

THE SHORT - TERM EFFECT
OF SACROILIAC
MANIPULATION ON HIP
MUSCLE STRENGTH IN
PATIENTS SUFFERING FROM
CHRONIC SACROILIAC
SYNDROME

By

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DEDICATION

This dissertation is dedicated to my parents, Francois and Julie, and my sister, Liesl, for their continued sacrifice, support and encouragement and their constant belief in my ability to achieve my greatest ambitions.

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ABSTRACT

Arthrogenic muscle inhibition (AMI) is the reflex inhibition of the muscles that surround an injured joint in consequence to disturbed afferent feedback originating from the receptors of that joint. The resultant altered afferent innervation of the motor neuron pool leads to a decrease in recruitment ability within the motor neuron pool, a decrease in contraction force of the muscles that fall within the motor neuron pool, and hence the clinical manifestation of AMI as a decrease in muscle strength.

Spinal manipulation has been proposed to activate mechanoreceptors and proprioceptors within and around the manipulated joint. The altered afferent input arising from their stimulation is thought to cause changes in motor neuron excitability. In this respect, sacroiliac manipulation has been shown to effectively reduce muscle inhibition and increase muscle strength of the quadriceps muscle group in patients with anterior knee pain.

The focus of AMI has been aimed primarily at the quadriceps muscle group whereas little information is available on the functional properties of the muscles moving the hip joint. Thus, the purpose of the present cohort study was to determine the short – term effect of sacroiliac manipulation on ipsilateral hip muscle strength and subjective low back pain intensity in thirty male subjects presenting with low back pain, attributable to chronic sacroiliac syndrome.

The first objective of the study was to evaluate the short – term effect of sacroiliac manipulation on the strength of the musculature of the ipsilateral hip joint for the actions of flexion, extension, adduction and abduction by means of the Cybex Orthotron II Isokinetic Rehabilitation System, with respect to objective clinical findings.

Whereas the second objective was to determine the short – term effect of sacroiliac manipulation on pain, utilizing the Numerical Pain Rating Scale, in terms of subjective clinical findings.

Objective measurements regarding concentric – concentric isokinetic muscle strength of the hip and subjective measurements regarding pain intensity were obtained prior to, immediately following and 1 day/24 hours following sacroiliac manipulation. Sacroiliac manipulation consisted of a high – velocity low – amplitude thrust in the side posture position, with the aim of correcting sacroiliac dysfunction.

All objective and subjective readings recorded pre – manipulation and immediately post - manipulation were obtained from a concurrent study that investigated the immediate effect of sacroiliac manipulation on ipsilateral hip muscle strength and subjective low back pain intensity in subjects presenting with chronic sacroiliac syndrome (Matkovich, 2004). These readings were combined with those generated by the present study in order to determine the short – term effect of sacroiliac manipulation on ipsilateral hip muscle strength and subjective low back pain intensity.

Inter – group analysis was conducted utilizing The Analysis of Variance (ANOVA) Tests, whereas intra – group analysis was conducted by means of Multiple Paired T – Tests. This procedure was applied to both the subjective and objective measurements. All the tests set the type 1 error at 5% ($\alpha = 0.05$).

The results of the study supported the hypotheses that sacroiliac manipulation results in the short – term reduction in subjects' perceived levels of pain that accompanies chronic sacroiliac syndrome, and the short - term reduction in AMI with a subsequent increase in hip muscle strength in subjects with chronic sacroiliac syndrome.

The observation of increased hip muscle strength, consequent to a reduction in AML as a result of sacroiliac manipulation, is intriguing and might point to the important effects of sacroiliac manipulation in the rehabilitation process and in addition, the possible value of sacroiliac manipulation in the treatment of lower limb AML.

Nevertheless, biases might have occurred, as the present study was solely an observation/clinical outcome – based study rather than a controlled design and the observation of increased hip muscle strength may well have been a placebo effect.

It is suggested the results of the present study should be verified in a randomized, controlled, double - blind clinical trial in order to substantiate claims regarding the short – term effect of sacroiliac manipulation on hip muscle strength.

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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).

Action potential

The explosive change in membrane potential that results from a rapid and massive movement of ions across the membrane of excitable cells, usually in response to a stimulus that causes a change in ion conductance across the membrane (Cohen, 1999:441).

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).

Afferent neurons

Nerve cells which carry information from peripheral receptors to the central nervous system (Crossman and Neary, 1995:2). This term is synonymous with the term *sensory nerve* (Cohen, 1999:442).

Anterior commissure

A bundle of nerve fibers in the spinal cord that interconnects the two sides of the cerebrum (Cohen, 1999:449).

Arthrogenic muscle inhibition

A presynaptic, ongoing reflex inhibition of the musculature surrounding a joint following distention or damage to that joint. AML is a natural response designed to protect that joint from further damage (Hopkins *et al.*, 2000).

Biomechanics

The application of mechanical principles to living structures (Redwood, 1997:334).

Contraindication

Any symptom or circumstance denoting the inappropriateness of a form of treatment that would otherwise be advisable (Redwood, 1997:335).

Disinhibited

The removal of an inhibitory input to a population of neurons, resulting in the return of their tonic activity levels (Cohen, 1999:449).

Dorsal horn

The dorsal horn is the dorsal portion of the spinal cord gray matter, posterior to the central gray. It is concerned mainly with sensory functions (Cohen, 1999:449).

Dorsal root ganglion

A sensory nerve cell body that is located outside the spinal cord, on its posterior aspect (Cohen, 1999:449).

Dorsolateral tract of Lissauer

White matter that occupies the region between the dorsal edge of the dorsal horn and the external dorsolateral surface of the spinal cord where the dorsal roots attach (Cohen, 1999:449).

Efferent

Conveyed away from a structure; efferent signals are outgoing signals (Cohen, 1999:449).

Efferent neuron

Efferent neurons carry impulses away from the central nervous system (Crossman and Neary, 1995:2). These are also termed *motor neurons* (Cohen, 1999:449).

Endurance

The ability of the muscles to perform repetitive contractions against a load for a prolonged period (Chan and Maffulli, 1996:6).

Explosive power

The time taken to reach peak power (Chan and Maffulli, 1996:6).

Extrafusal

The striated muscle fiber that is not part of the muscle spindle (Cohen, 1999:451).

Free nerve endings

Free nerve endings are non – specialized, non – encapsulated, unmyelinated (or finely myelinated) receptors that function as nociceptors and provide a crude awareness of initial joint movement (Hopkins and Ingersoll, 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).

Interneuron

An interneuron is a neuron that receives information from one neuron and transmits it to another. They receive projections from sensory afferent fibers, descending fibers and other interneurons (Hopkins and Ingersoll, 2000).

Intrafusal

The striated muscle fiber of the muscle spindle (Cohen, 1999:455).

Load cell

The force – sensing apparatus of the isokinetic dynamometer (Chan and Maffulli, 1996:13).

Manipulation

A manual procedure that involves a directed thrust to move a joint past the physiologic range of motion without exceeding the anatomical limit (Gatterman, 1995:12).

Mechanoreceptor

A receptor that is excited by mechanical pressures or distortions, as those responding to sound, touch and muscular contractions (Redwood, 1997:339). A mechanoreceptor acts to transduce energy from one form into a specific nerve signal (Hopkins and Ingersoll, 2000).

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).

Motor neuron

A motor neuron is 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

A motor unit consists of a spinal motor neuron, its axon, and all the muscle fibers it innervates (Cohen, 1999:457).

Muscle strength

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

Nociceptor

A receptor preferentially sensitive to a noxious stimulus or to a stimulus that would become noxious if prolonged (Redwood, 1997:341). Nociceptors are physical or chemical damage detectors in tissues (Guyton and Hall, 1997:376) and may be stimulated by mechanical, thermal, or chemical means (Cramer and Darby, 1996).

Paciniform nerve endings

Paciniform nerve endings are encapsulated sensory nerve endings that respond to mechanical distortion (Crossman and Neary, 1995:24). They are activated by any movement of the joint regardless of position, adapt quickly to a stimulus (Hopkins and Ingersoll, 2000) and are particularly important in detecting tissue vibration or other rapid changes in the mechanical state of the tissues (Guyton and Hall, 1997:384).

Power

Power is the rate of muscular work output and is expressed in units of work per unit of time viz. Joules per second/Watts (Chan and Maffulli, 1996:6).

Prevalence

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

Proprioception

A specialized variation of the sensory modality of touch that encompasses the sensation of joint movement and joint position (Lephart *et al.*, 1992).

Proprioceptor

Proprioceptors are located in muscles, joints and tendons (Crossman and Neary, 1995:24) and transduce information regarding the relationship between body segments (Hopkins and Ingersoll, 2000).

Receptors

Receptors are specialized cells or subcellular structures of sensory nerve endings that change their properties in response to specific stimuli of various types (Hopkins and Ingersoll, 2000).

Recruitment

Recruitment refers to the activation of motor units (Cohen, 1999:464).

Torque

Torque is the turning effect (or moment) of a force on an object. Torque is measured in Newton meters (Chan and Maffulli, 1996:110).

Work

Work is the output of mechanical energy, or the externally applied force multiplied by the distance through which it is applied. Work is a useful measure of energy expenditure and is measured in Joules (Chan and Maffulli, 1996:6).

CHAPTER ONE

INTRODUCTION

1.1 The problem and its setting

Arthrogenic muscle inhibition (AMI) is “a presynaptic, ongoing reflex inhibition of the musculature surrounding a distended or damaged joint” (Hopkins *et al.*, 2000). AMI is a natural response designed to protect that joint from further damage (Hopkins *et al.*, 2000) by reducing and discouraging its use (Ingersoll *et al.*, 2003).

AMI originates from the activity of numerous different mechanoreceptors that act on inhibitory interneurons that synapse with the motor neuron pool of the muscles surrounding the injured joint (Hopkins and Ingersoll, 2000). This is said to result in altered afferent innervation of the motor neuron pool, a decrease in recruitment ability of the motor neuron pool (Hopkins and Ingersoll, 2000) and consequently, a decrease in force of any contraction governed by that motor neuron pool (Suter *et al.*, 1999).

One of the early goals of the rehabilitation process should be to eliminate or reduce muscle inhibition (Suter *et al.*, 2000), as AMI may impede muscle strength restoration following joint pathology (Hurley, Jones and Newham, 1994) by hindering the engagement in more vigorous active exercises necessary to expedite the healing process (Hopkins *et al.*, 2000). In addition to impeding strength gains during rehabilitation, AMI also slows gains in proprioception and increases the susceptibility to further injury.

Many therapeutic techniques have been developed to safely increase muscle strength and neuromuscular control during joint rehabilitation, however these techniques are of little benefit if AMI cannot be overcome first (Hopkins *et al.*, 2002).

Manipulation of a joint has been proposed to activate mechanoreceptors and proprioceptors within and around the manipulated joint (Suter *et al.*, 2000). Sakamoto *et al.*, (2001) showed that the sacroiliac joint possessed mostly nociceptive mechanoreceptors. These may be activated in symptomatic sacroiliac syndrome, giving rise to inhibition of the innervated motor neuron pool (Suter *et al.*, 1999). Altered afferent input arising from mechanoreceptor stimulation following manipulation may cause a change in motor neuron excitability and a subsequent decrease in AMI (William, 1997:144, Suter *et al.*, 2000).

Sacroiliac joint manipulation was shown to be effective in reducing muscle inhibition and increasing muscle strength of the quadriceps muscle group in patients with anterior knee pain (Suter *et al.*, 1999, 2000).

The focus of AMI has been aimed solely at the quadriceps muscle group (Hopkins *et al.*, 2000) whereas little information is available on the functional properties of the muscles moving the hip joint (Arokoski *et al.*, 2002). To date, no studies have been conducted to investigate the effect of sacroiliac manipulation on the strength of the hip musculature.

1.2 Aim of the study

The aim of this study was to determine the short – term effect of sacroiliac manipulation on ipsilateral hip muscle strength and subjective low back pain intensity in thirty male subjects presenting with low back pain, attributable to chronic sacroiliac syndrome.

1.3 The problem statement

The purpose of this investigation was to determine the short – term effect of sacroiliac manipulation on ipsilateral hip muscle strength and subjective low back pain intensity in thirty male subjects presenting with low back pain, attributable to chronic sacroiliac syndrome.

1.4 Hypotheses

1.4.1 Hypothesis one

It was hypothesized that sacroiliac manipulation would result in the short – term augmentation in ipsilateral hip muscle strength consequent to a decrease in AMI of the musculature involved in the actions of flexion, extension, adduction and abduction, based on the results of Suter *et al.* (1999, 2000).

1.4.2 Hypothesis two

It was hypothesized that sacroiliac manipulation would result in the short – term reduction in patients' perceived levels of pain that accompanies chronic sacroiliac syndrome.

1.5. Assumptions

1. AMI renders a muscle unable to recruit all motor units of its motor neuron pool during a voluntary maximum effort muscle contraction. This results in a decrease in muscle strength of the muscle group governed by that motor neuron pool (Suter *et al.*, 2000).
2. AMI is caused by the stimulation of mechanoreceptors in a joint, causing altered afferent innervation of the motor neuron pool (Hopkins and Ingersoll, 2000). The sacroiliac joint possesses mainly nociceptive mechanoreceptors (Sakamoto, *et al.*, 2001) that might be activated in symptomatic sacroiliac syndrome (Suter *et al.*, 1999). The muscles responsible for hip flexion, extension, adduction and abduction fall within the sacroiliac joint's motor neuron pool (Moore, 1992). It was assumed that sacroiliac syndrome might cause their subsequent inhibition.

3. Spinal manipulation has been proposed to activate mechanoreceptors and proprioceptors within and around the manipulated joint. The altered afferent input arising from their stimulation is thought to cause changes in motor neuron excitability (Suter *et al.*, 2000).
4. Sacroiliac manipulation caused a decrease in muscle inhibition and an increase in muscle strength of the quadriceps muscle group in patients with anterior knee pain (Suter *et al.*, 1999, 2000). It was assumed that sacroiliac manipulation would have the same effect on hip muscle strength based on the mechanism and results of Suter *et al.* (1999, 2000).

1.6 The objectives

1.6.1 Objective one

The first objective was to evaluate the short – term effect of sacroiliac manipulation on the muscle strength of the ipsilateral hip joint in the actions of: flexion, extension, abduction and adduction, in patients with chronic sacroiliac syndrome, utilizing the Cybex Orthotron II Isokinetic Rehabilitation System, in terms of objective clinical findings.

1.6.2 Objective two

The second objective was to determine the short-term effect of sacroiliac joint manipulation in terms of subjective findings, utilizing the Numerical Pain Rating Scale.

1.7 Potential benefits of the study

1. Sakamoto *et al.* (2001) showed that the sacroiliac joint possessed mostly nociceptive mechanoreceptors. Stimulation of which, in symptomatic sacroiliac syndrome, can give rise to inhibition of the innervated motor neuron pool (Suter *et al.*, 1999). The muscles responsible for hip flexion, extension, abduction and adduction fall within the sacroiliac joint's motor neuron pool (Moore, 1992). It seemed plausible that sacroiliac syndrome might cause their subsequent inhibition. However, no studies have been conducted to investigate this.
2. A concurrent cohort study by Matkovich (2004) investigated the immediate effect of sacroiliac manipulation on muscle strength of the ipsilateral hip (flexion, extension, abduction and adduction). Suter *et al.* (1999) stated that the identification of the time course of the treatment effects of sacroiliac manipulation in reducing muscle inhibition should be addressed in future research. No studies have been conducted to investigate the short – term effect of sacroiliac manipulation on hip muscle strength.
3. Muscle inhibition is clinically manifested as a decrease in muscle strength (Suter *et al.*, 1999) and renders a patient unable to perform active exercises that are important in decreasing healing time (Hopkins and Ingersoll, 2000). The observation of increased muscle strength and decreased muscle inhibition following chiropractic manipulation might point to important effects of spinal manipulative adjustments (Suter *et al.*, 1999) and therefore, the possible role of sacroiliac joint manipulation in the rehabilitation process.
4. The majority of studies on muscle performance have been concerned with the muscles affecting the knee joint whereas little information is available regarding the functional properties of the muscles involved in

moving the hip joint (Arokoski *et al.*, 2002). This research aimed to add to the body of knowledge regarding the effects of sacroiliac manipulation on hip muscle strength. The knowledge generated from this study would enable chiropractors to develop and implement more effective treatment/rehabilitation protocols for patients with hip and/or low back pain.

CHAPTER TWO

REVIEW OF THE RELATED LITERATURE

2.1 Introduction

This chapter reviews the literature pertaining to AMI and sacroiliac joint syndrome. The possible affiliation between AMI and sacroiliac syndrome will also be explored. Thus, the objective of this chapter is three – fold:

Firstly, AMI will be defined and discussed according to the following headings: likely causes, related neurophysiological factors, clinical implications, methods employed in measuring AMI in a research setting, treatment interventions that may lessen or block AMI, and the benefits of removing AMI.

Secondly, sacroiliac syndrome will be defined and discussed, in brief covering the relevant topics of incidence and prevalence, symptoms, diagnosis, anatomy and biomechanics. Additionally, a concise discussion of the hip joint covering the topics of stability and mobility, movements, and the muscles of the hip joint involved in these movements will follow this section.

Thirdly, the mechanism involved in AMI development will be linked with the mechanism through which sacroiliac syndrome might cause pain and perhaps AMI. Subsequently, the neurophysiological effects of manipulation will be discussed and projected as a possible means of AMI diminution.

2.2 Arthrogenic muscle inhibition

2.2.1 Definition

Arthrogenic muscle inhibition (AMI) is the “presynaptic, ongoing reflex inhibition of the musculature surrounding a joint following distension or damage to that joint” (Hopkins *et al.*, 2000). 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. This, according to Reid (1992:49), is the resultant effect of decreased stimuli from the nervous system. Nevertheless, Hopkins and Ingersoll (2000) and Ingersoll, Palmieri and Hopkins (2003) consider AMI as the body’s natural response designed to protect an injured joint from further damage through reducing and discouraging its use.

2.2.2 Causes of arthrogenic muscle inhibition

Hopkins and Ingersoll (2000) state that AMI might develop as the result of a combination of multiple factors, some of which are yet to be determined. A review of the related literature revealed a large continuum of conditions that might cause AMI. Still, the most common denominator appears to be joint injury.

The potential etiologic factors of AMI include osteoarthritis (Arokoski *et al.*, 2002), operative trauma (Spencer, Hayes and Alexander, 1984), joint effusion (Hopkins *et al.*, 2002), immobilization (Reid, 1992:49), pain (Hopkins *et al.*, 2002 and Spencer, Hayes and Alexander, 1984) and traumatic injury/damage to joint structures (Hopkins *et al.*, 2000 and Hurley, Jones and Newham, 1994), such as ligament stretching (Spencer, Hayes and Alexander, 1984), ligament laxity (Ingersoll, Palmieri and Hopkins, 2003) or ligament rupture (Hurley, Jones and Newham, 1994), and capsular compression (Spencer, Hayes and Alexander, 1984).

According to Spencer, Hayes and Alexander (1984), these factors undoubtedly play a role in the development of AMI. However, despite their influence, muscle inhibition has been demonstrated in their absence (Spencer, Hayes and Alexander, 1984, Hurley, Jones and Newham, 1994 and Hopkins and Ingersoll, 2000). In particular, the role of pain in AMI development appears to be ambiguous, with some researchers showing significant correlations (Spencer, Hayes and Alexander, 1984 and Suter *et al.*, 1998), while others claim otherwise (Hurley, Jones and Newham, 1994 and Hopkins and Ingersoll, 2000).

2.2.3 Neurophysiological factors associated with arthrogenic muscle inhibition

2.2.3.1 Introduction

AMI stems from the activity of numerous different joint receptors (Hopkins and Ingersoll, 2000), including free nerve endings and specialized 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, according to Hopkins and Ingersoll (2000), have been proposed to act on inhibitory interneurons that synapse with the motor neuron pool of the musculature surrounding the injured joint.

The information conveyed by these inhibitory interneurons are said to result in an altered afferent innervation of the motor neuron pool, a decrease in the recruitment ability within the motor neuron pool (Hopkins and Ingersoll, 2000) and hence, a decrease in the force of any contraction governed by that motor neuron pool (Suter *et al.*, 1999).

2.2.3.2 Joint receptors

Joint receptors are specialized cells or sub – cellular structures that change their properties through responding to specific stimuli of various types. Most receptors are specialized endings of sensory nerve fibers (Hopkins and Ingersoll, 2000).

Joint receptors are located in joint capsules, ligaments and tendons (Levangie and Norkin, 2001:71). All synovial joints are said to contain four types of receptors that are classified, according to Wyke's classification system, as Types I, II, III and IV. Type I, II and III receptors are encapsulated mechanoreceptors that provide information regarding direction, velocity and joint movement, with Type IV receptors being free nerve endings that mediate nociception due to mechanical or inflammatory processes (Wyke, 1985, as cited by Darby and Daley in Cramer and Darby, 1995:253 and Leach, 1995:90).

From the above statement, the majority of joint receptors appears to be mechanoreceptors and, as previously stated, AML principally results from mechanoreceptor activity (Hopkins and Ingersoll, 2000).

The authors Biedert, Stauffer and Friederich (1992) stated that the majority of afferent impulses resulting from extreme joint movements originate from mechanoreceptors located in capsular ligament structures. Thus, mechanoreceptors not only serve a mechanical purpose, but also possess the additional ability of exerting protective effects on a joint through provoking a muscular reflex. In light of this statement, the statement by Hopkins and Ingersoll (2000) in the previous paragraph seems plausible, particularly when taking into consideration the causes of AML (as outlined under 2.2.2), being primarily joint injury that might result from such extreme joint movements.

Mechanoreceptors are receptors that are stimulated by mechanical pressures or distortions, such as sound, touch and muscular contractions (Redwood, 1997:339). They also possess the added capability of acting as

proprioceptors, that function to transduce information regarding the relationship between body segments (Hopkins and Ingersoll, 2000).

Joints contain three specific types of mechanoreceptors, namely Ruffini endings which are found in the joint capsule, encapsulated Paciniform endings, often found in the fibrous periosteum near the articular attachments, and Golgi endings, located in the ligaments of the joint (Jones in Cohen, 1999:119).

Ruffini endings are slowly adapting receptors (Hopkins and Ingersoll, 2000) with low mechanical thresholds (Johansson, Sjölander and Sojka, 1991). They are functionally and structurally similar to Type I joint receptors (Juliano and McLaughlin in Cohen, 1999:97) and consist of several large unmyelinated nerve fibers that end in a bundle of collagen fibers, surrounded by a cellular capsule (Snell, 1997:125).

According to their behavioral characteristics, these receptors may be categorized as static and dynamic mechanoreceptors (Johansson, Sjölander and Sojka, 1991). Thus, they are capable of signaling static joint position (Johansson, Sjölander and Sojka, 1991), increased capsular pressure as a result of joint effusion, and the amplitude and velocity of joint movement (Hopkins and Ingersoll, 2000).

Pacinian corpuscles are rapidly adapting mechanoreceptors (Snell, 1997:124) with low mechanical thresholds (Johansson, Sjölander and Sojka, 1991). They are structurally and functionally similar to Type II mechanoreceptors (Juliano and McLaughlin in Cohen, 1999:97) and consist of a capsule with a central core containing a nerve ending (Snell, 1997:124 – 125).

These mechanoreceptors provide information regarding joint acceleration and deceleration (Hopkins and Ingersoll, 2000). Consequently, they are regarded exclusively as dynamic mechanoreceptors (Johansson, Sjölander and Sojka, 1991).

Golgi endings are slowly adapting receptors, with high mechanical thresholds (Johansson, Sjölander and Sojka, 1991). They fire rapidly upon initial joint movement (Hopkins and Ingersoll, 2000) and are structurally and functionally similar to Type III mechanoreceptors (Juliano and McLaughlin in Cohen, 1999:97). Golgi endings provide important information regarding joint position (Hopkins and Ingersoll, 2000). In lieu of this statement, Johansson, Sjölander and Sojka (1991) declare this purpose to be attributed to their ability to effectively measure ligamentous tension at the extremes of range of motion of a joint as a result of their high thresholds.

In addition to mechanoreceptors, Ingersoll, Palmieri and Hopkins (2003) state that free nerve endings and specialized nociceptors might also play a role in the development of AML.

Free nerve endings are non – specialized, non – encapsulated, unmyelinated (or finely myelinated) receptors (Hopkins and Ingersoll, 2000) that are widely distributed throughout joint capsules, ligaments and tendons (Snell, 1997:121 – 122). These receptors are structurally and functionally similar to the Type IV receptors (Wyke, 1985, as cited by Darby and Daley in Cramer and Darby, 1995:253 and Leach, 1995:90).

Johansson, Sjölander and Sojka (1991) state that free nerve endings are primarily activated during abnormal mechanical deformation or by chemical substances such as histamines, bradykinins and prostaglandins that are released during inflammatory processes. In lieu of this statement, free nerve endings may be considered to serve a dual purpose. Firstly, they may act as nociceptors (Hopkins and Ingersoll, 2000) by transmitting information pertaining to pain and inflammation (Biedert, Stauffer and Friederich, 1992) and secondly, they may function as mechanoreceptors by providing a crude awareness of initial joint movement (Hopkins and Ingersoll, 2000).

Nociceptors are sensory receptors (Jacobs and Lowe in Cohen, 1999:78) that can detect physical or chemical damage in tissues (Guyton and Hall, 1997:376). They are classified as mechanical, thermal or polymodal

nociceptors (Kingsley, 1996:130). Mechanical nociceptors are excited by mechanical stimuli, thermal nociceptors by temperature extremes, and polymodal nociceptors by mechanical, thermal or chemical stimuli (Jacobs and Lowe in Cohen, 1999:78).

However, Darby and Daley in Cramer and Darby (1995:253) claim that all nociceptors are free nerve endings. As nociceptors, free nerve endings may be activated either mechanically or chemically (Biedert, Stauffer and Friederich, 1992). In light of these statements, nociceptors may be viewed as Type IV receptors, as classified according to Wyke (Wyke, 1985, as cited by Darby and Daley in Cramer and Darby, 1995:253 and Leach, 1995:90).

In addition, nociceptors and proprioceptors may be considered as different classes of mechanoreceptors. Sakamoto *et al.* (2001) declared that mechanoreceptors innervated by Type III or Type IV sensory fibers, and those innervated by Type II or Type III sensory fibers, are thought to be nociceptors and proprioceptors, respectively.

Thus, for the purpose of the present study, nociceptors, free nerve endings and proprioceptors will be considered different types of mechanoreceptors.

2.2.3.2.1 Sacroiliac joint receptors

The sacroiliac joint, its periarticular structures, joint capsule and ligaments have been shown to contain numerous mechanoreceptors.

Fortin *et al.* (1999) provided preliminary data of, and suggested that the periarticular tissues of the sacroiliac joint contained mechanoreceptors and nociceptors.

In this respect, Sakamoto *et al.* (2001) characterized the mechanical and electrical responses of discrete nerve fibers in a cat's sacroiliac joint and identified mechanosensitive afferent units within the joint and the adjacent tissues. The authors reported that 26 of the 29 units identified presumably

serve as nociceptors. The remaining 3 fibers were thought to serve as conductors for proprioceptive information.

Whereas Vilensky and colleagues (2002) conducted a histologic analysis of the neural elements in the human sacroiliac joint using histologic and immunohistochemical techniques. They identified mechanoreceptors (paciniform nerve endings, non – paciniform nerve endings, free nerve endings) and nerve fascicles in the posterior ligament of the sacroiliac joint. This discovery lead the authors to believe that proprioceptive, and possibly nociceptive information, might be transmitted from the sacroiliac joint towards the central nervous system.

2.2.3.3 Nerve fibers

2.2.3.3.1 Classification of nerve fibers

Nerve fibers may be classified according to two commonly recognized systems. The first system groups them according to their diameter into types A, B and C (Guyton and Hall, 1997:379 and Kinglsey, 1996:139). Type A fibers are further subdivided into alpha (α), beta (β), delta (δ) and gamma (γ) fibers (Guyton and Hall, 1997:379).

TABLE 2.1 *Classification of nerve fibers according to their diameter*

Fiber type	Fiber diameter	Myelination	Function
Type A			
alpha (α)	12 – 20	heavily myelinated	motor, skeletal muscle; sensory transmission of nociception
beta (β)	5 – 12	myelinated	sensory, touch, pressure, vibration
delta (δ)	2 – 5	thinly myelinated	pain (sharp, localized), temperature, touch
gamma (γ)	3 – 6	myelinated	muscle spindle
Type B	< 3	myelinated	preganglionic, autonomic
Type C	0.4 – 1.2	unmyelinated	pain (diffuse, deep), temperature, postganglionic autonomic

(Snell, 1997:101, Darby and Daley in Cramer and Darby, 1995:252, Jacobs and Lowe in Cohen, 1999:79 and Leach, 1995:90).

Type A fibers are the typical large myelinated fibers of spinal nerves (Guyton and Hall, 1997:379) that conduct impulses at high velocities (Cramer and Darby, 1996 and Colloca in Fuhr *et al.*, 1997:39). Type C fibers are small unmyelinated fibers that conduct impulses at low velocities (Guyton and Hall, 1997:379 and Colloca in Fuhr *et al.*, 1997:39), whereas type B fibers are myelinated preganglionic autonomic nerve fibers (Darby and Daley in Cramer and Darby, 1995:252).

The second classification system classifies certain sensory axons into types I to IV according to their origin, function and conduction velocity (Kingsley, 1996:139, Guyton and Hall, 1997:379 and Sakamoto *et al.*, 2001).

TABLE 2.2 *Classification of nerve fibers according to their origin, function and conduction velocity*

Fiber type	Origin	Function	Conduction velocity
Type I	mechanoreceptors	proprioception (muscle spindle, golgi tendon organ)	70 – 120
Type II	mechanoreceptors	cutaneous information from the skin	30 – 70
Type III	mechanoreceptors and nociceptors	pain, deep pressure, touch, temperature	4 – 30
Type IV	nociceptors	crude touch, pressure, pain and temperature	6 – 16

(Darby and Daley, 1995:252, Kingsley, 1996:140 and Guyton and Hall, 1997:379).

Both nomenclature systems are currently in use. These systems evolved independently, but share a certain degree of overlap that might result in some confusion (Kingsley, 1996:139).

2.2.3.4 Afferent fibers

The type A - β , A - δ and C fibers are the afferent fibers of importance for the present study. Their significance will be highlighted in a discussion of the gate control theory under 2.6, and the neurophysiological effects of spinal manipulation, under 2.7.

Mechanoreceptors transmit information via the A - β fibers (Darby and Daley in Cramer and Darby, 1995:252), whilst nociceptors conduct their information via the A - δ and C fibers (Colloca in Fuhr *et al.*, 1997:39). The type A - δ fibers conduct sharp pain impulses at great velocities, known as “fast” pain, whilst C fibers conduct a dull aching/burning pain at slower velocities, known as “slow” pain (Cramer and Darby, 1996 and Colloca in Fuhr *et al.*, 1997:39). The mechanical and thermal nociceptor classes conduct their information along the A - δ fibers, with polymodal nociceptors using C fibers (Darby and Daley in Cramer and Darby, 1995:253). Nociceptive information arising from free nerve endings are conducted along both the A - δ and C fibers (Snell, 1997:121 – 122).

Upon stimulation of a joint receptor, a change in membrane potential occurs through depolarization of the membrane (Hopkins and Ingersoll, 2000). This is followed by the development of an action potential (Hopkins and Ingersoll, 2000) viz. the receptor potential (Colloca in Fuhr *et al.*, 1997:39). This receptor potential is conducted along the sensory nerve fiber (Guyton and Hall, 1997:377) towards its cell body, located in the dorsal root ganglion (Hopkins and Ingersoll, 2000), where modulation of spinal nociception occurs (Cramer and Darby in Cramer and Darby, 1995:359).

2.2.3.5 The interneuron

According to Ingersoll, Palmieri and Hopkins (2003), the development of AMI appears to be mediated through interneuronal activity. On entering the dorsal horn of the spinal cord, the sensory nerve fiber branches to synapse on numerous interneurons (Hopkins and Ingersoll, 2000) that are located in the substantia gelatinosa (Benarroch *et al.*, 1999:175). These interneurons may receive information from segmental large and small primary afferent fibers and the descending supraspinal fibers (Benarroch *et al.*, 1999:175).

Interneurons may be excitatory or inhibitory (Benarroch *et al.*, 1999:175). Hence, the net effect of all information arriving at the interneuron may be expressed as either an inhibitory or excitatory response (Hopkins and Ingersoll, 2000).

Johansson, Sjölander and Sojka (1991) state that joint afferents have the ability to influence the spinal motor neurons through various reflex pathways, and via the type Ia and Ib interneurons. However, joint receptors appear to stimulate the type Ib inhibitory interneurons (Hopkins and Ingersoll, 2000), which contain GABA, enkephalins, or other neuropeptides, that are important in the local processing and modulation of pain transmission (Benarroch *et al.*, 1999:175).

The result of their stimulation is an alteration in the afferent innervation of the motor neuron pool through inhibition of the motor neuron pool (Hopkins and

Ingersoll, 2000), as type Ib inhibitory interneurons inhibit the α - motor neurons that are responsible for generating the force of contraction of that muscle (Iyer, Mitz and Winsten in Cohen, 1999:230).

2.2.3.6 The dorsal horn of the spinal cord and the dorsal root ganglion

The gray matter of the spinal cord is organized into ten laminae (Rexed's laminae), based upon the size of its neurons, cellular density, and staining characteristics (Benarroch *et al.*, 1999:434).

The dorsal horn of the spinal cord consists of laminae I through VI (Darby and Daley in Cramer and Darby, 1995:260). The neurons located in these laminae receive and integrate information prior to relaying it to the higher centers of the spinal cord (Jacobs and Lowe in Cohen, 1999:80).

The dorsal root ganglion is the modulator of spinal nociception. Cramer and Darby (1996) claim this role to be attributed to the neuron cell bodies located in the dorsal root ganglion that contain numerous neurotransmitters associated with nociception. The authors state that these substances are probably released from the peripheral terminals of sensory nerve fibers that transmit nociception.

2.2.3.7 The ascending spinal tracts

The ascending spinal tracts transmit information from nociceptors, cutaneous receptors, muscle receptors and joint receptors to the cerebral cortex and cerebellum (Crossman and Neary, 1995:46). A brief overview of the central transmission of mechanoreception and nociception follows.

2.2.3.7.1 The central transmission of mechanoreception

Mechanoreceptors respond to loads placed on tissues. Type II mechanoreceptors are of the dynamic variety, and respond to mechanical deformation, while Type I and III mechanoreceptors are of the static variety that sense loading (Colloca in Fuhr *et al.*, 1997:39 – 40).

Mechanoreceptors transmit information towards the dorsal horn of the spinal cord via the type A - β fibers (Darby and Daley in Cramer and Darby, 1995:252) where they synapse on interneurons and ascend via two pathways, namely the dorsal column medial – lemniscal system and the anterolateral system (Colloca in Fuhr *et al.*, 1997:42).

2.2.3.7.1.1 The dorsal column – medial lemniscal system

The dorsal column – medial lemniscal system transmit signals in the dorsal columns of the spinal cord (Colloca in Fuhr *et al.*, 1997:42). The majority of the type A - β fibers pass uninterrupted up the dorsal column to synapse in the dorsal column nuclei (the gracile and cuneate nuclei) of the medulla oblongata (Guyton and Hall, 1997:385 – 386 and Darby and Daley in Cramer and Darby, 1995:265).

From then on, signals are conducted along second – order neurons that cross over and ascend through the medial lemniscus towards the thalamus (Guyton and Hall, 1997:386, Colloca in Fuhr *et al.*, 1997:42 and Darby and Daley in Cramer and Darby, 1995:265) where they terminate in the ventrobasal complex and synapse on third – order neurons, projecting to the postcentral gyrus of the cerebral cortex viz. somatic sensory area I (Guyton and Hall, 1997:386).

2.2.3.7.1.2 The anterolateral pathway

The fibers of the anterolateral pathway originate in laminae I, IV, V and VI located in the dorsal horn of the spinal cord (Guyton and Hall, 1997:389). On entering the dorsal horn, these fibers cross over in the anterior commissure to the opposite anterior and lateral white columns, known as the anterior spinothalamic tract and lateral spinothalamic tracts, respectively (Colloca in Fuhr *et al.*, 1997:42 and Guyton and Hall, 1997:389).

Thereafter, fibers terminate throughout the brain stem reticular nuclei and in the ventrobasal complex and intralaminar nuclei of the thalamus. From here on, signals are transmitted to the somatic sensory cortex along with the signals from the dorsal column pathway (Guyton and Hall, 1997:389).

2.2.3.7.2 The central transmission of spinal nociception

Guyton and Hall (1997:392) illustrated two types of pain, namely fast – sharp and slow – chronic pain. Fast pain is conducted via the type A - δ fibers, whereas slow pain is conducted along the C fibers (Colloca in Fuhr *et al.*, 1997:39). For that reason, dual transmission of pain signals toward the central nervous system occurs (Guyton and Hall, 1997:393).

Both type A - δ and C fibers arrive at the tract of Lissauer, situated in the dorsal horn of the spinal cord (Colloca in Fuhr *et al.*, 1997:39). Some fibers continue directly into the dorsal horn gray matter, while their collateral branches may either ascend or descend numerous cord segmental levels prior to entering the dorsal horn (Cramer and Darby, 1995:361). Type A - δ fibers terminate in lamina I, and laminae IV through VI, whereas the type C fibers terminate in lamina II (Darby and Daley in Cramer and Darby, 1995:260).

From then on, the information received at the laminae ascend via the spinothalamic tract of the anterolateral system pathways towards the higher

centers of the spinal cord via its two divisions, namely the neospinothalamic and paleospinothalamic tracts (Jacobs and Lowe in Cohen, 1999:83 – 87, Guyton and Hall, 1997:393, Colloca in Fuhr *et al.*, 1997:39 and Cramer and Darby, 1995:269, 362).

2.2.3.7.2.1 The neospinothalamic tract for fast pain

The neospinothalamic tract is the pathway of fast pain conduction by means of the type A - δ fibers (Colloca in Fuhr *et al.*, 1997:39). Type A - δ fibers transmit primarily mechanical and acute thermal pain sensations, and terminate chiefly in Lamina I of the dorsal horn of the spinal cord to excite the second – order neurons of the neospinothalamic tract (Guyton and Hall, 1997:393).

These long second – order neuron fibers cross over to the opposite side of the spinal cord through the anterior commissure to ascend towards the brain by means of the anterolateral columns (Guyton and Hall, 1997:393). Next, the fibers terminate in the ventral posterior and posterior nuclei of the thalamus (Cramer and Darby in Cramer and Darby, 1995:362) where the conscious recognition of pain occurs (Colloca in Fuhr *et al.*, 1997:39). This information is then projected to other basal areas of the brainstem and ultimately, to the somatic sensory areas of the brain where the pain is interpreted (Guyton and Hall, 1997:393 – 394 and Colloca in Fuhr *et al.*, 1997:39).

2.2.3.7.2.2 The paleospinothalamic tract for slow pain

The paleospinothalamic tract is the pathway for slow pain conduction via the type C fibers (Guyton and Hall, 1997:394). The type C fibers terminate primarily in lamina II of the dorsal horn of the spinal cord (Darby and Daley in Cramer and Darby, 1995:260), which is also known as the substantia gelatinosa (Jacobs and Lowe in Cohen, 1999:81). The substantia gelatinosa

will be discussed in greater detail in a discussion of the gate control theory, under 2.6.

Most signals pass through one or more supplementary short fiber neurons within the dorsal horn prior to entering laminae V, VI, VII and VIII (Guyton and Hall, 1997:394). From then on, signals ascend by way of long axons that intermingle with those axons of the neospinothalamic pathway in their pathway through the anterior commissure to the opposite side of the spinal cord, proceeding upwards via the same anterolateral pathway (Guyton and Hall, 1997:394 and Benarroch *et al.*, 1999:173).

The paleospinothalamic tract fibers terminate in the midline and intralaminar nuclei of the thalamus (Benarroch *et al.*, 1999:173). From the nucleus, third – order neurons project to widespread areas of the cerebral cortex (Darby and Daley in Cramer and Darby, 1995:270) where the pain is interpreted (Guyton and Hall, 1997:393 – 394 and Colloca in Fuhr *et al.*, 1997:39).

2.2.3.8 The descending spinal tracts

The descending spinal tracts originate in the cerebral cortex and the brain stem. These tracts are concerned with the control of movements, muscle tone, spinal reflexes and spinal autonomic functions (Crossman and Neary, 1995:51). The purpose of this discussion is to highlight, in brief, the possible roles of selected descending spinal tracts that might play a role in the development of AML.

2.2.3.8.1 The corticospinal tract

The corticospinal tract transmits information regarding voluntary muscle activity (Darby and Daley in Cramer and Darby, 1995:276). This tract is the most direct pathway for information received and processed by the motor cortex, can reach the musculature to produce movement (Porter in Cohen, 1999:248).

The tract consists of large axon bundles originating in the motor and parietal cortices (Porter in Cohen, 1999:248). These cortical neurons synapse on α - motor neurons, γ - motor neurons and interneurons (Hopkins and Ingersoll, 2000).

One of several functions of the corticospinal tract includes the production of signals that govern the force of muscle contraction (Porter in Cohen, 1999:250). The majority of the cortical neurons of the corticospinal tract are excitatory. Though, some are inhibitory as they converge on inhibitory interneurons that inhibit normal afferent activity from causing a motor response (Hopkins and Ingersoll, 2000). Consequently, the force of muscle contraction might be reduced.

2.2.3.8.2 The vestibulospinal tract

"The vestibulospinal tract originates in the lateral vestibular nucleus located in the vestibular area in the floor of the fourth ventricle" (Darby and Daley in Cramer and Darby, 1995:280). The lateral vestibular nucleus receives proprioceptive input from the inner ear and the cerebellum (Snell, 1997:365) and regulates balance (Colloca in Fuhr *et al.*, 1997:158) and postural reflexes through projections to motor neurons and interneurons (Hopkins and Ingersoll, 2000).

According to Johansson, Sjölander and Sojka (1991), articular mechanoreceptor reflexes appear to be significantly involved in the normal reflex coordination of muscle tone in posture and movement, as these receptors operate polysynaptically via the γ - motor neuron loop. The authors go on to say that joint afferents in general, and ligamentous afferents in particular, seem to possess more potent effects at lower stimulation intensities on the γ - muscle – spindle system as opposed to α - motor neurons. Thus, joint mechanoreceptor reflexes operating via the γ - motor neuron loop might contribute to the preprogramming of stiffness of the musculature surrounding a joint, thereby regulating joint stiffness and joint stability.

According to Hopkins and Ingersoll (2000), postural reflexes change prior to voluntary movement. They state that these changes are mediated at the interneuron through the vestibular system and the cerebral cortex. Thus, the afferent innervation of the motor neuron pool might be altered as a result.

2.2.3.8.3 The rubrospinal tract

“The rubrospinal tract originates in the red nucleus of the midbrain” (Darby and Daley in Cramer and Darby, 1995:280). This tract has a powerful influence on spinal cord reflex activity and works in close association with the corticospinal tract to control the distal muscles (Porter in Cohen, 1999:270).

The rubrospinal tract has also been concerned in the inhibitory actions that affect interneurons that inhibit normal afferent activity from causing a motor response (Hopkins and Ingersoll, 2000). Johansson, Sjölander and Sojka (1991) cited Hongo, Jankowska and Lundberg (1969) who claimed that the activation of the rubrospinal tract “might disclose excitatory and inhibitory potentials that are evoked via low threshold joint afferents”. Hence, muscle strength might be reduced as a result of the altered afferent innervation of the motor neuron pool through inhibition of the motor neuron pool.

2.2.3.9 The spinal motor neurons

The contraction and extent of skeletal muscle contraction is governed by the spinal motor neurons. There are three types of motor neurons located in the ventral horn of the spinal cord, namely the alpha (α), beta (β), and gamma (γ) motor neurons (Darby and Daley in Cramer and Darby, 1995:283).

The α - motor neurons are the largest (Darby and Daley in Cramer and Darby, 1995:283), and fastest conducting neurons (Iyer, Mitz and Winstein in Cohen, 1999:220) of the motor neurons. These neurons solely innervate the

extrafusal muscle fibers that are the force – producing fibers of skeletal muscle (Iyer, Mitz and Winstein in Cohen, 1999:220).

The β - motor neurons are the second fastest motor neurons (Iyer, Mitz and Winstein in Cohen, 1999:220) and innervate both skeletal muscle and the muscle spindles (Darby and Daley in Cramer and Darby, 1995:284).

The γ - motor neurons are the smallest (Darby and Daley in Cramer and Darby, 1995:283) and slowest (Iyer, Mitz and Winstein in Cohen, 1999:220) motor neurons. They innervate the intrafusal muscle fibers of the muscle spindle in the muscle (Iyer, Mitz and Winstein in Cohen, 1999:220).

These three types of motor neurons are mixed together into groupings called motor neuron pools. A motor neuron pool innervates one particular muscle group (Darby and Daley in Cramer and Darby, 1995:284).

Each motor neuron receives thousands of synapses from the cerebral cortex, brainstem, distant spinal afferent neurons, nearby interneurons, and primary muscle afferents. These inputs converge and regulate how close the neuron is to threshold, viz. motor neuron excitability (Iyer, Mitz and Winstein in Cohen, 1999:220).

The motor neuron and the muscle fibers it innervates, work together as a unit known as a motor unit (Darby and Daley in Cramer and Darby, 1995:284). The greater the force required from the muscle, the more motor units are recruited. Thus, the number of motor units recruited governs the strength of muscle contraction (Iyer, Mitz and Winstein in Cohen, 1999:221).

The inhibitory interneurons mediate the altered afferent innervation of the motor neuron pool, resulting in a decrease in recruitment ability within the motor neuron pool (Hopkins and Ingersoll, 2000). In so doing, the efferent response of the muscles that are innervated by the motor neuron pool is also altered, resulting in fewer motor units being recruited and consequently, a

lesser percentage of the motor neuron pool being activated (Iyer, Mitz and Winsten in Cohen, 1999:221). Accordingly, the force of any contraction governed by that motor neuron pool is reduced and consequently, AMI is clinically manifested as a reduction in muscle strength (Suter *et al.*, 1999).

2.2.4 The clinical implications of arthrogenic muscle inhibition

Muscle inhibition plays an integral role in full muscle and joint recovery following injury (Hurley, Jones and Newham, 1994), as it retards the rehabilitation process, despite complete muscle integrity (Hopkins *et al.*, 2002). As a result, Suter *et al.* (2000) state that one of the early goals of rehabilitation should be to eliminate or reduce muscle inhibition. Nevertheless, the removal of AMI is generally not a stated goal in the rehabilitation process (Ingersoll, Palmieri and Hopkins, 2003).

Current joint rehabilitation protocols are dependent on the use of active exercise (Hopkins and Ingersoll, 2000). Early active exercise is considered essential for increasing the structural strength and stiffness of ligaments, collagen synthesis in tendons, proteoglycan content in articular cartilage, and the periosteal expansion of bone tissue (Hopkins *et al.*, 2002).

Still, the process of early active exercise in the joint rehabilitation process is significantly hindered by the patient's diminished ability to contract the musculature surrounding the injured joint (Hopkins and Ingersoll, 2000). AMI may also impede the engagement in increasingly vigorous active exercises that are necessary to expedite the healing process (Hopkins *et al.*, 2000).

In addition, Hopkins *et al.* (2002) claim that AMI slows gains in proprioception. Conscious proprioception is essential for proper joint function in sports, activities of daily living, and occupational tasks. Whereas unconscious proprioception modulates muscle function and initiates reflex stabilization (Lephart *et al.*, 1992). Thus, AMI might result in neuromuscular control deficiencies in addition to muscle atrophy and strength deficits (Hopkins and Ingersoll, 2000). For this reason, Hopkins and Ingersoll (2000) state that AMI

is often considered to be the cause of re – injury and premature return to competition.

AMI might also result in movement adaptations that allow for function. For example, an injured ligament, according to Johansson, Sjölander and Sojka (1991), is likely to cause persistently disturbed sensory feedback and therefore, the existing motor programs have to be modified accordingly. Ingersoll, Palmieri and Hopkins (2003) state that such activity, specifically originating from mechanoreceptors, will continuously alter the muscular activity surrounding the injured joint and that the patient will ultimately replace his/her normal muscle pattern of activation with an adapted functional motor program.

Thus, the presence of longstanding AMI might pose numerous long – term detrimental effects on various tissues in the body (Ingersoll, Palmieri and Hopkins, 2003), including muscles, bones and ligaments and neural activity (Hopkins *et al.*, 2000). These effects are highlighted in table 2.3.

TABLE 23 *The secondary effects of arthrogenic muscle inhibition on the tissues of the body*

Muscle	Bone	Ligament	Nerve
Type I fiber atrophy	Periosteal and subperiosteal resorption	Decreased tensile strength	Depolarized muscle fiber membrane
Decreased cross – sectional area	Decreased strength and stiffness	Decreased load to failure	Decreased potential at motor end plates
Decreased oxidative enzyme activity	Decreased load to failure	Elongation	Reduced Na ⁺ /K ⁺ transport across the membranes
	Decreased energy storing capacity	Decreased stiffness	

[Nordin and Frankel (1989) as cited by Ingersoll, Palmieri and Hopkins (2003)].

2.2.5 Measurement of arthrogenic muscle inhibition

The extent of AMI can be determined by measuring voluntary motor unit recruitment by means of a dynamometer (Ingersoll, Palmieri and Hopkins, 2003) or through electromyography (EMG) (Suter *et al.*, 1999). Whereas

involuntary measures of motor neuron recruitment may be calculated through the controlled stimulation of sensory fibers and the evaluation of the reflexive twitch contraction (Ingersoll, Palmieri and Hopkins, 2003), utilizing the Hoffmann reflex (H – reflex) (Hopkins and Ingersoll, 2000). In addition, a combination of a voluntary contraction with a superimposed electrical impulse may be employed as a measurement of AMI as with the interpolated twitch technique (Hopkins and Ingersoll, 2000 and Ingersoll, Palmieri and Hopkins, 2003).

EMG measures the extent of muscle activation through surface electrodes that are placed on the muscle belly, along the estimated direction of the muscle fibers. Electrical twitches are applied to the relaxed muscle and the peak of the evoked twitch torque is measured. The measured difference between two measurements is said to demonstrate the amount of AMI present (Suter *et al.*, 1999).

The Hoffmann reflex (H – reflex) is an indirect assessment of motor neuron pool recruitment and for that reason, requires no voluntary muscle contraction (Ingersoll *et al.*, 2003). A percutaneous stimulus is applied to a mixed nerve to elicit a monosynaptic reflex (Hopkins *et al.*, 2000) that results in depolarization of large afferents and ultimately, depolarization of motor neurons in the anterior horn of the spinal cord (Hopkins *et al.*, 2002). This leads to a twitch contraction of the effector muscle that can be measured by electromyography (EMG) (Hopkins *et al.*, 2002).

Any change in the number of motor neurons recruited within the motor neuron pool is represented as a change in H – reflex amplitude (Hopkins *et al.*, 2000). Inhibition or a decrease in the availability of motor neurons within a pool is reflected by a decrease in H – reflex, while facilitation is represented by an increased H – reflex (Hopkins *et al.*, 2002).

The interpolated twitch technique is a combination of a mean voluntary muscle contraction with an added supramaximal external stimulus (Hopkins and Ingersoll, 2000). This technique involves the superimposition of

electrically stimulated twitches while the patient performs a maximal voluntary muscle contraction (Young, 1993). The ensuing interpolated twitch torque represents the extent of motor units that are activated during the contraction (Suter *et al.*, 1998).

If the superimposed electrical stimulus does not increase torque, Suter *et al.* (1998) state that it is understood that the muscle is maximally activated. Conversely, in the case of incomplete muscle activation, the electrical nerve stimulation produces an increase in torque (Suter *et al.*, 1999, 2000). Suter *et al.*, (2000) state that the magnitude of this interpolated twitch torque represents the amount of muscle inhibition.

2.2.5.1 Isokinetic dynamometry

This study utilized the Cybex Orthotron II Isokinetic Rehabilitation System to quantify maximum voluntary muscle contractions of the hip musculature in the actions of flexion, extension, adduction and abduction, prior to, immediately following and 1 day/24 hours post sacroiliac manipulation.

2.2.5.1.1 Rationale for utilizing isokinetic dynamometry for the measurement of arthrogenic muscle inhibition in the present study

Ingersoll, Palmieri and Hopkins (2003) state that AMI is a reduction in motor neuron pool recruitment. Therefore, fewer motor units are recruited and a lesser percentage of the motor neuron pool is active (Iyer, Mitz and Winstein in Cohen, 1999:221). Thus, the force of any contraction governed by that motor neuron pool is reduced and AMI is clinically manifested as a decrease in muscle strength (Suter *et al.*, 1999).

Isokinetic dynamometers primarily measure muscle strength (Chan and Maffulli, 1996:9). Hopkins and Ingersoll (2000) claim that a difference in baseline maximum voluntary muscle contraction and a maximum voluntary muscle contraction following injury is inhibition. In this respect, Suter *et al.*

(1999) state that a reduction in AML might result in an increase in muscle strength.

In lieu of the statements by Hopkins and Ingersoll (2000) and Suter *et al.* (1999), a difference in baseline maximum voluntary muscle contraction prior to manipulation and a maximum voluntary muscle contraction following manipulation, should demonstrate the amount of inhibition, based upon the results of the studies by Suter *et al.* (1999, 2000).

2.2.5.1.2 Introduction to isokinetic dynamometry

Isokinetic dynamometers may be utilized for five major purposes, namely strength testing, rehabilitation, research, diagnosis of injury, and as training aids. Nevertheless, the primary function of isokinetic dynamometers appears to be the evaluation of muscle strength (Chan and Maffulli, 1996:9 – 10) viz. “a measure describing an individual’s ability to exert maximum muscular force, either statically or dynamically” (De Ste Croix, Deighan and Armstrong, 2003).

Isokinetic dynamometers measure angular velocity, the position of the moving body part, and either force or torque (Chan and Maffulli, 1996:11 – 12). Hence, isokinetic exercise permits the quantification of several muscle function indices, such as peak and average torque, and work and power (De Ste Croix, Deighan and Armstrong, 2003).

One of the main features of isokinetic dynamometers is that the resistance of the device matches the movement speed of the individual precisely, thus maintaining a constant velocity (Chan and Maffuli, 1996:7 and De Ste Croix, Deighan and Armstrong, 2003). Chan and Maffulli (1996:10) deemed this one of the major advantages of isokinetic testing procedures, particularly in the early rehabilitation process, as it allows for velocity modification to suit the patient’s ability, thereby providing safe and efficient treatment. In this regard, De Ste Croix, Deighan and Armstrong (2003) affirm that isokinetic

dynamometers have been primarily advocated for strength testing procedures.

Isokinetic dynamometers may measure muscle strength in one of three modes, namely the isometric mode, isoinertial/dynamic variable – resistance mode or the isokinetic mode. The isokinetic mode is described as a type of exercise and may be defined as “a dynamic muscular contraction that occurs at a constant velocity” (Chan and Maffuli, 1996:7).

Isokinetic testing produces two types of muscular contractions, namely concentric and eccentric muscle contractions, depending on the testing mode of the dynamometer (Chan and Maffulli, 1996:5). Concentric muscle contractions result in a decrease in distance between the origin and insertion of the muscle, while eccentric muscle contractions result in an increased distance between the origin and insertion of the muscle. Eccentric contractions generate greater muscle tension and as a result, require less muscle work as opposed to concentric muscle contractions (Chan and Maffulli, 1996:5, 7).

In this regard, Arokoski *et al.* (2002) state that concentric and eccentric muscular contractions do not resemble the nature of most joint movement during normal human movements. Nevertheless, the authors advocate isokinetic assessment, as it is the primary method available to investigate whether the static or dynamic properties of the muscle tested is intact or not.

2.2.5.1.3 Advantages and disadvantages of isokinetic dynamometry

TABLE 2.4 *Comparison and contrast of the advantages and disadvantages of isokinetic dynamometry*

Advantages	Disadvantages
Simple measure that may be performed with very little equipment.	Equipment is very costly and the process time – consuming.
Allows for maximal dynamic loading of the muscle throughout its range of motion and is therefore a direct assessment of motor neuron pool recruitment.	The patient must be willing and able to perform a maximum voluntary muscle contraction.
Objective, reproducible and quantifiable assessment that provides speed – specific through the velocity at a given range.	Difficult to reproduce and requires the assistance of specially trained personnel.
Weak muscles of a muscle group may be isolated by strapping and limiting range of motion to a specific angle of movement.	Consists of the contraction of several muscles. It is impossible to measure independent muscles separately.
Accommodating resistance provides additional safety, therefore dynamometers are effective in early rehabilitation.	May be difficult to obtain a maximum voluntary contraction following an acute injury.
Allows for functional pattern training protocols.	
Does not require pre – injury measurement for comparison in order to establish the presence of AML.	

(Hopkins and Ingersoll, 2000, Ingersoll, Palmieri and Hopkins, 2003 and Chan and Maffulli, 1996:8).

2.2.5.1.4 Contraindications to isokinetic dynamometry

The contraindications to isokinetic testing procedures are divided into absolute and relative contraindications. These contraindications are outlined by www.isokinetics.net (2003).

2.2.5.1.4.1 Absolute

1. Non – united fractures to the limb
2. Epilepsy
3. Cardiac insufficiency, unless closely monitored
4. Severe peripheral vascular disease
5. Aneurysms
6. Anticoagulants
7. Recent (< 3 months previous) X – ray/chemo therapy
8. Long – term steroid use (> 3 months)

9. Acute (< 7 days) muscle/ligament tear (> grade 1)
10. Pregnancy
11. Any neurological condition (e.g. stroke, Parkinson's disease), unless closely monitored
12. Skin problems under load cell
13. Severe osteoporosis
14. Malignancy in the area to be tested

2.2.5.1.4.2 Relative

1. Pain
2. Severe limited range of motion
3. Soft tissue healing
4. Bone healing
5. Effusions
6. Osteoporosis
7. Anemia
8. Rheumatoid arthritis
9. Recent surgery

2.2.5.1.5 Reliability of isokinetic dynamometry

"The application of a valid measuring instrument to dissimilar groups under different circumstances, should lead to the same observations". Mouton (1996:144) claims this to be the reliability of an instrument.

Arokoski *et al.* (2002) state that isokinetic assessment techniques should possess high test – retest reliability. In this respect, Davies (1992:35) assured that several studies have been conducted to substantiate the reliability and validity of the Cybex.

Chan and Maffulli (1996:22 - 23) cited a study by Magnusson, Gleim and Nicolas (1990) who demonstrated correlation coefficients between 0.93 and

0.99 with regard to the accuracy of peak torque, work, and power pertaining to isokinetic dynamometers.

Whereas Callaghan *et al.* (2000) conducted a study of reliability using a multiple joint attachment on the lower limb on a Boidex system 2 isokinetic dynamometer. The results of their study established a high test – retest reliability for isokinetic dynamometers (level of significance set at 5%).

Chan and Maffulli (1996:22 – 23) concluded that concentric muscle contractions had a greater reliability than eccentric muscle contractions and reported correlation coefficients between 0.93 and 0.99 when using an isokinetic dynamometer.

With regard to hip isokinetic testing procedures, the same authors state that the reliability of hip isokinetic testing procedures tend to be low. They claim that this might be attributed to the large range of motion of the hip joint and the relatively small amount of torque that may be produced by the muscles of the hip in certain movements. The authors go on to say that variations in the small torque produced by the muscles may become magnified, especially if the dynamometer utilized does not register decimal points, thereby allowing for a greater variation in the results of the small movement test to transpire. However, the authors did not specify which hip movements were involved.

In contrast, Arokoski *et al.* (2002) claimed otherwise. In addition to investigating hip flexion, extension, adduction and abduction isokinetic strength in male subjects presenting with hip osteoarthritis and comparing the results to age and sex matched healthy controls, these authors assessed the day – to – day reproducibility of hip muscle strength tests in 11 healthy and 9 subjects with hip osteoarthritis, on separate days, at an interval of 2 to 6 weeks. The authors demonstrated a moderate degree of reliability of hip isokinetic testing with respect to test and re – test conditions.

In conclusion, isokinetic dynamometers are commonly considered as reliable measurement tools. Yet, it appears that the reliability of hip isokinetic muscle

testing is questionable. It is the author's opinion that the reliability of hip isokinetic testing procedures warrants further investigation.

2.2.5.1.6 Validity of isokinetic dynamometry

Isokinetic dynamometers are considered valid measurement tools (www.isokinetics.net, 2003). Bernard (2000:46) defines validity as the "accuracy and trustworthiness of instruments, data and findings that ensures that future research utilizing that particular tool is accurate".

2.2.5.1.6.1 Content validity

Content validity has been demonstrated for Isokinetic dynamometry with respect to specific aspects of muscle performance. Hence, in some instances, the clinical setting of muscle testing may be analogous to real life situations. For example, the maximum power that may be derived from isokinetic testing during the action of plantar flexion is analogous to the functional velocity of toe off during normal ambulation (www.isokinetics.net, 2003).

2.2.5.1.6.2 Construct validity

2.2.5.1.6.2.1 Convergent validity

Convergent validity is dependent of numerous factors that might influence isokinetic strength testing procedures and the results obtained. Convergent validity has been established for isokinetic dynamometers through the recognition of these factors. A brief discussion of these factors follows.

2.2.5.1.6.2.1.1 Differences in body size

Differences in body size are of vital importance in isokinetic strength testing procedures, according to De Ste Croix; Deighan and Armstrong (2003). Chan and Maffulli (1996:4) state that smaller athletes possess a greater advantage,

as they have higher strength – to – mass ratios in contrast to their larger counterparts. On the contrary, De Ste Croix, Deighan and Armstrong (2003) claim that larger individuals are “more often than not stronger than their smaller counterparts”.

Consequently, there appears to be a lack of consensus regarding body size and the isokinetic test results. The possible relationship between body size and isokinetic muscle strength will be explored in brief in chapters four and five.

2.2.5.1.6.2.1.2 Age

De Ste Croix, Deighan and Armstrong (2003) claim that the intrinsic force – producing capability of a muscle appears to increase with age. Then again, age – related changes appear to be applicable to children and adolescents only. In general, muscle strength normally reaches its peak in the third decade. Thereafter it declines moderately with increasing age until the seventh decade where there is a steeper decline (www.isokinetics.net, 2003).

The relationship amid increasing age and isokinetic strength will be explored in brief in chapters four and five.

2.2.5.1.6.2.1.3 Sex differences

In general, men appear to be stronger than females (Chan and Maffulli, 1996:4). Brukner and Kahn (2002:677) corroborate this statement as they claim that females exhibit, on average, approximately two – thirds the strength of men.

However, the authors De Ste Croix, Deighan and Armstrong (2003) reported that the data of studies regarding the differences in isokinetic muscle strength between males and females are inconsistent. They state that while some studies suggest that males are significantly stronger, others report the contrary.

The present study was limited to male participants only. The exclusion of female participants allowed for a homogenous study sample and thus, an increase in the validity of the results. Nevertheless, no comparison could be made between male and female subjects. Thus, the comparison of isokinetic hip strength in males and females might be a topic for future investigation.

2.2.5.1.6.2.1.4 Body mass and stature

Body mass and stature appear to have independent influences on isokinetic strength (De Ste Croix, Deighan and Armstrong, 2003). Heavier individuals tend to produce higher isokinetic moments as the muscle mass in normal individuals is said to rise in proportion to body weight (www.isokinetics.net, 2003). Whereas increased stature is said to introduce a mechanical benefit (De Ste Croix, Deighan and Armstrong, 2003).

In light of these statements, heavier or taller participants of this study might demonstrate greater average isokinetic muscle strength. These relationships will be explored in brief in chapters four and five.

2.2.5.1.6.2.1.5 Muscle cross – sectional area

Chan and Maffulli (1996:111) state that muscle strength is principally dependent on muscle cross – sectional area. In this respect, De Ste Croix, Deighan and Armstrong (2003) affirm that the maximum force a muscle can generate is relative to its cross – sectional area. Conversely, according to Arokoski *et al.* (2002), reduced muscle cross – sectional area is not a direct indicator of decreased hip muscle strength in patients with osteoarthritis of the hip. Thus, the relationship between muscle cross – sectional area and strength warrants further investigation.

2.2.5.1.6.2.1.6 Activity level

According to Lee, Ooi and Nakamura (1995), a lack of daily activity in sedentary individuals might result in reduced muscle strength. Thus, the converse should also apply.

In lieu of the above statement, the results of Fughl – Meyer (1981), as cited by www.isokinetics.net (2003), supported this opinion, as their findings demonstrated significant strength differences in isokinetic ankle plantar – and dorsiflexion between trained versus sedentary individuals.

2.2.5.1.6.3 Predictive validity

Predictive validity is the ability of a measurement tool to forecast a future event. There are two main categories involved predictive validity, namely the prediction of dysfunction and the prediction of progress during the rehabilitation process (www.isokinetics.net, 2003).

With respect to the prediction of dysfunction, Nadler and colleagues (2001) aimed at assessing whether athletes (100 males and 60 females) with strength imbalances of the hip musculature would be more likely to seek treatment for their low back pain during the ensuing year. Overall (with respect to their entire study population), their results demonstrated no significant predictive validity in terms of subsequent treatment of low back pain. However, the authors did validate the concept of hip muscle imbalance being associated with low back pain occurrence in female athletes.

www.isokinetics.net (2003) state that Isokinetic dynamometers are able to provide feedback regarding the speed of recovery following injury. For this reason, isokinetic dynamometers have been proposed as valid progress prediction tools in the rehabilitation process. However, the aspects of predictive validity relating to isokinetic dynamometers warrant further investigation.

2.2.5.1.6.4 Methodological considerations associated with isokinetic testing procedures

2.2.5.1.6.4.1 Familiarization, warm up and continuous versus interrupted cycles

Chan and Maffulli (1996:117) state familiarization periods should comprise of sub – maximal, followed by maximum force contractions in order to familiarize the patient with the isokinetic testing procedure. A number of researchers have incorporated familiarization periods in their study protocols (Callaghan *et al.*, 2000, Arokoski *et al.*, 2002 and Suter *et al.*, 1999). Conversely, the inclusion of familiarization sessions in protocols to test concentric isokinetic strength does not appear to be universal (Lee, Ooi and Nakamura, 1995 and Nadler *et al.*, 2001).

De Ste Croix, Deighan and Armstrong (2003) state that a familiarization period might diminish the effect of learning on the test data. In this respect, a familiarization period assists the procedure by providing reliable and reproducible results (Chan and Maffulli, 1996:117).

General warm ups have been integrated in isokinetic testing protocols. These warm ups should preferably include submaximal efforts prior to each isokinetic test velocity. Warm ups usually consist of three to eight submaximal trials, followed by one to three maximal efforts (De Ste Croix, Deighan and Armstrong, 2003).

The use of continuous or interrupted protocols might have a significant effect on peak torque output. A short pause between actions appears to facilitate the neuromuscular demands of the testing protocol (De Ste Croix, Deighan and Armstrong, 2003).

2.2.5.1.6.4.2 Verbal encouragement

According to Hopkins and Ingersoll (2000), patients are required to perform maximum voluntary muscle contractions during isokinetic testing procedures to allow for the effective measurement of any differences in voluntary force production. Verbal encouragement has been shown to influence the test results (Chan and Maffulli, 1996:122) as it affects the patient's ability to perform a maximum voluntary muscle contraction through increasing their voluntary effort (De Ste Croix, Deighan and Armstrong, 2003).

For this reason, verbal encouragement of study participants has been included in research studies (Callaghan *et al.*, 2000 and Arokoski *et al.*, 2002). Yet, Chan and Maffulli (1996:122) state that such encouragement should be standardized, specifically when utilizing isokinetic dynamometry in the research setting, in order to increase the validity of the test results.

2.2.5.1.6.4.3 Gravity correction

The isokinetic assessment of a limb segment involves its movement through a gravity – dependent position. The validity and reliability of peak torque measurements rely on effective and correct gravity correction procedures. Hence, gravity correction procedures must be implemented to ensure that movements against gravity will not be underestimated and movements aided by gravity, not overestimated (De Ste Croix, Deighan and Armstrong, 2003).

With respect to hip isokinetic testing procedures, Chan and Maffulli (1996:120) state that gravity correction is of particular importance during the assessment of hip flexion/extension, in light of the above.

2.2.5.1.6.5 Additional considerations associated with isokinetic testing procedures

2.2.5.1.6.5.1 The patient's perceived level of pain

According to Ohnmeiss *et al.* (2000), a patient significantly influences isokinetic test values's due to their self – reported disability and pain expression. In lieu of this statement, Suter *et al.*, (1998) reported a weak but statistically significant relationship between AMI and pain, with high levels of pain being associated with high levels of AMI. Arokoski *et al.* (2002) demonstrated quite the opposite in that muscle strength did not correlate with the subjective severity of hip pain. Yet, the authors demonstrated significant negative correlations in the actions of flexion and abduction.

Consequently, it might be anticipated that participants of this study that account greater subjective pain disability might demonstrate reduced isokinetic strength, attributable to increased AMI, as opposed to their “reduced pain disability” counterparts. As previously stated under 2.2.2, the relationship between AMI and pain and the role of pain in AMI development appears to be ambiguous. Should the results of this study demonstrate significantly reduced muscle strength as a result of a significant amount of AMI in patients with higher reported pain disability, the results of the present study might support the role of pain in the development of AMI. The relationship between perceived level of pain and isokinetic strength will be explored in brief in chapters four and five.

2.2.5.1.6.5.2 Symptomatic versus asymptomatic subjects

Isokinetic testing procedures have been conducted on healthy and symptomatic populations. Symptomatic patients are inclined to exhibit considerably reduced average muscle strength in comparison to their asymptomatic counterparts. Arokoski *et al.* (2002) and Nadler *et al.* (2001) demonstrated reduced muscle strength values on the affected side in symptomatic patients with osteoarthritis of the hip and sacroiliac syndrome,

respectively. Whereas, the results of Lee, Ooi and Nakamura (1995) demonstrated reduced trunk and lower extremity muscle strength in subjects with a history of low back pain as opposed to a healthy control group.

A possible justification for this phenomenon could be based on the hypothesis of Lee, Ooi and Nakamura (1995) who speculated that increased pain severity might result in reduced activity levels, and consequently, weaker muscles.

The present study incorporated subjects that presented with chronic, symptomatic sacroiliac syndrome. Thus, the participants of this study should theoretically exhibit significantly lower average isokinetic muscle strength as opposed to average muscle strength compared to their asymptomatic counterparts, based on the results of the above authors.

However, due to the nature of the study, a control group was not included. This might pose to be one of the limitations of the study, as no comparison could be made to healthy individuals. However, the present study was solely a clinical outcome/observation study rather than a controlled design. Upcoming studies should evaluate any differences in isokinetic hip muscle strength comparing symptomatic and asymptomatic populations.

2.2.5.1.6.5.3 The presence of arthrogenic muscle inhibition in the contralateral limb

Young (1993) stated that unilateral joint injury might result in a degree of AMI in the contralateral limb. In this respect, Suter *et al.* (1998 and 1999) and Hurley, Jones and Newham (1994) demonstrated considerable amounts of muscle inhibition in the contralateral, uninjured leg in their studies.

Suter *et al.* (1998) proposed two potential explanations for the presence of AMI in the contralateral leg. Firstly, they anticipated that joint injury might lead to an alteration in physical activity and/or gait pattern, which in turn might modify the neuromuscular control on the involved muscles. Secondly, the authors proposed the concept of reflex neurogenic inflammation viz. the

transfer of unilateral inflammation towards the contralateral side by means of neural connections in the spinal cord.

Similarly, Young (1993) proposed the possibility of convergent input from additional tissues, together with the contralateral limb, to some ascending tract cells. This seems plausible as Hopkins and Ingersoll (2000) state that crossed spinal pathways transmit information to the contralateral leg, which may inhibit the joint musculature of the contralateral leg.

Hurley, Jones and Newham (1994) hypothesized that unilateral joint injury might produce abnormal afference, which may be perceived as having arisen bilaterally. Their hypothesis was based on the notion that spinal neurons receive bilateral nerve input.

A major implication of the presence of AMI in the contralateral leg is that the contralateral limb cannot be assumed to be a true normal control when comparing the involved side to the uninvolved side. The results of Suter *et al.* (1998) discarded this assumption, as the authors showed that the non – involved leg possessed a considerable amount of AMI, which was higher than AMI in the healthy population. The authors state that the supposition of the contralateral leg being a normal control leads to the underestimation of AMI in the involved leg.

From the above statement, it appears that the presence of AMI in the contralateral limb is more appropriate to studies that involve the comparison of the involved and uninvolved limbs. Yet, the existence of AMI in the contralateral limb cannot be disregarded in the present study, as participants presenting with bilateral sacroiliac syndrome were included in the study sample.

Hypothetically, the presence of bilateral sacroiliac syndrome might result in the bilateral presence of AMI. The existence of AMI in the “unaffected” hip muscles might result in the amplification of AMI in the affected limb hip

musculature on the more symptomatic side, based upon the results and statements above.

As a result, subjects that presented with bilateral sacroiliac syndrome might exhibit a greater amount of AMI, and consequently show a less significant reduction of AMI following manipulation, as only the "symptomatic" side was manipulated. Thus, the amount of AMI in the "symptomatic" limb might be underestimated.

This might pose to be another limitation of the study, as the homogeneity of the study sample was not maintained. In light of this limitation, the validity of the study might be compromised.

The presence of AMI in the contralateral limb due to bilateral sacroiliac syndrome and its effect on isokinetic strength will be explored in brief in chapters four and five.

2.2.5.1.7 Isokinetic testing protocol for the hip

The isokinetic testing protocol for the hip musculature utilized in this study was modified from Davies (1992: 44 – 50), Perrin (1993: 48), Suter *et al.* (2000), Chan and Maffuli (1996:169 – 170) and Jackson (2003).

Hip flexion and extension is tested with the patient in the supine position. This position allows for maximal flexion at the hip. The hip on the affected side is approximated to the power arm of the Cybex and the axis of movement of the power arm is aligned with the axis of movement of the hip joint at the femoral head. Therefore, the head of the femur is 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 is 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 is utilized to minimize any body

movements and isolate movement at the hip joint, as it enhances the reliability of the results. The affected limb is positioned with the hip in the fully flexed position (thigh more than 90 ° to the table). Therefore, the test commences with extension.

Hip adduction and abduction is tested in the lateral recumbent position, with the effected side up. The power arm of the Cybex is 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 is 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.

Next, the power arm is secured to the distal femur via Velcro straps, just proximal to the knee joint. A strap is utilized to secure the patient over the torso to minimize any body movements, thereby increasing the reliability of the results. The affected limb is positioned in the fully adducted position prior to commencement of the test. Thus, the first action to be tested is abduction.

Gravity correction procedures are implemented to ensure that movements against gravity are not underestimated and movements aided by gravity not overestimated, as the validity and reliability of peak torque measurements rely on effective and correct gravity correction procedures.

Isokinetic testing commences with a sub – maximal warm – up rep at 90°/sec followed by a 1-minute rest period, followed by 2 trial reps at maximal effort, followed by a 1-minute rest period. This allows patients to familiarize themselves with the isokinetic testing procedure, thereby increasing the reliability of the results. The familiarization period is followed by 3 reps at maximal effort at 60°/sec, followed by a 4-minute rest period.

Subjects are instructed not to support themselves by holding on to the machine or to gain leverage from their upper bodies. All participants receive

similar, equally enthusiastic verbal encouragement during testing to ensure their maximal effort.

2.2.6 Therapeutic interventions for arthrogenic muscle inhibition and their ability to cause an effective reduction in arthrogenic muscle inhibition

Numerous therapeutic techniques have been developed with the aim of increasing muscle strength and neuromuscular control during joint rehabilitation. Nevertheless, these techniques are of little advantage if the presence of AMI cannot be conquered first (Hopkins *et al.*, 2002).

Notwithstanding the existence and clinical importance of AMI, the treatment options available are restricted (Hopkins and Ingersoll, 2000), as only a small number of clinicians and researchers have attempted to propose ways of overcoming or neutralizing AMI in a clinical setting (Hopkins *et al.*, 2002). According to Ingersoll, Palmieri and Hopkins (2003), new therapeutic modalities and rehabilitation programmes should ideally aim at preventing the negative effects of AMI in the rehabilitation setting, while still allowing the protective effect of AMI to limit activity.

Pharmacological agents, such as the anesthetic lidocaine, could have an effect on AMI. At the outset of their study, Spencer, Hayes and Alexander (1984) hypothesized that subsequent to the injection of lidocaine, any inhibitory influences as a result of artificial knee joint effusion would be eliminated, thereby indicating a neurally mediated inhibition of the quadriceps muscle group as opposed to some mechanical effect. The results of their study supported this hypothesis as they demonstrated that the injection of 10 ml of 1 % lidocaine negated the inhibitory process of the quadriceps muscles.

On the other hand, Hopkins and Ingersoll (2000) criticized the use of lidocaine injections. They argued that the injection of lidocaine might compromise the essential feedback to both the patient and clinician due to a decrease in perceived pain.

Cryotherapy results in a decrease in general nerve conduction velocity, synaptic transmission, muscle spasm and pain, and is known to have a definitive slowing and blocking effect on sensory nerve fibers. The cooler the nerve becomes, the slower the impulse is carried (Knight, 1995:301). The resultant increase in action potential time might cause decreased peak-to-peak amplitude of depolarization at the interneuron (Hopkins and Ingersoll, 2000). This could result in a decrease in firing of the inhibitory interneuron with a successive increase in voluntary activation of the MN pool (Ingersoll, Palmieri and Hopkins, 2003).

Ingersoll, Palmieri and Hopkins (2003) state that trans cutaneous electrical nerve stimulation (TENS) is another appealing intervention that might result in the reduction of AMI. TENS is primarily advocated as a pain intervention modality, as it stimulates cutaneous type I nerve endings (Hopkins and Ingersoll, 2000). For this reason, TENS might compete for the same type I afferent fibers that carry information from the joint receptors to the spinal cord (Hopkins and Ingersoll, 2000).

Hopkins *et al.* (2002) attempted to examine the effects of cryotherapy versus TENS on AMI. They concluded that cryotherapy and TENS both "disinhibited" the quadriceps following knee joint effusion. However, cryotherapy further facilitated the quadriceps motor neuron pool, with this facilitation extending into the post – treatment phase. Conversely, TENS treatment failed to "disinhibit" the vastus medialis motor neuron pool by 30 minutes post – injection. Thus, cryotherapy appears to be a superior therapeutic intervention as opposed to TENS in the reduction of AMI.

Lidocaine injections, cryotherapy and TENS are principally aimed at decreasing joint pain, effusion and muscle atrophy. These therapeutic techniques may cause a reduction in AMI to varying degrees, but are considered inadequate in causing a significant reduction in AMI (Hopkins and Ingersoll, 2000).

In this respect, Ingersoll, Palmieri and Hopkins (2003) state that additional modalities or programs should be evaluated for their usefulness in eliminating or reducing AMI and its consequences. According to Hopkins and Ingersoll (2000), a desired therapeutic intervention should result in decreased inhibition whilst still allowing for the use of active exercises. The authors claim that this should lead to a speedier and more complete recovery.

Spinal manipulation might pose to be an interesting alternative treatment for AMI of the lower limb musculature. In a descriptive study, Suter *et al.* (1999) aimed at determining the effect of sacroiliac manipulation on muscle inhibition of the quadriceps muscle group in 18 patients (17 females and 1 male) with anterior knee pain due to patella femoral pain syndrome. Their study was motivated by the clinical observation that patients with lower extremity complaints typically showed sacroiliac joint and lumbar spine mechanical dysfunction of either symptomatic or subclinical nature.

The results showed a significant decrease in quadriceps muscle inhibition following sacroiliac manipulation. However, due to the nature of their study, a control group was not included and although their results were of clinical relevance, some degree of experimental bias or even placebo effects may have occurred.

One possible limitation of their study might be attributed to the lack of control of their study sample as some selected study participants (4 subjects) exhibited bilateral anterior knee pain. Whereas previous interventions for the subjects' knee pain ranged from surgery (6 subjects) to strengthening exercises, electrical therapy and orthotics (11 subjects). For this reason, the authors could not establish firm conclusions regarding the actual effect of sacroiliac spinal manipulative therapy.

Therefore, in order to establish a scientifically tenable relationship between sacroiliac manipulation and the reduction of knee extensor muscle inhibition, a follow – up randomized controlled double – blind study was required to verify the results. This follow – up study confirmed the findings of their previous

study. However, the decrease in muscle inhibition was found to be insignificant. The validity of their study may have been compromised due to a poorly controlled study sample, as stated above, as in their previous study (Suter *et al.*, 2000).

The mechanism through which spinal manipulation might cause a reduction in AMI can only be speculated on. The possible mechanism will be explored under the neurophysiological effects of spinal manipulation under 2.7.

2.2.7 The advantages of removing or reducing arthrogenic muscle inhibition

Ingersoll, Palmieri and Hopkins (2003) state that one of the major benefits of AMI eradication is the reduction in the cost and time of the rehabilitation process. Elimination of AMI, according to Hopkins and Ingersoll (2000) and Hopkins *et al.* (2002), would enable an athlete to contract the muscles surrounding the injured joint more efficiently, thereby facilitating the successful use of early active exercises and thus, speeding up the recovery process.

A reduction in AMI also allows an injured athlete to perform such exercises in a controlled environment, whilst healing is facilitated and decreases in strength and muscle mass are prevented (Hopkins and Ingersoll, 2000).

In addition, the riddance of AMI might possibly result in the reduction of its long – term negative effects (Ingersoll, Palmieri and Hopkins, 2003), as outlined in table 2.3. Thereby, enabling the athlete to return to competition following joint injury stronger and less vulnerable to additional injury (Hopkins and Ingersoll, 2000).

2.3 Sacroiliac syndrome

2.3.1 Definition

"Sacroiliac syndrome is a collection of symptoms and signs that result from mechanical irritation of the sacroiliac joint" (Cassidy and Mierau in Haldeman, 1992:216).

2.3.2 Incidence and prevalence of low back pain and sacroiliac syndrome

Low back pain (LBP) is a significant health problem in Western industrialized nations (Walker, 2000) and is considered a major cause of medical expenses, absenteeism and disablement (Van Tulder *et al.*, 1997). LBP is the leading cause activity limitation in young persons between the ages of 17 to 44 years old (Borenstein *et al.*, 1995:ivv).

Up to 80% of the adult population has sought, or at one time will seek, treatment for their LBP (Hendler *et al.*, 1995). LBP is the most common condition with which patients present to chiropractors in the private practice setting and to chiropractic teaching clinics (Haas *et al.*, 1995).

Worku (2000) analyzed the incidence of LBP in a random sample of 4001 mothers from the Maseru district in Lesotho. A total of 405 (10.12%) of the 4001 subjects in the study had severe LBP at the time of data collection. 513 (12.82%) complained of moderate LBP, while the remaining 1422 subjects experienced mild LBP. Docrat (1999) determined the lifetime incidence of LBP in a small sample of Indian and Coloured communities in South Africa to be 78.2% and 76.6%, respectively, whilst Van der Meulen (1997) established that the lifetime incidence of LBP amongst a small sample of Indigenous Africans in South Africa was 57.6%.

In the search for causes of LBP, the sacroiliac joint has gained renewed interest as a possible pain generator. Schwarzer, Aprill and Bogduk (1995),

Sakamoto *et al.*, (2001) and Murata *et al.* (2000 and 2001) established that the sacroiliac joint is a noteworthy source of pain in patients with LBP. Notwithstanding the above statement, Daum (1995) maintains that the sacroiliac joint itself and the specific diagnosis of sacroiliac dysfunction are both under appreciated causes of pain in the low back, pelvis and the proximal lower extremities.

The incidence of sacroiliac joint regional pain in patients with low back pain has been estimated to be between 55% and 61.5% (Cibulka *et al.*, 1998). Daum (1995) reported that as many as 40% of patients with LBP have sacroiliac syndrome. Whereas the prevalence of sacroiliac joint dysfunction has been documented to be between 19.3% and 47.9%, depending on the variables such as age, sex, level of physical fitness, employment and the degree of education in the study group (Toussaint *et al.*, 1999).

2.3.3 Symptoms

Patients with sacroiliac syndrome frequently complain of pain or tenderness directly over the posterior sacroiliac joint (Daum, 1995). Pain of sacroiliac joint origin usually radiates to the groin, posterior thigh, lateral calf (Hendler *et al.*, 1995) and occasionally to the ankle, foot and toes (Kirkaldy – Willis, Burton and Cassidy, 1992:123 – 124). Nevertheless, discomfort of sacroiliac origin is rarely known to extend beyond the knee (Daum, 1995). These pain referral patterns may be attributed to the extensive innervation of the sacroiliac joint (Daum, 1995, Murata *et al.*, 2000 and Murata *et al.*, 2001), which will be discussed under 2.4.4.

2.2.4 Diagnosis of sacroiliac syndrome

McCulloch and Transfeldt (1997:180 – 181) claim that sacroiliac syndrome has a “classic presentation”. This includes: pain located over the sacroiliac joint with local tenderness on palpation; pain referral to the groin, trochanter and buttock; aggravation of pain by provocation tests; clinical evidence of

increased movement or asymmetry of the sacroiliac joint; and the absence of any other apparent cause of the patient's sacroiliac joint pain localization.

The symptoms of sacroiliac dysfunction are generally exacerbated by activities of daily living that tend to preferentially load the pelvis asymmetrically (Daum, 1995) and pain is often increased by weight bearing, laying on the affected side (Hendler *et al.*, 1995), stair climbing and bicycle riding (Daum, 1995). In the seated position, patients usually demonstrate no generalized sitting intolerance however; symptomatic patients frequently favor the uninvolved side (Daum, 1995). Pain of sacroiliac joint origin may be reproduced by external rotation of the hip (Hendler *et al.*, 1995).

The diagnosis of sacroiliac syndrome is established by utilizing pain provocation tests, such as the Patrick Faber test, Gaenslen's test, Yeoman's (Erichson's) test (Kirkaldy – Willis, Burton and Cassidy in Kirkaldy – Willis and Burton, 1992:124 – 125) and the posterior shear test that aim to stress the joint in an attempt to reproduce the patient's symptoms (Laslet and Williams, 1994). These tests are discussed in chapter three under 3.6.1.1.

2.3.5 Motion palpation of the sacroiliac joints

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 to determine sacroiliac restrictions (Gattermann, 1995:460 – 462):

The patient is requested to stand with their arms outstretched towards the wall for stabilization and raises one leg at a time while the researcher palpates the joint.

Motion restrictions in the superior joint are detected by placing one thumb over the ipsilateral posterior superior iliac spine (PSIS) and the other over the second sacral tubercle. With flexion of the ipsilateral leg, the PSIS should move posterior inferior. This movement does not occur when the superior

part of the joint is fixated in flexion. Posterior and inferior movement of the second sacral tubercle is also indicative of a flexion fixation.

The examination of the superior joint for an extension fixation is conducted by placing of the thumbs in the same position as outlined above, however, the patient flexes the contralateral leg. When the superior joint moves as outlined above, the superior joint is fixated in extension.

Similarly, the inferior joints may be examined for flexion/extension fixations. The inferior joints are examined by placing one thumb on the ipsilateral ischial tuberosity and the other over the sacral apex. The same principles that apply for the detection of superior joint fixations, apply for the detection of fixations in the

2.4 Anatomy and biomechanics of the sacroiliac joint

The sacroiliac joint is a true synovial joint with an auricular shape and a very limited amount of range of motion (Indahl *et al.*, 1999).

2.4.1 Introduction

The sacroiliac joint is one of the most commonly discussed joints and yet, remains one of the most misunderstood joints in the body (Cibulka, 2002). The primary function of the sacroiliac joint is the transmission of forces from the spine towards the lower limbs. This function is achieved through the inherent stability of the joint, owed to its bony and ligamentous anatomical adaptations (Harrison, Harrison and Troyanovich, 1997, Snijders, Vleeming and Stoeckart, 1993 and Indahl *et al.*, 1999).

2.4.2 Bony anatomy

The sacroiliac joint is well suited for the transfer of large bending moments and compression. According to Snijders, Vleeming and Stoeckart (1993), this might be attributed to the predominantly flat articular shape of the joint. In

light of this statement, Harrison, Harrison and Troyanovich (1997) claim that this feature might serve to reduce stress on the sacroiliac ligaments, in so doing adding to the stability of the joint.

In addition, the articular surfaces of the sacroiliac joints have course contours (Daum, 1995). These ridges and depressions are thought to be the result of non – pathologic adaptations to the forces exerted at the sacroiliac joints (Hendler, *et al.*, 1995). According to Harrison, Harrison and Troyanovich (1997), the presence of these ridges restricts the mobility and increases the stability of the joint in transmitting weight from the spine to the lower limbs.

2.4.3 Ligamentous anatomy

In addition to the bony adaptation of the sacroiliac joints, several massive ligaments surround the area and limit their mobility (Harrison, Harrison and Troyanovich, 1997). This extensive network of strong ligaments contributes to the stability of the sacroiliac joints (Indahl *et al.*, 1999).

They comprise the anterior sacroiliac ligament; the interosseous; dorsal sacroiliac ligament; the sacrotuberous ligament; the sacrospinous ligament; the iliolumbar ligaments and the pubic symphysis (Harrison, Harrison and Troyanovich, 1997). However, Freeman, Fox and Richards (1990) identified an additional sacroiliac ligament. Illi's ligament is a superior intracapsular ligament, present in approximately 75% of dissections.

TABLE 2.5 *The sacroiliac ligaments*

Ligament	Characteristics	Function
Anterior sacroiliac	Anterior inferior thickening of the joint capsule, very well developed near the arcuate line and the posterior inferior iliac spine.	Opposes superior and inferior translation of the sacrum and separation of the joint surfaces.
Interosseous	Massive ligament and largest syndesmosis in the body, fills the irregular spaces posterior and superior to sacroiliac joint, strongest connection in the sacroiliac region.	Resists joint separation and translation along the y and z axes (vertical and anteroposterior).
Dorsal sacroiliac	Covers the interosseous ligament and together, they make up the posterior two thirds of the sacroiliac connections. These ligaments may branch into a long posterior sacroiliac ligament that is continuous with the sacrotuberous ligament.	
Sacrotuberous	Blends partially with dorsal ligaments	Opposes sacral rotation around the x – axis (flexion), rotation of the sacrum around the y – axis theoretically stresses sacrotuberous ligament on the ipsilateral side.
Sacrospinous	Thin and triangular	Counteracts rotation around the x and y axes.
Iliolumbar	Run from L4 and L5 transverse processes to iliac crests and blend with interosseous ligament	Limit motions between distal lumbar spine and sacrum, prevent translation of sacrum out of pelvic girdle and separation of ilia from sacrum.
Pubic symphyseal	Composed of three ligaments: superior pubic, arcuate pubic and interpubic ligaments	Resists shear stresses, y – axis rotation of sacrum and joint separations

(Harrison, Harrison and Troyanovich, 1997).

2.4.4 Innervation of the sacroiliac joint

The sacroiliac joint appears to be richly innervated. However, some uncertainty exists regarding its exact innervation patterns (Indahl *et al.*, 1999), including whether the joint is innervated from both the dorsal and ventral aspects or solely from the dorsal side (Murata *et al.*, 2001).

According to Cassidy and Mierau in Haldeman (1992:211 – 224), the segmental derivation of nerves to the sacroiliac joint ranges from as high as L2 to as low as S4. The authors state that the ventral aspect of the joint is most frequently innervated by L4 and L5, and the dorsal aspect most commonly from S1 and S2.

Daum (1995) states that the sacroiliac joint might be innervated from as cephalad as L2 to as caudad as L3 or L4. This is based on Hilton's law, which states that a joint may be innervated by the articular branches of the nerves that supply the muscles that cross that joint (Wyke, 1967 as cited by Lephart *et al.*, 1992).

Fortin *et al.* (1999) reviewed the current knowledge of human sacroiliac joint innervation and conducted a study on adult cadavers, with fetal correlation, to investigate sacroiliac innervation and pain. The authors concluded that the sacroiliac joint appears to be predominantly, if not entirely innervated by the sacral dorsal rami.

However, according to Suter *et al.* (2000), the anterior part of the sacroiliac joint is innervated by the anterior primary divisions of L2 through to S2, which project into the main lower limb nerves.

In this respect, Murata *et al.* (2001) investigated the sensory innervation of the ventral and dorsal aspects of the sacroiliac joint in rats. Their findings showed that the dorsal root ganglia from L1 to S2 mainly innervate the sacroiliac joint: The dorsal side is primarily innervated by the dorsal rami of the dorsal root

ganglia from L4 to S2, while the dorsal root ganglia from L1 to L3 exclusively innervate the ventral side.

In a previous study in 2000, Murata and colleagues attempted to investigate which levels of the dorsal root ganglia project sensory nerve fibers to the rat sacroiliac joint, and whether these sensory fibers might contribute to sacroiliac joint pain via the sympathetic trunk, utilizing a retrograde transport method. The results of their study showed that the sacroiliac joint was innervated by the sensory neurons in the dorsal root ganglions ipsilateral to the joint from L2 to S2. In addition, the sensory fibers from the L1 and L2 dorsal root ganglions were found to pass through the paravertebral sympathetic trunk.

Daum (1995) states that the extensive source of sacroiliac joint innervation could possibly explain the multiple manifestations of sacroiliac pain. In lieu of this statement, the results of Murata *et al.*, (2000) support the broad referral patterns of the sacroiliac joint, which might result in pain perceived in the low back, buttock, groin, thigh and calf. According to Murata *et al.* (2001), these multiple manifestations of referred pain of sacroiliac joint origin might be ascribed to the ventral nerve supply of the joint.

2.4.5 Biomechanics

The sacroiliac joint has two degrees of freedom (Cibulka, 2002) and a small amount of movement (Ro and Cramer in Cramer and Darby, 1995:234) that occurs in all three planes of the body (Cibulka, 2002).

Sacroiliac motion occurs as a simultaneous combination of rotation and translation (Harrison, Harrison and Troyanovich, 1997). Cibulka (2002) stated that most of this movement occurs around the sagittal (x – axis) plane with minor movements occurring around the frontal and transverse (y – and z – axis) planes. The amount of sacroiliac motion ranges from 0.5 to 1.6 mm in translation, and up to 4° of rotation (Indahl *et al.*, 1999).

Movement of the sacroiliac joint appears to be three – dimensional (Ro and Cramer in Cramer and Darby, 1995:234 – 235): The primary movements appear to be sacral nutation and counter – nutation. Sacral nutation is the anteroinferior nodding of the sacral base in relation to the ilium. Sacral counter – nutation is the posterosuperior nodding of the sacral base with respect to the ilium.

The second type of movement is rotation along an axis passing longitudinally through the iliac ridge of the sacroiliac joint. The posterior aspect of the ilium moves superomedially and inferolaterally.

The third type of motion is gapping of the superior and inferior aspects of the sacroiliac joints.

In light of the above, Cassidy and Mierau in Haldemann (1992:215) summarized the generally accepted trends that are applicable to sacroiliac joint biomechanics:

1. The sacroiliac joint has a small range of motion that decreases with increasing age.
2. Females have a greater range of motion compared to males, which increases during pregnancy.
3. Sacroiliac motions are coupled and dependent on some degree of joint separation.
4. The predominant motion is x – axis rotation, coupled with some degree of z – axis translation.

2.5 The hip joint

2.5.1 Introduction

The hip joint is a multi – axial ball and socket type synovial joint that is formed between the acetabulum of the innominate and the head of the femur (Sinnatamby, 1999:123).

2.5.2 Stability and mobility of the hip joint

The hip joint is a very strong and stable articulation (Moore, 1992:477, Sinnatamby, 1999:123 and Reid, 1992:604). Yet, this stability and strength has been gained at the expense of some mobility (Jenkins, 1998:245). Regardless of the loss of some mobility, the hip joint is still viewed as a good example of a joint in the body that provides a high degree of both stability and mobility (Sinnatamby, 1999:123 and Reid, 1992:604).

The stability of the hip joint may be attributed to the strong hip joint capsule and investing ligaments (Moore, 1992:477), the deep nature of the acetabulum (Jenkins, 1998:245), and the adaptation of the articular surfaces of the femur and the acetabulum (Moore, 1992:477). Whereas the large range of motion of the joint may be attributed to the fact that the neck of the femur is substantially smaller in circumference than the articular head of the femur (Reid, 1992:604, Sinnatamby, 1999:123).

2.5.3 Ligaments of the hip joint

The hip joint has a very strong and dense fibrous articular capsule. The thickened parts of the joint capsule are known as the intrinsic ligaments. These ligaments provide the joint with strength and stability. They constitute the iliofemoral, pubofemoral and ischiofemoral ligaments (Jenkins, 1998:245 and Moore, 1992:474).

TABLE 2.6 *The intrinsic ligaments of the hip joint*

Ligament	Description	Proximal attachment/s	Distal attachment/s	Function
Iliofemoral	Anterior thickening of the hip joint capsule. Very strong, y - shaped band covering the anterior aspect of the hip joint	Anterior inferior iliac spine; acetabular rim	Intertrochanteric line of the femur	Prevents undue extension of the hip joint due to its anterior position; maintains erect posture; limits medial rotation of the hip
Pubofemoral	Anterior and medial thickening of the hip joint capsule. Large ligament strengthening the anterior and inferior aspects of the fibrous capsule of the hip joint	Pubic portion of the acetabular brim and anteroinferior aspect of the hip joint	Blends with the medial portion of the iliofemoral ligament	Prevents excessive abduction of the femur; assists the iliofemoral ligament in checking extension of the hip joint; limits medial rotation of the hip
Ichiofemoral	Posterior thickening of the hip joint capsule. The weakest and least well developed of the three ligaments. Reinforces the fibrous capsule of the hip joint posteriorly	Ichial rim of the acetabulum, covering the posterior aspect of the joint	Blends with the circular fibers of the capsule	Tightens during extension of the hip to assist the other ligaments to stabilize the hip in the extended position; prevents hyperextension of the hip joint; limits medial rotation of the hip joint

(Moore, 1992:475, Jenkins, 1998:245 – 246, Sinnatamby, 1999:123 – 124 and Croley in Echternach, 1990:10 - 11).

2.5.4 Movements of the hip joint

Movement of the thigh at the hip joint consists of flexion, extension, adduction, abduction, circumduction, medial rotation and lateral rotation (Jenkins, 1998:247). The movements applicable to the present study are flexion, extension, adduction and abduction. Brief descriptions of these movements follow.

2.5.4.1 Hip flexion

Hip flexion is the largest range of motion occurring at the hip joint (Reid, 1992:605). It occurs in the saggittal plane (Oloff, 1994:70) and involves

rotation of the femoral head about a transverse axis that passes through both acetabulae (Sinnatamby, 1999:125).

The amount of hip flexion occurring ranges from 130° to 150°, averaging approximately 140° (Reid, 1992:604). Hip flexion is usually limited by the apposition of the soft tissues of the thigh on the abdomen (Reid, 1992:604) or the tension in the hamstrings when the knee is in the extended position (Sinnatamby, 1999:125). The primary muscles that are involved in producing hip flexion are the iliopsoas, tensor fascia latae and rectus femoris muscles (Moore, 1992:476). These muscles are discussed in table 2.7.

2.5.4.2 Hip extension

Hip extension occurs in the sagittal plane (Oloff, 1994:70). Reid (1992:607) states that, at best, approximately 10° to 20° only true extension viz. extension at the hip joint only, occurs. He attributes this to tension in the iliofemoral ligament, the ischiofemoral ligament and the iliopsoas muscle, located anteriorly. The muscles responsible for producing hip extension are the gluteus maximus, semitendinosus, semimembranosus and biceps femoris muscles (Moore, 1992:476). These muscles are discussed in table 2.8.

2.5.4.3 Hip adduction

Hip adduction occurs in the coronal plane (Oloff, 1994:70) and involves rotation of the acetabulum about an anteroposterior axis (Sinnatamby, 1999:125). The amount hip adduction ranges from 20° to 35° (Reid, 1992:605), averaging approximately 30° (Sinnatamby, 1999:125). Hip adduction is limited by the apposition of the soft tissues of the contralateral leg (Sinnatamby, 1999:125), though with flexion of the contralateral leg up to 40° of hip adduction may be achieved (Reid, 1992:609). The primary muscles involved in producing hip adduction are the adductor magnus, longus and brevis muscles (Moore, 1992:476). These muscles are described in table 2.9.

2.5.4.4 Hip abduction

Hip abduction occurs in the coronal plane (Oloff, 1994:70) and involves rotation of the acetabulum about an anteroposterior axis (Sinnatamby, 1999:125). The amount of hip abduction that may occur, ranges from 40° to 50° and averages approximately 45° (Reid, 1992:605). Hip abduction is limited by tension in the ipsilateral adductor muscles and the pubofemoral ligament (Sinnatamby, 1999:125). The prime movers of hip abduction are the gluteus medius and minimus muscles (Moore, 1992:476). These muscles are discussed in table 2.10.

2.5.5 Muscles of the hip joint

The primary movers involved in hip flexion, extension, adduction and abduction are of importance in the present study. They have been grouped into flexors, extensors, adductors and abductors. The individual muscles are discussed in tables 2.7 through 2.10 according to their proximal and distal attachments, innervation and main actions.

TABLE 27 *The hip flexors*

Muscle	Proximal attachment/s	Distal attachment/s	Innervation	Main action/s
Psoas major	T12 to L5 vertebrae, intervertebral discs, lumbar transverse processes.	Lesser trochanter of femur.	Ventral rami of L1, L2 and L3.	Hip flexion, extension and flexion of lumbar spine, lateral rotation of thigh, abduction of hip.
Psoas minor	Anterolateral aspects T12 to L2.	Pectineal line on superior ramus of pubic bone, iliopectineal eminence, iliac fascia.	Branch of first lumbar spinal nerve.	Hip flexion, extension and flexion of lumbar spine, lateral rotation of thigh, abduction of hip.
Iliacus	Upper two – thirds of inner surface of iliac fossa.	Join tendon of psoas major, remaining fibers attach to lesser trochanter and adjacent femur.	Femoral nerve (L2, L3).	Hip flexion, extension and flexion of lumbar spine, lateral rotation of thigh, abduction of hip.
Tensor fascia latae	Anterior outer lip of iliac crest, outer aspect anterior superior iliac spine, deep surface of fascia lata.	Blend with fibers of iliotibial tract that attaches to lateral condyle of the tibia.	Superior gluteal nerve (L4, L5).	Assists flexion, abduction, medial rotation of thigh at hip, maintains extended position of knee, steadies trunk on thigh.
Rectus femoris	Two tendons: one to anterior inferior iliac spine, second to a groove superior to posterior brim of acetabulum.	Proximal border of patella, tibial tuberosity via patellar ligament.	Femoral nerve (L2, L3, L4 and posterior divisions).	Extension of the leg at the knee, steadies hip joint, assists iliopsoas during flexion of the thigh.

(Moore, 1992:387 and Travell and Simons, 1999:91 – 93, 218, 220).

TABLE 28 *The hip extensors*

Muscle	Proximal attachment/s	Distal attachment/s	Innervation	Main actions
Gluteus maximus	Posterior border of ilium; posterior iliac crest; posterolateral surface of sacrum; side of the coccyx; aponeurosis of erector spinae muscles; length of the sacrotuberous ligament; fascia covering the gluteus medius.	Three thirds of the muscle attaches to the thick tendinous aponeurotic sheet crossing the greater trochanter and joining the iliotibial band that inserts into the lateral condyle of the tibia. Some fibers insert on the gluteal tuberosity of the femur.	Inferior gluteal nerve, L5, S1 and S2.	Extension and lateral rotation of the thigh at the hip. Steadies the thigh and assists in raising the trunk from a flexed position.
Semitendinosus	Ischial tuberosity.	Medial aspect of the superior part of the tibia.	Tibial division of the sciatic nerve, L5, S1, S2.	Extension of the thigh, flexion and medial rotation of the leg when the thigh and leg is flexed, extension of the trunk.
Semimembranosus	Ischial tuberosity.	Posterior aspect of the medial condyle of the tibia.	Tibial division of the sciatic nerve, L5, S1, S2.	Extension of the thigh, flexion and medial rotation of the leg when the thigh and leg is flexed, extension of the trunk.
Biceps femoris	The long head: posterior aspect of ischial tuberosity in a common tendon with the semitendinosus muscle. The short head: lateral lip of the linea aspera of the femur.	The long and short heads join in the distal thigh, forming a common tendon that attaches to the lateral aspect of the fibula, distally.	The long head: tibial division of the sciatic nerve (L5, S1 and S2). Short head: fibular (common peroneal) division of the sciatic nerve, L5, S1 and S2.	Flexion and lateral rotation of the leg and extension of the thigh (long head).

(Moore, 1992:423 and Travell and Simons, 1999:134 – 136, 318, 319).

TABLE 29*The hip adductors*

Muscle	Proximal attachment/s	Distal attachment/s	Innervation	Main action/s
Adductor magnus	Inferior pubic ramus, ramus of the ischium (adductor part) and the ischial tuberosity (hamstring part).	Gluteal tuberosity, medial linea aspera, supracondylar line (adductor part) and the adductor tubercle of the femur (hamstring part).	Adductor portion: obturator nerve (L2, L3 and L4). Hamstring portion: tibial division of the sciatic nerve, L4.	Adduction of the thigh. Adductor portion assists with flexion, and hamstring portion with extension.
Adductor longus	Body of the pubis, inferior to the pubic crest.	Middle third of the linea aspera of the femur.	Anterior branch of the obturator nerve, L2, L3 and L4.	Adduction of the thigh.
Adductor brevis	Inferior pubic ramus.	Pectineal line and proximal portion of the linea aspera of the femur.	Obturator nerve, L2, L3 and L4.	Adduction and flexion of the thigh.

(Moore, 1992:399 and Travell and Simons, 1999:292).

TABLE 210 *The hip abductors*

Muscle	Proximal attachment/s	Distal attachment/s	Innervation	Main actions
Gluteus medius	External surface of the ilium, between the anterior and posterior gluteal lines, gluteal aponeurosis.	Lateral surface of the greater trochanter of the femur.	Superior gluteal nerve, L5 and S1.	Abduction and medial rotation of the thigh, stabilizes the pelvis.
Gluteus minimus	Outer surface of the ilium and between the anterior and posterior gluteal lines.	Anterior surface of the greater trochanter of the femur.	Superior gluteal nerve, L5 and S1.	Abduction and medial rotation of the thigh, assists the gluteus medius in stabilizing the pelvis.

(Moore, 1992:417 and Travell and Simons, 1999:152, 153, 170, 172).

2.6 The gate control theory

Sacroiliac syndrome might play a role in AML development via a gate control – type mechanism. Melzak and Wall first described the gate control theory in 1965. Since then, Cramer and Darby (1996) state that the theory has been revisited. Yet, the authors maintain that the basic concepts of the theory remain unchanged.

The gate control theory involves the following classes of dorsal horn cells: small A - δ and C fibers (nociceptive afferents), large A - α and A - β fibers (mechanosensitive afferents), the substantia gelatinosa, and transmission or “T” cells (Jacobs and Lowe in Cohen, 1999:81, Wood in Kitchen and Bazin, 1998:85 and Cramer and Darby, 1995:364).

The substantia gelatinosa (lamina II) is located in the dorsal horn of the spinal cord and consists of a population of inhibitory interneurons (Cramer and Darby, 1995:364) that utilize enkephalins as neurotransmitters (Cramer and Darby, 1996). The substantia gelatinosa functions to regulate nociceptive activity through the input from mechanoreceptors via the A - β afferent fibers (Colloca in Fuhr *et al.*, 1997:42) and has a general inhibitory effect on the “T” cells (Jacobs and Lowe in Cohen, 1999:81 and Wood in Kitchen and Bazin, 1998:85).

The “T” cells are dorsal horn projection neurons that relay C fiber activity (pain) to the higher centers via the spinothalamic tract of the anterolateral system (Jacobs and Lowe in Cohen, 1999:81, Wood in Kitchen and Bazin, 1998:85 and Cramer and Darby, 1995:364). Reid (1992:51) states that C fiber activity has a stimulatory effect on the “T” cells, whereas the A fibers have a stimulatory effect on the substantia gelatinosa.

Impulses that travel along the large myelinated A - β fibers take precedence over the smaller diameter nociceptive A - δ and C fibers, causing the inhibition of nociceptive activity (Colloca in Fuhr *et al.*, 1997:42). Therefore, a

predominance in C fiber activity tends to open the gate to pain transmission by inhibiting the inhibitory effect of the substantia gelatinosa on the "T" cells. A predominance of activity from the large A fibers tend to close the gate to pain transmission by facilitating the inhibitory effect of the substantia gelatinosa on the "T" cells (Jacobs and Lowe in Cohen, 1999:82 and Wood in Kitchen and Bazin, 1998:85).

As previously stated under 2.2.3.2, Hopkins and Ingersoll (2000) claim that AMI primarily results from mechanoreceptor activity. However, free nerve endings and specialized nociceptors might play a role in the development of AMI, according to Ingersoll, Palmieri and Hopkins (2003). As previously noted under 2.2.3.2.1, the sacroiliac joint, its periarticular structures, joint capsule and ligaments contain numerous mechanoreceptors, nociceptors and free nerve endings (Fortin *et al.*, 1999, Sakamoto *et al.*, 2001 and Vilensky *et al.*, 2002). These receptors might be activated in a symptomatic sacroiliac syndrome, according to Suter *et al.* (1999). The afferent fibers that are responsible for conveying information from these receptors have been discussed under 2.2.3.4.

In light of the above, reduced mechanoreceptor input as a result of joint fixation could lead to an increase in pain through disinhibition of nociception and consequently, allowing for an increase in nociception transmission (Colloca in Fuhr *et al.*, 1997:42). Likewise, the sacroiliac joint has been recognized as a significant source of low back pain (Schwarzer, Aprill and Bogduk, 1995, Sakamoto *et al.*, 2001, Murata *et al.*, 2000 and Murata *et al.*, 2001). Thus, referred pain or disturbed afferent feedback caused by the dysfunctional sacroiliac joint might contribute to muscle inhibition (Suter, *et al.*, 1999).

In light of the above, it seems plausible that predominant nociceptive information from the symptomatic joint might open the gate, resulting in the central transmission of pain. This in turn, might result in the development of AMI in the muscles that fall within the motor neuron pool of the affected sacroiliac joint.

In their study, Sakamoto *et al.*, (2001) identified primarily nociceptive mechanoreceptors in the sacroiliac joint. In lieu of the above statement, afferent information from the symptomatic sacroiliac joint might be expected to be primarily nociceptive in nature. Thus, as previously stated under 2.2.5.1.6.5.1, the present study might support the relationship between pain and AMI, thereby implicating pain as a possible etiologic factor of AMI.

These events leading to AMI have been discussed under the neurophysiological factors associated with AMI development under 2.2.3.

2.7 The neurophysiological effects of spinal manipulation

Cassidy and Mierau in Haldeman (1992:221) state that manipulation should be the first line of treatment for sacroiliac syndrome. Apart from relieving the symptoms associated with sacroiliac syndrome, sacroiliac joint manipulation has been shown to effectively reduce AMI in the quadriceps muscle group.

In a descriptive study, Suter *et al.* (1999) aimed at determining the effect of sacroiliac manipulation on muscle inhibition of the quadriceps muscle group in 18 patients (17 females and 1 male) with anterior knee pain due to patella femoral pain syndrome. Their study was motivated by the clinical observation that patients with lower extremity complaints typically showed sacroiliac joint and lumbar spine mechanical dysfunction of either symptomatic or subclinical nature.

The results showed a significant decrease in quadriceps muscle inhibition following sacroiliac manipulation. However, due to the nature of their study, a control group was not included and although their results were of clinical relevance, some degree of experimental bias or even placebo effects may have occurred. One possible limitation of their study might be attributed to the lack of control of their study sample as some selected study participants (4 subjects) exhibited bilateral anterior knee pain. Whereas previous interventions for the subjects' knee pain ranged from surgery (6 subjects) to

strengthening exercises, electrical therapy and orthotics (11 subjects). For this reason, the authors could not establish firm conclusions regarding the actual effect of sacroiliac spinal manipulative therapy.

Therefore, in order to establish a scientifically tenable relationship between sacroiliac manipulation and the reduction of knee extensor muscle inhibition, a follow – up randomized controlled double – blind study was required to verify the results. This follow – up study confirmed the findings of their previous study. However, the decrease in muscle inhibition was found to be insignificant. The validity of their study may have been compromised due to a poorly controlled study sample, as stated above, as in their previous study (Suter *et al.*, 2000).

The mechanism through which spinal manipulation might cause a reduction in AMI can only be speculated on. Spinal manipulation might normalize mechanoreceptive and nociceptive afferent activity and consequently, the resultant efferent neuronal activity (Colloca in Fuhr *et al.*, 1997:42).

In their theory, Melzak and Wall postulated that large, myelinated A - α and A - β fibers exerted an inhibitory control over small, unmyelinated C fibers (Jacobs and Lowe in Cohen, 1999:81). The activation of the large afferents increase the inhibition impinging on the T cells via the substantia gelatinosa, thereby closing the gate to pain transmission through the T cells in the spinal cord (Wood in Kitchen and Bazin, 1998:85). Furthermore, Wood in Kitchen and Bazin (1998:85) states that any therapeutic technique (including joint manipulation) that involves the activation of the large diameter mechanosensitive afferents has the potential to modulate pain transmission in the spinal cord.

Therefore, it has been proposed that manipulation, applied in the form of a high – velocity low – amplitude thrust, results in passive joint movement and the activation of mechanoreceptors and proprioceptors within and around the manipulated joint (Suter *et al.*, 2000 and Colloca in Fuhr *et al.*, 1997:42). This

is said to result in the presynaptic inhibition of nociceptive afference and consequently, a reduction in pain transmission from the symptomatic sacroiliac joint to the spinal cord (Colloca in Fuhr *et al.*, 1997:42 and Wood in Kitchen and Bazin, 1998:85).

Thus, sacroiliac manipulation might alter the sensory input that affects the afferent pathways of the spine (Suter *et al.*, 2000). This should result in a change in motor neuron excitability (Suter *et al.*, 2000, Harrison, Harrison and Troyanovich, 1997) through closure of the gate. Thereby, causing an increase in motor unit recruitment and the subsequent decrease in AML (William, 1997:144, Suter *et al.*, 2000).

2.8 Conclusion

AMI is the reflex inhibition of the muscles that surround an injured joint in consequence to disturbed afference originating from the receptors of that joint. The resultant altered afferent innervation of the motor neuron pool leads to a decrease in recruitment ability within the motor neuron pool, a decrease in contraction force of the muscles that fall within the motor neuron pool, and hence the clinical manifestation of AML as a decrease in muscle strength.

The phenomenon of AML is considered a natural protective response of the body, as it discourages full use of an injured joint with the aim of preventing further damage to an already damaged joint. Although the occurrence of AML is considered favorable, its presence might be particularly detrimental during the early rehabilitation process as it impedes the rehabilitation of injured joints. Hence, the presence of AML might prevent full muscle and joint recovery following injury.

The sacroiliac joint is richly innervated and has been shown to contain numerous mechanoreceptors and nociceptors, which might be activated in symptomatic sacroiliac syndrome. The muscles of the hip joint involved in producing flexion, extension, adduction and abduction fall within the sacroiliac joint motor neuron pool due to a similarity in segmental nerve supply, as

discussed in chapter five under 5.3.1. Thus, symptomatic sacroiliac syndrome should cause their inhibition.

The few treatment options at our disposal that are aimed at reducing AMI might not be adequate in causing a significant reduction in AMI. In this respect, sacroiliac manipulation has been shown to effectively reduce quadriceps muscle inhibition and increase muscle strength. Thus, sacroiliac manipulation might be an attractive alternative treatment option for the reduction of AMI in the hip musculature and a subsequent increase in hip muscle strength.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

The details of the research study undertaken are discussed in this chapter. This involves a description of the methods utilized in data collection and the statistical methods employed for the interpretation of the data. Included, is a detailed description of the design, primary and secondary data, the subjects and the interventions used.

The objective of the present study was to determine the short – term effect of sacroiliac manipulation on ipsilateral hip muscle strength in individuals with chronic sacroiliac syndrome.

The first objective was to evaluate the short – term effect of sacroiliac manipulation on the muscle strength of the ipsilateral hip joint in the actions of: flexion, extension, abduction and adduction, in patients with chronic sacroiliac syndrome, utilizing the Cybex Orthotron II Isokinetic Rehabilitation System, in terms of objective clinical findings.

The second objective was to determine the short-term effect of sacroiliac joint manipulation in terms of subjective findings, utilizing the Numerical Pain Rating Scale.

3.2 Measurements and observations

3.2.1 The data

The data required for this study consisted of both primary and secondary data.

3.2.1.1 The primary data

1. The patient's response to the Numerical Pain Rating Scale – 101 (Appendix A) regarding their changing levels of pain prior to, immediately following and 1 day/24 hours post sacroiliac manipulation (Appendix B).
2. The data obtained utilizing the Cybex Orthotron II Isokinetic Rehabilitation System in order to establish the subjects' hip muscle strength prior to, immediately following and 1 day/24 hours post sacroiliac manipulation (Appendix C).

3.2.1.2 The secondary data

The secondary data was obtained during a search of related literature that included journal articles, textbooks, Medline and the internet (using the relevant search engines).

3.3 Study design and protocol

3.3.1 Study design

The study design chosen was cohort in nature. The present study was conducted alongside another cohort study (Matkovich, 2004) that aimed to investigate the immediate effect of sacroiliac manipulation on the strength of the ipsilateral hip musculature and subjective low back pain intensity in subjects presenting with chronic sacroiliac syndrome.

The subjective and objective data generated by that study (pre – manipulation and immediately post – manipulation), together with the subjective and objective data obtained from this study, was utilized to determine the short – term effect of sacroiliac manipulation on the strength of the hip musculature and subjective low back pain intensity in subjects presenting with low back pain, attributable to chronic sacroiliac syndrome.

3.3.2 The sample

Both research studies incorporated a sample of 30 male patients. The participants of the present study were recruited from the concurrent cohort study that used a non – probability, convenient sampling technique.

Subjects were informed of the study via advertisements that were posted on notice boards at the Durban Institute of Technology Chiropractic Day Clinic, sports clubs, gyms, health shops and local clinics. Subjects were also informed of the study by means of the Durban Institute of Technology intra – net, pamphlets and word of mouth (Matkovich, 2004).

3.3.3 Patient selection

Prospective participants underwent a brief telephonic interview with the researcher of the concurrent cohort study in order to establish their suitability. In instances where the patient already presented himself to the clinic, a face – to – face interview was conducted. This interview included questions pertaining to their age, medication usage and/or treatment, the location of their pain, and the natural history of their complaint (Matkovich, 2004).⁷

3.3.4 Standard of acceptance

Patients underwent a full case history (Appendix D), research physical examination (Appendix E) and a lumbar spine regional examination (Appendix F) by the researcher of the concurrent cohort study. During this process the patient was screened for sacroiliac syndrome and the candidate was assessed as to whether he met the inclusion and exclusion criteria. Only then was the patient accepted into the concurrent research study (Matkovich, 2004).

The researcher of the present study conducted a brief interview with each patient at the onset of his initial consultation, where the nature of the present study was explained to him. Subjects were accepted into this study once they agreed to participate by signing informed consent and had completed the concurrent cohort study.

3.3.5 Inclusion and exclusion criteria of subjects

The inclusion and exclusion criteria of the present study were governed by the inclusion and exclusion criteria of Matkovich (2004).

Subjects were included in this study based on the following inclusion criteria:

1. Participants had to be between the ages of 18 to 45 years of age. Brandt (2002) stated that little radiographic evidence of osteoarthritis existed in individuals below the age of 45 years. Therefore, patients older than 45 years were not included. The exclusion of participants below the age of 18 years eliminated the need for parental consent.
2. Participants were included if they presented with a main complaint of low back pain that could be attributed to chronic sacroiliac joint syndrome. Sacroiliac syndrome was considered chronic if it was present for thirteen weeks or longer (Giles and Muller, 2003).

3. Participants were accepted once they had given informed consent (Appendix G).
4. The diagnosis of sacroiliac syndrome was established for each patient, based on the diagnostic criteria of McCulloch and Transfeldt (1997:180 – 181), as described under 2.3.4.
5. Only English speaking individuals were considered for the study. The isokinetic testing procedure involved the verbal encouragement of each participant in order to obtain maximum voluntary muscle contractions. Any difficulty in communication between the researcher and the subjects would have compromised the validity of the isokinetic testing procedure.
6. Only male subjects were included. Brukner and Kahn (2002:677) stated that females exhibit on average between two – thirds the strength of males. In addition, anatomical differences between male and female pelves affect the hip joint (Moore, 1992:247). The exclusion of female participants ensured a homogenous sample group, thereby increasing the validity of the study.
7. Participants were only accepted once they completed the concurrent cohort study.

Participants were excluded from this study based on the following exclusion criteria:

1. Previous low back surgery.
2. Any persons that were currently taking either anti – inflammatory or analgesic medication were required to cease this intake 48 hours prior to their initial consultation. Mayer and Polatin in Haldeman (1992:543) state that these drugs are able to provide pain relief and

may thus hamper the establishment of the diagnosis of sacroiliac syndrome.

3. Patients were excluded if they were receiving any other form of treatment for their low back pain, as that would confound the results obtained from this study.
4. Patients who exhibited any contraindication to spinal manipulative therapy were excluded. The contraindications to manipulation, as outlined by Gatterman (1990), included, but were not limited to: disc herniations with increasing signs and symptoms of neurological deficit, abdominal aortic aneurysm, lumbar spine tumors, lumbar spine infections, and traumatic injuries of the lumbar spine.
5. Participants were excluded if they exhibited any contraindications to isokinetic muscle testing procedures, as outlined by www.isokinetics.net (2003) under 2.2.5.1.4.
6. Participants that were unable to perform the isokinetic testing procedure were excluded.
7. Patients that were unable to attend their follow – up consultation 1 day/24 hours post – manipulation, were excluded.

3.3.6 Interventions

3.3.6.1 Initial consultation

Matkovich (2004) conducted the initial consultations with the prospective participants. Any patient that presented with bilateral sacroiliac pain was required to make a subjective decision as to which side was more symptomatic. This decision was confirmed through the conduction of objective orthopedic tests.

Patients underwent a full case history (Appendix D), research physical examination (Appendix E) and a lumbar spine regional examination (Appendix F). This process screened the patient for sacroiliac syndrome and the candidate was assessed whether he met the inclusion and exclusion criteria.

The diagnosis of sacroiliac syndrome was confirmed utilizing the pain provocation tests that form part of the lumbar spine regional examination (Appendix F). The tests that were utilized included the Gaenslen's, Patrick Fabere, Yeoman's (Erichson's) tests (Kirkaldy – Willis, Burton and Cassidy in Kirkaldy – Willis and Burton, 1992:124 – 125) and the posterior shear test (Laslett and Williams, 1994).

According to Laslett and Williams (1994), pain provocation tests aim to stress the joint being tested in an attempt to reproduce the patient's symptoms. Cibulka (2002) states that a least three out of four pain provocation tests should be positive for sacroiliac dysfunction in order to establish a diagnosis of sacroiliac syndrome. Thus, for the purpose of that study, at least three of the abovementioned tests had to yield positive results in order to establish the diagnosis of sacroiliac syndrome.

3.3.6.1.1 The orthopedic tests

3.3.6.1.1.1 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 that joint (Reider, 1999:195).

3.3.6.1.1.2 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).

3.3.6.1.1.3 Yeoman's/Erichson's test

The Yeoman's/Erichson's test was performed with the patient in the prone position. The examiner flexed the patient's ipsilateral knee to 90°, while placing one hand under the knee and the other over the ipsilateral sacroiliac joint, thereby stabilizing the pelvis. As the examiner extended the hip, a deep pain in the sacroiliac joint was indicative of sacroiliac joint pathology (Magee 1997:447 and Sportelli and Tarola in Haldeman 1992:292).

3.3.6.1.1.4 Posterior shear test

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

Once the diagnosis of chronic sacroiliac syndrome was established, sacroiliac joint restrictions were identified utilizing the Gillet method of sacroiliac joint motion palpation, as described under 2.3.5.

All participants were provided with a letter of information (Appendix G) pertaining to the present study and were given the opportunity to ask questions regarding the study. Accepted participants were then required to complete a NRS – 101 questionnaire (Appendix A) and sign informed consent (Appendix H). Subjects did not receive any treatment during this consultation.

3.3.6.2 Second consultation

Second consultations were scheduled at the practice of a qualified biokineticist for all accepted participants. This consultation was conducted by Matkovich (2004) and was subject to the availability of the biokineticist and scheduled at the convenience of the patient.

Objective measurements, regarding concentric – concentric isokinetic muscle strength of the hip (flexion, extension, adduction and abduction), were obtained utilizing the Cybex Orthotron II Isokinetic Rehabilitation system prior to, and immediately following sacroiliac manipulation. Subjective measurements were obtained utilizing the NRS – 101 immediately following sacroiliac manipulation.

The isokinetic testing procedure commenced with a five – minute warm – up cycle on a stationary bike. This was followed by 3 sets of stretching (held for 20 seconds each) of the adductor, iliopsoas and gluteus medius muscles. Stretching was performed on the affected side only.

Hip flexion and extension was tested with the patient in the supine position. This position allows for maximal flexion at the hip. 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 utilized to minimize any body movements and isolate movement at the hip joint, as it enhances the reliability of the results. The affected limb was positioned with the hip in the fully flexed position (thigh more than 90 ° to the table). Thus, the test commenced with hip extension, followed by hip flexion.

Hip adduction and abduction was tested in the lateral recumbent position, with the effected 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.

Next, the power arm was secured to the distal femur via Velcro straps, just proximal to the knee joint. 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 the fully adducted position prior to commencement of the test. Thus, the first action tested was hip abduction followed by hip adduction.

Hence, isokinetic testing the hip musculature was performed in the following sequence: hip extension/flexion and thereafter, the movements of hip abduction/adduction. The same testing sequence was followed for each participant for each subsequent test. This procedure was adapted in order to enhance the validity of the test results.

Gravity correction procedures were implemented to ensure that movements against gravity were not underestimated and movements aided by gravity not overestimated, as the validity and reliability of peak torque measurements rely on effective and correct gravity correction procedures. In addition, subjects were instructed not to support themselves by holding on to the machine or to

gain leverage from their upper bodies. All participants received similar, equally enthusiastic verbal encouragement during the testing procedure in order to ensure their maximal effort.

Testing commenced with a sub – maximal warm – up rep at 90°/sec followed by a 1-minute rest period, followed by 2 trial reps at maximal effort, followed by a 1-minute rest period. This allowed patients the opportunity to familiarize themselves with the isokinetic testing procedure, thereby increasing the reliability of the results. The familiarization period was followed by 3 reps at maximal effort at 60°/sec, followed by a 4-minute rest period.

This procedure was followed by spinal manipulation. Spinal manipulation of the affected sacroiliac joint was performed according to a protocol, adapted from Schaefer and Faye (1990:260 – 283), Suter *et al.* (2000) and Suter *et al.* (1994).

Patients that presented with flexion fixations were positioned in the lateral recumbent position with the affected side up, whilst patients with extension fixations were positioned as per the recommended lateral recumbent position with the affected side down.

The researcher stood in a square stance and made contact with his caudad hand on the sacroiliac joint over the restriction whilst his cephalad hand stabilized the patient's upper body at the shoulder. Stress was initiated into the sacroiliac joint at the fixation and a body drop thrust was applied once the elastic barrier was met.

The adjustment consisted of a high velocity low amplitude thrust in an inferior direction. Only one thrust was delivered per adjustment. An audible cavitation was not considered to be an indication of a successful adjustment.

Sacroiliac manipulation was followed by second set of isokinetic testing that consisted of 3 reps at maximal effort at 60°/sec for each action. Thereafter, patients were required to complete a NRS – 101 questionnaire.

3.3.6.3 Third consultation

The researcher of the present study conducted the third consultation with participants following their completion of the concurrent cohort study. This appointment was scheduled approximately 1 day/24 hours post sacroiliac manipulation.

Conscious attempts were made to assess each subject at about the same time of day as their original assessment 1 day previously. However, as this appointment was subject to the availability of the biokineticist and at the convenience of the patient, this practice could not be maintained throughout the entire study sample.

Participants completed a NRS – 101 questionnaire at the onset of this consultation. Thereafter, a five – minute warm – up cycle on a stationary bike was performed, followed by 3 sets of stretching of the adductor, iliopsoas and gluteus medius muscles as outlined above.

Isokinetic testing was conducted by following the same protocol as described above. Testing commenced with a sub – maximal warm – up rep at 90°/sec followed by a 1-minute rest period, 2 trial reps at maximal effort, followed by a 1-minute rest period and 3 reps at maximal effort at 60°/sec, followed by a 4-minute rest period. Participants received no spinal manipulation at this consultation, as the sole purpose of this consultation was the collection of data.

3.4 Method of measurement

The subjects were assessed for both subjective and objective findings prior to, immediately following and 1 day/24 hours post spinal manipulation.

3.4.1 Subjective measurement

Subjective measurements were obtained utilizing the Numerical Pain Rating Scale (NRS – 101) questionnaire.

The NRS – 101 questionnaire measures the changing intensities of pain experienced by the patient. It includes two separate graphs; both ranging from 0 to 100, where 0 indicates “no pain”, and 100 indicates, “pain as bad as it could be”.

The subjects were required to record their perceived level of pain at the onset of their appointment 1 day/24 hours post sacroiliac manipulation. This was performed firstly, according to the pain intensity when it is at its least, and secondly according to the pain intensity when it is at its worst.

The average of these two scores were an indication of the patient’s pain level. This score was compared to the average NRS – 101 scores completed pre – and immediately post – manipulation, obtained from Matkovich (2004).

Jensen, Karoly and Braves (1986) conducted a study where six methods of pain intensity evaluation were compared to five criteria: ease of administration of the scoring, the relative rate of incorrect responding, sensitivity with regard to questions, sensitivity of statistical analysis, and the relationship to a combination of pain intensity indices.

They concluded that the NRS – 101 was superior to the other measures to which it was compared to due to its simple, practical method of administering

and scoring (which may be in written or verbal form), and the fact that its results did not appear to be age – dependent.

In a more recent study, Bolton and Wilkinson (1998) compared three pain scales, including the Visual Analogue Scale, the Verbal Rating Scale and the Numerical Pain Rating Scale – 101. The NRS – 101 was the most responsive questionnaire and the authors recommended it for most types of outcome studies.

3.4.2 Objective measurement

Objective measurements, regarding concentric – concentric isokinetic muscle strength of the hip (flexion, extension, adduction and abduction), were obtained using the Cybex Orthotron II Isokinetic Rehabilitation system. These readings were compared to the readings recorded pre – manipulation and immediately post – manipulation, obtained from Matkovich (2004).

The reliability, validity, methodological factors and additional factors associated with the use of isokinetic dynamometers have been discussed in detail in chapter two under the sections 2.2.5.1.5 and 2.2.5.1.6, respectively.

3.5 Criteria governing the admissibility of the data

The information obtained from the case history, research physical and lumbar regional examinations, the NRS – 101 questionnaires and the readings obtained with the Cybex Orthotron II Isokinetic Rehabilitation System, were utilized as the primary data for the present study. The NRS – 101 questionnaires were completed under the supervision of Matkovich (2004) (first and second consultations) and the researcher of the present study (third consultation).

Only the results of those subjects that met the criteria of the study and those able to attend their follow – up consultation of hip isokinetic strength testing, were utilized.

3.6 Ethical considerations

1. The rights and welfare of the subjects were protected.
2. Informed consent was obtained (Appendix G).
3. Subjects were not coerced into participating in this study.
4. Information was provided to the patient in an understandable language (Appendix H).
5. The research involved no more than minimal risk.
6. Confidentiality was maintained.
7. Participation in this study was voluntary and did not involve any financial benefit.
8. Subjects were free to withdraw from the study at any time.
9. Patients were eligible for four free treatments and the Durban Institute of Technology Chiropractic Day Clinic for their low back pain, following their completion of the two concurrent research studies. Excluded participants were provided with the option of attending these treatments following their exclusion from the study, for instance, to those participants that experienced pain during the isokinetic testing procedure.
10. Participants were given the opportunity to ask any questions pertaining to the to research studies. The researchers of both studies answered these questions.

3.7 Statistical analysis

The statistical analysis was conducted utilizing the SPSS (version 9) software suite. This statistical software program is manufactured by SPSS Inc, 444N. Michigan Avenue, Chicago, Illinois, USA.

Various descriptive and inferential statistical techniques were utilized. The descriptive procedures used were various tables and graphs and a few summary statistics that included, but was not limited to, means, proportions and percentages. Inferential statistics included various hypothesis-testing techniques.

The sample population consisted of thirty male patients ($n = 30$). This sample size allowed for the application of the central limit theorem and the use of stronger, more robust parametric testing techniques. All the tests set the type 1 error at 5% ($\alpha = 0.05$). If the p value reported was less than 0.05, a significant result was declared and the Null Hypothesis (H_0) was rejected.

3.7.1 The decision rule and the null hypothesis

The Null Hypothesis (H_0) states that there is no significant difference between the two variables that are being compared. The Alternative Hypothesis (H_1) states that there is a significant difference between the two variables that are being compared.

The Null Hypothesis for sub problem one stated that there was no significant difference in hip muscle strength for the actions of flexion, extension, adduction and abduction prior to, immediately following, and 1 day/24 hours post sacroiliac manipulation in terms of objective clinical findings.

The Alternative Hypothesis (H_1) for sub problem one stated that there was a significant difference in hip muscle strength for the actions of flexion, extension, adduction and abduction prior to, immediately following, and 1

day/24 hours post sacroiliac manipulation in terms of objective clinical findings.

The Null Hypothesis (H_0) for sub problem two stated that there was no significant improvement in the patients' perceived levels of pain prior to, immediately following, and 1 day/24 hours post sacroiliac manipulation in terms of subjective clinical findings.

The Alternative Hypothesis (H_1) for subproblem two stated that there was a significant improvement in the patients' perceived levels of pain prior to, immediately following, and 1 day/24 hours post sacroiliac manipulation in terms of subjective clinical findings.

H_0 : there was no significant difference

H_1 : there was a significant difference

The P – value is the “smallest level of significance that would lead to the rejection of the Null Hypothesis” (Montgomery, 1997:37).

$\alpha = 0.05$ = the level of significance

H_0 was rejected and the H_1 was accepted if $P < \alpha = 0.05$

H_0 was accepted and the H_1 was rejected if $P > \alpha = 0.05$

3.7.2 Treatment of the data

3.7.2.1 Subjective data

The two scores obtained from the NRS – 101 for each patient were added. The average of these two scores were an indication of the patient's pain level. This score was compared to the average NRS – 101 scores for each patient, completed pre – and immediately post – manipulation, obtained from Matkovich (2004).

3.7.2.2 Objective data

Three isokinetic recordings (prior to, immediately following and 1 day/24 hours post spinal manipulation) per action (flexion, extension, adduction and abduction) were recorded separately for each patient. The readings generated by the present study were compared to the readings recorded pre – manipulation and immediately post – manipulation, obtained from (Matkovich (2004).

3.7.3 Statistical analysis of the data

An external statistician was consulted for advice regarding the statistical analysis of the data used in this study. Due to the sample size ($n = 30$) parametric statistical techniques were utilized. The data was transferred into spreadsheet format and statistical analysis was conducted at a 95% confidence level (5% significance).

3.7.3.1 Subjective data analysis

The subjective measurement tool, namely the numerical pain rating scale (NRS – 101), was utilized to establish the patients' perceived levels of pain prior to, immediately following and 1 day/24 hours following sacroiliac manipulation. The data from the concurrent cohort study (Matkovich, 2004)

plus the data from this study was utilized, which gave three columns of readings.

3.7.3.1.1 Inter – group analysis

The Analysis of Variance (ANOVA) Tests were performed to establish whether a significant difference in population means occurred between the three NRS - 101 readings.

3.7.3.1.2 Intra – group analysis

A significant ANOVA Test was followed – up with Multiple Paired T-Tests to determine where such significant difference in population means occurred.

3.7.3.2 Objective data analysis

The objective measurement tool, namely the Cybex Orthotron II Isokinetic Rehabilitation System, was utilized for all four hip actions tested. For each action, the data was utilized from the concurrent cohort study (Matkovich, 2004) plus the data from this study, which gave three columns of readings per muscle group.

3.7.3.2.1 Inter – group analysis

The ANOVA Tests were conducted to establish whether significant differences in population means existed between the four actions of the hip tested. A significant test was followed up with Multiple Independent T-Tests to establish where such difference occurred.

3.7.3.2.2 Intra – group analysis

Multiple Paired T – Tests were utilized to determine whether any difference in population means occurred within each group. This procedure was applied to each of the four hip actions tested.

CHAPTER FOUR

THE RESULTS

4.1 Introduction

This chapter aims to present the findings obtained through the statistical analysis of the primary data. The data utilized was collected exclusively from the thirty participants that complied with the inclusion and exclusion criteria of the study.

The present study was conducted alongside another cohort study (Matkovich, 2004) that aimed to investigate the immediate effect of sacroiliac manipulation on the strength of the ipsilateral hip musculature and subjective low back pain intensity in subjects presenting with chronic sacroiliac syndrome.

The subjective and objective data generated by that study (pre – manipulation and immediately post – manipulation), together with the subjective and objective data obtained from this study, was utilized to determine the short – term effect of sacroiliac manipulation on the strength of the hip musculature and subjective low back pain intensity in male subjects presenting with low back pain, attributable to chronic sacroiliac syndrome.

4.1.1 The hypotheses

At the outset of the study, two hypotheses were established. The first hypothesis stated that sacroiliac manipulation would result in the short - term augmentation in ipsilateral hip muscle strength in consequence to a reduction in AMI of the hip musculature responsible for the actions of flexion, extension, adduction and abduction, based on the results of the two studies by Suter and colleagues in 1999 and 2000.

Whereas the second hypothesis stated that sacroiliac manipulation would result in the short – term reduction in patients' perceived levels of pain that accompany their chronic sacroiliac syndrome.

4.1.2 The primary data

The primary data of the study included the following:

4.1.2.1 Subjective data

Subjective measurements were obtained utilizing the Numerical Pain Rating Scale (NRS – 101) questionnaire. This data established the patient's changing levels of pain prior to, immediately following and 1 day/24 hours post - sacroiliac manipulation.

4.1.2.2 Objective data

Objective measurements, regarding concentric – concentric isokinetic muscle strength of the hip (flexion, extension, adduction and abduction), were obtained by means of the Cybex Orthotron II Isokinetic Rehabilitation System. This data reflected the subjects' hip muscle strength prior to, immediately following and 1 day/24 hours post - sacroiliac manipulation.

4.1.3 The analyzed data

The subjective and objective recordings were collated into spreadsheet format once they were rated and statistical analysis was conducted at a 95% confidence level (5 % level of significance). Thus, the data was analyzed at the $\alpha = 0.05$ level and the decision rule was applied as follows:

If the p value reported was less than 0.05, a statistically significant result was declared and the Null Hypothesis (H_0) was rejected.

If the p value reported was greater than 0.05, a statistically insignificant result was declared and the Null Hypothesis (Ho) was accepted.

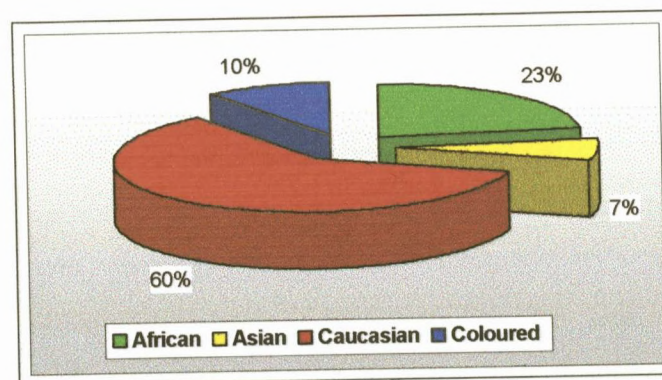
Thus, in order to declare a statistically significant improvement, the p – value had to be ≤ 0.05 .

4.2 Demographical data

Matkovich (2004) collected the demographical data during his initial consultations with the participants. The demographical data incorporated in the present study included the subjects' race, age, occupation, symptomatic side, height and weight.

4.2.1 Racial distribution

FIGURE 4.1



Racial distribution within the study sample (n = 30)

4.2.2 Age distribution

TABLE 4.1 *Age distribution within the study sample (n = 30)*

Age Group	No of Patients	Percentage
18 – 21 years old	7	23.3%
22 – 25 years old	7	23.3%
26 – 29 years old	6	20.0%
30 – 33 years old	3	10.0%
34 – 37 years old	2	6.7%
38 – 41 years old	2	6.7%
42 – 45 years old	3	10.0%

Age range: 19 – 44 years old

Mean age: 28 years

Youngest participant: 19 years old

Oldest participant: 44 years old

4.2.3 Patient occupations

TABLE 4.2 *Patient occupations within the study sample (n = 30)*

Occupation	No of patients
Artist	1
Chartered accountant	1
Cleaner	1
Technician	1
Cooks	3
Entertainer	1
Entrepreneurs	2
Assistant	1
IT consultants	1
Journalist	1
Sales representatives	2
Students	14
Umpire	1

4.2.4 Symptomatic side

FIGURE 4.2



Graphical representation and comparison of the affected side of sacroiliac syndrome within the study sample (n = 30)

4.2.5 Height

TABLE 4.3 *Height distribution within the study sample (n = 30)*

Height (in meters)	No of patients	Percentage
1.60 – 1.64	2	6.7%
1.65 – 1.69	3	10%
1.70 – 1.74	7	23.3%
1.75 – 1.79	7	23.3%
1.80 – 1.84	6	20%
1.85 – 1.89	5	16.7%

Height range: 1.60 - 1.89 m

Mean height: 1.76 m

Lowest height: 1.60 m

Greatest height: 1.89 m

4.2.6 Weight

TABLE 4.4 *Weight distribution within the study sample (n = 30)*

<u>Weight (in kg)</u>	<u>No. of patients</u>	<u>Percentage</u>
55 – 70	3	10 %
71 – 86	18	60 %
87 – 102	6	20 %
103 – 118	3	10 %

Weight range: 55 – 118 kg

Mean weight: 80 kg

Lowest weight: 55 kg

Highest weight: 118 kg

4.3 Subjective data analysis

The subjective data was obtained by means of the NRS – 101 questionnaires that were completed pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation. This data was utilized to establish the patients' perceived levels of pain prior to, immediately following and 1 day/24 hours following sacroiliac manipulation.

4.3.1 Inter – group analysis

The Analysis of Variance (ANOVA) Tests were utilized with the purpose of establishing any significant differences between the three NRS - 101 readings. Statistical analysis was conducted at a 95% confidence level (5 % level of significance).

TABLE 4.5 *Summary of the results obtained through inter – group analysis of the subjective data utilizing the ANOVA Tests (n = 30)*

NRS – 101	P – value ($\alpha = 0.05$)
Combined NRS – 101 scores obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation.	0.673

The Null Hypothesis (Ho) was accepted for the NRS – 101 questionnaires, indicating no significant difference in subjective pain improvement amid the readings obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (P = 0.673).

4.3.2 Intra – group analysis

Multiple Paired T-Tests were utilized in an attempt to establish any significant differences between the three NRS - 101 readings. Statistical analysis was conducted at a 95% confidence level (5 % level of significance).

TABLE 4.6 *Statistical results of the NRS – 101 questionnaires comparing the values obtained pre – manipulation and immediately post – manipulation (n = 30)*

NRS – 101	Mean	P – value ($\alpha = 0.05$)
NRS pre – manipulation	39.950	0.000
NRS immediately post – manipulation	31.467	

The Null Hypothesis (Ho) was rejected for the NRS – 101 questionnaire, indicating a significant subjective improvement in the patients' perceived levels of pain from pre – manipulation to immediately post – manipulation (P = 0.000) (Matkovich, 2004).

TABLE 4.7 *Statistical results of the NRS – 101 questionnaires comparing the values obtained immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)*

NRS – 101	Mean	P – value ($\alpha = 0.05$)
NRS immediately post – manipulation	31.467	0.690
NRS 1 day/24 hours post – manipulation	30.700	

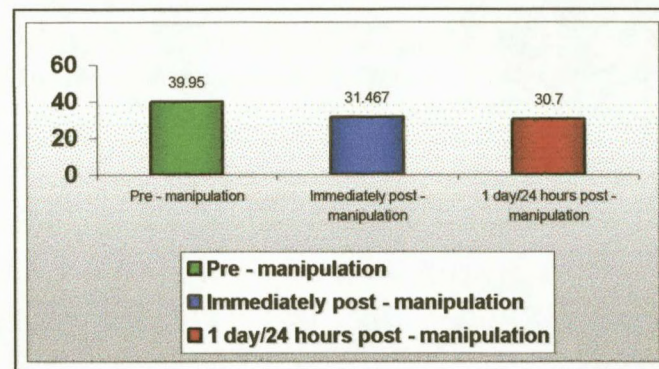
The Null Hypothesis (Ho) was accepted for the NRS – 101 questionnaire, indicating no significant subjective improvement in the patients' perceived levels of pain from immediately post – manipulation to 1 day/24 hours post – manipulation (P = 0.690).

TABLE 4.8 *Statistical results of the NRS – 101 questionnaires comparing the values obtained pre – manipulation and 1 day/24 hours post – manipulation (n = 30)*

NRS – 101	Mean	P – value ($\alpha = 0.05$)
NRS pre – manipulation	39.950	0.000
NRS 1 day/24 hours post manipulation	30.700	

The Null Hypothesis (Ho) was rejected for the NRS – 101 questionnaire, indicating a significant subjective improvement in the patients' perceived levels of pain from pre – manipulation to 1 day/24 hours post – manipulation (P=0.000).

FIGURE 4.3



Comparison of the mean NRS – 101 values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

4.4 Objective data analysis

The objective data was obtained by means of the Cybex Orthotron II Isokinetic Rehabilitation System. Three isokinetic readings (prior to, immediately following and 1 day/24 hours post spinal manipulation) per action (flexion, extension, adduction and abduction) were recorded separately for each patient.

4.4.1 Inter - group analysis

Inter - group analysis was conducted utilizing the ANOVA Tests in order to establish significant differences between the three readings. This procedure was applied to each of the four actions tested. Statistical analysis was conducted at a 95% confidence level (5% significance).

TABLE 4.9 *Summary of the results obtained through inter – group analysis of the objective data utilizing the ANOVA Tests (n = 30)*

Pair	P - value ($\alpha = 0.05$)
Pre – manipulation and immediately post – manipulation	0.726
Immediately post – manipulation and 1 day/24 hours post – manipulation	0.869
Pre – manipulation and 1 day/24 hours post – manipulation	0.736

The Null Hypothesis (H_0) was accepted for hip flexion, extension, adduction and abduction isokinetic strength, indicating no significant difference in objective improvement from pre – manipulation to immediately post – manipulation ($P = 0.726$) (Matkovich, 2004).

The Null Hypothesis (H_0) was accepted for hip flexion, extension, adduction and abduction isokinetic strength, indicating no significant difference in objective improvement from immediately post – manipulation to 1 day/24 hours post - manipulation ($P = 0.869$).

The Null Hypothesis (H_0) was accepted for hip flexion, extension, adduction and abduction isokinetic strength, indicating no significant difference in objective improvement from pre – manipulation to 1 day/ 24 hours post – manipulation ($P = 0.736$).

The above results yielded statistically insignificant P – values. A significant ANOVA Test was to be followed up with Multiple Independent T-Tests in order to establish where such difference occurred (as stated in chapter three, under 3.7.3.2.1). However, in lieu of the above statement and the results obtained, the application of Multiple Independent T - Tests could be omitted.

TABLE 4.10 *Summary of the results obtained through inter – group analysis of the objective data with respect to age, height, weight, perceived pain, joint cavitation, symptomatic side and the presence of bilateral sacroiliac syndrome utilizing the ANOVA Tests ($n = 30$)*

Factor	Pre – manipulation and immediately post – manipulation P – value ($\alpha = 0.05$)	Immediately post – manipulation and 1 day/24 hours post – manipulation P – value ($\alpha = 0.05$)	Pre – manipulation and 1 day/24 hours post – manipulation P – value ($\alpha = 0.05$)
Age	0.927	0.629	0.817
Height	0.541	0.477	0.595
Weight	0.108	0.398	0.162
Perceived pain	0.901	0.486	0.703
Joint cavitation	0.673	0.897	0.886
Symptomatic side	0.317	0.334	0.834
Bilateral sacroiliac syndrome	0.114	0.381	0.091

The Null Hypothesis (H_0) was accepted with respect to age, indicating no significant association between age and hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.927$), immediately post – manipulation and 1 day/24 hours post – manipulation ($P = 0.629$), and pre – manipulation and 1 day/24 hours post - manipulation ($P = 0.817$).

The Null Hypothesis (H_0) was accepted with respect to height, indicating no significant association between height and hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.541$), immediately post – manipulation and 1 day/24 hours post – manipulation ($P = 0.477$), and pre – manipulation and 1 day/24 hours post – manipulation ($P = 0.595$).

The Null Hypothesis (H_0) was accepted with respect to weight, indicating no significant association between weight and hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.108$), immediately post – manipulation and 1 day/24 hours post – manipulation ($P = 0.398$), and pre – manipulation and 1 day/24 hours post – manipulation ($P = 0.162$).

The Null Hypothesis (H_0) was accepted with respect to perceived pain, indicating no significant association between perceived pain and hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.901$), immediately post – manipulation and 1 day/24 hours post – manipulation ($P = 0.486$), and pre – manipulation and 1 day/24 hours post – manipulation ($P = 0.703$).

The Null Hypothesis (H_0) was accepted with respect to joint cavitation, indicating no significant association between joint cavitation and hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.673$), immediately post – manipulation and 1 day/24 hours post – manipulation ($P = 0.897$), and pre – manipulation and 1 day/24 hours post – manipulation ($P = 0.886$).

The Null Hypothesis (H_0) was accepted with respect to the symptomatic side of sacroiliac syndrome, indicating no significant association between the affected side and the hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.317$), immediately post – manipulation and 1 day/24

hours post - manipulation ($P = 0.334$), and pre - manipulation and 1 day/24 hours post - manipulation ($P = 0.834$).

The Null Hypothesis (H_0) was accepted with respect to the presence of unilateral versus bilateral sacroiliac syndrome, indicating no significant association between the presence of unilateral versus bilateral sacroiliac syndrome and hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre - manipulation and immediately post - manipulation ($P = 0.114$), immediately post - manipulation and 1 day/24 hours post - manipulation ($P = 0.381$), and pre - manipulation and 1 day/24 hours post - manipulation ($P = 0.091$).

The above results yielded statistically insignificant P - values. A significant ANOVA Test was to be followed up with Multiple Independent T-Tests in order to establish where such difference occurred (as stated in chapter three, under 3.7.3.2.1). However, in lieu of the above statement and the results obtained, the application of Multiple Independent T - Tests could be omitted.

4.4.2. Intra - group analysis

Intra - group statistical analysis of the objective data pertaining to hip flexion, extension, adduction and abduction was conducted at a 95% confidence level (5 % level of significance) utilizing Multiple Paired T - Tests.

4.4.2.1 Isokinetic hip flexion strength

TABLE 4.11 *Statistical results of isokinetic hip flexion strength comparing the values obtained pre – manipulation and immediately post – manipulation (n = 30)*

Isokinetic hip flexion strength	Mean	P-value ($\alpha = 0.05$)
Pre – manipulation	117.73	0.000
Immediately post – manipulation	130.03	

The Null Hypothesis (Ho) was rejected for isokinetic hip flexion strength, indicating a significant objective improvement from pre – manipulation to immediately post – manipulation (P = 0.000) (Matkovich, 2004).

TABLE 4.12 *Statistical results of isokinetic hip flexion strength comparing the values obtained immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)*

Isokinetic hip flexion strength	Mean	P-value ($\alpha = 0.05$)
Immediately post - manipulation	130.03	0.424
1 day/24 hours post - manipulation	132.27	

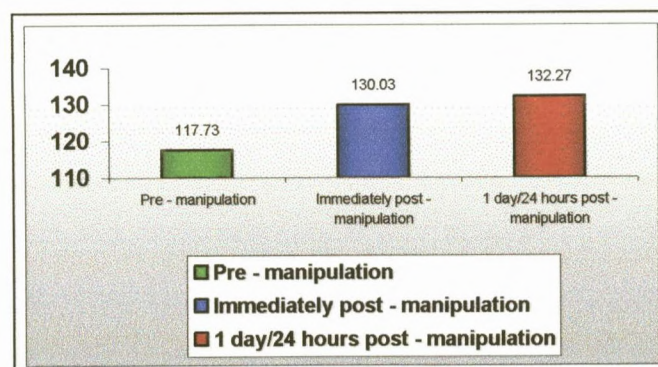
The Null Hypothesis (Ho) was accepted for isokinetic hip flexion strength, indicating no significant objective improvement from immediately post – manipulation to 1 day/24 hours post – manipulation (P = 0.424).

TABLE 4.13 Statistical results of isokinetic hip flexion strength comparing the values obtained pre – manipulation and 1 day/24 hours post – manipulation ($n = 30$)

Isokinetic hip flexion strength	Mean	P – value ($\alpha = 0.05$)
Pre – manipulation	117.73	0.000
1 day/24 hours post – manipulation	132.27	

The Null Hypothesis (H_0) was rejected for isokinetic hip flexion strength, indicating a significant objective improvement from pre – manipulation to 1 day/24 hours post – manipulation ($P = 0.000$).

FIGURE 4.4



Comparison of the mean isokinetic hip flexion strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation ($n = 30$)

4.4.2.2 Isokinetic hip extension strength

TABLE 4.14 *Statistical results of isokinetic hip extension strength comparing the values obtained pre – manipulation and immediately post – manipulation (n = 30)*

Isokinetic hip extension strength	Mean	P – value ($\alpha = 0.05$)
Pre – manipulation	176.47	0.067
Immediately post – manipulation	187.03	

The Null Hypothesis (H_0) was accepted for isokinetic hip extension strength, indicating no significant objective improvement from pre – manipulation to immediately post – manipulation ($P = 0.067$) (Matkovich, 2004).

TABLE 4.15 *Statistical results of isokinetic hip extension strength comparing the values obtained immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)*

Isokinetic hip extension strength	Mean	P – value ($\alpha = 0.05$)
Immediately post – manipulation	187.03	0.001
1 day/24 hours post – manipulation	207.33	

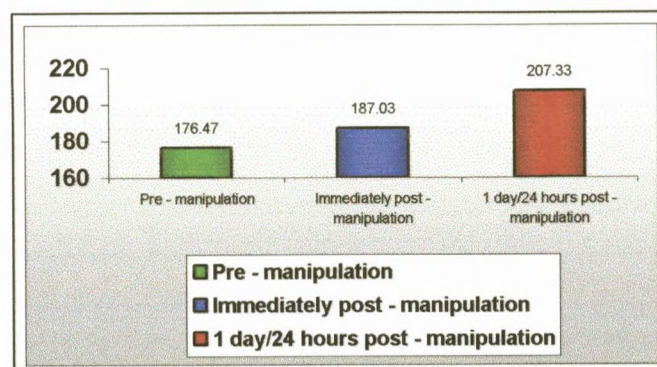
The Null Hypothesis (H_0) was rejected for isokinetic hip extension strength, indicating a significant objective improvement from immediately post – manipulation to 1 day/24 hours post – manipulation ($P = 0.001$).

TABLE 4.16 Statistical results of isokinetic hip extension strength comparing the values obtained pre – manipulation and 1 day/24 hours post – manipulation (n = 30)

Isokinetic hip extension strength	Mean	P – value ($\alpha = 0.05$)
Pre – manipulation	176.47	0.000
1 day/24 hours post – manipulation	207.33	

The Null Hypothesis (Ho) was rejected for isokinetic hip extension strength, indicating a significant objective improvement from pre – manipulation to 1 day/24 hours post – manipulation (P = 0.000).

FIGURE 4.5



Comparison of the mean isokinetic hip extension strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

4.4.2.3 Isokinetic hip adduction strength

TABLE 4.17 *Statistical results of isokinetic hip adduction strength comparing the values obtained pre – manipulation and immediately post – manipulation (n = 30)*

Isokinetic hip adduction strength	Mean	P – value ($\alpha = 0.05$)
Pre – manipulation	139.33	0.019
Immediately post – manipulation	147.77	

The Null Hypothesis (H_0) was rejected for isokinetic hip adduction strength, indicating a significant objective improvement from pre – manipulation to immediately post – manipulation ($P = 0.019$) (Matkovich, 2004).

TABLE 4.18 *Statistical results of isokinetic hip adduction strength comparing the values obtained immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)*

Isokinetic hip adduction strength	Mean	P – value ($\alpha = 0.05$)
Immediately post – manipulation	147.77	0.090
1 day/24 hours post – manipulation	155.63	

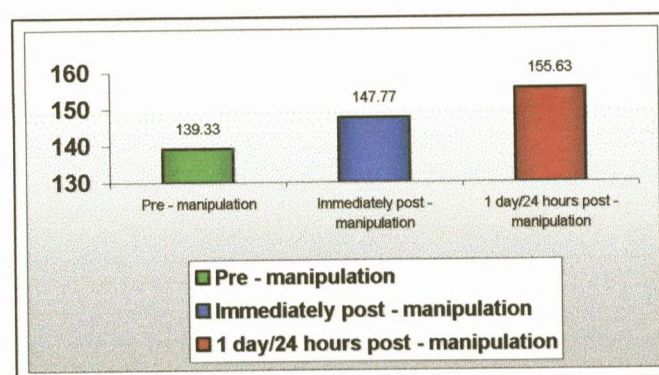
The Null Hypothesis (H_0) was accepted for isokinetic hip adduction strength, indicating no significant objective improvement from immediately post – manipulation to 1 day/24 hours post – manipulation ($P = 0.090$).

TABLE 4.19 Statistical results of isokinetic hip adduction strength comparing the values obtained pre – manipulation and 1 day/24 hours post – manipulation (n = 30)

Isokinetic hip adduction strength	Mean	P – value ($\alpha = 0.05$)
Pre – manipulation	139.33	0.002
1 day/24 hours post – manipulation	155.63	

The Null Hypothesis (H_0) was rejected for isokinetic hip adduction strength, indicating a significant objective improvement from pre – manipulation to 1 day/24 hours post – manipulation ($P = 0.002$).

FIGURE 4.6



Comparison of the mean isokinetic hip adduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

4.4.2.4 Isokinetic hip abduction strength

TABLE 4.20 *Statistical results of isokinetic hip abduction strength comparing the values obtained pre – manipulation and immediately post – manipulation (n = 30)*

Isokinetic hip abduction strength	Mean	P – value ($\alpha = 0.05$)
Pre – manipulation	100.47	0.047
Immediately post – manipulation	105.17	

The Null Hypothesis (H_0) was rejected for isokinetic hip abduction strength, indicating a significant objective improvement from pre – manipulation to immediately post – manipulation ($P = 0.047$) (Matkovich, 2004).

TABLE 4.21 *Statistical results of isokinetic hip abduction strength comparing the values obtained immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)*

Isokinetic hip abduction strength	Mean	P – value ($\alpha = 0.05$)
Immediately post – manipulation	105.17	0.147
1 day/24 hours post – manipulation	109.37	

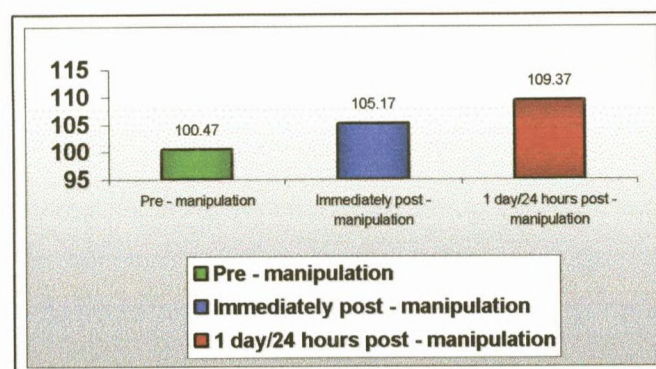
The Null Hypothesis (H_0) was accepted for isokinetic hip abduction strength, indicating no significant objective improvement from immediately post – manipulation to 1 day/24 hours post manipulation ($P = 0.147$).

TABLE 4.22 Statistical results of isokinetic hip abduction strength comparing the values obtained pre – manipulation and 1 day/24 hours post – manipulation (n = 30)

Isokinetic hip abduction strength	Mean	P – value ($\alpha = 0.05$)
Pre – manipulation	100.47	0.003
1 day/24 hours post – manipulation	109.37	

The Null Hypothesis (H_0) was rejected for isokinetic hip abduction isokinetic strength, indicating a significant objective improvement from pre – manipulation to 1 day/24 hours post – manipulation ($P = 0.003$).

FIGURE 4.7



Comparison of the mean isokinetic hip abduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

4.5 Conclusion

The data included in this chapter represents the subjective and objective measurements generated by the present study, together with the subjective and objective measurements (pre – manipulation and immediately post – manipulation), obtained from a concurrent study (Matkovich, 2004). The data has been statistically analyzed at a 95% confidence interval (5% level of significance) by means of parametric statistical techniques. A detailed discussion of the results follows in chapter five.

CHAPTER FIVE

DISCUSSION OF THE RESULTS

5.1 Introduction

The aim of this chapter is to discuss the results obtained through the statistical analysis of the subjective and objective data. This practice is essential in order to facilitate the process of conclusion making on whether the established hypotheses are substantiated or not.

The first hypothesis stated that sacroiliac manipulation would result in the short –term augmentation in ipsilateral hip muscle strength in consequence to a diminution of AMI in the hip musculature responsible for the actions of flexion, extension, adduction and abduction. Whereas the second hypothesis stated that sacroiliac manipulation would result in the short – term amelioration of perceived pain associated with chronic sacroiliac syndrome.

This chapter will focus on two main areas of analysis, namely subjective data analysis, and objective data analysis. The demographical data pertaining to the study sample was presented in chapter four under 4.2.

The subjective and objective data utilized for the purpose of statistical analysis included the data generated by the present study, together with the data obtained from a concurrent cohort study (pre – manipulation and immediately post – manipulation) that investigated the immediate effect of sacroiliac manipulation on the strength of the hip musculature and subjective low back pain intensity in subjects presenting with chronic sacroiliac syndrome (Matkovich, 2004).

The sample population of the present study consisted of thirty male participants with low back pain attributable to chronic sacroiliac syndrome. The data utilized was collected exclusively from the thirty participants that

complied with the inclusion and exclusion criteria of the study. In this regard, one participant was excluded from the study in consequence to technical difficulties associated with the dynamometer.

5.2 Interpretation of the subjective data

The subjective data was obtained by means of the NRS – 101 questionnaires that were completed pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation. This data reflected the patients' perceived levels of pain prior to, immediately following and 1 day/24 hours following sacroiliac manipulation. The statistical analysis of the data was conducted at a 95% confidence interval (5% significance).

5.2.1 Inter – group analysis

The ANOVA Test was utilized with the purpose of establishing significant differences between the three NRS - 101 readings. The test revealed a statistically insignificant P – value ($P = 0.673$), thus indicating that sacroiliac manipulation resulted in a consistent reduction and maintenance of pain in patients with chronic sacroiliac syndrome.

5.2.2 Intra – group analysis

Multiple Paired T-Tests were utilized in an attempt to establish significant differences between the three NRS - 101 readings.

Comparison of the NRS – 101 questionnaires completed pre – manipulation and immediately post – manipulation revealed a statistically significant improvement in patients' perceived levels of pain following sacroiliac manipulation ($P = 0.000$). Therefore, sacroiliac manipulation resulted in the immediate amelioration of pain in subjects with chronic sacroiliac syndrome (Matkovich, 2004).

Comparison of the NRS – 101 questionnaires completed immediately post manipulation and 1 day/24 hours post – manipulation revealed a statistically insignificant improvement in the patients' perceived levels of pain following sacroiliac manipulation ($P = 0.690$). Therefore, sacroiliac manipulation did not result in an additional statistically significant reduction in pain in subjects with chronic sacroiliac syndrome.

A possible explanation could be attributed to a mild increase in subjective pain perception experienced by some participants as a consequence to spinal manipulative therapy. Yet, an overall improvement with respect to subjective pain perception was evident and still, the results indicated that the immediate reduction of pain in subjects with chronic sacroiliac syndrome was sustained at 1 day/24 hours post – manipulation (Figure 4.3).

Comparison of the NRS – 101 questionnaires completed pre – manipulation and 1 day/24 hours post – manipulation revealed a statistically significant improvement in patients' perceived levels of pain following sacroiliac manipulation ($P = 0.000$). Therefore, sacroiliac manipulation resulted in the short – term amelioration of pain in subjects with chronic sacroiliac syndrome, thus supporting hypothesis two.

5.3 Interpretation of the objective data

Objective measurements regarding concentric – concentric isokinetic muscle strength of the hip in the actions of flexion, extension, adduction and abduction were obtained prior to, immediately following and 1 day/24 hours following sacroiliac manipulation. Statistical analysis was conducted at a 95% confidence level (5% significance).

5.3.1 Inter – group analysis

Inter - group analysis was conducted by means of the ANOVA Tests with the aim of establishing significant differences between the three readings. This procedure was applied to each of the four actions.

The results of the ANOVA Tests revealed statistically insignificant P - values with respect to the readings obtained pre – manipulation and immediately post – manipulation ($P = 0.726$) (Matkovich, 2004), immediately post – manipulation and 1 day/24 hours post – manipulation ($P = 0.869$), and pre – manipulation and 1 day/24 hours post – manipulation ($P = 0.736$).

Thus, the net effect of sacroiliac manipulation on hip muscle strength appeared to be comparable with respect to all four actions of the hip, with no single action responding neither superiorly nor inferiorly. A possible explanation could be ascribed to the similarity in segmental nerve supply of the sacroiliac joint and that of the hip musculature.

The results of a study by Suter *et al.*, (1999) demonstrated that sacroiliac manipulation was effective in reducing AML and increasing muscle strength of the quadriceps muscle group in patients with anterior knee pain. In light of their results, it was hypothesized that the quadriceps muscle group, with a segmental innervation of L2 to L4 (Suter *et al.*, 2000), fell within the sacroiliac joint motor neuron pool, as the sacroiliac joint has a segmental nerve supply of L1 to S2 (Murata *et al.*, 2001).

Thus, a similar assumption could be made with respect to the hip musculature, as the combined segmental nerve supply of the hip flexors (L1 to L5), extensors (L5 to S2), adductors (L2 to L4) and abductors (L5 and S1) correlate with that of the sacroiliac joint (Moore 1992:387, 399, 417 and 423 and Murata *et al.*, 2001).

5.3.1.1 The relationship between age and isokinetic strength moments

According to De Ste Croix, Deighan and Armstrong (2003), the intrinsic force – producing capability of a muscle appears to increase with age. In general, muscle strength is said to reach its peak in the third decade. Thereafter it

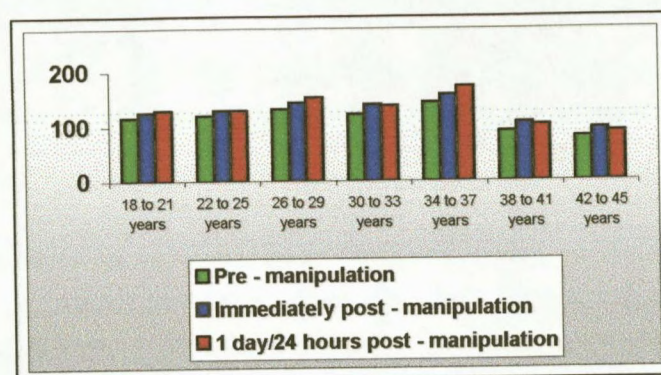
declines moderately with increasing age until the seventh decade, where a steeper decline ensues (www.isokinetics.net, 2003).

In light of the above, the relationship between age and isokinetic moments was analyzed by means of the ANOVA Tests, with the aim of establishing a statistically tenable association.

The ANOVA Test revealed statistically insignificant P - values with respect to age and the hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.927$), immediately post – manipulation and 1 day/24 hours post – manipulation ($P = 0.629$), and pre – manipulation and 1 day/24 hours post - manipulation ($P = 0.817$).

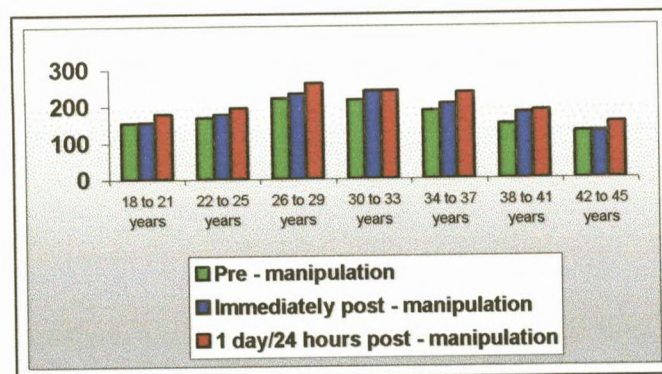
Yet, graphical representation of the results revealed slightly higher isokinetic strength moments between the ages of 26 to 37, thereby supporting the notion that muscle strength reaches its peak in the third decade (Figure 5.1 to 5.4). Still, the results of the present study cannot conclusively support the relationship between age and isokinetic strength moments. Thus, in accordance with De Ste Croix, Deighan and Armstrong (2003), age – related changes might be more applicable to children and adolescents.

FIGURE 5.1



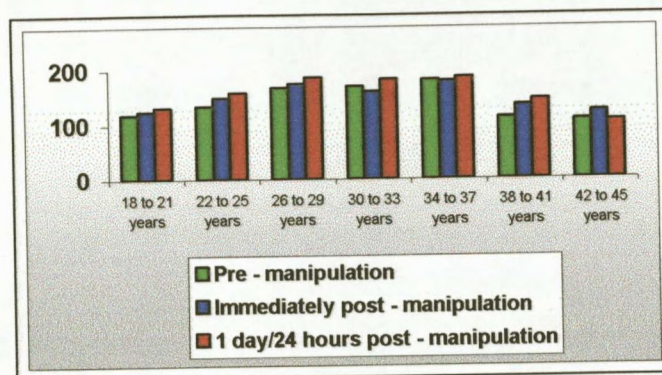
The relationship between age and isokinetic hip flexion strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.2



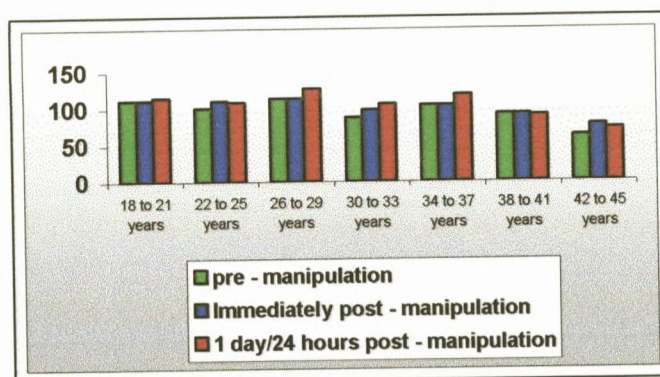
The relationship between age and isokinetic hip extension strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.3



The relationship between age and isokinetic hip adduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.4



The relationship between age and isokinetic hip abduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

5.4.1.2 The relationship between differences in body size and body mass and stature and isokinetic strength moments

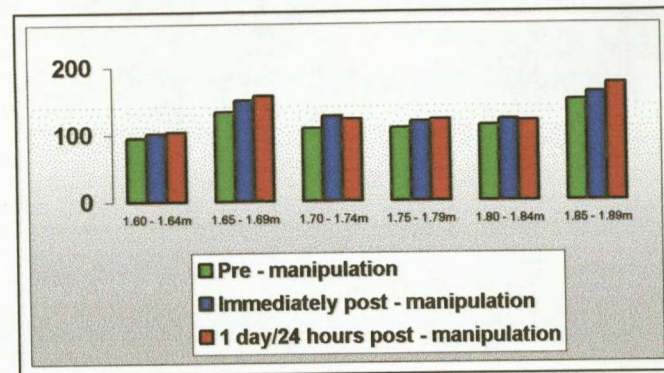
Differences in body size are of vital importance in isokinetic strength testing procedures (De Ste Croix, Deighan and Armstrong, 2003). Chan and Maffulli (1996:4) state that smaller athletes possess a greater advantage, as they have higher strength – to – mass ratios in contrast to their larger counterparts. On the contrary, De Ste Croix, Deighan and Armstrong (2003) claim that larger individuals are “more often than not stronger than their smaller counterparts”.

With respect to body mass and stature, De Ste Croix, Deighan and Armstrong (2003) claim them to have independent influences on isokinetic strength. Heavier individuals tend to produce higher isokinetic moments as the muscle mass in normal individuals is said to rise in proportion to body weight (www.isokinetics.net, 2003). Whereas increased stature is said to introduce a mechanical benefit (De Ste Croix, Deighan and Armstrong, 2003).

In light of the above, the relationships between height and weight and isokinetic moments were analyzed by means of the ANOVA Tests with the aim of establishing statistically tenable associations.

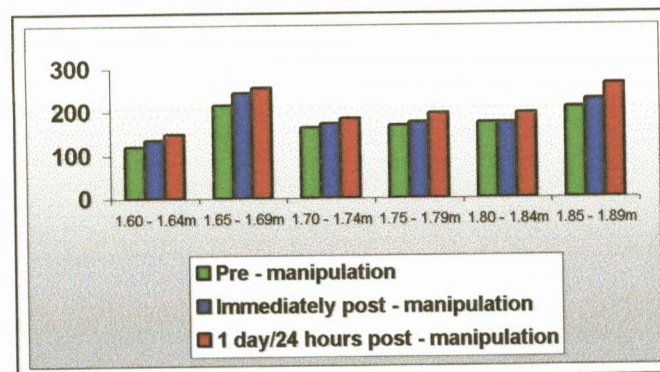
The ANOVA Tests revealed statistically insignificant P - values with respect to height and the hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.541$), immediately post – manipulation and 1 day/24 hours post – manipulation ($P = 0.477$), and pre – manipulation and 1 day/24 hours post - manipulation ($P = 0.595$). However, graphical representation of the results (Figures 5.5 to 5.8) revealed a linear relationship with respect to isokinetic strength moments and height.

FIGURE 5.5



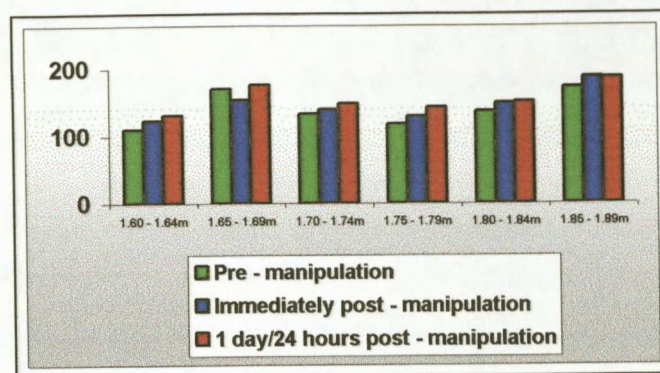
The relationship between height and isokinetic hip flexion strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.6



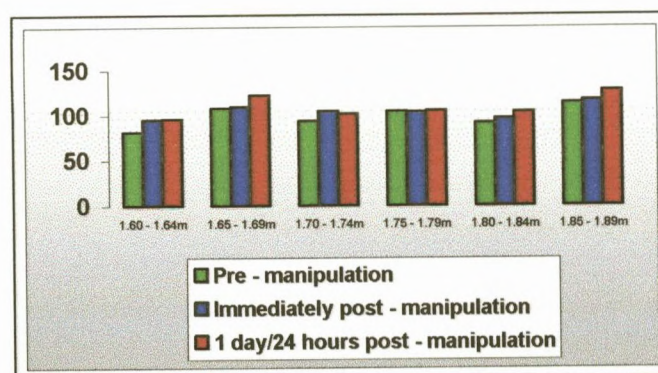
The relationship between height and isokinetic hip extension strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.7



The relationship between height and isokinetic hip adduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.8

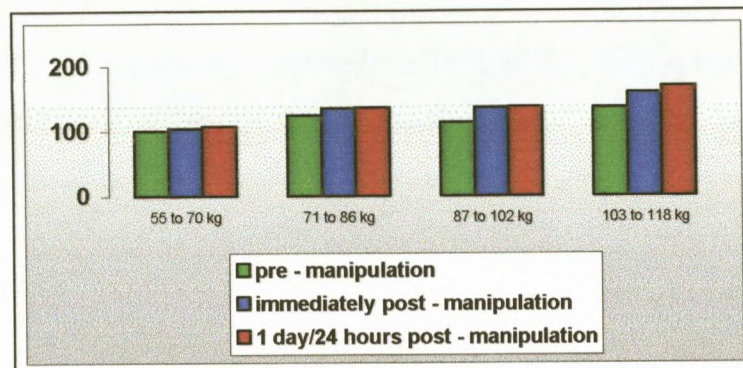


The relationship between height and isokinetic hip abduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

Accordingly, no significant association was established between weight and the hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.108$), immediately post – manipulation and 1 day/24 hours post –

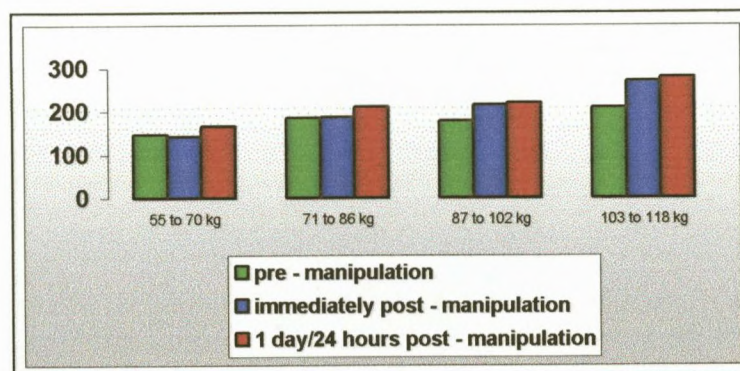
manipulation ($P = 0.398$), and pre – manipulation and 1 day/24 hours post – manipulation ($P = 0.162$). Yet, graphical representation of the results (Figures 5.9 to 5.12) revealed a linear relationship with respect to isokinetic strength moments and body weight.

FIGURE 5.9



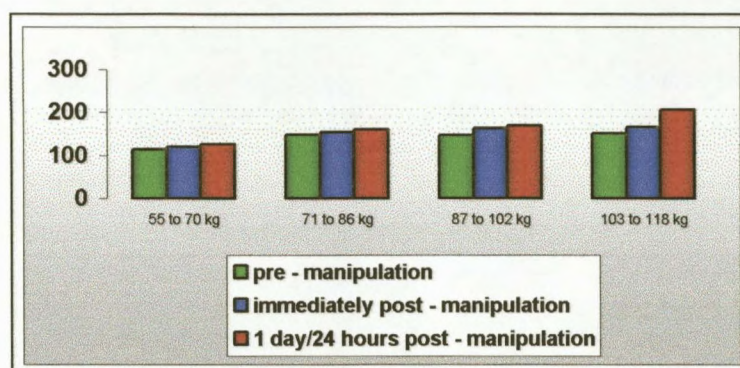
The relationship between weight and isokinetic hip flexion strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation ($n = 30$)

FIGURE 5.10



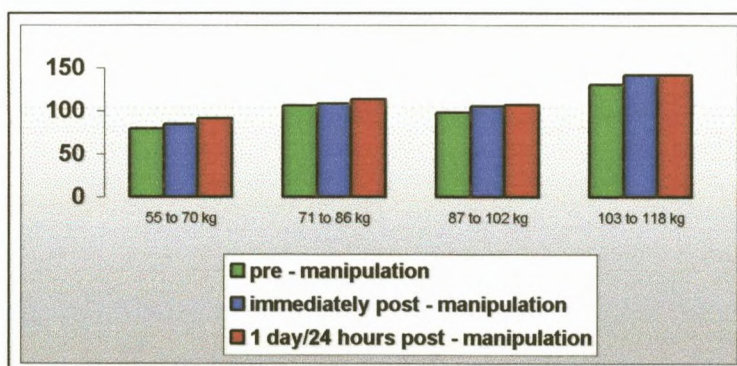
The relationship between weight and isokinetic hip extension strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation ($n = 30$)

FIGURE 5.11



The relationship between weight and isokinetic hip adduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.12



The relationship between weight and isokinetic hip abduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

In lieu of the above results, the present study cannot conclusively support the presence of statistically tenable relationships with respect to differences in body size, body mass and stature and isokinetic strength moments. It is possible that these relationships might be more applicable to athletic populations.

5.3.1.3 The relationship between perceived pain and isokinetic strength moments

According to Ohnmeiss *et al.* (2000), patients have the ability of significantly influencing isokinetic test values's due to self – reported disability and pain expression. In this respect, Arokoski *et al.* (2002) stated that the completion of pain questionnaires post – isokinetic testing could be useful in evaluating the influence of pain on muscle strength results.

Participants' perceived levels of pain were recorded, utilizing the NRS – 101, prior to, immediately following and 1 day/24 hours post – isokinetic testing. Thus, the present study was able to evaluate the influence of pain on isokinetic moments.

The ANOVA Test revealed statistically insignificant P – values with respect to perceived pain and hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.901$), immediately post – manipulation and 1 day/24 hours post - manipulation ($P = 0.486$), and pre – manipulation and 1 day/24 hours post – manipulation ($P = 0.703$).

Thus, in contrast to Ohnmeiss *et al.* (2000), perceived pain did not appear to have a significant influence on patients' abilities to produce maximum voluntary muscle contractions. Therefore, the results of the present study are in accordance with those of Arokoski *et al.* (2002), who demonstrated that muscle strength does not correlate with subjective pain severity.

A possible explanation could be attributed to participants' conscious efforts in making an impression on the researcher by producing greater isokinetic strength values, despite pain, over successive tests.

5.3.1.3.1 The role of pain in the development of arthrogenic muscle inhibition

The role of pain in the development of AMI development appears to be ambiguous, with some researchers showing significant correlations (Spencer, Hayes and Alexander, 1984 and Suter *et al.*, 1998), with others claiming otherwise (Hurley, Jones and Newham, 1994 and Hopkins and Ingersoll, 2000).

As stated under 2.2.5.1.6.5.1, it was hypothesized that participants of this study that demonstrated greater subjective pain disability could demonstrate reduced isokinetic strength values, attributable to increased AMI, as opposed to their "reduced pain disability" counterparts. In addition, as stated under 2.6, the afferent information arising from a symptomatic sacroiliac joint was anticipated to be primarily nociceptive in nature, based on Sakamoto and colleagues' (2001) discovery of principally nociceptive mechanoreceptors in cat sacroiliac joints.

In light of the above, the present study could have supported the relationship between pain and AMI, thereby implicating pain as a possible etiologic factor in its development. In this respect, Suter *et al.*, (1998) reported a weak but statistically significant relationship between AMI and pain, with high levels of pain being associated with high levels of AMI, thus implicating pain in the development of AMI.

However, in contrast to Suter *et al.* (1998), the results of this study do not demonstrate a statistically tenable relationship between subjective pain disability and reduced isokinetic strength values, attributable to increased AMI. Thus, the present study cannot conclusively support the role of pain as a possible etiologic factor in the development of AMI.

However, as previously stated under 5.4.1.3, a possible explanation for the results obtained could be attributed to participants' conscious efforts in

making an impression on the researcher by producing greater isokinetic strength values, despite pain, over successive tests, thereby influencing the results.

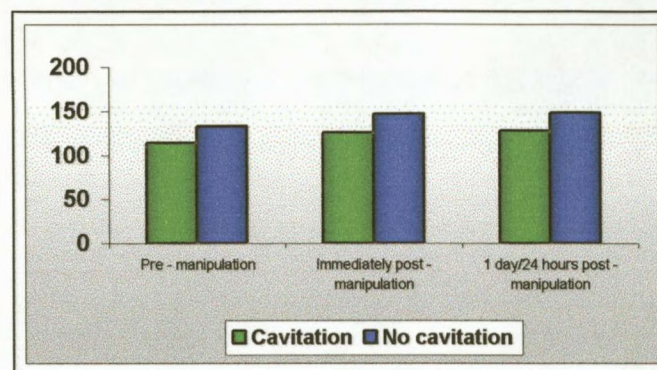
5.3.1.4 The relationship between the presence of an audible cavitation and isokinetic strength moments

During the course of the study, greater isokinetic strength moments were observed in the absence of audible cavitations as a result of sacroiliac manipulation, as opposed to the contrary.

The ANOVA Test revealed a statistically insignificant association between the presence of joint cavitation and the hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.673$), immediately post – manipulation and 1 day/24 hours post - manipulation ($P = 0.897$), and pre – manipulation and 1 day/24 hours post – manipulation ($P = 0.886$).

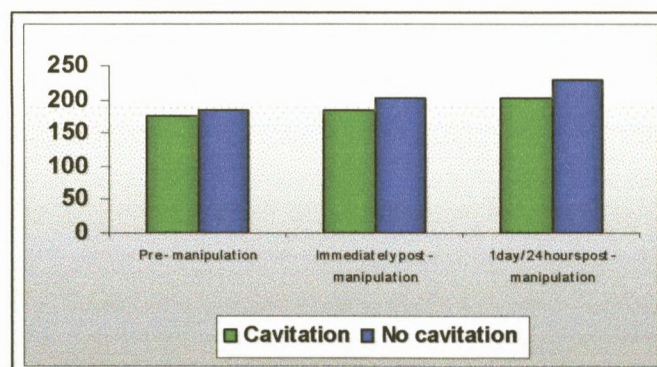
Yet, graphical representation of the results (Figures 5.13 to 5.16) revealed greater isokinetic strength moments in the absence of joint cavitation, as opposed to the contrary. Thus, in accordance with Suter *et al.* (1994), an audible cavitation might not be an indicator of a successful chiropractic adjustment. However, the results of the present study cannot conclusively support this notion.

FIGURE 5.13



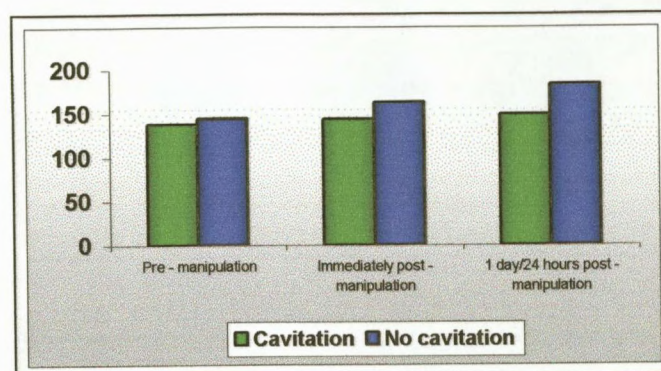
The relationship between cavitation and isokinetic hip flexion strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.14



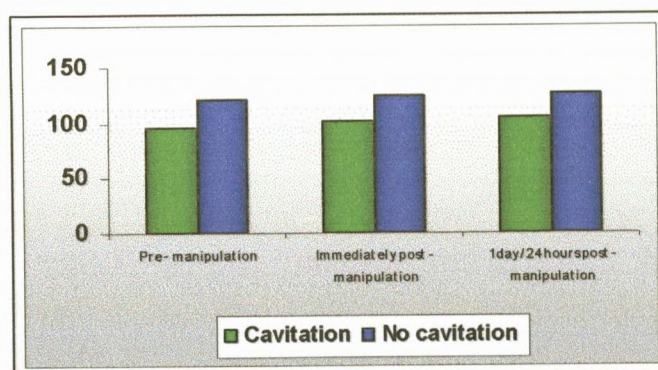
The relationship between cavitation and isokinetic hip extension strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.15



The relationship between cavitation and isokinetic hip adduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.16



The relationship between cavitation and isokinetic hip abduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

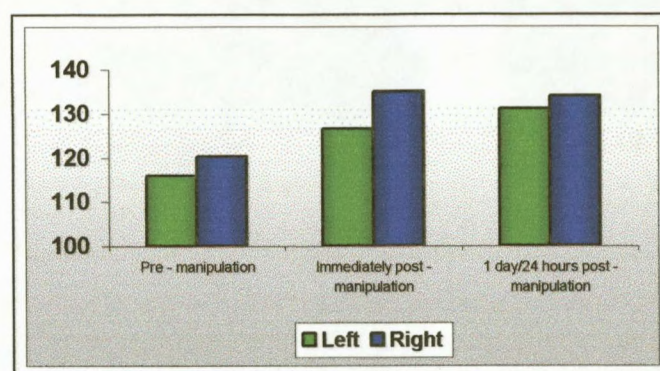
5.4.1.5 The relationship between the symptomatic side of sacroiliac syndrome and isokinetic strength moments

During the course of the study, participants presenting with right – sided sacroiliac syndrome were observed to exhibit greater isokinetic strength moments as opposed to those presenting with left – sided sacroiliac syndrome.

The ANOVA Test revealed a statistically insignificant P – value with respect to the affected side and the hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.317$), immediately post – manipulation and 1 day/24 hours post - manipulation ($P = 0.334$), and pre – manipulation and 1 day/24 hours post – manipulation ($P = 0.834$).

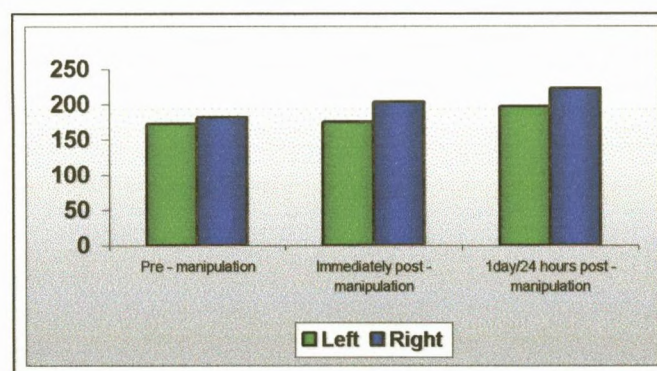
However, graphical representation of the results (Figures 5.17 to 5.20) revealed greater isokinetic strength moments with respect to the right side as opposed to the left. A possible explanation could be that the right leg was the dominant leg of those participants that produced higher isokinetic moments, with the left leg of the remainder of the participants being their non – dominant leg.

FIGURE 5.17



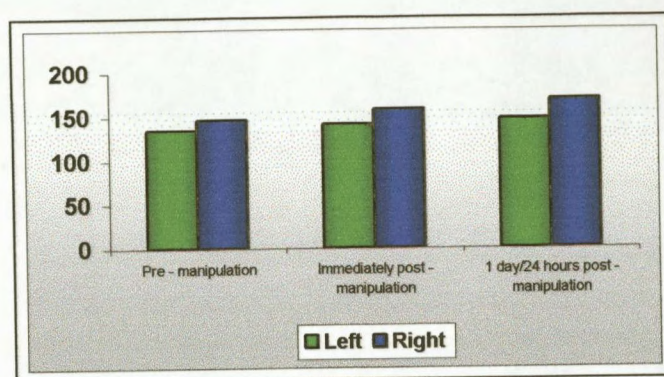
The relationship between the symptomatic side of sacroiliac syndrome and isokinetic hip flexion strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.18



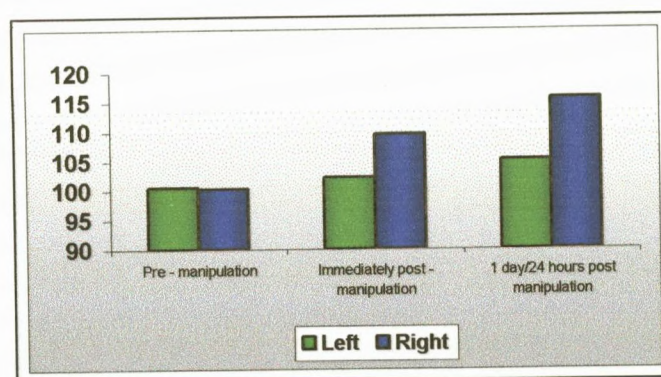
The relationship between the symptomatic side of sacroiliac syndrome and isokinetic hip extension strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.19



The relationship between the symptomatic side of sacroiliac syndrome and isokinetic hip adduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.20



The relationship between the symptomatic side of sacroiliac syndrome and isokinetic hip abduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

5.3.1.6 The relationship between the presence of bilateral sacroiliac syndrome and isokinetic strength moments

During the course of the study, the researcher hypothesized that participants presenting with bilateral sacroiliac syndrome could have exhibited the existence of AMI in the “unaffected” hip muscles, resulting in the amplification of AMI in the affected limb hip musculature on the more symptomatic side, as stated under 2.2.5.1.6.5.3.

As a result, it was thought that those subjects could have exhibited a greater amount of AMI, and consequently a lesser extent of AMI reduction, as only the “symptomatic” sacroiliac joint was manipulated. Thus, the amount of AMI in the “symptomatic” limb could have been underestimated.

In light of the above, the relationship between the presence of unilateral or bilateral sacroiliac syndrome and isokinetic moments was analyzed by means of the ANOVA Tests with the aim of establishing a statistically tenable association.

The ANOVA Tests revealed statistically insignificant P - values with respect to the presence of unilateral or bilateral sacroiliac syndrome and the hip flexion, extension, adduction and abduction isokinetic strength readings obtained pre – manipulation and immediately post – manipulation ($P = 0.114$), immediately post – manipulation and 1 day/24 hours post – manipulation ($P = 0.381$), and pre – manipulation and 1 day/24 hours post - manipulation ($P = 0.091$).

However, in contrast to the above hypothesis, graphical representation of the results (Figures 5.21 to 5.24) revealed that subjects presenting with bilateral sacroiliac syndrome responded superiorly to those presenting with unilateral sacroiliac syndrome.

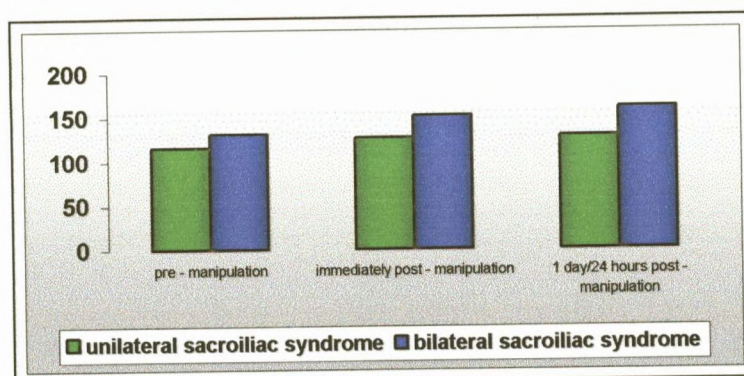
Suter *et al.* (1999) hypothesized that the effects of unilateral sacroiliac manipulation on the presence of a bilateral pathologic condition of the knee joint may not be limited to the treatment side but may beneficially affect both

sides. In this respect, the authors showed a reduction in AMI in the contralateral in addition to a reduction in AMI in the affected leg.

Thus, with respect to the present study, the effect of unilateral sacroiliac manipulation could have resulted in bilateral AMI reductions, thereby reducing a possible amplification in AMI on the more symptomatic side, and subsequently, resulting in the amplification of muscle strength in the affected limb.

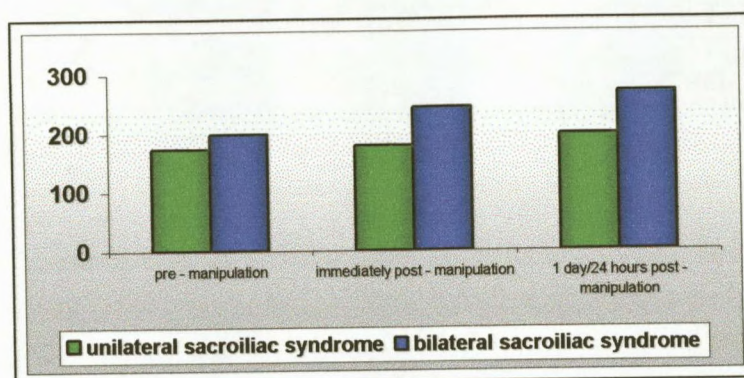
However, due to the small number of participants that presented with bilateral sacroiliac syndrome ($n = 4$), no firm conclusions could be drawn from this observation.

FIGURE 5.21



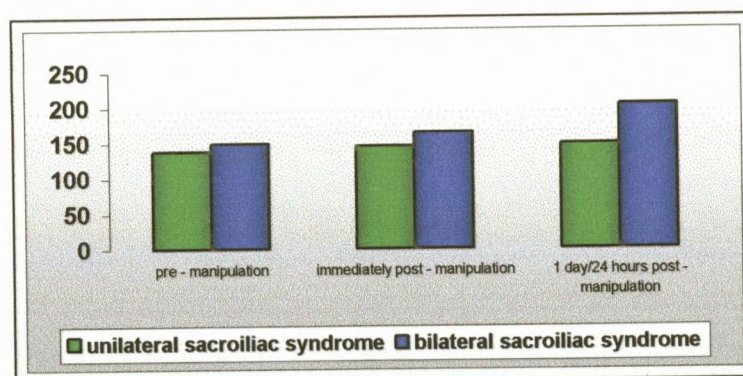
The relationship between the presence of unilateral or bilateral sacroiliac syndrome and isokinetic hip flexion strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation ($n = 30$)

FIGURE 5.22



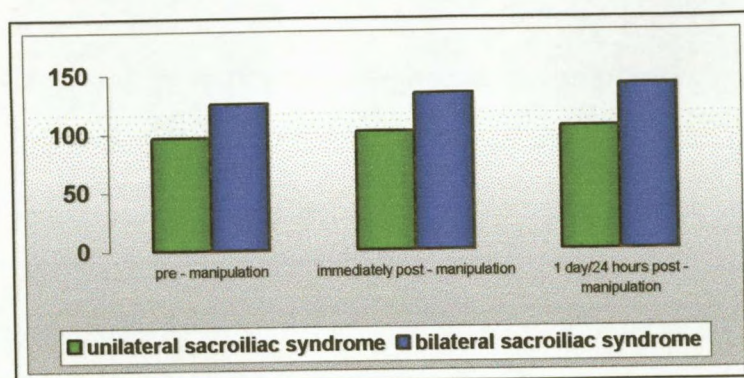
The relationship between the presence of unilateral or bilateral sacroiliac syndrome and isokinetic hip extension strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.23



The relationship between the presence of unilateral or bilateral sacroiliac syndrome and isokinetic hip adduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

FIGURE 5.24



The relationship between the presence of unilateral or bilateral sacroiliac syndrome and isokinetic hip abduction strength values obtained pre – manipulation, immediately post – manipulation and 1 day/24 hours post – manipulation (n = 30)

5.3.2 Intra – group analysis

Intra - group statistical analysis of the objective data, pertaining to hip flexion, extension, adduction and abduction, was conducted by means of Multiple Paired T - Tests.

5.3.2.1 Isokinetic hip flexion strength

Comparison of isokinetic hip flexion strength readings obtained pre – manipulation and immediately post – manipulation revealed a statistically significant improvement ($P = 0.000$). Thus, sacroiliac manipulation was associated with an immediate increase in hip flexion strength, consequent to an immediate reduction in AMI (Matkovich, 2004).

Comparison of isokinetic hip flexion strength readings obtained immediately post – manipulation and 1 day/24 hours post – manipulation revealed a statistically insignificant improvement ($P = 0.424$). Hence, no additional

A possible explanation could be attributed to either a mild increase in subjective pain perception experienced by some participants as a consequence to spinal manipulative therapy, or the presence of muscle stiffness or soreness as a result of isokinetic muscle testing the previous day.

In lieu of this statement, pain or fear of pain provocation during the isokinetic testing procedure could have resulted in reduced isokinetic strength measurements for some participants.

Still, the above results indicate that the immediate increase in hip flexion strength, consequent to the immediate reduction in AMI, was sustained at 1 day/24 hours post – manipulation.

Comparison of isokinetic hip flexion strength readings obtained pre – manipulation and 1 day/ 24 hours post – manipulation revealed a statistically significant improvement ($P = 0.000$). Therefore, sacroiliac manipulation was associated with a short – term increase in hip flexion strength, consequent to a short – term reduction in AMI, thus supporting hypothesis one.

5.3.2.2 Isokinetic hip extension strength

Comparison of isokinetic hip extension strength readings obtained pre – manipulation and immediately post – manipulation revealed a statistically insignificant improvement ($P = 0.067$). Therefore, no statistically significant augmentation in hip extension strength or reduction in AMI occurred (Matkovich, 2004), even though a slight improvement was evident (Figure 4.5).

The above finding could be the result of a mild increase in subjective pain perception experienced by some participants as a consequence to spinal manipulative therapy. Thus, pain or fear of pain provocation during the isokinetic testing procedure could have resulted in decreased isokinetic strength measurements for some participants.

In addition, the presence of fatigue could have resulted in reduced isokinetic strength measurements for some participants, even though all participants were allowed a 4-minute rest period prior to the commencement of their second isokinetic assessment.

Comparison of isokinetic hip extension strength readings obtained immediately post – manipulation and 1 day/24 hours post – manipulation revealed a statistically significant improvement ($P = 0.001$). Therefore, sacroiliac manipulation resulted in an additional increase in hip extension strength, consequent to an additional reduction in AMI.

Thus, the immediate increase in hip extension strength, consequent to an immediate reduction in AMI (although statistically insignificant) was sustained through an additional improvement that occurred at 1 day/24 hours post – manipulation.

Comparison of isokinetic hip extension isokinetic strength readings obtained pre – manipulation and 1 day/ 24 hours post – manipulation revealed a statistically significant improvement ($P = 0.000$). Therefore, sacroiliac manipulation was associated with a short – term increase in hip extension strength, consequent to a short – term reduction in AMI, thus supporting hypothesis one.

5.3.2.3 Isokinetic hip adduction strength

Comparison of isokinetic hip adduction strength readings obtained pre – manipulation and immediately post – manipulation revealed a statistically significant improvement ($P = 0.019$). Therefore, sacroiliac manipulation was associated with an immediate increase in hip adduction strength, consequent to an immediate reduction in AMI (Matkovich, 2004).

Comparison of isokinetic hip adduction strength readings obtained immediately post – manipulation and 1 day/24 hours post - manipulation

revealed a statistically insignificant improvement ($P = 0.090$). Therefore, no additional statistically significant improvement in hip adduction strength or reduction in AMI occurred, even though a slight improvement in hip adduction strength was evident (Figure 4.6).

A possible explanation could be attributed to either a mild increase in subjective pain perception experienced by some participants as a consequence to spinal manipulative therapy, or the presence of muscle stiffness or soreness as a result of isokinetic muscle testing the previous day.

In lieu of this statement, pain or fear of pain provocation during the isokinetic testing procedure could have resulted in reduced isokinetic strength measurements for some participants.

Still, the immediate increase in adduction strength, consequent to an immediate reduction in AMI was sustained at 1 day/24 hours post – manipulation.

Comparison of isokinetic hip adduction strength readings obtained pre – manipulation and 1 day/ 24 hours post – manipulation revealed a statistically significant improvement ($P = 0.002$). Therefore, sacroiliac manipulation was associated with a short – term increase in hip adduction strength, consequent to a short – term reduction in AMI, thus supporting hypothesis one.

5.3.2.4 Isokinetic hip abduction strength

Comparison of isokinetic hip abduction strength readings obtained pre – manipulation and immediately post – manipulation revealed a statistically significant improvement ($P = 0.019$). Therefore, sacroiliac manipulation was associated with an immediate increase in hip abduction strength, consequent to an immediate reduction in AMI (Matkovich, 2004).

Comparison of isokinetic hip abduction strength readings obtained immediately post – manipulation and 1 day/24 hours post - manipulation

revealed a statistically insignificant improvement ($P = 0.090$). Therefore, no additional statistically significant increase in hip abduction strength or a reduction in AMI occurred, even though a slight improvement was evident (Figure 4.7).

A possible explanation could be attributed to either a mild increase in subjective pain perception experienced by some participants as a consequence to spinal manipulative therapy, or the presence of muscle stiffness or soreness as a result of isokinetic muscle testing the previous day.

In lieu of this statement, pain or fear of pain provocation during the isokinetic testing procedure could have resulted in reduced isokinetic strength measurements for some participants.

Still, the immediate increase in abductor muscle strength, consequent to an immediate reduction in AMI was sustained at 1 day/24 hours post – manipulation.

Comparison of isokinetic hip abduction strength readings obtained pre – manipulation and 1 day/ 24 hours post – manipulation revealed a statistically significant improvement ($P = 0.002$). Therefore, sacroiliac manipulation was associated with a short – term increase in hip abduction strength consequent to a short - term reduction in AMI, thus supporting hypothesis one.

5.3.3 Conclusion

The observation of increased muscle strength post – sacroiliac manipulation could be attributed to the neurophysiological effects of spinal manipulation, as discussed under 2.7. Thus, spinal manipulation could have resulted in an increase in muscle strength, consequent to a decrease in AMI, by means of a gate – control – type mechanism.

As previously stated under 2.2.3, AMI originates from an abnormal disturbance in joint receptor afference that results in the altered afferent

innervation of the motor neuron pool, a decrease in recruitment ability within the motor neuron pool, and a decrease in contraction force of the muscles that fall within the motor neuron pool and thus, a decrease in muscle strength (Hopkins and Ingersoll, 2000 and Suter *et al.*, 1999).

The sacroiliac joint and its surrounding structures have been shown to contain numerous mechanoreceptors and nociceptors (Fortin *et al.*, 1999, Sakamoto *et al.*, 2001 and Vilensky *et al.*, 2002), which could be activated in a symptomatic sacroiliac syndrome (Suter *et al.*, 1999) and result in the altered afferent innervation of the muscles that fall within the motor neuron pool.

In this respect, as proposed under 5.4.1, the hip flexor, extensor, adductor and abductor muscles fall within the sacroiliac joint's motor neuron pool, as their segmental innervation shows a degree of overlap with that of the sacroiliac joint (Moore 1992:387, 399, 417 and 423 and Murata *et al.*, 2001).

As proposed by Suter *et al.* (2000) and Colloca in Fuhr *et al.* (1997:42), manipulation of the symptomatic sacroiliac joint could have resulted in the activation of the mechanoreceptors within and around it. This could have resulted in a change in motor neuron excitability (Suter *et al.*, 2000, Harrison *et al.*, 1997), an increase in motor unit recruitment, a reduction in AML (William, 1997:144, Suter *et al.*, 2000) and hence, an increase in muscle strength.

Thus, it is possible that sacroiliac manipulation resulted in the modification of the abnormally altered afferent innervation of the hip musculature, as stated above, thereby reducing AML and subsequently altering the resultant efferent responses of the hip musculature.

However, the observation of increased hip muscle strength, consequent to a reduction in AML, may well have been a placebo effect. It is possible that participants' conscious efforts in making an impression on the researcher by producing greater isokinetic strength values over successive tests could have resulted in higher isokinetic moments. In addition, familiarization of the

subjects with the isokinetic testing procedure may well have contributed to higher voluntary efforts over successive tests.

5.4 Interpretation of the clinical findings

5.4.1 Hypothesis one

The first hypothesis stated that sacroiliac manipulation would result in the short –term augmentation in ipsilateral hip muscle strength in consequence to a diminution of AMI in the hip musculature responsible for the actions of flexion, extension, adduction and abduction.

5.4.1.1 Inter – group analysis

Inter – group analysis of the objective data revealed that the net effect of sacroiliac manipulation on hip muscle strength was comparable with respect to all four actions of the hip, with no single action responding neither superiorly nor inferiorly.

5.4.1.2 Intra – group analysis

Intra – group analysis of the objective data revealed that sacroiliac manipulation was associated with a significant short - term increase in hip muscle strength, consequent to the reduction of AMI, for the actions of flexion, extension, adduction and abduction, thus supporting hypothesis one.

5.4.2 Hypothesis two

The second hypothesis stated that sacroiliac manipulation would result in the short – term amelioration of perceived pain associated with chronic sacroiliac syndrome.

5.4.2.1 Inter – group analysis

Inter – group analysis of the subjective data revealed that sacroiliac manipulation resulted in the unfailing, consistent amelioration and maintenance of pain in patients with chronic sacroiliac syndrome.

5.4.2.2 Intra – group analysis

Intra – group analysis of the subjective data revealed that sacroiliac manipulation was associated with a significant short - term reduction in perceived pain that accompanies chronic sacroiliac syndrome, thus supporting hypothesis two.

5.5 Problems encountered with the data

5.5.1 The subjective data

During the course of the study, three problematic areas were identified with respect to the subjective data.

Firstly, misunderstanding of the NRS – 101 questionnaires by the participants could have influenced their response and thus, the outcome of the results.

Secondly, the possibility could have existed that participants recorded improvements beyond those actually experienced, in order to make an impression on the researchers.

Thirdly, participants could have rated their subsequent questionnaires by means of recalling their previous recording/s, thus influencing the outcome of the results.

5.5.2 The objective data

Accordingly, three problematic areas were identified with respect to the objective data.

Firstly, participants insisted that the researchers reveal their isokinetic test results. Thus, the possibility could have existed that participants consciously produced higher isokinetic strength moments during subsequent tests, in order to make an impression on the researchers.

Secondly, of the thirty subjects that participated in the study, five subjects complained of post – isokinetic stiffness and soreness of the piriformis, quadratus lumborum, gluteus medius and iliopsoas muscles. It is the researcher's opinion that the presence of post – isokinetic stiffness and soreness could have influenced the isokinetic tests results, as participants may well have produced lower isokinetic test moments as a result of pain or fear of pain provocation during their test.

The third problem was related to the appointments scheduled at the practice of the biokineticist. As stated in chapter three under 3.3.1, the short – term effect of treatment may be defined as the resultant effect of a treatment intervention 1 day/24 hours prior. In this respect, conscious attempts were made to schedule both appointments at or about the same time of day.

However, as these appointments were scheduled at the availability of the biokineticist and at the convenience of the patient, this practice was not maintained at all times. It is the researcher's opinion that such an inconsistency could have influenced the isokinetic results obtained.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This study comprised of thirty male subjects with low back pain attributable to chronic sacroiliac syndrome. All participants of this study were recruited from a concurrent cohort study that investigated the immediate effect of sacroiliac manipulation on hip muscle strength.

Prior to the onset of the studies the researcher of the concurrent study, 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, research physical examination and regional examination of the low back.

On acceptance, two appointments were scheduled on consecutive days at the practice of a qualified biokineticist. The researcher of the concurrent study conducted the first appointment whereas the researcher of the present study conducted the second. At these appointments, participants underwent concentric - concentric isokinetic strength testing of the hip musculature for the actions of flexion, extension, adduction and abduction on the ipsilateral side of their symptomatic sacroiliac syndrome.

Subjective measurements with respect to patients' perceived levels of pain were obtained by means of the NRS – 101 questionnaire whereas objective measurements regarding concentric – concentric isokinetic hip strength were obtained utilizing the Cybex Orthotron II Isokinetic Rehabilitation System. Both the subjective and objective measurements were obtained prior to, immediately following and 1 day/24 hours post – sacroiliac manipulation in order to establish the short – term effect of sacroiliac syndrome on hip muscle strength and perceived pain in patients with chronic sacroiliac syndrome.

6.2 Conclusions

6.2.1 Subjective data

Analysis of the subjective data obtained by means of the NRS – 101 questionnaires, revealed that sacroiliac manipulation resulted in a consistent reduction and maintenance of pain in patients with chronic sacroiliac syndrome. In addition, sacroiliac manipulation was shown to be associated with a significant short - term reduction in patients' perceived levels of pain that accompanied their chronic sacroiliac syndrome, thus supporting hypothesis two.

6.2.2 Objective data

Analysis of the objective data obtained by means of the Cybex Orthotron II Isokinetic Rehabilitation System, revealed that sacroiliac manipulation was associated with a significant short - term augmentation in hip muscle strength, consequent to a short – term diminution of AMI in the hip musculature responsible for the actions of flexion, extension, adduction and abduction, thus supporting hypothesis one. Furthermore, data analysis revealed that the net short - term effect of sacroiliac manipulation on hip muscle strength was comparable with respect to all four actions of the hip, with no single action responding neither superiorly nor inferiorly.

With respect to the objective data analysis, a review of the related literature revealed a number of factors that may have influenced the isokinetic test results obtained. In this regard, the existence of possible relationships between age, body size, body mass and stature, perceived pain, and the presence of unilateral or bilateral sacroiliac syndrome and isokinetic strength moments were statistically analyzed with the aim of establishing statistically tenable associations.

The results of the present study could not provide conclusive support of the presence of statistically tenable relationships with respect to age, body size, and body mass and stature and isokinetic strength moments. However, the trends observed suggest that further investigation is warranted.

The role of pain as a possible etiologic factor in the development of AMI is very controversial, with some researchers demonstrating significant correlations whereas others report the contrary. The present study could not demonstrate a statistically tenable relationship between subjective pain disability and reduced isokinetic strength values, attributable to increased AMI. Thus, the role of pain as a possible etiologic factor in the development of AMI requires further investigation.

It has been suggested that patients' could significantly influence the isokinetic strength moments obtained due subjective pain intensity and self – reported disability. In contrast, the results of this study demonstrated that patients' perceived levels of pain did not appear to significantly influence their abilities to produce maximum voluntary muscle contractions. Further investigation is recommended in this regard.

During the course of the study, two observations were acknowledged. Firstly, greater isokinetic strength moments were observed in the absence of audible cavitations as a result of sacroiliac manipulation, as opposed to the contrary. This observation could point to the concept that an audible cavitation might not be an indicator of a successful adjustment. However, as the results could not conclusively support this notion, further investigation is recommended.

Secondly, participants presenting with right – sided sacroiliac syndrome were observed to exhibited greater isokinetic strength moments as opposed to those presenting with left – sided sacroiliac syndrome. A possible explanation could be that the right leg was the dominant leg of those participants that produced higher isokinetic moments, with the left leg of the remainder of the participants being their non – dominant leg. However, no firm conclusions could be established.

During the course of the study, the researcher hypothesized that participants presenting with bilateral sacroiliac syndrome could have exhibited the existence of AMI in the "unaffected" hip muscles, resulting in the amplification of AMI in the affected limb hip musculature on the more symptomatic side.

It was thought that those subjects could have exhibited a greater amount of AMI, and consequently a lesser extent of AMI reduction, as only the "symptomatic" sacroiliac joint was manipulated. Thus, the amount of AMI in the "symptomatic" limb could have been underestimated.

Statistical analysis of the results revealed insignificant P – values however, graphical presentation of the results revealed the contrary as subjects presenting with bilateral sacroiliac syndrome responded superiorly to those presenting with unilateral sacroiliac syndrome.

The researcher hypothesized that the effect of unilateral sacroiliac manipulation could have resulted in bilateral AMI reductions, thereby reducing a possible amplification in AMI on the more symptomatic side, and subsequently, resulting in the amplification of muscle strength in the affected limb.

6.2.3 Final conclusion

This study supports the hypotheses that sacroiliac manipulation results in the short – term reduction in subjects' perceived levels of pain that accompanies chronic sacroiliac syndrome, and the short - term reduction in AMI with a subsequent increase in hip muscle strength in subjects with chronic sacroiliac syndrome. In lieu of the above, the present study also supports the existence of AMI.

The observation of increased hip muscle strength consequent to a reduction in AMI as a result of sacroiliac manipulation is intriguing and might point to the important effects of sacroiliac manipulation in the rehabilitation process and in

addition, the possible value of sacroiliac manipulation in the treatment of lower limb AML.

6.3 Recommendations

The present study was purely a clinical outcome/observation study and with all its possible biases, the observation of increased hip muscle strength post – sacroiliac manipulation may well have been placebo or training effects. It is suggested these results are verified in a randomized, controlled, double - blind clinical trial that includes sham treatments, in order to substantiate claims regarding the short – term effect of sacroiliac manipulation on hip muscle strength.

The time course of the treatment effects of sacroiliac manipulation on hip muscle strength should be addressed in future research. It is suggested that 1 week and 1 month follow – up consultations are included post - spinal manipulation in order to determine the intermediate and long - term effects of sacroiliac manipulation on hip muscle strength.

The possible mechanisms involved in AML reduction as a result of sacroiliac manipulation warrant further investigation.

Should this study be repeated, a larger sample size should be utilized in order to increase the validity of the study. Inclusion of an equal number of female participants would allow for effective comparison making between males and females.

Furthermore, the effect of an additional sacroiliac manipulation during a successive consultation should be investigated.

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APPENDIX A

NUMERICAL PAIN RATING SCALE – 101 QUESTIONNAIRE

Patient Name: _____ File no.: _____ Date: _____

Please indicate on the line below, the number between 1 and 100 that best describes the pain you experience when it is at its least. A zero (0) would mean "no pain at all", and one hundred (100) would mean, "pain as bad as it could be". Please write only the number.

Please indicate on the line below, the number between 1 and 100 that best describes the pain you experience when it is at its worst. A zero (0) would mean "no pain at all", and one hundred (100) would mean, "pain as bad as it could be". Please write only the number.

APPENDIX B

NRS – 101 VALUES

PATIENT NAME: _____

FILE NO: _____

	<u>PRE – SACROILIAC MANIPULATION</u>	<u>IMMEDIATELY POST – SACROILIAC MANIPULATION</u>	<u>1 DAY/24 HOURS POST – SACROILIAC MANIPULATION</u>
<u>PAIN AT ITS LEAST</u>			
<u>PAIN AT ITS WORST</u>			

ISOKINETIC TESTING DATA SHEET

PATIENT NAME: _____

FILE NO: _____

<u>ACTION</u>	<u>MEAN VALUE</u> Pre - manipulation	<u>MEAN VALUE</u> Immediately post - manipulation	<u>MEAN VALUE</u> 1 day/24 hours post - manipulation
Flexion			
Extension			
Adduction			
Abduction			

DURBAN INSTITUTE OF TECHNOLOGY APPENDIX D
CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient: _____ Date: _____

File # : _____ Age: _____

Sex : _____ Occupation: _____

Intern : _____ Signature _____

FOR CLINICIANS USE ONLY:

Initial visit

Clinician: _____ Signature : _____

Case History:

Examination:

Previous:

Current:

X-Ray Studies:

Previous:

Current:

Clinical Path. lab:

Previous:

Current:

CASE STATUS:

PTT:

Signature:

Date:

CONDITIONAL:

Reason for Conditional:

Signature:

Date:

Conditions met in Visit No:

Signed into PTT:

Date:

Case Summary signed off:

Date:

Intern's Case History:

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

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

4. **Other Complaints:**
5. **Past Medical History:**
 - ▶ General Health Status
 - ▶ Childhood Illnesses
 - ▶ Adult Illnesses
 - ▶ Psychiatric Illnesses
 - ▶ Accidents/Injuries
 - ▶ Surgery
 - ▶ Hospitalizations

6. Current health status and life-style:

- Allergies
- Immunizations
- Screening Tests incl. 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

PHYSICAL EXAMINATION: SENIOR/RESEARCH

Patient Name : _____

File no : _____ Date :

Interns Name :

Signature :

VITALS:

Pulse rate:

Respiratory rate:

Blood pressure: R

L

Temperature:

Height:

Weight:

Recent change: Yes No

GENERAL EXAMINATION:

General Impression:

Skin:

Jaundice:

Pallor:

Clubbing:

Cyanosis (Central/Peripheral):

Oedema:

Lymph nodes - Head and neck:

- Axillary:

- Epitrochlear:

- Inguinal:

Urinalysis:

Clinicians Name:

Signature :

SYSTEM SPECIFIC
EXAMINATIONCARDIOVASCULAR EXAMINATION:RESPIRATORY EXAMINATION:ABDOMINAL EXAMINATION:NEUROLOGICAL EXAMINATION:COMMENTS:

Clinicians Name:

Signature :

REGIONAL EXAMINATION - LUMBAR SPINE AND PELVIS

Patient: _____
 Intern/Resident: _____

File#: _____ Date: ____/____/____
 Clinician: _____

STANDING:

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

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

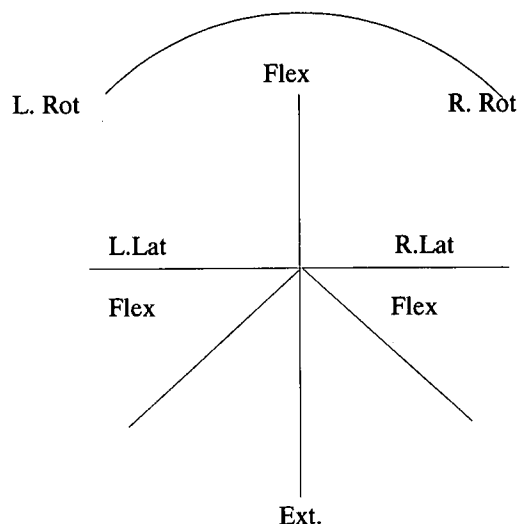
GAIT:

Normal walk
 Toe walk
 Heel Walk
 Half squat

ROM:

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

L/R Lateral Flexion = 15-20°



Which mvmt. reproduces the pain or is the worst?

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

SUPINE:

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

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

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

SITTING:

Spinous Percussion
 Valsalva
 Lhermitte

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

Slump 7 test	L										
	R										

LATERAL RECUMBENT:

L

R

Ober's		
Femoral n. stretch		
SI Compression		

PRONE:

L

R

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

MF tp's

Latent

Active

Radiation

QL			
Paraspinal			
Glut Max			
Glut Med			
Glut Min			
Piriformis			
Hamstring			
TFL			
Iliopsoas			
Rectus Abdominis			
Ext/Int Oblique muscles			

NON ORGANIC SIGNS:

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

NEUROLOGICAL EXAMINATION

Fasciculations

Plantar reflex

level	Tender?	Dermatomes		DTR		
		L	R		L	R
T12						
L1						
L2						
L3						
L4				Patellar		
L5				Med h/s		
S1				Achilles		
S2				Incont?		
S3						

MYOTOMES

Action	Muscles	Levels	L	R	
Lateral Flexion spine	Muscle QL	T12-L4			
Hip flexion	Psoas, Rectus femoris	L1,2,3,4			5+ Full strength
Hip extension	Hamstring, glutes	L4,5;S1,2			4+ Weakness
Hip internal rotat	Glutmed, min;TFL, adductors				3+ Weak against grav
Hip external rotat	Gluteus max, Piriformis				2+ Weak w/o gravity
Hip abduction	TFL, Glut med and minimus				1+ Fascic w/o gross movt
Hip adduction	Adductors				0 No movement
Knee flexion	Hamstring,	L4,5;S1			
Knee extension	Quad	L2,3,4			W - wasting
Ankle plantarflex	Gastroc, soleus	S1,2			
Ankle dorsiflexion	Tibialis anterior	L4,5			
Inversion	Tibialis anterior	S1			
Eversion	Peroneus longus	L4			
Great toe extens	EHL	L5			

BASIC THORACIC EXAM

History

Passive ROM

Orthopedic

BASIC HIP EXAM

History

ROM: Active

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

INFORMED CONSENT FORM

Date: _____

Title of research project:

The short-term effect of sacroiliac manipulation on hip muscle strength in patients suffering from chronic sacroiliac syndrome.

Names of supervisors: Dr. H. L. White (031) 2042505

Mr. D. Jackson (031) 5662165

Name of research student: Melissa Terblanche (031) 2042205

Name of institution: Durban Institute of Technology

Thirty patients suffering from low back pain (chronic sacroiliac syndrome) will receive manipulative treatment for their low back pain by the researcher of a concurrent peer study. The short-term effect of manipulative treatment on hip muscle strength will be investigated 1 day/24 hours later.

Please circle the appropriate answer:

1. Have you read the patient information sheet? YES/NO
2. Have you had the opportunity to ask questions regarding this study? YES/NO
3. Have you received satisfactory answers to your questions? YES/NO
4. Have you had the opportunity to discuss this study? YES/NO
5. Have you received enough information about this study? YES/NO
6. Who have you spoken to? YES/NO
7. Do you understand the implications of your involvement in this study? YES/NO
8. Do you understand that you are free to withdraw from this study? YES/NO
 - a) At any time
 - b) Without having to give reason for withdrawing, and
 - c) Without affecting your future health care.

9. Do you agree to voluntary participate in this study?

YES/NO

PATIENT NAME: SIGNATURE:

WITNESS NAME: SIGNATURE:

RESEARCH STUDENT: SIGNATURE:

IF YOU ANSWERED NO TO ANY OF THE ABOVE QUESTIONS, PLEASE DO NOT HESITATE TO CONTACT
MY RESEARCH SUPERVISORS, WHO WILL BE ABLE TO ASSIST YOU.

LETTER OF INFORMATION

Dear patient. Welcome to my research study. My study will be running concurrently with a study by Grant Matkovich. Grant will be determining the immediate effect of adjusting the low back (sacroiliac joint) on the strength of the muscles of the hip, while I will be determining the short – term effects. Only once you have completed his study, will you be accepted into mine. You will then be required to attend a follow – up visit at the Medigate Medical Centre.

Title of study:

The short-term effect of sacroiliac manipulation on hip muscle strength in patients suffering from chronic sacroiliac syndrome.

Supervisors:

Dr. H.L. White (031) 2042505

Mr. D. Jackson (031) 5662465

Research Student:

Melissa Terblanche (031) 2042205/0836332104

Institution:

Durban Institute of Technology

Purpose of the study:

The purpose of this study is to determine the short – term effect adjusting the low back (sacroiliac joint) has on the strength of the muscles of the hip. Thirty patients with low back pain (chronic sacroiliac syndrome) will be included in this study.

Procedures:

The consultation for this appointment will take place at the Medigate Medical Centre in Umhlanga Rocks (directions attached). At this consultation, you will be required to undergo the same testing procedure as with Grant the previous day. You will also

be required to complete the same pain questionnaire of the previous day. This appointment will be approximately half an hour long.

Risks/Discomfort:

The testing of your muscle strength is relatively harmless. However, some of you may experience some muscle stiffness after testing.

Benefits:

Your contribution to this study, by volunteering to partake, will help us as Chiropractors to build on our knowledge. This will benefit you as a patient in the long run, as we will be able to provide you with more effective health care in the future. On the completion of your participation in this study, you will be eligible to 2 free treatments at the Durban Institute of Technology Chiropractic Day Clinic.

New findings:

You will be made aware of any new findings during the course of this study.

Reasons why you may be withdrawn from this study without your consent:

You may be removed from participating in this study without your consent for the following reasons:

- If you are unable to attend your follow – up appointment.
- If you have changed any lifestyle habits during your participation in this study that may effect the outcome of this research (e.g. medication, supplements or treatment).

**AS A VOLUNTARY PARTICIPANT IN THIS RESEARCH STUDY, YOU ARE FREE
TO WITHDRAW FROM THE STUDY AT ANY TIME, WITHOUT GIVING A
REASON.**

Remuneration:

You will NOT be receiving a travel allowance in order to attend your appointment at the Medigate Medical Centre in Umhlanga Rocks.

Cost of the study:

The testing procedure will be free of charge and your participation in this study is voluntary.

Confidentiality:

All patient information is confidential. The results from this study will be used for research purposes only. Only individuals that are directly involved in this study and Grant's study (Dr. H.L. White, Dr M. Atkinson, Mr. D. Jackson, Grant Matkovich and myself) will be allowed access to these records.

Persons to contact should you have any problems or questions:

Should you have any questions that you would prefer being answered by an independent individual, feel free to contact my supervisors on the above numbers. If you are not satisfied with a particular area of this study, please feel free to forward any concerns to the Durban Institute of Technology Research and Ethics Committee.

Thank you for participating in my research study.

Melissa Terblanche
(6th year Chiropractic Intern)

Dr. H. L. White
(Supervisor)

Mr. D. Jackson
(Co-Supervisor)