementation for the period of your participation in this study, as this may have an effect on the results of the study

You may be withdrawn should you experience significant discomfort during the isokinetic testing session.

Thank you for your participation in this study

Jane Lewis
Intern

Dr C Korporaal
Supervisor

APPENDIX F

Are you aged between 18 - 45 years

and suffer from

LOW BACK PAIN?

Research is currently being carried out

at the

**DURBAN INSTITUTE OF
TECHNOLOGY
CHIROPRACTIC DAY CLINIC.**

FREE TREATMENT

Is available

ON COMPLETION OF THE STUDY

for more information

Contact

JANE

on

(031) 2042205/2512