An evaluation of objective hip joint functional ability measures after sacroiliac joint manipulation in patients with sacroiliac syndrome.

By

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I, Beverley Morgan, do hereby declare that this dissertation represents my own work in both concept and execution.

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DEDICATION

To Mom and Dad,
Thank you for being my ultimate role models. Your love, understanding, sacrifices and advice have not gone unnoticed.

To Debbie, Tracey and Diane,
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I love you all

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ABSTRACT

In symptomatic sacroiliac syndrome, nociceptors located within the capsule and ligaments of the sacroiliac joint are said to be activated which in turn act on inhibitory interneurons that synapse with the motor neuron pool of the muscles of that joint (muscles responsible for hip flexion, extension, abduction and adduction fall within the sacroiliac motor neuron pool). These inhibitory interneurons relay information that decreases the recruitment ability of that motor neuron pool.

This is termed Arthrogenic muscle inhibition (AMI) and it has been stated that the number of motor units innervating a muscle relates positively to the strength of that muscle and hence may have an effect on the functional ability of that muscle. However, it has been proposed that spinal manipulation activates mechanoreceptors (Wyke receptors) from structures in and around the manipulated joint causing changes in motor neuron excitability through the altered afferent input and thereby causing an increase in motor neuron recruitment and a decrease in AMI.

Furthermore, it has been found that sacroiliac joint problems have often been related to reduced or asymmetric range of motion (ROM) of the hip and / or lack of proprioceptive ability in the ipsilateral limb. In light of the above, manipulation has been found to cause a re-establishment of normal muscle tone and joint kinematics, therefore relaxing the muscles in that area and restoring normal ROM of the involved joint.

This study presents the results of sacroiliac manipulation on objective hip measures (including peak torques, ROM and proprioception).

This study consisted of 40 symptomatic patients and 20 asymptomatic patients. The symptomatic patients were randomly divided into two groups of twenty (i.e. 40 divided into male and female of twenty respectively), with each group having had two subgroups of ten (i.e. male group A received a sacroiliac joint manipulation and male group B was the control group, this was applicable to the female group of 20 as well). The asymptomatic patients formed the third group.

The symptomatic patients were seen 7 times over a three-week period and the asymptomatic patients were seen once to obtain the base line readings. Objective measurements were obtained by means of the Inclinometer (ROM and proprioceptive measures) and Cybex Orthotron.

Data analysis was done in SAS version 9.1 (SAS Institute Inc., Cary, NC). Baseline comparisons between the categorical baseline variables and the group to which the participant was assigned were done using Fisher's exact test. Continuous baseline variables that were not normally distributed were compared between groups using a non-parametric Wilcoxon Mann-Whitney test. Continuous normally distributed baseline data were compared using the two sample t-test.

Results showed:

With respect to Cybex Orthotron: Results revealed that immediately after the adjustment measurements increased with respect to all movements (flexion, extension, abduction and adduction). Hence one could conclude that immediately following the adjustment AMI decreased and muscle strength (measured as peak torque) increased in all movements of the hip. Measurements long after the adjustment (measurements taken before the cross-over), with the exception of flexion, were higher than the initial measurements (measurements obtained before any treatment was given), showing that the increase in muscle strength was sustained during the treatment process. Furthermore, final measurements revealed that muscle strength was still higher than the initial measurements in respect to all movements (including flexion); hence the researcher concluded that sacroiliac manipulation was effective in blocking/ slowing AMI of the musculature related to the hip. It must however be noted that although the results improved, they were statistically insignificant in terms of period, treatment and group effect. Perhaps a larger sample size would have altered the results.

With respect to ROM: ROM increased in all movements immediately after the adjustment, even long after the adjustment measurements were still higher than the initial measurements. The measurements at the final visit were all above the initial measurements in all movements, leading the researcher to conclude that sacroiliac manipulation improved ROM in all movements of the hip. Flexion, extension,

abduction, adduction and external rotation showed a statistically significant treatment effect when we analyzed the immediate effect. Extension and internal rotation showed a statistically significant treatment effect when we analyzed the delayed effect

With respect to proprioception: All of the measurements, except for the delayed effect of treatment of 20º internal rotation, revealed a statistically insignificant result, even though a mild change was observed. For all movements the measurements at visit seven were closer to normal than the measurements at visit one, indicating the patients proprioception continued to improve over time.

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DEFINITION OF TERMS

Abduction

A basic movement in which the limb distal to the joint in question moves away from the midline of the body in the coronal plane (Reider, 1999:371).

Acute

1. Of recent onset (hours or days)
2. Sharp, poignant, having a short and relatively severe course

(Gatterman, 1990: 405).

Active range of motion

The arc through which a joint can be moved by the muscles associated with that joint (Reider, 1999:371).

Adduction

A basic movement in which the limb distal to the joint in question moves toward or across the midline of the body in the coronal plane (Reider, 1999:371).

Afferent

Going from the periphery toward the central nervous system (Cohen, 1999: 442).

Adjustment

Specific form of direct articular manipulation (see manipulation) utilizing either long or short leverage techniques with specific contacts, characterized by a dynamic thrust of controlled velocity, amplitude and direction (Gatterman, 1995:405).

Arthrogenic muscle inhibition

A presynaptic, ongoing reflex inhibition of the musculature surrounding a joint following distention or damage to that joint (Hopkins *et al.* 2002).

Articulation

1. Place of union or junction between two or more bones of the skeleton
2. Active/ passive process of moving a joint through its entire range of motion

(Gatterman, 1990: 405).

Asymmetry

Lack or absence of symmetry of position or motion (Gatterman, 1990: 406).

Biomechanics

Application of mechanical laws to living structures. The study and knowledge of biological function from an application of mechanical principles (Gatterman, 1990: 406).

Chronic

Long standing (weeks, months or years) but not necessarily incurable. Symptoms may range from mild to severe (Gatterman, 1990: 406).

Contraindication

Any condition, especially any condition or disease, that renders one particular line of treatment improper or undesirable (Gatterman, 1990: 407).

Degenerative

Deterioration or breaking down of a part or parts of the body (Gatterman, 1990: 407).

Diagnosis

Art of distinguishing one disease from another, the determination of the nature of a cause of a disease (Gatterman, 1990: 407).

Extension

Motion in a limb, a digit or the spine that tends to straighten the involved body segment or in the case of the shoulder and hip, to move the limb posterior to the trunk (Reider, 1999:373).

External rotation

Axial rotation at a joint that tends to rotate the distal limb away from the midline when the patient is viewed from the anterior position (Reider, 1999: 373).

Fascia

Tissue layers under the skin or between muscles, which form the sheaths of muscles or invest other deep, definitive structures, as nerves and vessels (Gatterman, 1990: 408).

Fixation

1. Absence of motion of a joint in a position of motion, usually at the extremity of such motion.
2. State whereby a vertebra or pelvic bone has become temporarily immobilized in a position that it may normally occupy during any phase of physiological spinal movement.
3. Immobilization of a vertebra in a position of movement when the spine is at rest, or in a position of rest when the spine is in movement

(Gatterman, 1990: 408).

Fixation subluxation

Lack of movement of a joint, caused by muscular spasm, a shortened ligament or an intraarticular blocking (Gatterman, 1990: 408).

Flexion

Motion in a limb, digit or the spine that tends to bend the involved body segment or in the case of the shoulder and hip, to move the limb anterior to the trunk in the saggital plane (Reider, 1999: 373).

Free nerve endings

Non-specialized, non-encapsulated, unmyelinated receptors that function as nociceptors and provide a crude awareness of initial joint movement (Hopkins *et al*. 2000).

Incidence

A rate which refers to the number of persons with new back pain occurring over a given time period among a known number of persons who were previously without back pain (Giles and Singer, 1997: 18).

Inhibition

Effect of one neuron upon another, tending to prevent it from initiating impulses (Gatterman, 1990: 409).

Innervation

Distribution of nerves to a part (Gatterman, 1990: 409).

Internal rotation

Axial rotation that tends to rotate the distal limb toward the midline when the patient is viewed from the anterior position (Reider, 1999: 375).

Interneuron

A neuron that receives information from one neuron and transmits it to another (Hopkins *et al.* 2000).

Joint dysfunction

Joint mechanics showing area disturbances of function (Gatterman, 1990: 409).

Joint receptors

Transmit information about the status of the joint to the central nervous system (Norkin and Levangie, 1992: 63).

Kinematics

Diversion of mechanics that deals with the geometry of the motion of bodies, displacement velocity, and acceleration without taking into account the forces that produce the motion (Gatterman, 1990: 409).

Manipulation

Passive maneuver in which specifically directed manual forces are applied to vertebral and extravertebral articulations of the body, with the object of restoring mobility to restricted areas (Gatterman, 1990: 410).

Mechanoreceptor

A receptor that is excited by mechanical pressures or distortions, as those responding to sound, touch and muscular contractions (Redwood, 1997: 339).

Moment arm

The distance of the line of action of the force applied by the leg on the dynamometer to the center of rotation of the dynamometer arm (Suter *et al*. 1998).

Motion palpation

Palpatory diagnosis of passive and active segmental joint range of motion (Gatterman, 1990:412).

Motor neuron

An efferent neuron that innervates skeletal muscle and causes movement (Crossman and Neary, 1995:2).

Motor neuron pool

A group of spinal motor neurons that innervate a single muscle (Cohen, 1999: 457).

Motor neuron excitability

The motor neuron's capability to respond to an input (Cohen, 1999: 457).

Motor unit

Functional unit of striated muscle comprised of the motor neuron and all the muscle fibers supplied by the neuron (Gatterman, 1990: 411).

Muscle strength

A measure describing an individual's ability to exert maximum muscular force, statically or dynamically (De Ste Croix, Deighan and Armstrong, 2003).

Nociceptor

Physical or chemical damage detectors in tissues (Guyton and Hall, 1997: 376).

Prevalence

The number of persons who have experienced back pain ever, even if they are not affected at present (Giles and Singer, 1997: 18).

Prone

Lying with the ventral surface downwards (Gatterman, 1990: 413).

Proprioception

Sensing the motion and position of the body (Gatterman, 1990: 413).

Proprioceptors

Sensory nerve terminals that give information concerning movements and position of the body. They occur chiefly in the muscles, tendons, joints and labyrinths (Gatterman, 1990: 413).

Recruitment

Activation of motor units (Cohen, 1999: 464).

Reflex

Result of transforming an ingoing sensory impulse into an outgoing efferent impulse without the act of will (Gatterman, 1990: 414).

Rehabilitative

Procedures necessary for re-education or functional restoration of a disabled body system or part (Gatterman, 1990: 414).

Sacroiliac fixation

Absence of normal motion at the sacroiliac joint, demonstrable by motion palpation in which the axis of rotation has shifted to either the superior or inferior portion of the sacroiliac joint, or a situation in which there is total joint locking with no axis of rotation (Gatterman, 1990: 414).

Spasm

Shortening of a muscle due to non-involuntary motor nerve activity. Spasm cannot be stopped by voluntary relaxation (Gatterman, 1990: 414).

Subluxation

Restriction of motion of a joint in a position exceeding normal physiologic motion, although the anatomic limits have not been exceeded (Gatterman, 1990: 415).

Supine

Lying with the ventral side upward (Gatterman, 1990: 415).

CHAPTER ONE
INTRODUCTION

1.1) THE PROBLEM AND ITS SETTING

Kirkaldy-Willis and Hill (1979) in Cassidy and Mierau (Cassidy and Mierau in Halderman, 1992) believe that sacroiliac syndrome is a collection of symptoms and signs that is thought to result from a mechanical irritation of the joint (Cassidy and Mierau in Halderman, 1992) which occurs when the ilium slips on the sacrum, causing an irregular prominence of one articular surface to become wedged upon the prominence of an opposed articular surface (Hendler *et al*. 1995: 171). Sacroiliac joint dysfunction may take the form of simple joint locking or joint locking with compensatory hypermobility in adjacent articulations (Gatterman, 1990: 114).

Sacroiliac syndrome is a common but frequently overlooked source of low back pain (Bernard and Cassidy, 1991: 2114). Bernard and Kirkaldy-Willis (1987) performed a retrospective review of 1293 patients with lower back pain treated over a 12-year period. They reported that a primary diagnosis of chronic sacroiliac syndrome was made in 23% of all cases (Cassidy and Mierau in Halderman, 1992: 217). Furthermore, Daum (1995) found that as many as 40% of patients who presented with back complaints included sacroiliac joint disease.

Posteriorly, the capsule and ligaments of the sacroiliac joint are innervated by articular branches of the posterior primary rami from S1 and S2, and anteriorly by articular branches of the anterior primary rami from L3 to S2 (Ombregt *et al.* 1999:691). Furthermore, the muscles responsible for movements of the hip (Flexion, extension, abduction, adduction, internal rotation and external rotation) fall within the motor neuron pool of the sacroiliac joint (Moore, 1992 and Gray's Anatomy, 1995: 870-879).

In symptomatic sacroiliac syndrome, nociceptors, which make up most of the sacroiliac joint (Sakamoto *et al*. 2001:470) are activated, which in turn are thought to act on inhibitory interneurons that synapse with the motor neuron pool of the muscles of that joint (Ingersoll, Palmieri and Hopkins, 2003). These inhibitory

interneurons relay information that impedes the recruitment ability of the motor neuron pool (Ingersoll, Palmieri and Hopkins, 2003). This failure to activate all motor units of a muscle during maximal voluntary effort has been termed arthrogenic muscle inhibition (AMI) (Suter *et al*. 1998).

It can therefore be concluded that sacroiliac syndrome may have an effect on the functional ability of the muscles controlling the movement of the hip (defined in this study as range of motion (ROM), peak torque and proprioception).

This assertion is based on a study done by Suter *et al*. (1999). The results of this study showed that after sacroiliac manipulation there was a significant increase in knee extensor torques and a decrease in muscle inhibition (using the Cybex dynamometer, muscle stimulation and electromyography as measurement tools), leading them to conclude that correction of sacroiliac dysfunction facilitates activation of the knee extensor muscles in patients with anterior knee pain muscle inhibition (Suter *et al.* 1999). The quadriceps muscle falls within the motor neuron pool of the sacroiliac joint thus providing a possible explanation for the reduction in quadriceps muscle inhibition observed. Hence one could conclude that manipulation is a successful intervention in blocking or slowing AMI. Furthermore, spinal manipulation has been proposed to activate mechanoreceptors (Wyke receptors- explained under 2.5.3) from structures in and around the manipulated joint (Suter *et al.* 2000). The altered afferent input arising from their stimulation is thought to cause changes in motor neuron excitability (Suter *et al*. 2000).

In addition to this problems with the sacroiliac joint have often been related to reduced or asymmetric ROM of the hip (Cibulka, 1998: 1009), with resultant proprioceptive derangements and manipulation has been found to cause re-establishment of normal muscle tone and joint kinematics (Bernard and Cassidy, 1991: 2125).

Therefore, based on the above literature it leads the researcher to hypothesize that firstly sacroiliac manipulation will have an effect in blocking or slowing AMI and secondly it will have an effect in restoring normal ROM to the involved joint (hip joint)

and thereby allowing restoration of the functional ability of the hip musculature, as measured by range of motion, joint position sense and torque ratios.

1.2) THE OBJECTIVES AND HYPOTHESES OF THE STUDY

Thus the aim of this investigation was to determine the effect of sacroiliac manipulation on objective measures of hip functional ability in males and females with sacroiliac syndrome.

1.2.1) THE FIRST OBJECTIVE

The first objective was to determine a baseline norm, in both males and females, with respect to Cybex dynamometry and inclinometry (ROM and proprioception) in the asymptomatic population.

1.2.2) THE FIRST HYPOTHESIS

A norm exists with respect to the asymptomatic population in respect to Cybex dynamometry and inclinometry (ROM and proprioception)

1.2.3) THE SECOND OBJECTIVE

The second objective was to determine the change in Cybex due to a treatment protocol involving sacroiliac manipulation, in male and female patients suffering with sacroiliac syndrome.

1.2.4) THE SECOND HYPOTHESIS

It was hypothesized that sacroiliac manipulation would be effective in blocking or slowing AMI.

1.2.5) THE THIRD OBJECTIVE

The third objective was to determine the change in the inclinometry (ROM and proprioception) due to a treatment protocol involving sacroiliac manipulation, in male and female patients suffering with sacroiliac syndrome.

1.2.6) THE THIRD HYPOTHESIS

It was hypothesized that this blockage or slowing down of AMI and restoration of hip ROM would allow for restoration of the functional ability of the hip musculature, as measured by range of motion, joint position sense and torque ratios.

1.2.7) THE FOURTH OBJECTIVE

The fourth objective was to determine if any correlation exists between the changes in the Cybex dynamometry and the objective clinical measures.

1.2.8) THE FOURTH HYPOTHESIS

There is a correlation between the Cybex dynamometry and the objective clinical measures.

1.3) THE LIMITATIONS OF THE STUDY

1.3.1) THE FIRST LIMITATION

This study aimed to address objective clinical improvement only and not to explain the mechanisms responsible. However, suggestions regarding the possible mechanisms are given in chapter 5 to allow for further research.

CHAPTER TWO
REVIEW OF THE RELATED LITERATURE

2.1) INTRODUCTION

This chapter gives a review of the available literature describing the incidence, prevalence, clinical features and diagnosis of sacroiliac syndrome, as well as the anatomy and biomechanics of the sacroiliac joint. It gives an overview of the anatomy of the hip joint, the movements of the hip joint, the muscles responsible for those movements and the innervation. It explains the relationship between the sacroiliac joint and the hip joint. Furthermore, it reviews the literature pertaining to arthrogenic muscle inhibition (AMI) in terms of its definition, likely causes, neurophysiological factors, measuring AMI and the treatment protocols that may lessen AMI and the possible benefits thereof.

The possible affiliation between AMI and sacroiliac syndrome will also be discussed and the effects of manipulation on decreasing / slowing down AMI and its effects on objective hip measurements.

In addition this chapter explains the relationship between sacroiliac syndrome, hip range of motion and proprioception. The effect of sacroiliac manipulation on hip range of motion and proprioception is also explained.

2.2) ANATOMY OF THE SACROILIAC JOINT

2.2.1) BONY ANATOMY

The sacroiliac joint is in a unique and precarious position, both anatomically and functionally (Daum, 1995: 475). It is either the end of the spine or the beginning of the lower extremity and is called upon to bear significant forces but has little intrinsic articular stability (Daum, 1995: 475).
The sacroiliac joint is a true diarthrodial (synovial) joint (Daum, 1995: 475). The articular cartilage on the sacrum is more than twice as thick as that on the ilium (Kirkaldy-Willis in Kirkaldy-Willis and Burton, 1992: 71). The sacral side consists of

hyaline cartilage and the iliac side consists of fibrocartilage (Kirkaldy-Willis in Kirkaldy-Willis and Burton, 1992: 71). Furthermore, these surfaces have irregular elevations and depressions, which result in partial interlocking of the bones (Moore, 1992: 251). The sacroiliac joint is covered by a strong articular capsule attached close to the articulating surfaces of both the sacrum and ilium (Moore, 1992: 251). The dense strong ligamentous complex, the irregular interlocking joint surfaces and great magnitude of force required to disrupt the joint suggest the sacroiliac joint is very stable and capable of only minimal movement (Cassidy and Mierau in Halderman, 1992: 215).

2.2.2) LIGAMENTS OF THE SACROILIAC JOINT

Further stability is provided by the posterior and interosseous sacroiliac ligaments, the strongest ligaments in the body, and the anterior sacroiliac ligaments (Moore, 1992:251).

In summary:

- The posterior sacroiliac ligaments consist of strong, short transverse fibres joining the ilium and the first and second tubercles of the sacrum as well as long vertical fibres uniting the third and fourth transverse tubercles of the sacrum to the posterior iliac spines (Moore, 1992:251).
- The interosseus sacroiliac ligaments are massive, very strong ligaments uniting the iliac and sacral tuberosities (Moore, 1992: 251).
- The anterior sacroiliac ligaments are thin, wide sheets of transverse fibres located on the anterior and inferior aspects of the sacroiliac joint (Moore, 1992: 251).

Accessory ligaments include iliolumbar, sacrotuberous and sacrospinous ligaments (Moore, 1992: 251).

2.2.3) MUSCLES OF THE SACROILIAC JOINT

It has been found that the sacroiliac joint is not crossed by any muscles but the adjacent muscles have fibrous expansions that blend with the anterior and posterior sacroiliac joints ligaments (Walker, 1992: 904). These muscles include:

- Quadratus Lumborum,
- Erector Spinae,
- Gluteus Maximus and Minimus,
- Piriformis,
- Iliacus and
- Latissimus Dorsi.

This is in congruence with Harrison, Harrison and Troyanovich (1997:610) who state that there is not one single muscle group or muscle that crosses the sacroiliac joint. However, the ligaments of the sacroiliac joint and lumbar spine fuse with the thoraco-lumbar fascia. These ligaments and fascia are the primary attachment sites for the main movers and stabilizers of the spine and lower extremity. The major muscles and fascia involved include:
Gluteus Maximus and Medius, Latissimus Dorsi, Multifidus, Biceps Femoris, Psoas, Piriformis, Obliqus and Transversus Abdominus and Thoracolumbar fascia.

2.2.4) BIOMECHANICS OF THE SACROILIAC JOINT

Cassidy and Mierau in Halderman (1992: 215) summarized the generally accepted trends applicable to sacroiliac biomechanics as:

- The sacroiliac joint has a small range of motion (ROM) that will decrease with increasing age.
- Females have greater ROM compared to males, which increases during pregnancy.
- Motions are coupled and dependent on some degree of joint separation.
- The predominant motion is x-axis rotation, coupled with some degree of z-axis translation.

2.2.5) INNERVATION OF THE SACROILIAC JOINT

The sacroiliac joint has extensive sensory innervation (Daum, 1995). Posteriorly, the capsule and ligaments of the sacroiliac joint are innervated by articular branches of the posterior primary rami from S1-S2 and anteriorly by articular branches of the anterior primary rami from L3-S2 (Ombregt *et al.* 1999: 691).

Palastanga *et al*. (1998: 394) state that the nerve supply to the joint is by twigs directly from the sacral plexus and dorsal rami of the first and second sacral nerves. In addition it also receives branches from the superior gluteal and obturator nerves as they pass close to the joint. The joint is therefore supplied by roots L4-S2 (Palastanga *et al.* 1998: 394). Bernard and Cassidy (1991: 2111) state that the synovial capsule of the sacroiliac joint and overlying ligaments have unmyelinated free nerve endings that transmit pain and thermal sensation information.

2.3) INTRODUCTION TO SACROILIAC SYNDROME

2.3.1) DEFINITION

Kirkaldy-Willis and Hill (1979) in Cassidy and Mierau (Cassidy and Mierau in Halderman, 1992) believe that sacroiliac syndrome is a collection of signs and symptoms that is thought to result from a mechanical irritation of the sacroiliac joint (Cassidy and Mierau in Halderman, 1992) which occurs when the ilium slips on the sacrum (Hendler *et al.* 1995: 171).

2.3.2) INCIDENCE AND PREVALENCE

Lehmann *et al*. (1993) in Hendler *et al*. (1995) state that lower back pain is the most common, costly and disabling musculoskeletal condition (Hendler *et al*. 1995: 169). Toussaint *et al*. (1999) state that in the medical literature the prevalence of sacroiliac dysfunction is between 19,3% and 47,9% and Schwarzer *et al.* (1995:36) found the prevalence of sacroiliac syndrome to be between 13% and 30%. Bernard and Kirkaldy-Willis (1987) performed a retrospective review of 1293 patients with lower back pain treated over a 12-year period. They reported that the primary diagnosis of sacroiliac syndrome was made in 23% of all cases.

Therefore sacroiliac dysfunction evidently establishes itself as an important clinical entity.

2.3.3) CLINICAL PRESENTATION AND DIAGNOSIS

Symptomatic sacroiliac syndrome is characterized by pain over the sacroiliac joint with possible referral to the groin, trochanter and buttock (McCulloch and Transfeldt, 1997: 180-181). Occasionally the pain may extent down to the lateral or posterior calf to the ankle, foot and toes (Gatterman, 1990: 115), due to the extensive joint innervation (Daum, 1995: 476). The pain does not follow a true radicular pattern (Daum, 1995: 476).

On physical examination, the patient appears most comfortable while sitting on the unaffected buttock. While sitting the patient may also assume a typically forward flexed posture that removes tension from the hamstrings that apply traction to the diseased joint. In contrast, forward bending while standing is limited and painful, since the tension of the hamstrings limits the forward excursion of the pelvis (Hendler *et al*. 1995: 170). Pain is increased by, amongst other factors, weight-bearing, lying on the affected side, stair climbing and bicycle riding (Daum, 1995).
The diagnosis of sacroiliac syndrome is established by utilizing pain provocation tests such as Patrick Fabere test, Gaeslen's test, Extension (Erichson's) test (Kirkaldy- Willis in Kirkaldy-Willis and Burton, 1992: 124-125 and Reider, 1999: 195) and posterior shear test that aim to stress the joint in an attempt to reproduce the patient's symptoms (Laslett and Williams, 1994). These tests are discussed in chapter three under 3.8.

Once a diagnosis of sacroiliac syndrome is established, motion palpation is utilized to determine sacroiliac restrictions prior to manipulation. The Gillet method is the most commonly utilized method (Bergman *et al.* 1993: 494). This method is described in chapter three under 3.8.

2.4) THE HIP JOINT

2.4.1) ANATOMY OF THE HIP JOINT

The hip joint is a multiaxial ball and socket type of synovial joint between the head of the femur and the acetabulum of the hip bone (Moore, 1992: 472).
The hip joint is a very strong and stable articulation (Moore, 1992:477). The stability of the joint is determined by the shape of the articular surfaces, the strength of the joint capsule and the associated ligaments and the insertion of muscles crossing the joint (Palastanga *et al*. 1998: 404).

2.4.2) LIGAMENTS OF THE HIP JOINT

Four main groups of longitudinal capsular fibres or intrinsic ligaments are given names according to the region of the hip bone which they attach to the femur (Moore, 1992: 474). These intrinsic ligaments are thickened parts of the fibrous capsule that strengthens the hip joint and are known as the Iliofemoral ligament, the Pubofemoral ligament and the Ischiofemoral ligament (Moore, 1992: 475).

2.4.3) INNERVATION OF THE HIP JOINT

The nerve supply to the hip joint is from the lumbar plexus by twigs from the femoral and obturator nerve and from the sacral plexus from the superior gluteal nerve to the quadratus femoris muscle, with a root value of L2-S1 (Palastanga *et al.* 1998: 414). This is a typical example of articular innervation in that the nerve supply to the joint is derived from the same nerves that supply the musculature crossing the joint (Palastanga *et al*. 1998: 414). The articular supply consists of sensory nerve fibres, transmitting proprioceptive information (Palastanga *et al*. 1998: 414).

2.4.4) MOVEMENTS OF THE HIP JOINT, MUSCLES RESPONSIBLE AND THE INNERVATION THEREOF

The range of movement of the hip joint is decreased somewhat to provide stability and strength (Moore, 1992: 474). The movements of the hip joint include flexion,

extension, abduction, adduction, internal and external rotation, these movements are listed in the table below together with the muscles responsible and innervation thereof (Moore, 1992 and Gray's Anatomy, 1995: 870-879).

MOVEMENT	MUSCLE	INNERVATION
Flexion	Iliosoas, Rectus Femoris and Tensa Fascia Lata	L1-S1
Extension	Gluteus Maximus and Biceps Femoris	L5-S2
Abduction	Gluteus Medius and Minimus	L4-S1
Adduction	Adductor Magnus, Longus and Brevis	L2-L4
Internal rotation	Tensa Fascia Lata, Gluteus Medius and Minimus	L4-S1
External rotation	Obturator Internus and Externus, Gemelli, Quadratus Femoris and Piriformis	L3-S2

It is important to note that these muscles fall within the sacroiliac joint motor neuron pool

In addition to this the normal active range of motion of the hip joint according to movements is defined as follows:

Flexion = 110-120 degrees
Extension = 10-15 degrees
Abduction = 30-50 degrees
Adduction = 30 degrees
Internal rotation = 30-40 degrees
External rotation = 40-60 degrees

(Magee, 1992: 335).

2.4.5) THE RELATIONSHIP BETWEEN THE SACROILIAC JOINT AND THE HIP JOINT

When we look at the above literature we notice that the sacroiliac joint and the hip joint have many things in common:

Weight transfer from the torso to the lower limb. The sacroiliac joint is in a unique and precarious position, it is either the end of the spine or the

beginning of the lower extremity (Daum, 1995:475). The hip joint connects the lower limb to the trunk, and therefore is involved in the transmission of weight (Palastanga *et al.* 1998: 404).

They are responsible for stability and therefore have reduced mobility. The sacroiliac joint is a very stable joint and capable of only minimal movement (Cassidy and Mierau in Halderman, 1992: 215). The hip joint is a very strong and stable articulation (Moore, 1992: 477).

They have a similar innervation, the hip joint is innervated from L2-S1 (Palastanga *et al.* 1998: 414) and the sacroiliac joint is innervated from L3-S2 (Ombregt, 1999) and according to Palastanga *et al*. (1998) it is innervated from L4-S2.

The hip joint and the sacroiliac joint have the following muscles in common: Gluteus maximus, medius and minimus, piriformis, iliopsoas and biceps femoris (Moore, 1992; Gray's Anatomy, 1995: 870-879, Walker, 1992: 904).

2.5) ARTHROGENIC MUSCLE INHIBITION

2.5.1) DEFINITION

AMI is a presynaptic, ongoing reflex inhibition of musculature surrounding (e.g. the piriformis and gluteal muscles) a joint (sacroiliac joint) after distention or damage to that joint (Hopkins *et al*. 2002). This joint damage commonly results in severe weakness of associated muscles (Young, 1993: 829). Efforts to restore strength are often unsuccessful because of the underlying inhibition of motorneurons by afferent signals from in and around the affected joint (Young, 1993: 829).

Furthermore, Suter *et al*. (2000) state that AMI reduces the ability of a muscle to utilize all motor units of its muscle group to their full extent during a maximum effort voluntary muscle contraction. AMI not only slows strength gains, it also slows gains in proprioception (Hopkins *et al*. 2002).

2.5.2) CAUSES OF AMI

Potential etiologic factors of AMI include osteoarthritis (Arokoski *et al*. 2002), joint effusion (Hopkins *et al*. 2002), immobilization (Reid, 1992: 49), pain (Hopkins *et al.* 2002) and traumatic injury / damage to joint structures (Hopkins *et al*. 2002 and Hurley *et al*. 1994). However, the most common denominator appears to be joint injury. Following joint injury (as would be the evident from a sacroiliac syndrome) the patient experiences some deficits in range of motion and immobilization (Hopkins and Ingersoll, 2000). Immobilization could result from swelling, pain and / or muscle spasm (Hopkins and Ingersoll, 2000). It is thought that each of these, in there own manner, stimulate the inhibitory interneuronal pathways, which initiate AMI reflex pathways. This results in AMI playing a central role in maintaining this cycle (Hopkins and Ingersoll, 2000) in patients with sacroiliac syndrome.

2.5.3) NEUROPHYSIOLOGICAL FACTORS ASSOCIATED WITH AMI

Joint receptors transmit information about the status of the joint to the central nervous system (Norkin and Levangie, 1992: 63). The central nervous system interprets the information sent by the joint receptors and responds by coordinating muscle activity around the joint to meet joint mobility and stability requirements (Norkin and Levangie, 1992: 63). Joint receptors are located in joint capsules and ligaments (Levangie and Norkin, 1992: 64). All synovial joints are said to contain four types of receptors that are classified according to Wyke's classification system as type I, II, III, IV. Type I, II, III are encapsulated mechanoreceptors and type IV are free nerve endings (Leach, 1994: 90). In this respect Sakamoto *et al*. (2001) found most of the mechanoreceptors identified in the sacroiliac joint were nociceptors, making the proportion of nociceptive units in the sacroiliac joint 97%.

Vilensky *et al*. (2002) identified mechanoreceptors and nerve fascicles in the posterior ligaments of the sacroiliac joint, leading authors to believe that proprioceptive and possible nociceptive information might be transmitted from the sacroiliac joint to the central nervous system.

AMI is thought to stem from the activity of these joint receptors (Ingersoll, Palmieri and Hopkins, 2003) including free nerve endings and special nociceptors (Ingersoll, Palmieri and Hopkins, 2003) however, the primary effect appears to be the result of mechanoreceptor activity (Ingersoll, Palmieri and Hopkins, 2003).

These receptors then act on inhibitory interneurons that synapse with the motor neuron pool of the musculature surrounding the injured joint (Ingersoll, Palmieri and Hopkins, 2003). These inhibitory interneurons relay information that decreases the recruitment ability of the motor neuron pool (Ingersoll, Palmieri and Hopkins, 2003), hence resulting in a decrease in the force of any contraction governed by that motor neuron pool (Ingersoll, Palmieri and Hopkins, 2003). As mentioned above the hip musculature falls within the sacroiliac motor neuron pool.

In symptomatic sacroiliac syndrome joint receptors (primarily mechanoreceptors) are activated (Suter *et al.* 1999). As previously stated AMI primarily results from mechanoreceptor stimulation (Ingersoll, Palmieri and Hopkins, 2003). Therefore it leads the researcher to believe that in symptomatic sacroiliac syndrome AMI will be present and could therefore be influenced by an intervention therapy (e.g. manipulation).

2.5.4) CLINICAL IMPLICATIONS OF AMI

If AMI contributes to the muscle atrophy, which occurs with joint pathology, there may be impedance of the restoration of muscle strength, thus hindering effective rehabilitation (Hurley *et al*.1994: 305). This is supported by Hopkins *et al.* (2000: 1199) who state that AMI retards rehabilitation despite complete muscle integrity. AMI not only slows strength gains, it also slows gains in proprioception (Hopkins *et al*. 2002).

If AMI were removed or diminished more vigorous active exercise could be maintained and this would decrease rehabilitation time, facilitate return to activity and diminish the negative effects of AMI on tissues (Hopkins *et al*. 2000:1199), in terms of strength as well as proprioception.

2.5.5) MEASUREMENT OF AMI

AMI is a reduction in motor neuron pool recruitment and may be measured indirectly by any measurement that assesses changes in recruitment (Ingersoll, Palmieri and Hopkins, 2003). It may include voluntary motor unit recruitment as measured by dynamometry or electromyelography (EMG) (Ingersoll, Palmieri and Hopkins, 2003). Also involuntary measure of motor neuron recruitment for example, Hoffman's reflex, recruitment inhibition and paired reflex depression (Ingersoll, Palmieri and Hopkins, 2003).

2.5.6) ISOKINETIC DYNAMOMETRY

2.5.6.1) INTRODUCTION

This study utilized the Cybex Orthotron II isokinetic rehabilitation system to assess muscle strength of the hip musculature in the actions of flexion, extension, abduction and adduction.

AMI is a reduction in motor unit recruitment (Ingersoll, Palmieri and Hopkins, 2003), and hence the force of any contraction governed by that motor neuron pool is reduced and AMI is clinically manifested as a decrease in muscle strength[1] (Ingersoll, Palmieri and Hopkins, 2003).

Isokinetic assessment has primarily been recommended for strength testing as maximal force is applied during all phases of the movement at a constant velocity (De Ste Croix, Deighan and Armstrong, 2003: 729). However it has also been stated that Isokinetic dynamometer measures torque which is a function of muscle force (De Ste Croix, Deighan and Armstrong, 2003: 729), which is a direct measure of strength.

[1] The term muscular strength refers to a measure describing an individual's ability to exert maximal muscular force statically or dynamically (De Ste Croix, Deighan and Armstrong, 2003: 729).

2.5.7) THERAPUETIC INTERVENTIONS CAUSING A DECREASE IN AMI

AMI can be eliminated or diminished by removing, over riding or altering inhibitory interneuron activity (Ingersoll, Palmieri and Hopkins, 2003). Various therapeutic techniques have been investigated in causing a reduction in AMI, such as

- Lidocaine injections (Hopkins *et al.* 2002)
- Cryotherapy (Hopkins *et al*. 2002) and
- Transcutaneous electrical stimulation (TENS) (Ingersoll, Palmieri and Hopkins, 2003).

These are primarily aimed at reducing joint pain, effusion and muscle atrophy. These techniques show promise to reduce AMI but other modalities or techniques should be evaluated (Ingersoll, Palmieri and Hopkins, 2003).

In a study done by Suter *et al*. (1999), results showed a significant increase in knee extensor torques (indirectly an increase in muscle strength) and a decrease in muscle inhibition following sacroiliac manipulation in patients with anterior knee pain. Leading them to conclude that sacroiliac manipulation facilitates activation of the knee extensor muscles in anterior knee pain patients with muscle inhibition (Suter *et al*. 1999), possibly due to the fact that the quadriceps muscle group falls within the sacroiliac motor neuron pool.

This study will assess the effects of sacroiliac manipulation on hip muscle strength (as well as other objective measures) as the hip musculature falls within the sacroiliac motor neuron pool.

2.5.8) THE NEUROPHYSIOLOGICAL EFFECTS OF SPINAL MANIPULATION ON AMI

Sacroiliac manipulation has been shown to effectively reduce AMI in the quadriceps muscle group (Suter *et al.* 1999). It has been proposed that manipulation, applied in the form of a high velocity, low amplitude thrust, results in activation of mechanoreceptors and proprioceptors within and around the manipulated joint (Suter *et al*. 2000). The altered afferent input arising from the joint stimulation causes

changes in motor neuron excitability (Suter *et al.* 2000), thereby causing an increase in motor unit recruitment and a decrease in AMI (Suter *et al*. 2000).

In addition to this, this study aims to measure the effects of sacroiliac manipulation on objective measures including ROM and proprioception.

2.5.9) THE RELATIONSHIP BETWEEN SACROILIAC SYNDROME AND HIP ROM

It has been found that the sacroiliac joint is widely accepted as a potential source of low back pain (Toussaint *et al.* 1999: 134) furthermore, problems with the sacroiliac joint have often been related to reduced or asymmetric range of motion of the hip (Cibulka, 1998: 1009).

Investigators have proposed that low back pain may be related to hip pain secondary to limited range of motion in the hip (Cibulka, 1998: 1009).
Cibulka (1998: 1010) conducted a study to determine whether a characteristic pattern of hip rotation range of motion existed in patients with low back pain and whether those patients classified as having sacroiliac joint dysfunction had a different pattern of hip range of motion compared to those with no signs of sacroiliac dysfunction. Cibulka (1998: 1013) found hip rotation asymmetry present in patients classified as having sacroiliac joint regional pain. Furthermore, Cibulka (1992) found that by treating the sacroiliac joint and restoring symmetrical hip rotation, the patient no longer complained of low back pain.

Furthermore, Bisset (2003) conducted a study to determine the effects of sacroiliac manipulation on internal and external range of motion of the hip. It was found that sacroiliac manipulation resulted in an increase in hip internal rotation on the side of manipulation and a slight increase in internal and external rotation on the side not manipulated.

2.5.10) THE EFFICACY OF SACROILIAC MANIPULATION ON HIP ROM

Cassidy (1998) in Bernard and Cassidy (1991: 2126) hypothesize that a high velocity, short amplitude manipulation suddenly forces the hypertonic muscles into a

stretch, leading to a barrage of afferent impulse signals to the central nervous system. The resultant reflex inhibition of gamma and alpha neurons may lead to readjustment of muscle tone and relaxation (Bernard and Cassidy, 1991: 2126). This is supported by Indahl *et al*. (1997: 2834-2840) who postulate that manipulation might produce a stretch reflex from joint capsules that may lead to inhibition of muscle spasm of muscles surrounding the joint. This is further supported by Korr (1975) in Leach (1994) who proposed two mechanisms in which manipulation could relax muscle spasm (Leach, 1994: 99). First stretching the intrafusal fibers by forcefully stretching the muscle against its spindle maintained resistance would produce a barrage of afferent impulses intense enough to signal the central nervous system to reduce the gamma motorneuron discharge (Leach, 1994: 99). Secondly, the golgi tendon organs would be stimulated by forced stretch of the skeletal muscles causing both gamma and alpha motorneuron inhibition (Leach, 1994:99).

In congruence and addition to the above, Paris (1979) in Bernard and Cassidy (1991: 2126) believe that manipulation may also affect the joints by stimulating type I and II articular mechanoreceptors as well as type III mechanoreceptors in the associated ligaments. This would send afferent signals along medium and large diameter nerve fibers which would then inhibit pain impulses traveling through smaller fibers (Bernard and Cassidy, 1991: 2126).

Therefore in light of the above it is suggested that manipulation causes a re-establishment of normal muscle tone and joint kinematics (Bernard and Cassidy, 1991: 2125), leading the researcher to believe that sacroiliac manipulation will relax the muscles in that area and restore normal ROM to the involved hip joint.
Thus this study will asses the effects of sacroiliac manipulation on hip ROM based on a suggestion by Nadler *et al.* (2001: 573) who supports the need for assessment and treatment of hip muscle imbalances in individuals with low back pain.

2.5.11) THE RELATIONSHIP BETWEEN SACROILIAC SYNDROME AND PROPRIOCEPTION AND THE EFFICACY OF SACROILIAC MANIPULATION ON PROPRIOCEPTION

Patterson and Steinmetz (1986) in Leach (1994: 101) state that, when there is segmental dysfunction (as would be found in sacroiliac syndrome) with accompanying motion disorder and muscle tension, if the initiating stimulus is sufficient or lasts long enough there may be segmental facilitation even after this instigating stimulus is removed. Once this facilitation occurs, despite the removal of the afferent source of stimulation, the abnormal segmental reflex circuit itself participates in maintaining the symptoms (Leach, 1994:101). This is validated by studies that have utilized anesthesia to study "spinal learning" (in rats). It was found that there was an altered position of the limb / joint which remained even

after the anesthesia had taken effect (Patterson and Steinmetz (1986) in Leach, 1994: 100).

This leads the researcher to believe that there are spinal reflexes (that function at a level which is unaffected by pain or mechanical stimuli), which maintain the abnormal joint or limb position in the absence of a painful or mechanical stimulus. One such spinal reflex that would be able to occur even after the application of the anesthesia to the study subjects (rats) is that of the proprioceptive reflex and related reflexes (Darby and Daley in Cramer and Darby, 1995), as these reflexes act for the most part on the subconscious level, although they may be perceived consciously (Darby and Daley in Cramer and Darby, 1995). This therefore means that these reflexes would maintain the subject's abnormal position post the injury and removal of the initiating stimulus, and is therefore not linked to the presentation of pain or inflammation related to the syndrome (Darby and Daley in Cramer and Darby, 1995).

To support this Patterson and Steinmetz (1986) in Leach (1994:101) go further to state that spinal manipulation may be effective in restoring normal limb / joint position, through the theory proposed by Korr (1975) as found in Leach (1994:98), where Korr (1975) states that the proposed model follows the following mechanisms:

- A sudden increase in the facilitation of the segment causes the supraspinal structures to reset their sensitivity (reset “gamma gain”) as the supraspinal structures receive a sudden barrage of impulses post the manipulation.
- This resetting allows for the normalization of the joint structures through mechanical replacement as well as for the normalization of the firing patterns of the different receptors including those of proprioception, with resultant normalization of the posture / joint position sense of the patient / subject.

It must however be noted that Korr (1975) in Leach (1994:98) emphasizes that this is only a theory that requires further clinical and experimental validation.

2.5.12) CONCLUSION

In conclusion, sacroiliac syndrome is a common but frequently overlooked source of low back pain, that is thought to result in the generation of an AMI mediated reflex (with AMI being a presynaptic, ongoing reflex inhibition of muscles surrounding a joint and reduces the ability of a muscle to utilize all motor units of its muscle group during maximal voluntary contraction). This AMI reflex stems from joint receptor activity, primarily mechanoreceptors, which are stimulated in symptomatic sacroiliac syndrome. This effect acts on inhibitory interneurons that synapse with the motor neuron pool of the surrounding musculature and cause a decrease in the contractile ability of the muscles falling within that motor neuron pool.

As a result of the hip musculature falling within the sacroiliac joints motor neuron pool, it is hypothesized that the muscles of the hip would show changes consistent with AMI. In addition to this studies have shown that asymmetric hip ROM is present in patients with sacroiliac joint problems (e.g. sacroiliac syndrome), and these have also been associated with proprioceptive derangements.

With respect to these changes in contractile ability of the muscle, ROM and proprioception, manipulation has been found to:

- Effectively reduce AMI by altering the motor neuron excitability.

- Effectively restore ROM and is thought to
- Effectively restore proprioceptive ability.

Therefore this research addressed the effect of manipulation on objective hip measures as measured by peak torque, ROM and proprioception.

CHAPTER THREE

MATERIALS AND METHODS

3.1) INTRODUCTION

In this chapter

a. A detailed description of the design of the study
b. The interventions
c. The methods employed in data collection
d. As well as the statistical methods used for the analysis and interpretation of the data will be discussed.

A description of each treatment group is given, as well as the criteria for inclusion or exclusion of patients.

3.2) DESIGN

A pre post, prospective cross over clinical experiment.

3.3) PATIENT RECRUITMENT

The public was informed about the nature of the research by way of pamphlets, newspaper advertisements, posters (appendix B for symptomatic patients and appendix c for asymptomatic patients) and word of mouth at the Chiropractic Day clinic and other public venues such as supermarkets, pharmacies, sports clubs, gyms, schools, libraries etc.

Only English speaking patients were considered, as verbal encouragement needed to be given by the researcher during the isokinetic testing to ensure maximal effort. English is the researcher's first language and helped to reduce possible linguistic confusion between participants and the researcher.

3.4) SAMPLING

Participates were obtained by means of a convenience sampling technique for the 20 male and 20 female symptomatic patients that where involved in the study and non-probability purposive sampling technique for the 10 male and 10 female

asymptomatic patients (in order that they reflected similar demographics to the symptomatic group) residing in the province of Kwa-Zulu Natal.

3.5) PATIENT CONSULTATION

Where necessary, telephonic consultations were conducted to the prospective patients to ascertain whether they were eligible to participate in the study in accordance with the inclusion criteria, and to ensure that they had signs and symptoms indicating a strong possibility that they did indeed suffer from sacroiliac syndrome (see appendix A for the questions that were posed in the telephonic interview).

Following which, a face to face interview was conducted to determine if the patient fitted the rest of the inclusion and exclusion criteria.

The patient was informed about the nature of the study at this point and was provided with an explanatory letter (appendix H) and an informed consent form (appendix I). In order to ensure that the patients completely understood the research and to protect their interests, the patients were required to read and sign the abovementioned explanatory letter and informed consent form. At any stage the patient had the opportunity to ask any questions pertaining to the research. Thereafter a full history (appendix D), revised physical (appendix E), lumbar (appendix F) and hip regional examination (appendix G) was conducted in order to assess the inclusion and exclusion criteria.

3.6) RANDOMIZATION

Group	**Treatment (A)**	**Experimental (B)**	**Asymptomatic**
Male	10	10	10
Female	10	10	10
	20 Treatment group	20 Experimental group	20 Asymptomatic

Of the symptomatic patients, each gender had an equal chance of being in any one of the two treatment groups allocated to them. This was done by placing an

alphabetical letter A and B in a hat and therefore patients were able to select either group on presentation. Of the asymptomatic group, the patients where matched by age and gender according to the profile of the symptomatic group.

3.7) INCLUSION AND EXCLUSION CRITERIA

3.7.1) INCLUSION CRITERIA

- In order to increase group homogeneity, patients were required to have a pain rating scale between 50 and 100 on the numerical pain rating scale in order to be included in this trial.
- Patients had to be diagnosed with sacroiliac syndrome - A diagnosis was made if all of the following were found:
    1. Pain felt over the sacroiliac joint, with possible referral to the groin, trochanter and buttock (Riggien, 2003)
    2. Sacroiliac joint was tender to palpation (McCulloch and Transfeldt, 1997: 180-181)
    3. The pain was aggravated by 2 of the 4 provocation tests, such as Gaenslen's, Patrick fabere, Erichson's and posterior shear tests (Riggien, 2003 and McCulloch and Transfeldt, 1997:180-181).

- Patients between the ages of 25-45 were included. Brandt (2002) found little radiographic evidence of osteoarthritis in patients below the age of 45 years.
- Only English speaking patients were included, as verbal encouragement needed to be given by the researcher during the isokinetic testing to ensure maximal effort. English is the researcher's first language and helped to reduce possible linguistic confusion between participants and the researcher.
- Patients were only accepted if they had read and signed the informed consent form, undergone a full history, physical examination, lumbar and hip regional examination.
- After the initial consultation, patients were required to attend seven follow-up visits.

3.7.2) EXCLUSION CRITERIA

- Patients were excluded if they had any of the following contra indications to manipulation (Gatterman, 1990).
    1. Disc herniations with increasing signs and symptoms of neurological deficit
    2. Abdominal aortic aneurysm
    3. Lumbar spine tumors
    4. Lumbar spine infections
    5. Lumbar spine traumatic injuries
    6. Cauda equina syndrome
    7. Spondlolisthesis
- Patients currently on medication (Poul, West and Buchanan, 1993) or receiving treatment for low back pain were excluded (Haldeman, 1992).
- Patients who have had previous lower back surgery were also excluded.
- Patients suffering from any hip pathologies including instability were excluded. Hip pathologies were ruled out subjectively by a history of groin pain, and objectively by means of a basic hip examination including Quadrant scouring test, Patrick Fabere test, and decreased or painful internal rotation of the hip.
- All patients not meeting the inclusion criteria were replaced.
- Patients displaying any contra-indications to Cybex testing, such as severe pain, extremely limited range of motion and severe effusion were excluded (Davies, 1992:24).

3.8) ORTHOPEDIC TESTS

3.8.1) GAENSLEN'S TEST

Gaenslen's test is an indirect stress test for sacroiliac joint dysfunction. The test was performed with the patient in the supine position with his buttock on the affected side projecting over the edge of the examination bed. The patient was instructed to draw both knees up to his chest while the examiner stabilized the patient as the ipsilateral thigh was allowed to drop off the side of the table, thereby fully extending the hip. This maneuver stresses the ipsilateral sacroiliac joint. Pain in the sacroiliac joint suggested pathology of the joint (Reider, 1999: 195).

3.8.2) PATRICK FABERE TEST

This test was performed with the patient in the supine position, with the limb to be examined guided into a figure- four position with the ipsilateral ankle resting across the contralateral thigh, proximal to the knee joint. The examiner applied a downward pressure on the ipsilateral knee with one hand while providing counter- pressure with the other hand on the contralateral anterior superior iliac spine. This maneuver stresses the sacroiliac joint on the side being tested. Posterior hip pain was indicative of sacroiliac joint pathology (Reider, 1999: 195).

3.8.3) EXTENSION/ERICHSON'S TEST

The Extension / Erichson's test was performed with the patient in the prone position. The examiner placed one hand under the thigh above the knee on the suspected side and extends the hip. With the other hand the examiner pressed downward over the crest of the ilium on the same side. A positive test elicited pain in the sacroiliac joint to which the pressure was applied (Kirkaldy- Willis in Kirkaldy-Willis and Burton, 1992: 125).

3.8.4) POSTERIOR SHEAR TEST

The posterior shear test was performed with the patient in the supine position. The examiner flexed and slightly adducted the patient's hip and knee on the affected side of the sacroiliac dysfunction and applied a posterior shearing stress to the sacroiliac joint through the femur with the examiner's one hand under the sacroiliac joint. Pain in the sacroiliac joint was indicative of sacroiliac joint pathology (Laslett and Williams, 1994).

Once the diagnosis of sacroiliac syndrome was established, sacroiliac joint restrictions were identified utilizing the Gillet motion palpation procedure.

3.8.5) GILLET METHOD OF SACROILIAC JOINT MOTION PALPATION

The patient was seated while the examiner stressed the end feel in the upper and lower aspects of the sacroiliac joints, at the same time comparing the relative end feel with the contralateral side. When the end feel felt hard or blocked a joint restriction at that level was noted. If there was uncertainty as to the exact location of the manipulable lesion, a modification of the motion palpation procedure described by Bergmann *et al*. (1993:494) was used:

1. The patient was asked to stand whilst holding onto a support for balance.
2. The examiner stood behind the patient and placed a thumb contact on the patient's posterior superior iliac spine (PSIS) and the second or fourth sacral tubercle (depending on whether the joint restriction was suspected in the upper or lower aspect of the sacroiliac joint).
3. The patient was then asked to raise the ipsilateral leg to approximately 90 degrees thereby flexing the hip and sacroiliac joint.
4. With normal movement the examiners thumbs approximated as the PSIS moved posteriorly and inferiorly relative to the stationery sacral tubercle.
5. A flexion restriction was suspected when the thumbs did not approximate.
6. A similar procedure is done to detect an extension restriction, however raising the contra lateral leg. This induces posterior nodding of the sacral base and sacroiliac extension on the side of palpation. With normal movements the examiners thumbs move apart as the PSIS moves anteriorly and superiorly away from the sacral tubercle.

This was done by another examiner and not by the researcher to ensure blinding.

3.9) RESEARCH METHODOLOGY

A clinical evaluation included:

- Active hip range of motion testing using an inclinometer (Appendix K)
- Undergoing hip rotation range of motion testing using an Inclinometer in order to measure joint position sense (JPS) and thus proprioception of the hip joint. This was done pre- and post- treatment. (See appendix L).

Intervention:

In order to standardize the evaluations and treatments, all evaluations were done by the researcher and all treatments were done by a nominated person. This standardized each of them and ensured there was a blinding process.

Treatment A:

- Motion palpation of the sacroiliac joints and a sacroiliac manipulation

Treatment B:

- Motion palpation of the sacroiliac joints

The procedures for the patients are summarized on the accompanying table.

Week	**Visit**	**Group A**	**Group B**
0	0	Case history, physical and lumbar regional examination	Case history, physical and lumbar regional examination
	1	Cybex Clinical evaluation Treatment A Cybex Clinical evaluation	Cybex Clinical evaluation Treatment B Cybex Clinical evaluation
1	2	Treatment A	Treatment B
	3	Treatment A	Treatment B
	4	Clinical Evaluation Cybex ***CROSS OVER*** Treatment B Cybex Clinical evaluation	Clinical Evaluation Cybex ***CROSS OVER*** Treatment A Cybex Clinical evaluation
2	5	Treatment B	Treatment A
	6	Treatment B	Treatment A
3	7	Cybex Clinical Evaluation	Cybex Clinical Evaluation

3.10) OBJECTIVE MEASUREMENTS

To measure the objective outcomes the following was used.

1. The **Inclinometer** was used to measure changes in ***range of motion*** of the hip joint. According to Magee (1992:335) the normal range of motion of the hip joint is:
    - Flexion= 110-120 degrees
    - Extension= 10-15 degrees
    - Abduction=30-50 degrees
    - Adduction=30 degrees

    The inclinometer used in this study was the Dualer system of inclinometry (Jtech Medical industries 4314 Zevex Park lane, Salt lake city, UT 84123 USA, tel 801/264-1001). As a result of inclinometer insensitivity to placement, inclinometers are more accurate than goniometers for measuring range of motion of the large extremities (Livingston, 1992:3). (See appendix K for the measurement procedure).

2. **Hip proprioception** was assessed by means of measuring ***joint position sense*** of the hip joint pre- and post- treatment using an Inclinometer. In a study conducted by Deshpande *et al.* (2003) to determine the reliability and validity of ankle proprioceptive measures, results showed that joint position sense was a reliable tool for measuring proprioception, and that active movement was a reliable method for measuring joint position sense. (See appendix L for the steps taken to measure joint position sense.

3. The **Cybex Orthotron II isokinetic rehabilitation system** was used to establish whether a deviation from normal in the torque curve occurred in patients with sacroiliac joint syndrome before and after manipulation, and whether it remained same or changed after further treatments, thereby indicating whether restoration of functional ability had occurred or not (See appendix J for the Cybex protocol).

   It has been reported that research confirming the reliability and validity of the Cybex machine has been conducted (Davies, 1992: 35).

3.11) STATISTICS

The symptomatic patients were seen seven times. Objective measures (ROM, Proprioception and Cybex) were taken on visit one, four and seven. In this study there was a control group and a treatment group. Symptomatic patients randomly selected which group they went into. Group A was the treatment group and received treatment (a sacroiliac manipulation) on visit one, two and three. On visit four a cross over occurred and group A become the control group, receiving only a motion palpation for visit four, five and six. On visit seven only measurements were taken. Group B started off being the control group, receiving only a motion on visit one, two and three. On visit four they changed over into the treatment group and received treatment on visit four, five and six. Visit seven was only measurements.

The asymptomatic patients were seen only once. Objective measurements (ROM, Proprioception and Cybex) were taken during this visit to establish base line norms. These base line norms will be compared with the symptomatic population.

Data analysis was done in SAS version 9.1 (SAS Institute Inc., Cary, NC). Baseline comparisons between the categorical baseline variables and the group to which the participant was assigned were done using Fisher's exact test. Continuous baseline variables that were not normally distributed were compared between groups using a non-parametric Wilcoxon Mann-Whitney test. Continuous normally distributed baseline data were compared using the two sample t-test.

CHAPTER FOUR
RESULTS AND DISCUSSION OF RESULTS

4.1) INTRODUCTION

This chapter aims to present the results obtained through the statistical analysis of the primary data. The data utilized was collected exclusively from the forty symptomatic and twenty asymptomatic participants that fitted the inclusion and exclusion criteria of the study.

Primary data: This study looked only at objective data (Cybex and Inclinometer) to determine the effect of sacroiliac manipulation on objective hip measures (peak torque, ROM and proprioception).

Secondary data: As found in the literature pertinent to this study.

4.2) THE HYPOTHESES

At the outset of the study, four hypotheses were established.

- The first hypothesis stated that a norm exists with respect to the asymptomatic population in respect of Cybex dynamometry and inclinometry (ROM and proprioception).
- The second hypothesis stated that sacroiliac joint manipulation would be effective in blocking or slowing AMI.
- The third hypothesis stated that this blockage or slowing down of AMI and restoration of hip ROM would allow for restoration of the functional ability of the hip musculature, as measured by range of motion, joint position sense and torque ratios and
- The forth hypothesis stated that there is a correlation between the Cybex dynamometry and the objective clinical measures.

At the conclusion of this chapter these hypotheses will either be accepted or rejected based on the outcomes of the relevant statistical tests applied to the data.

4.3) THE DATA

Objective measurements regarding concentric-concentric isokinetic muscle strength of the hip (flexion, extension, abduction and adduction) were obtained by means of the Cybex Orthotron rehabilitation system. Objective measurements regarding ROM and proprioception were obtained by means of the Dualer system of inclinometry.

4.4) METHODS

Data analysis was done in SAS version 9.1 (SAS Institute Inc., Cary, NC). Baseline comparisons between the categorical baseline variables and the group to which the participant was assigned were done using Fisher's exact test. Continuous baseline variables that were not normally distributed were compared between groups using a non-parametric Wilcoxon Mann-Whitney test. Continuous normally distributed baseline data were compared using the two-sample t-test.

The follow-up measures were summarised according to the treatment received. The baseline measurement is the measurement for both groups of symptomatic patients at Visit 1 before they received any manipulation. The measurement immediately before and after the treatment and control is summarised, as well as the measurement at the beginning of the following phase. This measurement is regarded as an indication of the long-term effect of the previous treatment.

The immediate treatment effect was evaluated by getting the difference between the pre- and post-treatment values. The differences obtained in each of the periods of the cross-over design are then analysed using a repeated measures analysis of variance (ANOVA). There are three main issues to consider in a crossover trial, namely period, treatment, and group or carryover effects.

To determine whether the adjustment had a long-term effect in patients treated with the adjustment first (Group A), the readings were summarised for Group A only at pre-adjustment Visit 1 and at Visit 7. No statistical analysis was done on this, since the same datapoints did not exist for the control group.

The scores for flexors, extensors, abductors and adductors obtained on the Cybex Orthotron and by means of the Inclinometer (ROM) were correlated using Person's correlation coefficient. The scores for all visits were combined in the calculation of these coefficients.

4.5) RESULTS AND DISCUSSION

4.5.1) Baseline analysis

4.5.1.1) Continuous demographic data

	N	Mean	SD	Minimum	Median	Maximum	p-value
Age (years)							
Total symptomatic	40	32.7	6.36	25	31.5	45	0.2220[1]
Group A	20	31.3	5.31	25	31.0	43	
Group B	20	34.2	7.12	25	32.5	45	
Asymptomatic	20	32.9	6.44	25	32.5	45	
Weight (kg)							
Total symptomatic	40	76.1	16.03	49	75.5	115	0.0960[2]
Group A	20	71.9	15.24	54	69.5	115	
Group B	20	80.3	16.06	49	80.0	110	
Asymptomatic	20	77.6	18.7	45	79	125	

[1] Wilcoxon Mann-Whitney test for comparison between Group A and Group B of the symptomatic population

[2] t-test for independent groups for comparison between Group A and Group B of the symptomatic population

4.5.1.2) Categorical demographic data

		N	%	p-value
Race – Total symptomatic	Black	5	12.5	1.0000[1]
	White	26	65.0	
	Coloured/Indian	9	22.5	
Race – Group A	Black	3	15.0	
	White	13	65.0	
	Coloured/Indian	4	20.0	
Race – Group B	Black	2	10.0	
	White	13	65.0	
	Coloured/Indian	5	25	
Race – Asymptomatic	White	18	90	
	Coloured/Indian	2	10	
Gender – Total symptomatic	Male	20	50	1.0000[1]
	Female	20	50	
Gender – Group A	Male	10	50	

	Female	10	50	
Gender – Group B	Male	10	50	
	Female	10	50	
Gender – Asymptomatic	Male	10	50	
	Female	10	10	
Side treated – Total symptomatic	Left	19	47.5	1.000[1]
	Right	21	52.5	
Side treated – Group A	Left	10	50	
	Right	10	50	
Side treated – Group B	Left	9	45	
	Right	11	55	
Side tested – Asymptomatic	Left	10	50	
	Right	10	50	
Acute/Chronic– Total symptomatic	Acute	4	10	0.2592[1]
	Chronic	23	57.5	
	Acute on chronic	13	32.5	
Acute/Chronic – Group A	Acute	2	10.0	
	Chronic	9	45.0	
	Acute on chronic	9	45.0	
Acute/Chronic – Group B	Acute	2	10.0	
	Chronic	14	70.0	
	Acute on chronic	4	20.0	
SI syndrome – Total symptomatic	Bilateral	23	57.5	1.0000[1]
	Unilateral	17	42.5	
SI syndrome – Group A	Bilateral	11	55.0	
	Unilateral	9	45.0	
SI syndrome – Group B	Bilateral	12	60.0	
	Unilateral	8	40.0	

[1] Fisher's exact test for comparison between Group A and Group B of the symptomatic population

4.5.2) Comparison of symptomatic and asymptomatic groups

4.5.2.1) Joint position sense (Proprioception)

Summary of symptomatic and asymptomatic groups

	N	Mean	SD	Minimum	Median	Maximum
10 internal – asymptomatic	20	10.70	1.34	8.00	10.00	13.00
10 internal – symptomatic	40	11.73	2.06	8.00	11.00	17.00
20 internal – asymptomatic	20	19.90	2.71	10.00	20.00	24.00
20 internal – symptomatic	40	20.98	2.45	15.00	21.00	26.00
10 external – asymptomatic	20	11.15	2.43	9.00	10.00	20.00
10 external - symptomatic	40	11.80	2.90	6.00	11.50	18.00
20 external – asymptomatic	20	20.75	1.29	18.00	21.00	24.00
20 external - symptomatic	40	20.55	3.18	15.00	20.00	29.00

For all the measurements the median for the asymptomatic group was a normal value (10º or 20º), except for the 20º external rotation measurement, where the asymptomatic group has a median of 21º. For all the measurements the median for the symptomatic group was slightly above normal (11º, 21º or 11.5º), except for the 20º external rotation measurement, where the symptomatic group has a median of 20º, which is normal.

Patterson and Steinmetz (1986) in Leach (1994: 101) have found that with segmental dysfunction, as in sacroiliac syndrome, if the initiating stimulus is sufficient or lasts long enough there may be segmental facilitation even after this instigating stimulus is removed. Once this facilitation occurs, despite the removal of the afferent source of stimulation, the abnormal segmental reflex circuit itself participates in maintaining the symptoms (Leach, 1994: 101). This means that these abnormal segmental reflexes maintain the subject's abnormal position post the injury and removal of the instigating stimulus. This is shown in the above table where the proprioception of the symptomatic group has a mean that is greater than the mean for the asymptomatic group, indicating that the symptomatic group is not able to return to the normal position, therefore implying that the proprioceptive sensitivity has been disturbed.

4.5.2.2) Range of Motion

Summary of symptomatic and asymptomatic groups (Degrees)

	N	Mean	SD	Minimum	Median	Maximum
Flexion – asymptomatic	20	105.60	7.35	92.00	108.00	120.00
Flexion – symptomatic	40	98.33	13.16	45.00	101.00	119.00
Extension – asymptomatic	20	31.55	4.06	23.00	32.00	38.00
Extension – symptomatic	40	22.60	7.99	6.00	22.00	40.00
Abduction – asymptomatic	20	77.75	10.97	58.00	79.00	94.00
Abduction - symptomatic	40	72.30	13.58	35.00	75.00	93.00
Adduction – asymptomatic	20	12.85	2.11	10.00	12.00	18.00
Adduction – symptomatic	40	8.58	3.84	3.00	8.00	22.00
Internal – asymptomatic	20	43.45	7.95	33.00	41.00	57.00
Internal – symptomatic	40	43.83	10.05	27.00	42.50	66.00
External – asymptomatic	20	50.95	9.40	32.00	49.50	68.00
External – symptomatic	40	42.15	10.13	13.00	42.00	68.00

With the exception of the internal rotation measurements, the mean ROM was smaller for the symptomatic group than for the asymptomatic group.

Following injury to any pain sensitive structure of the spine, as in sacroiliac syndrome, there is reflex muscle spasm (Gatterman, 1995: 110) and hence the mean ROM being lower for the symptomatic group than for the asymptomatic group.

Cibulka (1998: 1009) states that problems with the sacroiliac joint have often been related to reduced or asymmetric ROM in the hip (flexion, extension, abduction, adduction, internal and external rotation). However, the study done by Cibulka (1998) aimed at assessing purely rotation asymmetries in patients with sacroiliac syndrome and found that patients with sacroiliac syndrome had more external rotation than internal rotation. In the present study the symptomatic patients had slightly more internal rotation than external rotation, this is in contrast to Cibulka (1998). Furthermore internal rotation measurements between symptomatic and asymptomatic patients indicate very little change, this is however in contrast to the hypothesis that with sacroiliac dysfunction, there is associated piriformis hypertonicity, which should indicate a decrease in the degree of internal rotation. LaBen *et al*. (1978) in Cibulka (1992: 917) found asymmetry in hip mobility with a reduction in abduction and external rotation in patients with sacroiliac dysfunction. If we analyse the results of this study abduction in the symptomatic group is significantly less than that of the asymptomatic group, as well as external rotation in the symptomatic group when compared to the asymptomatic group.

Kankaanpaa (1998) and Leinonen (2000) in Nadler *et al*. (2001: 533) demonstrated poor endurance in the Gluteus Maximus muscle in those with chronic low back pain (Nadler *et al.* 2001: 533). In support of his finding, when we look at the results of this study, extension in the symptomatic group is significantly less than when we compare it to the asymptomatic group.

These noted differences could be related to the fact that Cibulka (1998: 1013) raised in this respect – i.e. the differences and similarities in the stated range of motion, are attributed to the different methods for determining the endpoint of movement, to different patient populations and to whether motion was active or passive (Cibulka, 1998: 1013). Therefore it would seem that these parameters are not easily measured between research studies unless the exact method of measure is indicated.

4.5.2.3) Cybex Dynamometry

Summary of symptomatic and asymptomatic groups – Peak torque (Nm)

	N	Mean	SD	Minimum	Median	Maximum
Flexors – asymptomatic	20	80.30	35.77	34.00	77.00	167.00
Flexors – symptomatic	40	75.93	37.25	14.00	64.00	160.00
Extensors – asymptomatic	20	105.45	67.03	40.00	90.50	314.00
Extensors – symptomatic	40	109.00	59.49	29.00	83.00	260.00
Abductors –asymptomatic	20	60.40	24.50	20.00	61.00	105.00
Abductors - symptomatic	40	63.70	35.30	17.00	58.00	151.00
Adductors –asymptomatic	20	58.70	37.40	16.00	43.00	131.00
Adductors – symptomatic	40	59.50	41.17	8.00	49.00	170.00

For flexors, extensors and abductors, the symptomatic group had lower median measurements than the asymptomatic group. For adductors, the symptomatic group had a higher median measurement than the asymptomatic group.

With regards to the decreased peak torque, in the symptomatic sacroiliac syndrome, nociceptors which make up most of the joint (Sakamoto *et al*. 2001: 470) are activated, which in turn act on inhibitory interneurons that synapse with the motor neuron pool of the muscles of the joint (Hip muscles fall within the sacroiliac joints motor neuron pool, Moore, 1992 and Gray's anatomy, 1995: 870-879). These inhibitory interneurons relay information that impedes the recruitment ability of the motor neuron pool (Ingersoll, Palmieri and Hopkins, 2003). This failure to activate all motor neurons of a muscle during maximal voluntary effort has been termed AMI. One could conclude in symptomatic sacroiliac syndrome, AMI is present which results in a failure to activate all motor units, resulting in a reduction of motor neuron recruitment (Ingersoll, Palmieri and Hopkins, 2003) and hence the force of any contraction governed by that motor neuron pool is reduced and AMI is clinically manifested as a decrease in muscle strength. This would therefore support the findings of this study except for the median peak torque for the movement of adduction in the symptomatic group, which is slightly higher than the asymptomatic group. A possible reason for this could be related to the compensatory position of the patient when taking the reading, where the compensation and utilisation of different muscle groups would be related to the position of most pain.

4.5.3) Follow-up over time

The N for each entry in each table in this section is 40 and is not included in every table.

4.5.3.1) Cybex Dynamometry

4.5.3.1.1) FLEXORS: Peak torque (Nm)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	75.9	37.25	14	64.0	160
Immediately pre-adjustment	79.0	41.20	14	65.0	168
Immediately post-adjustment	80.3	40.78	33	69.0	182
Long after adjustment*	77.0	39.19	34	59.0	182
Immediately pre-control	74.9	34.12	36	60.5	158
Immediately post-control	75.7	36.17	29	59.5	142
Long after control*	80.0	41.60	20	63.5	168

* These measurements were taken at the beginning of the following cross-over period.

The flexors measurements increased slightly during treatment as shown by the mean immediately pre-adjustment score that increased from 79.0 Nm to 80.3 Nm immediately post-adjustment. It would not seem as if this improvement was sustained, since the flexors long after the adjustment was 77.0 Nm, which is even lower than the pre-adjustment score. A slight mean increase in flexors was also observed from immediately pre-control to immediately post-control.

Spinal manipulation has been shown to effectively reduce AMI in the Quadriceps muscle group (Suter *et al.* 1999). It has been proposed that manipulation results in activation of mechanoreceptors and proprioceptors within and around the manipulated joint (Suter *et al*. 2000). The altered afferent input arising from the joint stimulation causes changes in motor neuron excitability (Suter *et al*. 2000) thereby causing an increase in motor unit recruitment and a decrease in AMI (Suter *et al*. 2000). As mentioned above a decrease in AMI should result in an increase in muscle strength, hence the increase in flexor strength immediately following the adjustment. The flexor reading long after adjustment (this reading was taken before the cross-over) decreased, a possible explanation for this could be explained using the Patterson-Steinmetz model (1986) in Leach (1994: 100). When one looks at this model, one can see the possibility exists that a “neural scar” could develop as a

result of chronic low back pain or pain sustained over a period of time. The development of this “neuronal scar” indicates that the pathological reflexes that have been “learned” by the patient become ingrained in the patients neural system and therefore difficult to remove by means of an intervention. It would therefore appear that the patients presenting to this study seemed to revert back to the learned neural patterns at the long after adjustment stage indicating that a short period of treatment (3 adjustments) is not enough to break the pathological pattern of neural firing (Patterson-Steinmetz (1986) in Leach (1994: 100). However, although this theory is possible it is unlikely in this study because although the measurements decreased long after the adjustment, the measurements at the final visit increased again, showing that the patients did in fact improve.

Therefore, a more plausible explanation could be due to the fact that patients experienced some post adjustment stiffness and that resulted in a decrease in the long after adjustment reading (this was taken before the cross-over but 1-2 days after the last adjustment, hence the post adjustment stiffness may still have been present).

Another possible explanation is that the immediate effects of a manipulation are of reflex origin (Swenson in Halderman, 1992: 110) and this reflex effect is dependant on reflex neurological responses, which do not necessarily continue past the immediate effect. This is supported by Kuntz (1945) in Leach (1994:305), where the theory of immunity is explained. It is stated that immediately after the antigen is injected there is production of immune substances, representing a reflex secretory reaction and that an immune reaction, once initiated may continue in the absence of nervous influences. This can be related to spinal manipulation as well, where the immediate effect is reflex and thereafter the effects continue even though no intervention is given (referred to as continued physiological effects).

The readings during the control period increased slightly even though no intervention was applied. This could possibly be due to the motion palpation of the sacroiliac joints stimulating cutaneous receptors. Tactile sensation can be described as simple touch (which includes light touch, touch pressure and crude localization) and tactile

discrimination (which includes deeper pressure and spatial localization) (Darby and Daley in Cramer and Darby, 1995: 253).
In line with this another possible reason (if the patients started in group A) is that the spinal dysfunction has now been corrected and therefore eliminates the ongoing pathological reflexes that had developed as a result of segmental facilitation (Swenson in Halderman, 1992: 110).

4.5.3.1.2) Immediate effect of adjustment on flexors

Average change from pre- to post flexor reading (Nm)

	Mean	SD	Minimum	Median	Maximum
Adjustment (post- pre)	1.3	13.82	-46	0.5	35
Control (post-pre)	0.8	14.90	-35	-1.0	45

This shows a larger increase in the flexor measurements when the adjustment is done than when the control is done.

This could be explained by Korr's theory (1975) in Leach (1994: 99) whereby a manipulation can relax muscle spasm by two mechanisms.

- Firstly stretching intrafusal fibres would produce a barrage of afferent impulses intense enough to signal the central nervous system to reduce the gamma motorneuron discharge.
- Secondly, the golgi tendon organs would be stimulated by forced stretch of the skeletal muscles causing both alpha and gamma motorneuron inhibition. Therefore, by relaxing the hamstring muscle spasm by the above theory, it would allow for greater flexion.

It has also been hypothesised that immediate effects of a manipulation are of reflex origin, whereas the more sustained changes may represent correction of spinal dysfunction, thereby eliminating ongoing pathologic reflexes (Swenson in Halderman, 1992: 110), hence the increase noted during the control period. This is further explained using the immune theory under 4.5.3.1.1. This increase could also be related to tactile stimulation as explained under 4.5.3.1.1.

Repeated measures ANOVA

Effect	p-value
Period	0.0858
Treatment (group*period)	0.8779
Group (order of treatments)	0.3827

Flexors did not show a significant period, treatment or group effect. The carryover effect is the same as the effect for group, thus there was no carryover effect for flexors from the one period to the other.

As stated before immediate effects of manipulation are of reflex origin (Swenson in Halderman, 1992) and this reflex effect is dependent on reflex neurological responses, which do not necessarily continue past the immediate effect.

The period effect is noted to be almost significant and perhaps a time differential would alter this or a larger sample size, which would create greater homogeneity between patients.

4.5.3.1.3) Delayed effect of adjustment on flexors

Average change from pre-visit reading to the reading at the following visit (Nm)

	Mean	**SD**	**Minimum**	**Median**	**Maximum**
Adjustment (post- pre)	-2.0	17.44	-49	-1.5	32
Control (post-pre)	5.1	17.72	-35	1.5	53

This shows a decrease in the flexor reading over a long time for the adjustment and an increase over a long time for the control.
This may be explained using the Patterson-Steinmetz model (1986) in Leach (1994: 100). When one looks at this model, one can see the possibility exists that a “neural scar” could develop as a result of chronic low back pain or pain sustained over a period of time. The development of this “neuronal scar” indicates that the pathological reflexes that have been “learned” by the patient become ingrained in the patients neural system and therefore difficult to remove by means of an intervention.

Another possibility is once again the patient may have developed post adjustment stiffness resulting in a decrease in the reading long after the adjustment and an

increase during the control period (once the stiffness has worn off and the effects of the adjustment are taking place).

A further possibility is that the reflex effect of the manipulation doesn't necessarily last after the immediate effect, as explained under 4.5.3.1.1, other effects start to take place.

The increase noted in the control period may be once again due to tactile stimulation or if they started in group A, correction of the segmental dysfunction, as explained under 4.5.3.1.1.

Repeated measures ANOVA

Effect	**p-value**
Period	0.8365
Treatment (group*period)	0.0929
Group (order of treatments)	0.7874

Flexors did not show a significant period, treatment or group effect over a longer period of time.

The treatment effect is noted to be almost significant and perhaps a larger sample size, which would create greater homogeneity between patients, would alter the significance of the results.

4.5.3.1.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, Flexors (Nm)

	Mean	**SD**	**Minimum**	**Median**	**Maximum**
Visit 1 (pre-adjustment)	71.30	35.42	14.00	64.00	160.00
Visit 7	73.40	36.81	36.00	58.50	164.00

The mean reading at Visit 7 was higher than at Visit 1, indicating that the patients continued to improve over time.

This tells us the time effects of an adjustment and that it continues to have an effect over time. As stated before, with segmental dysfunction, segmental facilitation

occurs, resulting in abnormal segmental reflex circuits (Patterson and Steinmetz (1986) in Leach, 1994). However, with a manipulation the immediate effects are reflex in origin and the sustained changes are due to the fact that the spinal dysfunction is corrected and therefore it eliminates these ongoing pathologic reflexes (Swenson in Halderman, 1992) resulting in the sustained effects as seen in the final reading.

4.5.3.2.1) EXTENSORS

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	109.0	59.49	29	83	260
Immediately pre-adjustment	118.2	69.954	29	88.5	319
Immediately post-adjustment	125.3	73.829	41	106.5	351
Long after adjustment*	122.3	70.253	43	102.5	322
Immediately pre-control	112.7	57.461	46	104.5	260
Immediately post-control	112.4	59.274	41	93	300
Long after control*	123.0	70.518	41	102	319

* These measurements were taken at the beginning of the following cross-over period.

Extensors - Peak torque (Nm)

The extensor measurements increased during treatment as shown by the mean immediately pre-adjustment score that increased from 118.2 Nm to 125.33 Nm immediately post-adjustment. This improvement was somewhat sustained, since the extensors long after the adjustment was 122.33 Nm, which is higher than the value immediately pre-adjustment. The immediately pre- and post-control mean values are almost identical, while the mean long after control is higher than the mean immediately pre-control.

The extensors demonstrate a similar pattern to the flexors; therefore the same comments are applicable as per 4.5.3.1.1.

The measurements immediately pre-control to immediately post-control decrease minimally, this is however in contrast to the theories of cutaneous receptor stimulation and continuous physiological reflexes. However, the reading long after control increases again showing that the continuous physiological reflexes did have an effect but at a later stage. We can still conclude that the adjustment had an effect

in breaking the pathological reflex cycle, hence the decrease in AMI and the increase in muscle strength at the final reading.

4.5.3.2.2) Immediate effect of adjustment on extensors

Average change from pre- to post-extensor reading (Nm)

	Mean	SD	Minimum	Median	Maximum
Adjustment (post- pre)	7.13	25.484	-62	-7	66
Control (post-pre)	-0.28	28.029	-66	-3	66

The above results show an increase in the extensor reading during the adjustment period, this follows a similar pattern to the flexors as explained under 4.5.3.1.2. and a minimal decrease during the control period as explained under 4.5.3.2.1.

Repeated measures ANOVA

Effect	p value
Period	0.9248
Treatment (group*period)	0.1678
Group (order of treatments)	0.1196

Extensors did not show a significant treatment, period or group effect.

4.5.3.2.3) Delayed effect of adjustment on extensors

Average change from pre visit reading to the reading at the following visit (Nm)

	Mean	SD	Minimum	Median	Maximum
Adjustment (post- pre)	4.13	39.379	-147	10.5	76
Control (post-pre)	10.35	38.632	-93	4	139

A mean increase in the extensor readings in both treatments is noted, with a larger mean increase in the control group, indicating a delayed effect.

This could be explained by the fact that during the treatment the patients may have experienced some post adjustment stiffness, hence the smaller increase in the readings during the treatment period. Also possibly due to the reflex effect not being sustained, as explained under 4.5.3.1.1. The readings increased during the control possibly due to cutaneous receptor stimulation as well as the fact that the spinal

dysfunction has now been corrected and therefore the pathologic reflexes are now eliminated (if the patients started in group A), as per 4.5.3.1.1.

Repeated measures ANOVA

Effect	**p-value**
Period	0.2591
Treatment (group*period)	0.5290
Group (order of treatments)	0.5195

Extensors did not show a significant period, treatment or group effect.
Perhaps a larger sample size, which would create greater homogeneity between patients, would alter the significance of the results.

4.5.3.2.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, Extensors (Nm)

	Mean	**SD**	**Minimum**	**Median**	**Maximum**
Visit 1 (pre-adjustment)	103.45	57.02	29.00	79.50	206.00
Visit 7	113.05	60.52	52.00	102.00	307.00

The mean reading at Visit 7 was higher than at Visit 1, indicating that the patients continued to improve over time.
This once again tells us the time effects of an adjustment and the fact that the adjustment lasted, this is explained under 4.5.3.1.4.

4.5.3.3.1) ABDUCTORS

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	63.70	35.304	17	58.0	151
Immediately pre-adjustment	67.13	36.647	17	60.0	161
Immediately post-adjustment	71.20	32.633	24	64.5	150
Long after adjustment*	70.33	34.930	30	66.0	166
Immediately pre-control	65.48	31.402	22	58.0	137
Immediately post-control	67.20	35.273	26	59.5	154
Long after control*	68.08	33.261	29	58.5	161

* These measurements were taken at the beginning of the following cross-over period.

Abductors - Peak torque (Nm)

The abductor measurements increased during treatment as shown by the mean immediately pre-adjustment score that increased from 67.1 Nm to 71.2 Nm immediately post-adjustment. The abductor measurement also increased in the control period but to a lesser extent (from 65.5 Nm to 67.2 Nm). This improvement was somewhat sustained, since the abductor long after the adjustment was 70.3 Nm, which is higher than the value immediately pre-adjustment.

This follows a similar pattern to the flexors and extensors and supports the theories that were reflected in this respect before under 4.5.3.1.1 and 4.5.3.2.1.

4.5.3.3.2) Immediate effect of adjustment on abductors

Average change from pre- to post abductor reading (Nm)

	Mean	SD	Minimum	Median	Maximum
Adjustment (post- pre)	4.08	9.736	-21	5.0	25
Control (post-pre)	1.73	9.468	-22	1.5	26

Results show a mean increase in the abductor readings when the adjustment and control is done; the increase is larger when the adjustment is done than when the control is done.

This follows a similar pattern to the flexors explained under 4.5.3.1.2 and 4.5.3.2.2. The mean increase in the abduction and adduction readings is lower than the extensor readings. This could be due to the fact that the flexor – extensors work around the x-axis of the sacroiliac joint therefore the improvement would be greater than when compared to the adductor / abductor muscle group which does not work around the same axis and therefore has a decreased effect on the sacroiliac joint. However, this is not true for flexion, where the mean increase is less than abduction and adduction. This may however be related to both the stretch reflex as well as the manipulation reflex effects that make the effect greater on the extensors, where this is not present for the flexors (other than the manipulation reflexes).

Furthermore the abductors should increase greater than the adductors as the innervation of the abductors in more correlated with the innervation of the SI than the adductors; however this is in contrast to the results obtained.

Another fact to consider would be that if the axis of rotation around which the muscle activity is tested is not optimal for both muscle groups, then it becomes a problem for one or both muscles, where one muscle shows a marked improvement as it is in a mechanically advantageous position whereas the other is in a mechanically disadvantageous position. This could result in one muscle reporting higher gains than another, when they should be equal in response or in the inverse.

Repeated measures ANOVA

Effect	**p-value**
Period	0.0905
Treatment (group*period)	0.2770
Group (order of treatments)	0.9074

Abductors did not show a significant period, treatment or group effect.
Perhaps a larger sample size, which would create greater homogeneity between patients, would alter the significance of the results.

4.5.3.3.3) Delayed effect of adjustment on abductors

Average change from pre visit reading to the reading at the following visit (Nm)

	Mean	SD	Minimum	Median	Maximum
Adjustment (post- pre)	3.20	13.762	-24	-1.0	45
Control (post-pre)	2.60	12.526	-26	1.0	44

An increase in the abductor readings in both adjustment and control is shown above, with a slightly larger increase when the adjustment is done.

The increase during the control period is explained under 4.5.3.1.2.

The increase during the adjustment period is explained by Korr's theory (1975) under 4.5.3.1.2. The increase is smaller for abduction than extension as explained under 4.5.3.3.2.

Repeated measures ANOVA

Effect	p-value
Period	0.1214
Treatment (group*period)	0.8374
Group (order of treatments)	0.1860

Abductors did not show a significant period, treatment or group effect over a longer period. Perhaps a larger sample size, which would create greater homogeneity between patients, would alter the significance of the results.

4.5.3.3.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, Abductors (Nm)

	Mean	SD	Minimum	Median	Maximum
Visit 1 (pre-adjustment)	62.60	35.21	17.00	57.00	151.00
Visit 7	64.50	27.75	30.00	56.00	140.00

The readings at Visit 7 were higher than at Visit 1, indicating that the patients continued to improve over time.

Showing that the adjustment lasted, explained under 4.5.3.1.4.

4.5.3.4.1) ADDUCTORS

Adductors - Peak torque (Nm)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	59.50	41.174	8	49.0	170
Immediately pre-adjustment	63.60	42.498	8	54.5	183
Immediately post-adjustment	69.83	41.413	13	62.0	179
Long after adjustment*	71.83	41.103	19	64.5	206
Immediately pre-control	63.20	37.142	9	53.0	170
Immediately post-control	65.43	36.734	11	59.0	150
Long after control*	71.88	39.431	17	61.5	183

* These measurements were taken at the beginning of the following cross-over period.

The adductor measurements increased during treatment as shown by the mean immediately pre-adjustment score that increased from 63.6 Nm to 69.8 Nm immediately post-adjustment. The adductor measurement also increased in the control period, but to a lesser extent (from 63.2 Nm to 65.4 Nm). This improvement was sustained, since the mean adductor readings long after the adjustment and control were 71.8 Nm and 71.9 Nm, respectively, which is higher than the value immediately pre-adjustment and pre-control.

Adductors show a slightly different pattern to the flexors, extensors and abductors because the measurement long after the adjustment was higher than the previous reading whereas in the others it decreased slightly. One could possibly state that:

- post adjustment stiffness affects adduction to a lesser extent than flexion, extension and abduction.
- the adduction movement improves faster than the others.

Another possible reason is that if the axis of rotation around which the muscle activity is tested is not optimal for both muscle groups, then it becomes a problem for one or both muscles, where one muscle shows a marked improvement as it is in a mechanically advantageous position whereas the other is in a mechanically

disadvantageous position. This could result in one muscle reporting higher gains than another, when they should be equal in response or in the inverse.

4.5.3.4.2) Immediate effect of adjustment on adductors

Average change from pre- to post-adductor reading (Nm)

	Mean	SD	Minimum	Median	Maximum
Adjustment (post- pre)	6.23	9.286	-20	5.5	30
Control (post-pre)	2.23	10.334	-20	2.0	27

This shows an increase in the adductor readings for both treatments, although the increase was larger when the adjustment was done. This follows a similar pattern to the flexors, extensors and abductors and is explained under 4.5.3.1.2.

The increase here is much higher than the abductors possibly due to the axis of rotation around which the muscle activity is tested is not optimal for both muscle groups, then it becomes a problem for one or both muscles, where one muscle shows a marked improvement as it is in a mechanically advantageous position whereas the other is in a mechanically disadvantageous position. This could result in one muscle reporting higher gains than another, when they should be equal in response or in the inverse.

Repeated measures ANOVA

Effect	p value
Period	0.5362
Treatment (group*period)	0.0825
Group (order of treatments)	0.1022

Adductors did not show a significant period, treatment or group effect. Perhaps a larger sample size, which would create greater homogeneity between patients, would alter the significance of the results.

4.5.3.4.3) Delayed effect of adjustment on adductors

Average change from pre visit reading to the reading at the following visit (Nm)

	Mean	SD	Minimum	Median	Maximum
Adjustment (post- pre)	8.23	19.413	-31	7	68
Control (post-pre)	8.68	14.628	-42	9	40

The improvement in adductors was sustained on both treatments.
The improvement here is much higher than the abductors, explained under 4.5.3.4.2.

Repeated measures ANOVA

Effect	p-value
Period	0.7724
Treatment (group*period)	0.9202
Group (order of treatments)	0.9139

Adductors did not show a significant period, treatment or group effect over a longer period. Perhaps a larger sample size, which would create greater homogeneity between patients, would alter the significance of the results.

4.5.3.4.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, Adductors (Nm)

	Mean	SD	Minimum	Median	Maximum
Visit 1 (pre-adjustment)	56.60	37.97	8.00	46.00	129.00
Visit 7	73.15	32.02	32.00	63.50	143.00

The readings at Visit 7 were higher than at Visit 1, indicating that the patients continued to improve over time. The effects of the adjustment were sustained as explained under 4.5.3.1.4.

4.5.4.1) Range of Motion

4.5.4.1.1) FLEXION

Flexion (degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	98.33	13.16	45.00	101.00	119.00
Immediately pre-adjustment	97.70	13.30	45.00	99.50	119.00
Immediately post-adjustment	100.33	12.09	72.00	102.00	125.00
Long after adjustment*	102.53	13.25	75.00	104.00	135.00

Immediately pre-control	101.00	11.97	76.00	103.00	122.00
Immediately post-control	100.33	13.12	71.00	102.00	130.00
Long after control*	102.35	11.82	67.00	104.00	120.00

* These measurements were taken at the beginning of the following cross-over period.

The flexion measurements increased during treatment as shown by the mean immediately pre-adjustment score that increased from 97.7 degrees to 100.3 degrees immediately post-adjustment. This improvement was sustained, since the flexion reading long after the adjustment was 102.5 degrees, which is higher than the value immediately pre-adjustment. The flexion measurement decreased slightly in the control period.

The readings increased with each adjustment this is in accordance with Korr's theory (1975) in Leach (1994:99) that an adjustment relaxes muscle spasm, explained under 4.5.3.1.2. The readings long after the adjustment also increased, this is in contrast to the results of the Cybex where the readings long after the adjustment decreased. It was believed that the Cybex readings decreased long after the adjustment because of post adjustment stiffness affecting the isokinetic results. This may also be the case for ROM, but because the patient didn't have any resistance while performing ROM as they did with the Cybex, the post adjustment stiffness may not have influenced the ROM results as it was suggested to have done with the Cybex. It could also be possible that the adjustment had a greater effect on ROM than it did on AMI and that once muscle spasm had been alleviated it remained that way.

The final readings increased showing the adjustment effects, causing a decrease in muscle spasm, lasted, as explained under 4.5.3.1.4.

4.5.4.1.2) Immediate effect of adjustment on flexion

Average change from pre- to post-flexion reading (degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Adjustment (post-pre)	2.63	6.93	-12.00	2.50	27.00
Control (post-pre)	-0.68	6.67	-19.00	0.00	14.00

The results show an increase in the flexion when the adjustment is done, and a slight decrease when the control is done. The increase during the adjustment period is

explained under 4.5.3.1.2. The slight decrease during the control period follows a similar pattern to the extensors and is explained under 4.5.3.2.1.

Repeated measures ANOVA

Effect	**p-value**
Period	0.3843
Treatment (group*period)	0.0256
Group (order of treatments)	0.1584

Flexion showed a significant treatment effect and we can conclude that the adjustment made a significant change to the flexion score. There was no effect of the period or group. The carryover effect is the same as the effect for group, thus there was no carryover effect for flexion from the one period to the other.
The significant treatment effect observed shows that the results improved closer to the intervention. This would support the presence of an immediate reflex effect or neurological response to the intervention alleviating the muscle spasm as opposed to a physiological response leading to and maintaining the effect seen.

4.5.4.1.3) Delayed effect of adjustment on flexion

Average change from pre visit reading to the reading at the following visit (degrees)

Visit	**Mean**	**SD**	**Minimum**	**Median**	**Maximum**
Adjustment (post-pre)	4.83	10.46	-14.00	5.50	40.00
Control (post-pre)	1.35	8.83	-21.00	1.00	25.00

This shows an increase in the flexion readings in both treatments, with a larger increase when the adjustment is done. This is in congruence with the theory explained under 4.5.3.1.1 and 4.5.3.1.2 that the effects continue after the initial reflex effect even in the absence of an intervention.

Repeated measures ANOVA

Effect	**p-value**
Period	0.1761
Treatment (group*period)	0.4155

Group (order of treatments)	0.0739

Flexion did not show a significant period, treatment or group effect over a longer period. Perhaps a larger sample size, which would create greater homogeneity between patients, would alter the significance of the results.

4.5.4.1.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, Flexion (degrees)

	Mean	SD	Minimum	Median	Maximum
Visit 1 (pre-adjustment)	96.35	14.81	45.00	98.50	119.00
Visit 7	105.65	11.13	82.00	109.50	120.00

The readings at Visit 7 were higher than at Visit 1, indicating that the patients continued to improve over time. The results increased immediately following the adjustment due to the reflex response to the adjustment. The continued physiological response kicked in after the reflex response and maintained the effects even though no intervention was given. The increase in readings may be due to either the restored motion in the sacroiliac joint or by the increased ability of the now non-hypertonic muscles to contract or a combination of the two. Thus it would seem that the increased motion due to decreased spasm or restored motion is maintained after the spasm has been alleviated.

4.5.4.2.1) EXTENSION

Extension (degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	22.60	7.99	6.00	22.00	40.00
Immediately pre-adjustment	22.65	8.63	6.00	23.00	40.00
Immediately post-adjustment	26.15	7.10	11.00	27.50	42.00
Long after adjustment*	28.20	7.82	11.00	29.00	42.00
Immediately pre-control	24.70	8.25	11.00	24.00	42.00
Immediately post-control	25.48	7.24	11.00	24.00	40.00
Long after control*	24.15	7.40	7.00	24.00	37.00

* These measurements were taken at the beginning of the following cross-over period.

The extension measurements increased during adjustment as shown by the mean immediately pre-adjustment score that increased from 22.7 degrees to 26.2 degrees immediately post-adjustment. The extension measurement increased slightly during the control period, from 24.7 degrees to 25.5 degrees. This improvement was sustained, since the extension long after the adjustment was 28.2 degrees, which is higher than the value immediately pre-adjustment.

The extensor measurements during the adjustment period followed a similar pattern to the flexors and therefore we use the same theories to explain this, see 4.5.4.1.1.

In the control group, the measurements went up slightly indicating the tactile stimulation again and possible latent effects of the adjustment, as explained under 4.5.3.1.1.

4.5.4.2.2) Immediate effect of adjustment on extension

Average change from pre- to post extension reading

Visit	Mean	SD	Minimum	Median	Maximum
Adjustment (post-pre)	3.50	5.31	-10.00	2.50	13.00
Control (post-pre)	0.78	2.99	-7.00	1.00	8.00

This shows a larger increase in the extension reading when the adjustment is done than when the control is done, this is explained under 4.5.3.1.2.

Repeated measures ANOVA

Effect	p-value
Period	0.1114
Treatment (group*period)	0.0046
Group (order of treatments)	0.6063

Extension showed a significant treatment effect. There was no effect of the periods or groups. The carryover effect is the same as the effect for group, thus there was no carryover effect for extension from the one period to the other. We can conclude that the adjustment made a significant change to the extension score.
The significant treatment effect may be as a result of the reflex effect immediately following the adjustment, as explained under 4.5.3.1.1.

4.5.4.2.3) Delayed effect of adjustment on extension

Average change from pre visit reading to the pre reading at the following visit

Visit	Mean	SD	Minimum	Median	Maximum
Adjustment (post-pre)	5.55	9.07	-22.00	4.50	29.00
Control (post-pre)	-0.55	5.53	-14.00	1.00	9.00

The extension measurement long after the adjustment increased, as explained under 4.5.3.1.2, and a minimal decrease in the long after the control reading, however this reading was still greater that the initial baseline reading, showing that the adjustment did have an effect.

Repeated measures ANOVA

Effect	p-value
Period	0.7233
Treatment (group*period)	0.0036
Group (order of treatments)	0.1467

Extension showed a significant sustained treatment effect, this could mean that the extension effect is perpetuated into normalcy by increased ROM at the sacroiliac joint or by the increased ability of a non-hypertonic muscle to contract. There was no effect of the periods or groups. We can conclude that the adjustment made a significant change over a longer time to the extension score.

4.5.4.2.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, Extension (degrees)

	Mean	SD	Minimum	Median	Maximum
Visit 1 (pre-adjustment)	22.50	9.30	6.00	20.50	40.00
Visit 7	25.50	6.48	14.00	24.00	36.00

The readings at Visit 7 were higher than at Visit 1, indicating that the patients continued to improve over time, this is explained under 4.5.4.1.4.

4.5.4.3.1) ABDUCTION

Abduction (degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	72.30	13.58	35.00	75.00	93.00
Immediately pre-adjustment	70.23	13.42	30.00	73.50	87.00
Immediately post-adjustment	75.80	11.40	48.00	78.00	97.00
Long after adjustment*	75.33	15.61	17.00	78.50	99.00
Immediately pre-control	75.43	12.99	48.00	77.50	99.00
Immediately post-control	74.85	13.61	46.00	78.00	98.00
Long after control*	74.45	15.11	30.00	78.00	97.00

* These measurements were taken at the beginning of the following cross-over period.

The abduction measurements increased during adjustment as shown by the mean immediately pre-adjustment score that increased from 70.2 degrees to 75.8 degrees immediately post-adjustment. The abduction measurement decreased slightly in the control period. This improvement was sustained, since the abduction long after the adjustment was 75.3 degrees, which is higher than the value immediately pre-adjustment.

The measurements immediately after the manipulation increased, this is in congruence with the theory explained under 4.5.3.1.1. The reading long after adjustment decreases slightly from the previous reading, which follows a different pattern to flexion and extension; however, it is still higher than the initial reading. A possible explanation can be due to the theory described by the Patterson-Steinmetz model (1986) in Leach (1994) under 4.5.3.1.3.

4.5.4.3.2) Immediate effect of adjustment on abduction

Average change from pre- to post-abduction reading

Visit	Mean	SD	Minimum	Median	Maximum

Adjustment (post-pre)	5.58	8.27	-6.00	5.00	27.00
Control (post-pre)	-0.58	5.99	-11.00	-1.00	14.00

There is a large increase in the abduction reading when the adjustment is done, as explained under 4.5.3.1.2 and a small decrease when the control is done, as explained under 4.5.3.2.1.

Repeated measures ANOVA

Effect	**p-value**
Period	0.4764
Treatment (group*period)	0.0002
Group (order of treatments)	0.8230

Abduction showed a significant treatment effect. There was no effect of the periods or groups. The carryover effect is the same as the effect for group, thus there was no carryover effect for abduction from the one period to the other. We can conclude that the adjustment made a significant change to the abduction score. The significant treatment effect may be as a result of the reflex effect immediately following the adjustment, as explained under 4.5.3.1.1.

4.5.4.3.3) Delayed effect of treatment on abduction

Average change from pre visit reading to the reading at the following visit

Visit	**Mean**	**SD**	**Minimum**	**Median**	**Maximum**
Adjustment (post-pre)	5.10	16.68	-70.00	6.00	25.00
Control (post-pre)	-0.98	10.55	-24.00	-0.50	27.00

The results show a large increase in the abduction reading when the adjustment is done, as explained under 4.5.3.1.1 and a small decrease when the control is done, as explained under 4.5.4.2.3.

Repeated measures ANOVA

Effect	**p-value**
Period	0.5721
Treatment (group*period)	0.0955
Group (order of treatments)	0.1045

Abduction did not show a significant period, treatment or group effect over a longer period, perhaps a larger sample size would alter the significance of the results.

4.5.4.3.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, Abduction (degrees)

	Mean	SD	Minimum	Median	Maximum
Visit 1 (pre-adjustment)	70.55	14.26	35.00	74.50	86.00
Visit 7	79.00	16.09	42.00	86.50	97.00

The readings at Visit 7 were higher than at Visit 1, indicating that the patients continued to improve over time. As explained under 4.5.4.1.4.

4.5.4.4.1) ADDUCTION

Adduction (degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	8.58	3.84	3.00	8.00	22.00
Immediately pre-adjustment	8.53	3.82	3.00	8.00	22.00
Immediately post-adjustment	9.65	3.56	5.00	9.00	22.00
Long after adjustment*	9.98	3.64	4.00	9.00	22.00
Immediately pre-control	8.93	3.50	4.00	8.50	19.00
Immediately post-control	9.05	3.62	3.00	8.50	18.00
Long after control*	9.03	3.71	4.00	8.00	20.00

* These measurements were taken at the beginning of the following cross-over period.

The adduction measurement increased during the adjustment and control period, but the change was larger during the adjustment period than during the control period. The increase was sustained for both adjustment and control.
This follows a similar pattern to the flexors and extensors and the possible theory is explained under 4.5.4.1.1.

4.5.4.4.2) Immediate effect of adjustment on adduction

Average change from pre- to post adduction reading

Visit	Mean	SD	Minimum	Median	Maximum
Adjustment (post-pre)	1.13	2.13	-6.00	1.00	8.00

Control (post-pre)	0.13	1.22	-4.00	0.00	3.00

This shows a large increase in the adduction reading when the adjustment is done, and a small increase when the control is done, as explained under 4.5.3.1.2.

Repeated measures ANOVA

Effect	**p-value**
Period	0.5740
Treatment (group*period)	0.0291
Group (order of treatments)	0.5532

Adduction showed a significant treatment effect. There was no effect of the periods or groups. The carryover effect is the same as the effect for group, thus there was no carryover effect for adduction from the one period to the other. We can conclude that the adjustment made a significant change to the adduction measurement. The treatment effect may be a result of the reflex effect immediately following the adjustment as explained under 4.5.3.1.1.

4.5.4.4.3) Delayed effect of adjustment on adduction

Average change from pre visit reading to the reading at the following visit

Visit	**Mean**	**SD**	**Minimum**	**Median**	**Maximum**
Adjustment (post-pre)	1.45	2.55	-8.00	2.00	6.00
Control (post-pre)	0.10	3.55	-14.00	0.00	8.00

There is an increase in the adduction readings during both treatments, with a larger increase when the adjustment is done, as explained under 4.5.3.1.1.

Repeated measures ANOVA

Effect	**p-value**
Period	0.1941
Treatment (group*period)	0.0680
Group (order of treatments)	0.4083

Adduction did not show a significant period, treatment or group effect over a longer period, perhaps a larger sample size would alter the significance of the results.

4.5.4.4.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, Adduction (degrees)

	Mean	SD	Minimum	Median	Maximum
Visit 1 (pre-adjustment)	8.45	4.06	3.00	8.00	22.00
Visit 7	9.45	3.80	4.00	8.00	15.00

The readings at Visit 7 were higher than at Visit 1, indicating that the patients continued to improve over time, this is explained under 4.5.4.1.4.

4.5.4.5.1) INTERNAL ROTATION

Internal Rotation (Degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	43.83	10.05	27.00	42.50	66.00
Immediately pre-adjustment	42.45	10.33	27.00	40.00	66.00
Immediately post -adjustment	44.48	11.37	23.00	44.50	69.00
Long after adjustment*	47.18	12.16	20.00	46.50	74.00
Immediately pre-control	45.18	11.80	20.00	44.00	74.00
Immediately post control	45.03	11.49	24.00	43.00	69.00
Long after control*	44.38	11.10	24.00	45.50	70.00

* These measurements were taken at the beginning of the following cross-over period.

The internal rotation measurements increased during the treatment period as shown by the mean immediately pre-adjustment score that increased from 42.5º to 44.5º immediately post-adjustment. The internal rotation measurement stayed almost the same during the control. The improvement during the adjustment was sustained, since the internal rotation measurement long after the adjustment was 47.2º, which is higher than the value immediately pre-adjustment. This follows a similar pattern to the flexors, extensors and adductors, explained under 4.5.4.1.1.

4.5.4.5.2) Immediate effect of adjustment on internal rotation

Average change from pre- to post internal rotation reading

Visit	Mean	SD	Minimum	Median	Maximum
Adjustment (post-pre)	2.03	7.89	-21.00	1.50	20.00
Control (post-pre)	-0.15	4.12	-14.00	0.00	11.00

There is an increase in the internal rotation reading when the adjustment is done, as explained under 4.5.3.1.2 and a slight decrease when the control is done, as explained under 4.5.3.2.1.

Repeated measures ANOVA

Effect	**p-value**
Period	0.0144
Treatment (group*period)	0.0599
Group (order of treatments)	0.0085

Internal rotation did not have a significant treatment effect. There was a significant effect of period and group. The carryover effect is the same as the effect for group, thus there was a significant carryover effect for internal rotation from the one period to the other. There also was a significant effect of the period, meaning that the order of the treatments had an effect on the effectiveness of the treatment.

4.5.4.5.3) Delayed effect of adjustment on internal rotation

Average change from pre visit reading to the pre reading at the following visit

Visit	**Mean**	**SD**	**Minimum**	**Median**	**Maximum**
Adjustment (post-pre)	4.73	8.53	-24.00	5.50	20.00
Control (post-pre)	-0.80	7.96	-21.00	0.00	16.00

This shows an increase in the internal rotation readings when the adjustment is done and a decrease when the control is done. The increase is explained under 4.5.4.1.4. The decrease in the control period is in contrast to the theories that the physiological effects are established even in the absence of an intervention, however, the readings long after the control are higher than the initial baseline readings showing that they did establish themselves but possibly at a later stage.

Repeated measures ANOVA

Effect	**p-value**
Period	0.0616
Treatment (group*period)	0.0109
Group (order of treatments)	0.9609

Internal rotation showed a significant treatment effect over a longer period, we could therefore assume that the adjustment had a sustained effect over time. The period and group effects were not statistically significant.

4.5.4.5.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, Internal rotation (degrees)

	Mean	SD	Minimum	Median	Maximum
Visit 1 (pre-adjustment)	42.65	11.22	28.00	39.50	66.00
Visit 7	46.50	12.27	24.00	48.00	70.00

The readings at Visit 7 were higher than at Visit 1, indicating that the patients continued to improve over time, as explained under 4.5.4.1.4.

4.5.4.6.1) EXTERNAL ROTATION

External Rotation (Degrees)

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	42.15	10.13	13.00	42.00	68.00
Immediately pre-adjustment	41.93	10.78	13.00	41.00	68.00
Immediately post -adjustment	45.83	9.91	20.00	46.00	69.00
Long after adjustment*	43.70	10.20	21.00	45.50	68.00
Immediately pre-control	42.50	9.45	21.00	43.00	68.00
Immediately post control	42.63	8.96	23.00	44.50	65.00
Long after control*	42.25	10.02	20.00	42.50	68.00

* These measurements were taken at the beginning of the following cross-over period.

The external rotation measurements increased during the adjustment period as shown by the mean immediately pre-adjustment score that increased from 41.9º to 45.8º immediately post-adjustment. This improvement was not sustained, since the external rotation measurement long after the adjustment was 43.7º. The mean external rotation measurement stayed almost the same during control. This follows a similar pattern to abduction; the theory explaining this is explained under 4.5.4.3.1.

4.5.4.6.2) Immediate effect of adjustment on external rotation

Average change from pre- to post external rotation reading

Visit	Mean	SD	Minimum	Median	Maximum
Adjustment (post-pre)	3.90	4.60	-6.00	3.00	15.00
Control (post-pre)	0.13	5.35	-14.00	-0.50	16.00

The above results show an increase in the external rotation measurement when the adjustment is done, and almost no change when the control is done, as explained under 4.5.3.1.2.

Repeated measures ANOVA

Effect	p-value
Period	0.1724
Treatment (group*period)	0.0033
Group (order of treatments)	0.7875

External rotation showed a significant treatment effect. We can conclude that the adjustment made a significant change to the external rotation score. There was no effect of the periods or groups. The treatment effect may be a result of the reflex effect immediately following the adjustment as explained under 4.5.3.1.1.

4.5.4.6.3) Delayed effect of adjustment on external rotation

Average change from pre visit reading to the reading at the following visit

Visit	Mean	SD	Minimum	Median	Maximum
Adjustment (post-pre)	1.78	7.98	-22.00	3.50	17.00
Control (post-pre)	-0.25	5.93	-13.00	-1.00	11.00

This shows an increase in the external rotation measurements when the adjustment is done, as explained under 4.5.3.1.1 and a slight decrease when the control is done, as explained under 4.5.4.2.3.

Repeated measures ANOVA

Effect	p-value
Period	0.4886
Treatment (group*period)	0.2737

Group (order of treatments)	0.5044

External rotation did not show a significant period, treatment or group effect over a longer period, perhaps a larger sample size would have increased the significance of the results.

4.5.4.6.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, External Rotation (degrees)

	Mean	SD	Minimum	Median	Maximum
Visit 1 (pre-adjustment)	41.95	12.56	13.00	41.00	68.00
Visit 7	42.60	11.18	20.00	43.50	68.00

The readings at Visit 7 were higher than at Visit 1, indicating that the patients continued to improve over time, as explained under 4.5.4.1.4.

4.5.5) Correlation between ROM and Cybex

	Correlation coefficient	p-value
Flexors	0.241	0.0006
Extensors	0.351	< 0.0001
Abductors	0.225	0.0014
Adductors	0.481	< 0.0001

The p-value is < 0.05 in all instances indicating that all the variables had a correlation coefficient that is statistically significantly different from 0. A value of 0 indicates a perfect correlation. This shows a correlation between Cybex and ROM (especially for extensors and adductors, but also true of flexors and abductors but to a lesser degree). This is significant because both of these are objective measures and a correlation between the two shows that they could be used as interchangeable measures that could indicate improvement in either modality (i.e. a practitioner in the field could utilize the simple ROM testing to ascertain improvement in the patient's ability as reflected on a Cybex).

4.5.6.1) Joint Position Sense (Proprioception)

4.5.6.1.1) 10º INTERNAL ROTATION

10º internal rotation

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	-1.73	2.06	-7.00	-1.00	2.00
Immediately pre-adjustment	-1.30	1.79	-6.00	-1.00	2.00
Immediately post -adjustment	-1.38	2.39	-6.00	-2.00	5.00
Long after adjustment*	-1.75	2.47	-9.00	-2.00	2.00
Immediately pre-control	-1.93	2.64	-9.00	-2.00	2.00
Immediately post control	-1.83	2.32	-8.00	-2.00	2.00
Long after control*	-1.10	1.69	-5.00	-1.00	3.00

* These measurements were taken at the beginning of the following cross-over period.

No large changes were observed from pre-adjustment to post-adjustment or from pre-control to post-control.

Immediately following the adjustment the readings moved further away from normal. A possible explanation for this could be that the neural scar (as described by the Patterson-Steinmetz model (1986) in leach (1994:101) (under 4.5.3.1.1) was deeply ingrained and the initial reflex effect from the adjustment was not enough to overcome the learned abnormal position. The measurements long after the adjustment still moved further away from normal showing that the physiological effects had not yet been established. In the control period the physiological effects must have started taking effect because the readings moved closer to normal and the final measurements were closer to normal than the initial measurements, showing that the adjustment did have an effect, just at a different stage. Further research needs to be conducted on when these reflexes and physiological responses manifest themselves.

4.5.6.1.2) Immediate effect of adjustment on 10º internal rotation

Repeated measures ANOVA

Effect	p-value
Period	0.9102
Treatment (group*period)	0.7925
Group (order of treatments)	0.4428

10º internal rotation did not show a significant treatment, period or group effect; perhaps a larger sample size would alter the significance of the results.

4.5.6.1.3) Delayed effect of adjustment on 10º internal rotation

Repeated measures ANOVA

Effect	p-value
Period	0.9301
Treatment (group*period)	0.1414
Group (order of treatments)	0.9521

10º internal rotation did not show a significant treatment, period or group effect; perhaps a larger sample size would alter the significance of the results.

4.5.6.1.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, 10º Internal Rotation

	Mean	SD	Minimum	Median	Maximum
Visit 1 (pre-adjustment)	-1.45	2.11	-6.00	-1.00	2.00
Visit 7	-1.05	1.96	-5.00	-0.50	3.00

The readings at Visit 7 were closer to normal than the readings at Visit 1, indicating that the patients continued to improve over time, this is explained under 4.5.6.1.1.

4.5.6.2.1) 20º INTERNAL ROTATION

20º internal rotation

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	-0.98	2.45	-6.00	-1.00	5.00
Immediately pre-adjustment	-0.60	2.41	-5.00	0.00	5.00

Immediately post -adjustment	-0.53	3.33	-7.00	0.00	10.00
Long after adjustment*	-1.73	3.88	-19.00	-1.50	3.00
Immediately pre-control	-1.45	3.95	-19.00	-0.50	3.00
Immediately post control	-1.35	2.64	-8.00	0.00	3.00
Long after control*	0.08	1.94	-4.00	0.00	3.00

* These measurements were taken at the beginning of the following cross-over period.

The 20 internal measurements did not show large changes immediately after either treatment. The sustained effect differed between the treatments, since the scores moved further from normal long after the adjustment and closer to normal long after the control.

The measurement went closer to normal immediately after the adjustment, this is possibly due to the fact that spinal manipulation is hypothesized to produce significant short-term bursts of proprioceptive transmission in the large calibre myelinated alpha afferent fibres arising from the spinal joint capsules and ligaments (Shahid Ilyas Dhami and DeBoer in Halderman, 1992:115). However, long after the adjustment the readings went further away from normal indicating that the effect didn't last. It is stated in Shahid Ilyas Dhami and DeBoer in Halderman (1992: 115) that the adjustment produces short-term bursts of proprioception providing a possible explanation for the change away from normal. This may also be due to the reflex effect immediately following the adjustment and the physiological reflex having its effects at a later stage. This is supported by the fact that the final reading was closer to normal than the initial reading. A possible explanation for this is that the initial effect was reflex in origin and was not sustained; however, the reading went closer to normal at the end of the study because the three manipulations had sorted out the segmental dysfunction and hence broke the abnormal reflex pathways and therefore the proprioceptive function returned to normal. In addition to this the physiological reflexes would have taken effect as explained under the immune theory under 4.5.3.1.1.

4.5.6.2.2) Immediate effect of adjustment on 20º internal rotation

Repeated measures ANOVA

Effect	**p-value**
Period	0.0853

Treatment (group*period)	0.9714
Group (order of treatments)	0.0629

20º internal rotation did not show a significant treatment, period or group effect; perhaps a larger sample size would alter the significance of the results.

4.5.6.2.3) Delayed effect of adjustment on 20º internal rotation

Repeated measures ANOVA

Effect	**p-value**
Period	0.6379
Treatment (group*period)	0.0428
Group (order of treatments)	0.0676

Over a longer time 20º internal rotation showed a significant treatment effect. The period or group effect was not statistically significant. The significant treatment effect is because of the same theories explained under 4.5.6.2.1.

4.5.6.2.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, 20º Internal Rotation

	Mean	**SD**	**Minimum**	**Median**	**Maximum**
Visit 1 (pre-adjustment)	-1.10	2.86	-5.00	-1.50	5.00
Visit 7	0.25	2.12	-4.00	0.00	3.00

The readings at Visit 7 were closer to normal than the readings at Visit 1, indicating that the patients continued to improve over time, showing the manipulation had an effect on proprioception as explained under 4.5.6.2.1.

4.5.6.3.1) 10º EXTERNAL ROTATION

10º External Rotation

Visit	**Mean**	**SD**	**Minimum**	**Median**	**Maximum**
Baseline	-1.80	2.90	-8.00	-1.50	4.00
Immediately pre-adjustment	-1.98	2.60	-8.00	-2.00	2.00
Immediately post -adjustment	-1.53	2.49	-7.00	0.00	4.00
Long after adjustment*	-1.75	2.17	-6.00	-2.00	4.00

Immediately pre-control	-1.45	2.43	-6.00	-1.00	4.00
Immediately post control	-1.45	2.47	-7.00	-1.00	3.00
Long after control*	-1.38	1.89	-5.00	-1.50	2.00

* These measurements were taken at the beginning of the following cross-over period.

The 10º external rotation measurement showed a larger change during the adjustment than during the control (where it stayed almost constant). This follows a similar pattern to 20º internal rotation and is explained under 4.5.6.2.1.

4.5.6.3.2) Immediate effect of adjustment on 10º external rotation

Repeated measures ANOVA

Effect	**p-value**
Period	0.9350
Treatment (group*period)	0.4645
Group (order of treatments)	0.4266

10 external rotation did not show a significant treatment, period or group effect. The readings did go closer to normal immediately after the adjustment but a larger sample size would be required to alter the significance of the results.

4.5.6.3.3) Delayed effect of adjustment on 10º external rotation

Repeated measures ANOVA

Effect	**p-value**
Period	0.9537
Treatment (group*period)	0.8618
Group (order of treatments)	0.1018

10 external rotation did not show a significant treatment, period or group effect; perhaps a larger sample size would alter the significance of the results.

4.5.6.3.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, 10º External Rotation

	Mean	**SD**	**Minimum**	**Median**	**Maximum**
Visit 1 (pre-adjustment)	-2.65	3.17	-8.00	-2.00	2.00
Visit 7	-1.45	2.11	-5.00	-2.00	2.00

The readings at Visit 7 were closer to normal than the readings at Visit 1, indicating that the patients continued to improve over time, showing the manipulation had an effect on proprioception as explained under 4.5.6.2.1.

4.5.6.4.1) 20º EXTERNAL ROTATION

20º external rotation

Visit	Mean	SD	Minimum	Median	Maximum
Baseline	-0.55	3.18	-9.00	0.00	5.00
Immediately pre-adjustment	-0.78	2.87	-9.00	0.00	4.00
Immediately post -adjustment	-0.73	2.36	-7.00	0.00	6.00
Long after adjustment*	-0.53	1.83	-5.00	0.00	4.00
Immediately pre-control	-0.33	2.38	-6.00	0.00	5.00
Immediately post control	-0.90	2.96	-8.00	-0.50	4.00
Long after control*	-0.60	1.98	-7.00	0.00	3.00

* These measurements were taken at the beginning of the following cross-over period.

The measurements showed a small mean change during the adjustment period and a larger mean change when the control was done. This change was away from normal. The immediate move closer to normal is in congruence with the theories that the effect is reflex in origin. The reading long after the adjustment continued to move closer to normal, possibly related to the piriformis muscle, which was no longer hypertonic (Korr (1975) in Leach, 1994: 99). A possibility is that the initial reflex effect was great enough to be sustained. The measurements during the control period went further away from normal; this is also in contrast to the other proprioceptive measures. However, at the final reading it moved closer to normal once again, showing that the physiological reflexes did have an effect but at a later stage.

4.5.6.4.2) Immediate effect of adjustment on 20º external rotation

Repeated measures ANOVA

Effect	p-value
Period	0.4117
Treatment (group*period)	0.4117
Group (order of treatments)	0.5274

20º external rotation did not show a significant treatment, period or group effect; perhaps a larger sample size would alter the significance of the results.

4.5.6.4.3) Delayed effect of adjustment on 20º external rotation

Repeated measures ANOVA

Effect	p-value
Period	0.9765
Treatment (group*period)	0.5364
Group (order of treatments)	0.5074

20º external rotation did not show a significant treatment, period or group effect; perhaps a larger sample size would alter the significance of the results.

4.5.6.4.4) Delayed effect of adjustment in Group A only

Readings for Group A only, N = 20, 20º External Rotation

	Mean	SD	Minimum	Median	Maximum
Visit 1 (pre-adjustment)	-0.90	3.65	-9.00	0.00	4.00
Visit 7	-0.55	2.14	-5.00	0.00	3.00

The readings at Visit 7 were closer to normal than the readings at Visit 1, indicating that the patients continued to improve over time. This shows that the immediate effect was reflex in origin and once the pathological reflex circuits had been broken by the adjustment, the proprioception normalized.

4.6) CONCLUSION

- **The first hypothesis stated that a norm exists with respect to the asymptomatic population in respect of cybex dynamometry and inclinometry (ROM and proprioception).**

With respect to proprioception

For all measurements, except 20º external rotation, the asymptomatic group was normal (10º or 20º). 20 º external rotation had a median of 21º which is slightly

above normal (20º). For all measurements, except 20º external rotation, the symptomatic group was slightly above normal. 20º external rotation had a median of 20º, which is normal.

With respect to ROM

With the exception of internal rotation, the ROM of the asymptomatic group was greater than the symptomatic group. Internal rotation was slightly higher in the symptomatic group.

With respect to cybex orthotron

With respect to isokinetic testing, a number of factors could have influenced the isokinetic test results obtained, such as age, body size, body mass and stature.
The results of this study could not provide conclusive support of the presence of statistically tenable relationships with respect to age, body size, body mass and stature, hence have not been included for statistical purposes.
The median peak torque for the movements of flexion, extension and abduction was higher in the asymptomatic group than the symptomatic group. Adduction was higher in the symptomatic group.

Therefore, the above hypothesis is rejected, as proprioception should be normal (10º or 20º) in the asymptomatic group, however, 20º external rotation had a median of 21º and one would expect the symptomatic group to have a measurement away from normal, however, 20º external rotation had a median of 20º which is normal. With regards to the other movements, *this hypothesis is accepted*. With respect to ROM one would expect the symptomatic group to have a smaller ROM than the asymptomatic group but in this study internal rotation was higher in the symptomatic group. With regards to the other movements, *this hypothesis is accepted*. With respect to Cybex, one would expect the peak torque for the symptomatic group to be smaller than the asymptomatic group, however, in this study adduction was higher in the symptomatic group. *With regards to the other movements this hypothesis is accepted*.

- **The second hypothesis stated that sacroiliac joint manipulation would be effective in blocking or slowing AMI.**

As previously stated AMI is a reduction in motor unit recruitment (Ingersoll, Palmieri and Hopkins, 2003) and hence the force of any contraction governed by that motor neuron pool is reduced and AMI is clinically manifested as a decrease in muscle strength (Ingersoll, Palmieri and Hopkins, 2003). We used the cybex orthotron to obtain peak torque measurements which indirectly measure strength.

Although the results improved, they were statistically insignificant in terms of period, treatment and group effect. Perhaps a larger sample size would have altered the results.

Results revealed that immediately after the adjustment measurements increased with respect to all movements (flexion, extension, abduction and adduction). Hence one could conclude that immediately following the adjustment AMI decreased and peak torque (torque is a function of muscle force (De Ste Croix, Deighan and Armstrong, 2003: 729), which is a direct measure of strength) increased in all movements of the hip. Measurements long after the adjustment, with the exception of flexion, were higher than the initial measurements (measurements obtained before any treatment was given), showing that the increase in muscle strength was sustained during the treatment process. The possible decrease in the flexion measurement is explained under 4.5.3.1.1. Furthermore, final measurements revealed that muscle strength was still higher than the initial measurements in respect to all movements, hence the researcher concluded that sacroiliac manipulation was effective in blocking/ slowing AMI of the musculature related to the hip, thus supporting hypothesis two, and the effects lasted three weeks (period of study).

Therefore, the above hypothesis is accepted.

- **The third hypothesis stated that this blockage or slowing down of AMI and restoration of hip ROM would allow for restoration of the functional**

ability of the hip musculature, as measured by range of motion, joint position sense and torque ratios.

With respect to ROM

Flexion, extension, abduction, adduction and external rotation showed a statistically significant treatment effect when we analyzed the immediate effect.
Extension and internal rotation showed a statistically significant treatment effect when we analyzed the delayed effect.

ROM increased in all movements immediately after the adjustment, even long after the adjustment measurement was still higher than the initial measurements.
The measurements at the final visit were all above the initial measurements in all movements, leading the researcher to conclude that sacroiliac manipulation improved ROM in all movements of the hip.

With respect to proprioception

All of the measurements, except for the delayed effect of treatment of 20º internal rotation, revealed a statistically insignificant result, even though a mild change was observed.
For all movements the measurements at visit seven were closer to normal than the measurements at visit one, indicating the patients proprioception continued to improve over time.

Therefore, *the above hypothesis is accepted* with respect to blocking / slowing down AMI and improving ROM of the hip, however is rejected in respect of restoring functional ability of the hip, the study improved the functional ability of the hip but not necessarily restored it back to normal.

- **The forth hypothesis stated that there is a correlation between the cybex dynamometry and the objective clinical measures.**

There was a correlation between cybex and ROM.

Therefore, the above hypothesis is accepted.

CHAPTER FIVE
CONCLUSIONS AND RECCOMENDATIONS

5.1) INTRODUCTION

This study comprised of twenty male and twenty female symptomatic patients and ten male and ten female asymptomatic patients with regard to sacroiliac syndrome. Prior to the onset of the study, the researcher, with the aim of establishing suitable study participants, undertook a screening process of the prospective participants. In this regard, all participants underwent a case history, physical examination, lumbar and hip regional examination.

Thereafter the following took place:

Week	**Visit**	**Group A**	**Group B**
0	0	Case history, physical and lumbar regional examination	Case history, physical and lumbar regional examination
	1	Cybex Clinical evaluation Treatment A Cybex Clinical evaluation	Cybex Clinical evaluation Treatment B Cybex Clinical evaluation
1	2	Treatment A	Treatment B
	3	Treatment A	Treatment B
	4	Clinical Evaluation Cybex ***CROSS OVER*** Treatment B Cybex Clinical evaluation	Clinical Evaluation Cybex ***CROSS OVER*** Treatment A Cybex Clinical evaluation
2	5	Treatment B	Treatment A
	6	Treatment B	Treatment A
3	7	Cybex Clinical Evaluation	Cybex Clinical Evaluation

Objective measurements regarding isokinetic hip strength were obtained utilizing the Cybex Orthotron and objective measurements regarding ROM and proprioception were obtained utilizing the Dualer system of inclinometry.

5.2) CONCLUSIONS

5.2.1) CYBEX ORTHOTRON

For all movements the readings at visit seven (final visit) were higher than the readings at visit one. This showed us that sacroiliac manipulation was effective in blocking or slowing AMI.

5.2.2) RANGE OF MOTION

For all movements ROM was higher at visit seven than visit one showing sacroiliac manipulation was effective in improving hip ROM.

5.2.3) PROPRIOCEPTION

For all movements, the measurements at visit seven were closer to normal than the readings at visit one, indicating the patients proprioception continued to improve over time.

5.3) FINAL CONCLUSION

Although some of the results were statistically insignificant, a change was observed immediately after the adjustment (in all objective measures) and this change was sustained throughout the entire research (three weeks). This leads the researcher to conclude that sacroiliac manipulation does have on effect on objective hip measures and perhaps a larger sample size would have increased the significance of the results.

5.4) RECOMMENDATIONS

An increase in all objective measures of the hip was observed during the research, it can be recommended that sacroiliac manipulation is utilized in conjunction to other treatments when treating hip problems.

A larger sample size would be required to increase the validity of the study.

The effects of the adjustment on hip objective measures was still present at the end of the study, further research needs to be conducted to assess how much longer the effects last.

The possible mechanisms involved in AMI reduction as a result of sacroiliac manipulation warrants further investigation.

Measurements were only taken on the side of manipulation, further research can be conducted assessing the measurements in the contralateral limb. In addition to this research can be conducted assessing measurements after both sides have been manipulated.

This study involved three treatments, it is not known whether one manipulation would have had the same effects as the three, research can be conducted assessing the effect of one manipulation and how long the effects last.

This study was purely a clinical outcomes study, it is recommended that further research into the possible mechanisms for the increased objective measurements observed is conducted.

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APPENDIX A:

TELEPHONIC CONSULTATION:

1. Are you between 25-45 years of age?
2. Where is your pain located?
3. How long have you had this pain?
4. Have you been diagnosed with Sacroiliac syndrome or any other low back or hip condition before?
5. Have you had any surgery to the lower back or hip?
6. On a scale of 0-100, with 0 being no pain and 100 being the worst pain ever experienced, where would you place yourself?

APPENDIX B:

Are you aged between 25-45 years and suffering from

LOWER BACK PAIN?

Research is currently being carried out on

SACROILIAC SYNDROME

at the Durban Institute of Technology
Chiropractic Day Clinic.

FREE TREATMENT

Is available to those who qualify to take part in this study.

Contact **Bruce Turner** or **Beverley Morgan** on (031) 2042205 for more information

APPENDIX C:

Research is currently been done at the Durban Institute of Technology Chiropractic Day Clinic.

Are you between 25 and 45 years and

AND ARE PREPARED TO PARTICIPATE IN A RESEARCH TRIAL EVEN THOUGH YOU HAVE NO LOWER BACK PAIN

Contact **Beverley Morgan** on (031) 2042205 for more information

YOU WILL RECEIVE A FREE ASSESSMENT (INCLUDING ISOKINETIC TESTS)

APPENDIX D: **DURBAN INSTITUTE OF TECHNOLOGY**
CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient:_____ Date:_____

File # : _____ Age:_____

Sex: _____ Occupation: _____

Intern : _____ Signature:_____

FOR CLINICIANS USE ONLY:

Initial visit

Clinician: Signature :

Case History:

Examination: Previous:
Current:

X-Ray Studies: Previous:
Current:

Clinical Path. lab: Previous:
Current:

CASE STATUS:

PTT:	Signature:	Date:

CONDITIONAL: Reason for Conditional:
Signature: Date:

Conditions met in Visit No:	Signed into PTT:	Date:
Case Summary signed off:		Date:

Intern's Case History:

1. **Source of History:**

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

3. **Present Illness:**

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

DURBAN INSTITUTE OF TECHNOLOGY
PHYSICAL EXAMINATION

SENIOR & RESEARCH

Patient:_____ **File#:**_____ **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

APPENDIX G: **HIP REGIONAL EXAMINATION**

Patient: _____ **File no:** _____

Date: _____

Intern / Resident: _____ Signature: _____

_____

Clinician: _____ Signature: _____

_____

Observation

- Gait: _____ • Posture: _____
- Weight-bearing symmetry: _____
- Balance and proprioception (Stork-standing test): _____
- Bony / soft tissue contours: Buttock contour _____
  Hip flexion contracture _____
  Lumbar lordosis _____
  Scoliosis _____
- Skin: _____ • Swelling: _____
- Leg length inequality: _____

Palpation

- Anterior aspect:

Iliac crests _____ ASIS's _____
Greater trochanter _____ Inguinal ligament _____
Pubic symphysis and tubercle_____ Inguinal hernia _____
Femoral head _____ Muscles - Quadriceps _____
Femoral Δ - femoral artery _____ - Adductors_____
- lymph nodes _____ - Abductors_____
- Psoas _____

- Posterior aspect:

Iliac crests posteriorly _____ PSIS's _____
Ischial tuberosity _____ Sciatic notch _____
Muscles - Piriformis _____ SI joints _____
- Gluteals _____ Lumbar Spine _____

- Hamstrings _____ Sacrum + coccyx _____

Active Movements (note ROM and pain)

Flexion (110-120°) _____
Extension (10-15°) _____
Adduction (30°) _____
Abduction (30-50°) _____
Medial rotation (30-40°) _____
Lateral rotation (40-60°) _____

Passive Movements (note end-feel, ROM and pain)

Flexion (tissue stretch or approximation) _____
Extension (tissue stretch) _____
Adduction (tissue stretch or approximation) _____
Abduction (tissue stretch) _____
Medial rotation (tissue stretch) _____
Lateral rotation (tissue stretch) _____

Resisted Isometric Movements (note strength and pain)

Flexion _____ Medial rotation _____
Extension _____ Lateral rotation _____
Adduction _____ Knee flexion _____
Abduction _____ Knee extension _____

Joint Play Movements

Caudal glide (long axis traction) _____
Compression _____
Lateral distraction _____
Quadrant (scouring) test _____

Special Tests

Patrick's FABER Test _____
Trendelenberg Test _____
Craig's Test _____
Leg Length: Actual _____ (L) _____ (R) Apparent _____ (L) _____ (R)
Sign of the Buttock _____
Thomas Test (hip flexion contracture) _____
Rectus Femoris Contracture Test _____
Ely's Test (rectus femoris hypertonicity) _____
Ober's Test (ITB contracture) _____
Noble Compression Test (ITB Friction Syndrome) _____
Piriformis Test _____

Hamstrings: Hamstring Contracture Test _____
90°-90° SLR Test _____
Tripod Test _____

Radiological Examination: _____
_____
_____
_____
_____

Diagnosis: _____
_____
_____

Management Plan: _____
_____
_____
_____
_____
_____
_____

Appendix H:

Dear Participant

Welcome to my research.

Title of research: **An evaluation of objective hip joint functional ability measures after sacroiliac joint manipulation in patients with sacroiliac joint syndrome.**

NAME OF RESEARCH STUDENT

Beverley Morgan Contact number: (031) 2042205 or 0721223215

NAME OF RESEARCH SUPERVISOR

Dr C. Korporaal Contact number: (031) 2042611
M.Tech: Chiropractic (SA), CCFC (SA), CCSP (USA), ICSSD (FICS)

You have been selected to take part in a clinical investigation to determine the effect of sacroiliac joint manipulation on the functional ability of the hip musculature. Sacroiliac syndrome is a well-documented cause of lower back pain, resulting pain over the sacroiliac joint with possible referral to the groin, trochanter or buttock. The aim of this study is to evaluate assess the correlation between cybex dynamometry and clinical findings in terms of hip functional ability, pre and post a treatment protocol involving sacroiliac joint manipulation, in male and female patients suffering with sacroiliac syndrome.

Research procedure:
Forty symptomatic and twenty asymptomatic people will be required to complete this study. All symptomatic participants fitting the inclusion and exclusion criteria for this study will be randomly divided into two groups of ten patients each. One group will receive a sacroiliac joint manipulation and the other group will be a control group. The asymptomatic population will form a third group.

Treatment frequency:
At the initial consultation, a full case history, modified physical examination and lower back regional will be performed. Thereafter you will be required to attend 7 consultations. Your treatment will depend on what group you are assigned to. At certain consultations various measurements will be taken, some of which will be done at the rooms of a registered biokinetisist at the Kings Park medical center.

Patient medication and lifestyle:
If you are taking any medication, or undergoing any other form of treatment for your lower back pain, you may be excluded from the study. Please try not to alter your normal lifestyle or daily activities in any way as this could interfere with the results of this study.

Benefits of taking part in the research:
The sacroiliac joint manipulation will in most cases decrease the pain in the region of the sacroiliac joint. You will be given 2 free standard treatments for your lower back pain if it is still a significant clinical problem for yourself.

Risks of taking part in the research:
The treatment is safe and is unlikely to cause any discomfort or adverse side effects, although post treatment stiffness has been noted.

Costs:
All treatments and evaluations will be preformed under the supervision of a qualified Chiropractor and Biokineticist and will be free of charge.

Confidentiality:
All patient information is confidential and the results of the study will be made available in the Durban Institute of Technology library in the form of a mini-dissertation.

You are free to withdraw at any stage.

Please feel free to ask any questions regarding any aspect of this study. Your full co-operation will assist the Chiropractic profession in expanding its knowledge of this condition.

Thank-you
Yours Faithfully,

Beverley Morgan
(Researcher)

Dr Charmaine Korporaal
(Supervisor)

APPENDIX I:

INFORMED CONSENT FORM

(To be completed by patient / subject)

Date:

Title of research project: **An evaluation of objective hip joint functional ability measures after sacroiliac joint manipulation in patients with sacroiliac joint syndrome.**

Name of supervisor: Dr C. Korporaal **(**M.Tech: Chiropractic (SA), CCFC (SA), CCSP (USA), ICSSD (FICS)

Tel: (031) 2042611

Name of research student: Beverley Morgan

Tel: (031) 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? Yes No
   at any time
   without having to give any a reason for withdrawing, and
   without affecting your future health care.
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 J:

CYBEX PROTOCOL:

Hip flexion, extension, abduction and adduction were tested using the Cybex dynanometer. Hip internal and external rotation was not tested as these movements could not be tested on the Cybex Dynometer.

Patients received verbal encouragement from the researcher during the isokinetic contraction in order to ensure maximal effort. The readings of all contractions were recorded. Enabling the researcher to assess the correlation between cybex dynamometry and clinical findings in terms of hip functional ability.

The isokinetic testing protocol for the hip musculature utilized in this study was adapted from Terblanche (2004).

Hip flexion and extension was tested with the patient in the supine position. This position allows for maximal hip flexion. The hip on the affected side was approximated to the power arm of the cybex and the axis of movement of the power arm was aligned with the axis of movement of the hip joint at the femoral head. Therefore, the head of the femur was used as the bony landmark to match the axis of rotation of the hip joint with the axis of rotation of the dynamometer resistance adapter.

The power arm was then adjusted to incorporate the entire length of the femur and secured via Velcro straps to the distal aspect of the femur, just proximal to the knee joint. An abdominal strap was used to minimize any body movements and to isolate the movement at the hip joint. This enhances the reliability of the results. The affected limb was positioned with the hip in the fully extended position, therefore the test commenced with flexion.

Hip abduction and adduction was tested in the lateral recumbent position, with the affected side up. The power arm of the cybex was aligned with the axis of movement of the hip joint at the femoral head and then adjusted to incorporate the entire length of the femur. Hence, the head of the femur was used as the bony landmark to match the axis of rotation of the hip joint with the axis of rotation of the dynamometer resistance adapter.

The power arm was then secured to the distal femur via the Velcro straps, just proximal to the knee. A strap was utilized to secure the patient over the torso to minimize any body movements, thereby increasing the reliability of the results. The affected limb was positioned in full adduction prior to commencement of the test therefore; the first action tested was abduction.

The patient was given two trial repetitions to familiarize themselves with the movement, thereafter they had to perform five maximal repetitions.

The patients were given verbal encouragement during the testing to ensure maximal effort.

APPENDIX K:

Range of motion measurement procedure: (Livingston, 1992)

Hip forward flexion:

1. Attach the master sensor to the thigh in any orientation.
2. Place the subject in neutral position (supine) with the opposite hip flexed and locked.
3. With the leg extended in neutral position, zero the sensor
4. Have subject flex hip until the iliac spine begins to move. Record the angle.

Hip backward extension:

1. Attach the master sensor to the thigh in any orientation.
2. Place the subject in neutral position (prone).
3. With the leg extended in neutral position, zero the sensor.
4. Have subject extend maximally. Record the angle.

Hip abduction/adduction: (Verbal consultation with A.K. Gangat)

1. Attach the master sensor to the thigh in any orientation.
2. Place the subject on a table in a side lying position.
3. With the leg extended in neutral position, zero the sensor.
4. Have subject abduct maximally and record the angle.
5. Have subject adduct maximally and record the angle.

Hip external/internal rotation: (Cibulka et al. 1998 and Ellison et al. 1990)

1. Place the subject in the prone position, and place a strap around the posterior superior iliac spines to prevent pelvic movement.
2. Place the hip to be measured in 0 degrees abduction while the contra-lateral hip is abducted 30 degrees.
3. Flex the knee of the hip to be measured to 90 degrees and attach the inclinometer just below the ankle.
4. Ensure that the tibia is aligned at 90 degrees, and zero the sensor.
5. Have subject externally rotate maximally and record the angle.
6. Have subject internally rotate maximally and record the angle.

APPENDIX L:

Steps taken for measuring joint position sense:

- Place the subject in the prone position, and place a strap around the posterior superior iliac spines to prevent pelvic movement.
- Place the hip to be measured in 0 degrees abduction while the contra-lateral hip is abducted 30 degrees.
- Flex the knee of the hip to be measured to 90 degrees and attach the inclinometer just below the ankle.
- Ensure that the tibia is aligned at 90 degrees, and zero the sensor.
- Ask the subject to slowly externally rotate their hip. When they reach 10 degrees ask the subject to stop and inform them that that is 10 degrees. Wait 5 seconds. Continue external rotation until 20 degrees and again ask the subject to stop and inform them of this. Wait 5 seconds.
- Ask the subject to return their leg to 90 degrees and then ask them to straighten and bend their knee a few times.
- Flex the knee and ensure that the tibia is aligned at 90 degrees, and zero the sensor. Be sure to only touch the subject's foot.
- Again ask the subject to slowly externally rotate their hip, but ask them to stop when they think they have reached 10 degrees. Record the reading on the sensor. Continue external rotation until they think they have reached 20 degrees. Record the reading on the sensor.
- Repeat using hip internal rotation.

APPENDIX M

Data Collection Sheet:

Patient Name:_____

Gender:_____

File Number:_____

Joint Position Sense (Proprioception):

Visit	Pre-10 internal	Post-10 internal	Pre-20 internal	Post-20 internal	Pre-10 external	Post-10 external	Pre-20 external	Post-20 external
1								
2								
4								
5								
7								

Range Of Motion:

Visit	Flexion		Extension		Abduction		Adduction		Internal		External	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1												
2												
4												
5												
7												