

THE EFFECT OF SACROILIAC JOINT MANIPULATION, WHEN COMBINED WITH CONVENTIONAL TREATMENT, IN THE MANAGEMENT OF CHRONIC HAMSTRING STRAINS

By

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DEDICATION

This study is dedicated to my daughter Chloë, who has kept me distracted through the hard times with her beautiful smile and gorgeous antics. Having you in my life has changed me into the man I am today, and watching you grow up has helped me to realize my own potential. You are the light of my life and my driving force. Dada loves you forever.

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To God, my Heavenly Father, who created me and looks over me. You alone know me and everything I do is part of your plan for my life. I pray you continue to guide and protect me, and draw me ever closer to you.

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ABSTRACT

Background: Hamstring muscle strains are a common musculoskeletal injury amongst athletes, with a high rate of recurrence that suggests room for improvement in the treatment and management of these injuries. Cibulka et al. (1986) suggest a possible link between injuries of the hamstring muscles and dysfunction of the sacroiliac joint. A study by Fyfer (2005) found that sacroiliac manipulation alone had a positive effect in the treatment of recurrent hamstring strains, but this was not combined with or compared to conventional treatment for muscle strain. Fox (2006) found that sacroiliac manipulation added to hamstring stretching increased the resultant flexibility of uninjured hamstring muscles.

Objective: The purpose of this study was to determine the relative effectiveness that manipulation may have when combined with and compared to a regime of hamstring stretching and strengthening in the treatment of chronic hamstring strains.

Method: Thirty two participants suffering from chronic hamstring injuries and concomitant dysfunction of the sacroiliac joint were randomly allocated into two treatment groups. Both groups attended six consultations over a period of three weeks. Group one received treatment in the form of proprioceptive neuromuscular feedback (PNF) stretching and resisted isometric exercises of the hamstring, and were taught a home routine consisting of static stretching of the hamstring and Theraband® exercises directed at the hamstring. Group two received the same treatment and home routine as those in Group one, with the addition of Chiropractic manipulation of the dysfunctional sacroiliac joint. Outcomes were obtained by using the Numerical Pain Rating Scale (NRS-101), inclinometer testing of passive straight leg raiser test, and algometer assessment of pain threshold in the injured hamstring muscle and ipsilateral sacroiliac joint.

Results: Data was analysed using the SPSS version 18.0 (SPSS Inc. Chicago, Ill, USA). Subjective and objectives outcomes were measured quantitatively. The effect of the intervention was measured using repeated measures ANOVA testing. The time versus treatment group interaction effect assessed whether the effect of the different treatment over time is the same, with a p value of <0.05 being

considered significant. Both treatment groups showed improvement of outcomes, and manipulation showed a marginally non-significant trend of greater improvement with regards to sacroiliac joint algometry.

Conclusion: This study did not provide conclusive evidence of either a benefit or no benefit of manipulation, but where non-significant trends were shown, it is likely that this was due to lack of statistical power and that with an appropriate a priori analysis being done a greater sample size may have shown the same effect to be statistically significant.

TABLE OF CONTENTS

DEDICATION	ii
ACKNOWLEDGEMENTS.....	iii
ABSTRACT	iv
LIST OF APPENDICES	ix
LIST OF TABLES.....	x
LIST OF FIGURES	xi
DEFINITION OF TERMS	xii
LIST OF ABBREVIATIONS.....	xiv
CHAPTER ONE.....	1
1. INTRODUCTION	1
1.1 INTRODUCTION	1
1.2 OBJECTIVES OF THE STUDY	2
1.3 RATIONALE	3
1.4 POTENTIAL BENEFITS OF THE STUDY	3
1.5 LIMITATIONS	4
1.6 OUTLINE OF CHAPTERS.....	4
CHAPTER TWO	6
2. LITERATURE REVIEW	6
2.1 INTRODUCTION	6
2.2 THE SACROILIAC JOINT	6
2.2.1 Functional Anatomy	6
2.2.2 Ligamentous and Muscular Structures.....	7
2.2.3 Innervation.....	13
2.3 BIOMECHANICS	13
2.3.1 Sacroiliac Joint Mechanics.....	13
2.3.2 Standing Biomechanics	16
2.3.3 Ambulatory Biomechanics	17
2.4 SACROILIAC JOINT DYSFUNCTION	19
2.4.1 Epidemiology	20
2.4.2 Etiology.....	20
2.4.3 Clinical Presentation	22

2.4.4	Diagnosis.....	22
2.4.5	Treatment.....	24
2.5	THE HAMSTRING MUSCLES.....	25
2.5.1	Functional Anatomy.....	25
2.5.2	Innervation.....	27
2.6	HAMSTRING MUSCLE DYSFUNCTION.....	27
2.6.1	Epidemiology.....	29
2.6.2	Predisposing Factors.....	30
2.6.3	Diagnosis.....	33
2.6.4	Management and Treatment.....	34
2.7	SPINAL MANIPULATIVE THERAPY.....	37
2.8	CONCLUSION.....	38
CHAPTER THREE		40
3. METHODOLOGY		40
3.1	INTRODUCTION.....	40
3.2	STUDY DESIGN.....	40
3.2.1	Sampling Procedure.....	40
3.2.2	Sample Allocation.....	41
3.2.3	Sample Characteristics.....	41
3.3	METHOD.....	42
3.4	INTERVENTION.....	43
3.4.1	Hamstring Directed Interventions.....	43
3.4.2	Spinal Manipulative Therapy.....	44
3.5	DATA COLLECTION.....	45
3.5.1	Subjective Data.....	45
3.5.2	Objective Data.....	45
3.6	ETHICAL CONSIDERATIONS.....	46
3.7	STATISTICAL ANALYSIS.....	46
CHAPTER FOUR		48
4. RESULTS		48
4.1	INTRODUCTION.....	48
4.2	ABBREVIATIONS.....	48
4.3	PRIMARY DATA.....	48
4.4	SECONDARY DATA.....	48
4.5	PARTICIPANT LOSS DUE TO DROPOUT.....	49

4.6	RESULTS	51
4.6.1	Demographics	51
4.6.2	The Effect of the Manipulation	53
4.7	SUMMARY AND CONCLUSION	57
4.8	HYPOTHESIS TESTING	57
CHAPTER FIVE	.....	58
5. DISCUSSION	.....	58
5.1	INTRODUCTION	58
5.2	DEMOGRAPHICS	58
5.3	BASELINE READINGS	59
5.4	INFERENTIAL ANALYSIS	60
5.4.1	Digital Inclinoetry	60
5.4.2	Pressure Algometry	62
5.4.3	Summary	64
5.5	SUBJECTIVE DATA	65
5.5.1	Numerical Pain Rating Scale 101	65
5.5.2	Summary	65
CHAPTER SIX	.....	67
6. CONCLUSION AND RECOMMENDATIONS	.....	67
6.1	CONCLUSION.....	67
6.2	RECOMMENDATIONS.....	68
REFERENCES	.....	70

LIST OF APPENDICES

Appendix A: Ethics clearance certificate

Appendix B: Advertisement

Appendix C: Letter of Information and Consent

Appendix D: Case History

Appendix E: Physical Examination

Appendix F: Lumbar spine regional

Appendix G: Hip regional

Appendix H: Knee regional

Appendix I: SOAPE

Appendix J: Numerical Pain Rating Scale (NRS-101)

Appendix K: Measurement Sheet

Appendix L: Stretch and Exercise Diary

LIST OF TABLES

Chapter Two

Table 2.1: Muscles of the sacroiliac joint

Chapter Four

Table 4.1: Group by gender

Table 4.1: Age by group

Table 4.3: Baseline outcome measurements by treatment group

Table 4.4: Within-subjects and between –subjects effects for digital inclinometer

Table 4.5: Within-subjects and between –subjects effects for hamstring pressure algometer

Table 4.6: Within-subjects and between –subjects effects for sacroiliac pressure algometer

Table 4.7: Within-subjects and between –subjects effects for NRS-101

Chapter Five

Table 5.1: Digital Inclinometer straight leg raiser

Table 5.2: Hamstring pressure algometry

Table 5.3: Sacroiliac pressure algometry

Table 5.4: Numerical Pain Rating Scale (NRS-101) (Average pain)

LIST OF FIGURES

Chapter Two

Figure 2.1: Diagram depicting sacroiliac ligaments anteriorly and posteriorly

Figure 2.2: Diagram depicting sacroiliac ligaments in vertical cross section

Figure 2.3: Diagram depicting sacroiliac ligaments posteriorly

Figure 2.4: Diagram depicting loading of the sacroiliac joint

Figure 2.5: Diagram depicting hamstring muscles

Chapter Four

Figure 4.1: Consort diagram showing patient flow

Figure 4.2: Profile plot of mean digital inclinometer measurement by group and time

Figure 4.3: Profile plot of mean hamstring pressure algometer measurement by group and time

Figure 4.4: Profile plot of mean sacroiliac pressure algometer measurement by group and time

Figure 4.5: Profile plot of mean NRS-101 measurement by group and time

DEFINITION OF TERMS

Chronic Hamstring Strain:

Refers to injuries of the hamstring lasting for longer than 21 days (Orchard and Best, 2002).

Conventional Treatment:

For the purposes of this study conventional treatment of hamstring muscle strains was defined as a protocol of stretching and strengthening of the hamstring.

Joint Dysfunction:

Joint mechanics showing area disturbances of function without structural change; subtle joint dysfunctions affecting quality and range of motion. It is diagnosed with the aid of motion palpation and stress and motion radiography investigation. Definition embodies disturbances in function that can be represented by decreased motion, increased motion, or aberrant motion (Bergmann and Peterson, 2011).

Joint Play:

Discrete, short-range movements of a joint independent of the action of voluntary muscles, determined by springing each vertebra in the neutral position (Bergmann and Peterson, 2011).

Lesion:

Any pathologic or traumatic discontinuity of tissue or loss of function (Bergmann and Peterson, 2011).

Manipulation:

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

Motion Palpation:

Palpatory diagnosis of passive and active segmental joint range of motion (Bergmann and Peterson, 2011).

Pelvic Tilt:

A deviation of the pelvis in the sagittal plane from a neutral position (Bergmann and Peterson, 2011).

Sacroiliac Joint Fixation:

The absence of normal motion at the sacroiliac joint, demonstrated by motion palpation in which the axis of rotation has shifted to either the superior or inferior portion of the sacroiliac joint, or rarely, a situation in which there is total joint locking with no axis of rotation (Bergmann and Peterson, 2011).

Strain:

An overstretching and tearing of musculotendinous tissue (Bergmann and Peterson, 2011).

Stretching:

Separation of the origin and insertion of a muscle or attachments of fascia or ligaments by applying constant pressure at a right angle to the fibers of the muscle or fascia (Gatterman, 1990).

Thera-band®:

This is a natural rubber latex resistance band available in a progressive variety of resistance strengths, and used to provide elastic resistance in exercise programmes. Proper use of these systems for resistive exercise provides both positive and negative force on the muscles, improving strength, range of motion and co-operation of muscle groups (Resistance Band and Tubing Instruction Manual, 2006).

LIST OF ABBREVIATIONS

ANOVA:	Analysis of variance
HVLAT:	High velocity, low amplitude thrust
MRI:	Magnetic resonance imaging
NRS-101:	Numerical pain rating scale 101
NSAIDs:	Non-steroidal anti-inflammatory drugs
PNF:	Proprioceptive neuromuscular facilitation
RICE:	Rest, ice, compression, elevation
SMT:	Spinal manipulative therapy

CHAPTER ONE

1. INTRODUCTION

1.1 INTRODUCTION

Hamstring muscle injuries are common in most sports and also have the highest prevalence of all muscle injuries in sports that involve high speed running and acceleration (Hoskins and Pollard, 2005a). These injuries also have a very high re-injury rate and Verral et al. (2001) and Prior et al. (2009) state that the highest risk for a hamstring injury is a previous injury of that hamstring.

Conventional treatment for hamstring strains that have passed the acute phase focuses on improving strength and flexibility in the affected muscle and typically involves stretching and strengthening of the hamstring muscle (Clanton and Coupe, 1998; Brukner and Kahn, 2006).

Cibulka et al. (1986) suggested a biomechanical relationship between hamstring muscle strains and dysfunctional sacroiliac joints, which is congruent with the more recent findings by Hoskins and Pollard (2005b and c) reinforce this. In contrast, Hopkins and Ingersoll (2000) describe arthrogenic muscle inhibition as a presynaptic, reflex inhibition that can limit the functional recovery of a muscle after injury, and Hillermann (2003) associates sacroiliac dysfunction with arthrogenic muscle inhibition of the hamstring muscles.

Historically manipulation has been found to be effective in the treatment of sacroiliac joint dysfunction (Hendler et al., 1995; Haldeman, 2005; Morris, 2006; Bergmann and Peterson, 2011). Correction of the joint dysfunction may counter the arthrogenic muscle inhibition reflex, as demonstrated in the study by Suter et al. (2000), in which manipulation of sacroiliac joint dysfunction was shown to reduce reflex inhibition of the quadriceps femoris muscle. As the hamstring muscles share a common innervation at the levels of L5 to S2 with the sacroiliac joints (Moore and Dalley, 2006; Standring, 2008; Martini et al., 2012), it may be possible for sacroiliac joint dysfunction to reflexly inhibit the hamstring muscles.

A study by Cibulka et al. (1986) combined mobilisation of the sacroiliac joint with a conventional approach of moist heat and stretching in the management of hamstring strains and found results favouring mobilisation. Fyfer (2005) found that

sacroiliac manipulation alone had a positive effect in the treatment of recurrent hamstring strains, but this was not combined with or compared to conventional treatment for muscle strain, whereas Fox (2006) found that sacroiliac manipulation added to hamstring stretching increased the resultant flexibility of the hamstring. As such, sacroiliac manipulation could be a useful addition to the treatment and rehabilitation regime of hamstring muscle strains, but none of the previous studies investigated the addition of a sacroiliac manipulation to a conventional hamstring stretching and strengthening regime for the treatment of hamstring strains.

This study aimed to investigate the effect of chiropractic manipulation of the sacroiliac joint performed in conjunction with a hamstring stretching and strengthening regime, in the treatment of chronic hamstring injury.

1.2 OBJECTIVES OF THE STUDY

The purpose of this study was to determine whether manipulation of the sacroiliac joint would have any effect on the management of chronic hamstring strains when combined with conventional stretching and strengthening, as compared to conventional stretching and strengthening treatment alone.

1. The first objective was to determine the effectiveness of stretching and strengthening as a treatment for chronic hamstring strains, in terms of subjective and objective measurements.
2. The second objective was to determine the effectiveness of sacroiliac manipulation in conjunction with stretching and strengthening as a treatment for chronic hamstring strains, in terms of subjective and objective measurements.
3. The third objective was to compare the difference between the two groups in terms of subjective and objective measurements.

Null hypothesis:

It was hypothesized that manipulation combined with hamstring stretching and strengthening had no effect on hamstring injury recovery when compared to hamstring stretching and strengthening alone.

1.3 RATIONALE

Hamstring muscle strains are an extremely common muscle injury in most sports and have the highest prevalence of all muscle injuries in sports that involve high speed running and acceleration. These injuries also have a significant recurrence rate, with a previous hamstring injury being the greatest risk factor for strain of the hamstrings. (Verral et al., 2001; Orchard and Seward, 2002; Sherry and Best, 2004; Heiderscheit et al., 2005; Hoskins and Pollard, 2005a; Hoskins and Pollard, 2005b; Verral et al., 2006; Clark, 2008; Heiderscheit et al., 2010; Linklater et al., 2010; Elliot et al., 2011;). Recurrence of hamstring injuries is a significant concern, with secondary injuries being more severe and often requiring twice the recovery time of the initial injury (Brookes et al., 2006; Koulouris et al., 2007). The risk of re-injury is most increased after an early return to sport by the athlete, after the initial injury (Koulouris et al., 2007; Orchard, 2001). More effective treatment protocols might improve the recovery rate and reduce the risk of recurrence of these injuries.

Dysfunctional joints can inhibit and adversely affect their surrounding musculature (Hopkins and Ingersoll, 2000; Suter et al., 2000). Sacroiliac joint dysfunction has been associated with hamstring muscle inhibition and strains (Cibulka et al., 1986; Hillermann, 2003; Fyfer, 2005; Fox, 2006). Resolution of sacroiliac dysfunctions may aid in the rate of recovery of hamstring injuries or decrease the risk of injury.

Manipulation is an effective form of treatment for sacroiliac joint dysfunction (Hendler et al., 1995; Haldeman, 2005; Morris, 2006; Bergmann and Peterson, 2011). Manipulation might then be effective in the treatment of sacroiliac joint dysfunctions that are associated with hamstring injuries, improving the recovery rate of these injuries and decreasing the risk of re-injury.

1.4 POTENTIAL BENEFITS OF THE STUDY

As a frequently recurring injury, the treatment of hamstring muscle strains needs to be all inclusive and all possible causes and risk factors must be assessed. The link between sacroiliac dysfunction and hamstring muscle strains, both through biomechanical routes (Cibulka et al., 1986) and arthrogenic muscle inhibition (Hillermann, 2003; Hillerman et al., 2006), means that assessment of the

sacroiliac joint and treatment of any dysfunction may be beneficial in the treatment of a strained hamstring muscle.

Sacroiliac manipulation can provide a safe, non-invasive adjunct to conventional rehabilitation of an injured hamstring muscle, and may assist in resolving a chronic or recurrent hamstring strain.

Athletes suffering from chronic or recurrent hamstring injuries may benefit from sacroiliac manipulation with a quicker and more complete recovery, and a reduced risk of re-injury.

1.5 LIMITATIONS

Limitations in the design of the study included the lack of imaging techniques to confirm the presence of hamstring muscle strains and assist in the grading of these injuries, with diagnosis being based on history and physical examination.

A greater differentiation of posterior thigh pain and myofascial trigger points would have helped to isolate hamstring muscle injuries specifically.

The criteria for sacroiliac dysfunction was also non-specific and resulted in a variety of different dysfunctions with differing levels of chronicity and severity.

There was no blinded allocation in this study as patients were aware of their treatment group due to the letter of information that explained the study. This may have resulted in psychological bias towards the manipulation group or against the control group.

The researcher performed all measurements and treatments, and this lack of a blinded assessor may result in a bias of results.

Subjective measurements made with the Numerical Pain Rating Scale (NRS-101) are patient dependant which may result in bias by the participants.

1.6 OUTLINE OF CHAPTERS

In Chapter Two the research will review the literature on hamstring muscle strains and sacroiliac joint dysfunction. Chapter Three will detail the methodology of this study, Chapter Four will present the results of this study, and Chapter Five will

discuss these results. The research will conclude with a suggestion of improvements for future studies of hamstring strains in Chapter Six.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 INTRODUCTION

This chapter aims to describe the anatomy, neurology, physiology and biomechanics of both the sacroiliac joints and the hamstring muscle groups, as well as create an understanding of sacroiliac dysfunction and hamstring injury.

2.2 THE SACROILIAC JOINT

2.2.1 Functional Anatomy

The sacroiliac joint is a unique compound joint consisting of a synovial joint between the auricular surfaces of the sacrum and ilia, and posterior to this, a syndesmosis between the tuberosities of the sacrum and ilia. The synovial portion of the sacroiliac joint has C-shaped articular surfaces which lie obliquely to the sagittal plane and are reciprocally irregular and ridged. The sacral articular surface is composed of hyaline cartilage while the articular surface of the ilia is covered by an unusual type of fibrocartilage. There is a large variation in the thickness of the articular cartilage, with the sacral surface being up to three times thicker than that of the iliac articular surface. Surrounding the joint and enclosing the synovial fluid is a joint capsule composed of an outer fibrous layer and inner synovial layer. The anterior portion of the capsule is clearly distinguishable from the anterior sacroiliac ligament, the posterior portion is intimately blended with the deep interosseous ligaments, and the inferior capsule is continuous with the periosteum of the sacrum and ilia (Schafer and Faye, 1990; Mooney, 1997; Lee, 2004; Moore and Dalley, 2006; Standring, 2008; Martini et al., 2012).

Closely associated with the sacroiliac joints are the lumbosacral joints and the pubic symphysis. The lumbosacral joints consist of an intervertebral disc between the L5 vertebral body and the sacral base, and two posterior zygapophyseal joints between the posteromedially facing articular processes of the sacrum and the anterolateral facing inferior articular facets of the L5 vertebra (Moore and Dalley, 2006). The pubic symphysis is a secondary cartilaginous joint consisting of a fibrocartilagenous disc and surrounding ligaments, that lies between the bodies of the pubic bones (Moore and Dalley, 2006).

Sacroiliac joint motion is very limited and there are no muscles that directly affect the position or movement of the sacroiliac joint. Motion is restricted to anterior-posterior rotation around a transverse axis, and this commonly becomes restricted in the elderly due to ankylosis of the sacroiliac joint (Yochum and Rowe, 2005, Morris, 2006). The structure of the sacroiliac joint is largely determined by its two functions. Firstly, it transfers load from the axial skeleton to the pelvis and legs, and secondly it absorbs twisting forces placed upon the pelvis during ambulation (Bergmann and Peterson, 2011). The first function is provided for by the irregular, interlocking surfaces of the sacroiliac joint, which prevent downward glide of the wedge shaped sacrum between the two ilia (Standring, 2008; Martini et al., 2012). Within the pelvic ring the sacroiliac joint is paired with the pubic symphysis, and the role of the sacroiliac joint here is to absorb the torsional stresses placed upon the pelvis by human gait (Bergmann and Peterson, 2011). This ability to absorb and relieve stress is provided for by the strong ligaments that surround and support the sacroiliac joint (Bogduk, 2005; Moore and Dalley, 2006).

2.2.2 Ligamentous and Muscular Structures

The sacroiliac joint is surrounded by a number of deep ligaments that are closely associated with the articular capsule, and two superficial ligaments that are remote to the joint itself. These ligaments provide for both the strength and limited mobility requirements of the sacroiliac joint to function as a large, weight-bearing and stress absorbing joint (Standring, 2008; Bergmann and Peterson, 2011; Martini et al., 2012).

The anterior sacroiliac ligament is formed by part of the anterior fibrous capsule of the sacroiliac joint, and its long transverse fibres extend from the ala and anterior surface of the sacrum to the anterior surface of the ilium. The anterior sacroiliac ligament is the weakest of the surrounding ligamentous structures and serves to bind the ilium to the sacrum and prevent anterior diastasis of the sacroiliac joint (Moore and Dalley, 2006; Bergmann and Peterson, 2011).

The interosseous sacroiliac ligament is the strongest of the sacroiliac ligaments and its fibres lie deeply between the lateral sacral crest and iliac tuberosity. The fibres of the interosseous sacroiliac ligament can be divided into a deep layer attaching to the three fossae of the dorsal sacral surface and to the iliac

tuberosity, and a superficial layer attaching to S1 and S2 lateral sacral crest and to the medial iliac crest. The superior-most portion of the superficial layer of the interosseous sacroiliac ligament is highlighted as the short posterior sacroiliac ligament, and its posterior location allows it to prevent posterior diastasis of the sacroiliac joint (Moore and Dalley, 2006; Standring, 2008).

The long posterior sacroiliac ligament lies dorsally and attaches to the S3 and S4 lateral sacral crest and to the posterior superior iliac spine and the inner lip of the iliac crest. The longitudinal orientation of the long posterior sacroiliac ligament limits backward tilting of the sacrum (Lee, 2004; Bogduk, 2005; Moore and Dalley, 2006; Standring, 2008).

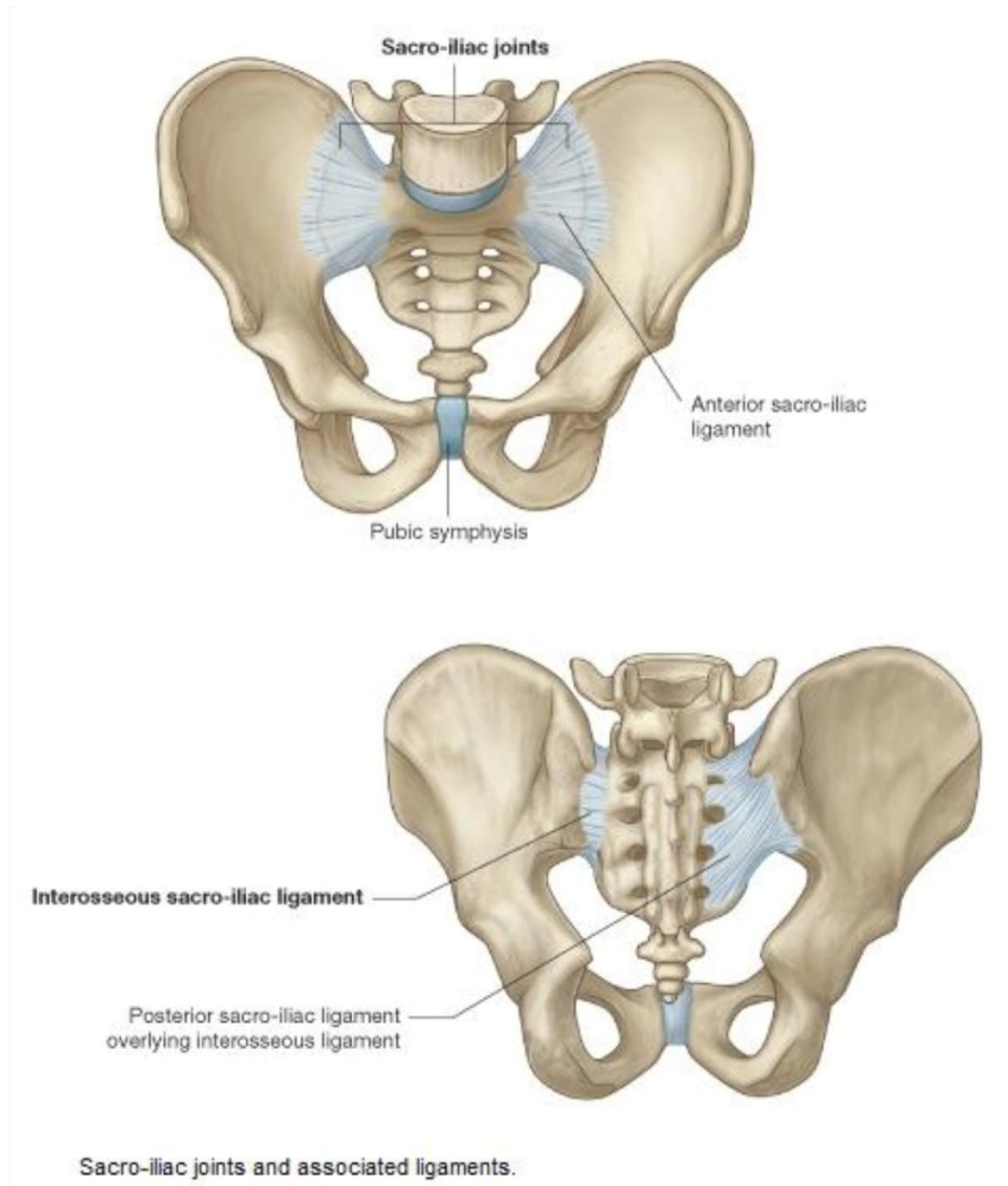


Figure 2.1: Diagram depicting sacroiliac ligaments anteriorly and posteriorly

(Physical Therapy Protocols, <http://therapyprotocols.webs.com/Sljointdysfunction.htm>, 2008)

The sacrotuberous and sacrospinous ligaments are more remote to the sacroiliac joint and share a common function of anchoring the sacrum and preventing forward tilting (Moore and Dalley, 2006; Bergmann and Peterson, 2011). The sacrospinous ligament originates with a broad attachment to the lower, lateral edge of the sacrum and coccyx, and it inserts at the ischial spine. The sacrotuberous ligament originates at the posterior superior iliac spine, lower sacral

transverse tubercles and lateral margin of the sacrum, and inserts at the ischial tuberosity (Martini et al., 2012). The sacrotuberous ligament has anatomical importance as the biceps femoris tendon can attach directly to its superficial fibres, and the S2 and S3 perforating cutaneous nerve passes through it (Willard, 1997; Lee, 2004; Bogduk, 2005; Moore and Dalley, 2006).

This anatomical diagram illustrates the right half of a human pelvis and the sacrum. The bony structures shown include the ilium, ischium, pubis, and the sacrum. Key ligaments and joints are labeled with dashed lines and arrows pointing to their locations. The diagram highlights the following structures:

- Anterior longitudinal ligament:** Located along the anterior surface of the vertebral column.
- Lumbosacral joint (articular disc):** The joint between the L5 vertebra and the sacrum.
- Wing of the ilium:** The large, flat, wing-like part of the ilium.
- Anterior superior iliac spine:** A small projection on the anterior surface of the ilium.
- Promontory of sacrum:** The prominent upper border of the sacrum.
- Linea terminalis:** A line on the internal surface of the ilium, marking the boundary between the greater and lesser sciatic foramina.
- Obturator membrane:** A fibrous band connecting the anterior superior iliac spine to the lesser sciatic foramen.
- Interpubic disc, symphysis pubis:** The fibrocartilaginous joint between the pubic bones.
- Ischial spine:** A small projection on the posterior surface of the ischium.
- Ischial tuberosity:** The large, rounded, lower part of the ischium.
- Sacrum:** The triangular bone at the base of the spine.
- Greater sciatic foramen:** The large opening in the sacrum through which the greater sciatic foramen passes.
- Sacral canal:** The canal running through the center of the sacrum.
- Sacrospinous ligament:** A ligament connecting the greater sciatic foramen to the sacrum.
- Lesser sciatic foramen:** The smaller opening in the sacrum through which the lesser sciatic foramen passes.
- Sacrotuberous ligament:** A ligament connecting the lesser sciatic foramen to the ischial tuberosity.

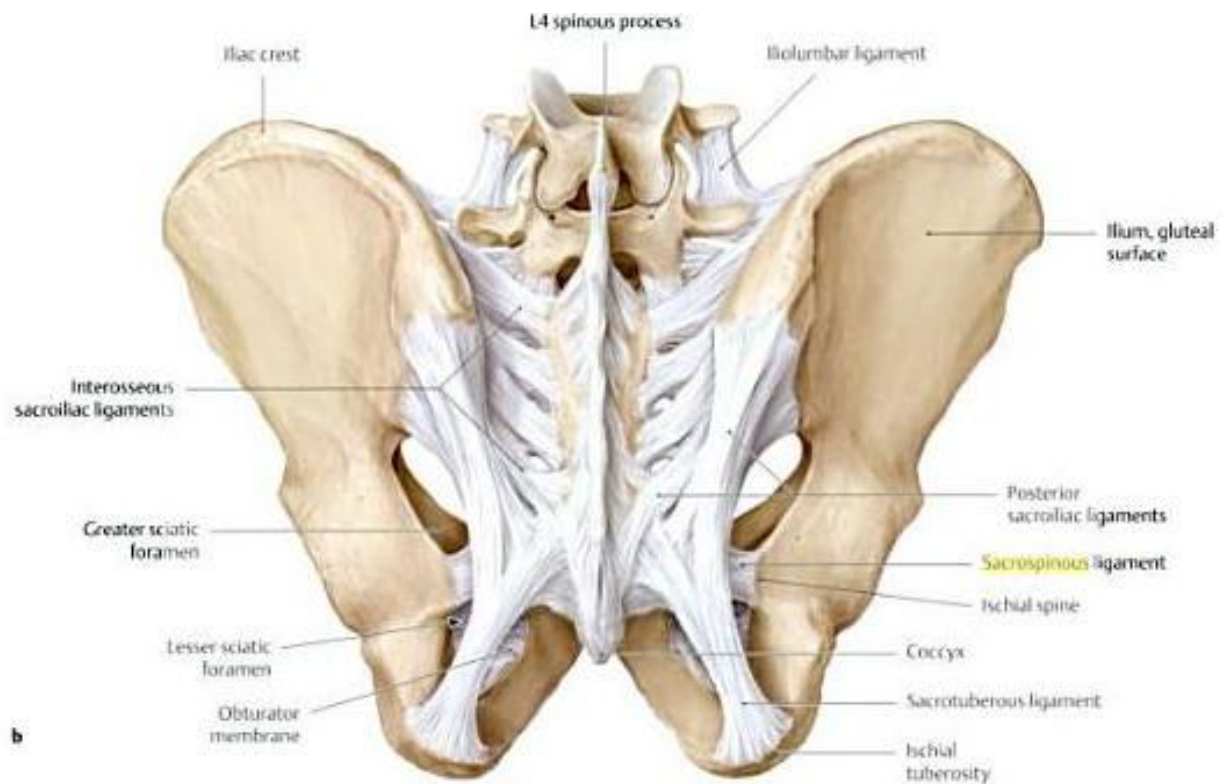


Figure 2.3: Diagram depicting sacroiliac ligaments posteriorly

(Korean Medical Library Engine, <http://www.kmle.co.kr>, 2012)

The thoracolumbar fascia is a complex of fascia attaching to the vertebral column medially, the latissimus dorsi laterally and the iliolumbar ligaments inferiorly. This extensive fascia encloses and envelops muscles of the back, separating them into superficial, intermediate and deep layers (Moore and Dalley, 2006).

There are a number of muscles that lie in close relation to the sacroiliac joint and pelvis that are important in understanding the movements of the sacroiliac joint and pelvis (Moore and Dalley, 2006).

Table 2.1 Muscles of the sacroiliac joint (Adapted from Moore and Dalley, 2006).

Muscle	Origin	Insertion	Innervation	Main Action
Gluteus maximus	Posterior ilium, dorsal surface of sacrum and coccyx, and sacrotuberous ligament	Lateral condyle of tibia	Inferior gluteal nerve (L5, S1, S2)	Extension of thigh
Gluteus medius	External surface of ilium	Lateral surface of greater trochanter of femur	Superior gluteal nerve (L5, S1)	Abduct and medially rotate thigh
Gluteus minimus	External surface of ilium	Anterior surface of greater trochanter of femur	Superior gluteal nerve (L5, S1)	Abduct and medially rotate thigh
Latissimus dorsi	Spinous processes of inferior six thoracic vertebrae, thoracolumbar fascia, iliac crest, and inferior three ribs	Intertubercular groove of humerus	Thoracodorsal nerve (C6, C7, C8)	Extends, adducts and medially rotates humerus
Erector spinae (iliocostalis, longissimus and spinalis)	Posterior iliac crest, posterior surface of sacrum, sacroiliac ligaments, sacral and inferior lumbar spinous processes, and supraspinous ligament	Iliocostalis: angles of lower ribs and cervical transverse processes. Longissimus: mastoid process of temporal bone, thoracic and cervical transverse processes, and ribs. Spinalis: Spinous processes of upper thoracic vertebrae, and cranium.	Posterior rami of spinal nerves	Extend vertebral column when acting bilaterally. Laterally flex vertebral column when acting unilaterally
Pectineus	Superior rami of pubis	Pectineal line of femur	Femoral nerve (L2, L3)	Adducts and flexes thigh
Psoas major	Sides of T12-L5 vertebrae and discs, transverse processes of lumbar vertebrae	Lesser trochanter of femur	Anterior rami of lumbar nerves (L1, L2, L3)	Flexes thigh at hip joint
Psoas minor	Sides of T12-L1 vertebrae and intervertebral disc	Pectineal line of femur	Anterior rami of lumbar nerves (L1, L2)	Flexes thigh at hip joint
Iliacus	Iliac crest, iliac fossa, ala of sacrum, and anterior sacroiliac ligaments	Tendon of psoas major, lesser trochanter and femur distal to it	Femoral nerve (L2, L3)	Flexes thigh at hip joint
Sartorius	Anterior superior iliac spine	Superior part of medial surface of tibia	Femoral nerve (L2, L3)	Flexes, abducts and laterally rotates thigh at hip joint, and flexes leg at knee joint
Rectus femoris	Anterior inferior iliac spine and ilium superior to acetabulum	Via quadriceps tendon to tibial tuberosity	Femoral nerve (L2, L3, L4)	Extend leg at knee joint, assists in flexing thigh at hip joint

2.2.3 Innervation

The sacroiliac joint is a structure richly innervated by both nociceptors and proprioceptors, making the joint sensitive to pain, pressure and position (Indahl et al., 1999; Bogduk, 2005). Indahl et al. (1999) reported sacroiliac joint innervation from L3 to S2. Suter et al. (2000) describe the nerve supply of the anterior sacroiliac joint as originating from the anterior primary divisions of L2 to S2. Maitland et al. (2001) suggested that the sacroiliac joint received its diverse innervation from the spinal levels of L2 to S4. Murata et al. (2001) elaborate further on sacroiliac joint innervation, stating that the anterior joint receives its primary innervation from the dorsal root ganglia of L4 to S2, and the posterior joint receives its innervation from the dorsal root ganglia of L1 to L3. However, Bogduk (2005) found that these innervations can vary slightly from sample to sample, and study to study.

The variety of thick, thin and unmyelinated nerve fibres of the sacroiliac joint suggest a wide range of sensory receptors, in particular mechanoreceptors (Indahl et al., 1999).

Type I and II receptors can have a suppressive effect on pain sensation conducted by the much slower nociceptors, which is described as the Gate Control Mechanism. Stimulation of type I and II receptors can also have a spinal reflex effect that results in optimisation of muscle activity (Bogduk, 2005).

Bernard (1997) describes the Arthrokinetic reflex in which articular nerves that are common to overlying muscles, provide a unique feedback mechanism whereby articular mechanoreceptors regulate muscle tone. This can be considered an important link between sacroiliac joint pain and dysfunction, and dysfunction of the surrounding musculature.

2.3 BIOMECHANICS

2.3.1 Sacroiliac Joint Mechanics

Sacroiliac joint motion has been highly contested in the past, in terms of both planes of motion and extent. Many authors agree that small degrees of motion do occur, but not around specific, fixed axes (Schafer and Faye, 1990; DonTigny, 1997; Willard, 1997; van Wingerdan et al, 1997; Vleeming and Stoeckart, 2007).

The role of the sacroiliac joint as a transfer point between the trunk and lower limbs means that motion of this joint is directly affected by that of the hip joints and lumbosacral joints. Weight bearing load has a large influence on the mechanics and motion of the sacroiliac joint, and as such standing versus supine/prone biomechanics has large variations (Mooney, 1997; Morris, 2006).

Schafer and Faye (1990) describe the pelvis as a three-joint complex consisting of the two sacroiliac joints posteriorly and the pubic symphysis anteriorly, and as such has six degrees of freedom when viewed as a unit.

2.3.1.1 Kinematics

Schafer and Faye (1990) describe sacroiliac motion as upward, downward, forward, backward and rotational movement about a transverse axis, as the sacrum effectively 'floats' within the pelvic ring.

The movements of the sacroiliac joint can be further classified into three categories (Schafer and Faye, 1990; Bergmann and Peterson, 2011):

- 1) Posterior-anterior and anterior-posterior rotation of the ilia relative to the sacrum,
- 2) Movement of the sacrum relative to the ilia and
- 3) Changes in the relationship between ilia and sacrum when sitting or standing

The main movements described in the sacroiliac joints are the posterior-anterior and anterior-posterior rotary movements of the ilia relative to the sacrum, or forward tilting of the sacrum relative to the ilia (nutration) and backward tilting (counter-nutation). Nutation is described as the sacral promontory moving in an anterior-inferior direction while the posterior superior iliac spine moves in a posterior-inferior direction, and is increased during loaded situations like standing or sitting. Counter-nutation is best described as posterior-superior movement of the sacral promontory and antero-superior movement of the posterior superior iliac spine, and is shown to occur during supine lying and as the lumbar lordosis is decreased (Schafer and Faye, 1990; Bergmann and Peterson, 2011).

2.3.1.2 Self-locking Mechanism

There are two physiological mechanisms that lock the sacroiliac joint and these are known as 'form closure' and 'force closure' (Chaitow and DeLany, 2002; Vleeming and Stoeckart, 2007).

Form closure is a stable state whereby the joint is locked without the aid of outside forces. The close-fitting, reciprocally irregular surfaces of the sacroiliac joints approximate with each other and reduce movement. The degree of form closure will be determined by the amount of axial loading. If the sacroiliac joint possessed perfect fitting form closure, then overall mobility would be lost. As a result, force closure involves the addition of outside forces provided by various ligamentous and muscular structures, in order to compress the joint surfaces and increase stability and decrease shear. The self-locking mechanism is thereby the combination of both form and force closure in the sacroiliac joint (Pool-Goudzwaard et al, 1998; Chaitow and DeLany, 2002; Vleeming and Stoeckart, 2007).

Nutation is crucial in force closure of the sacroiliac joints as it places the interosseous and short posterior sacroiliac ligaments under tension, and increases compression of the sacroiliac joint. The sacrotuberous and long posterior sacroiliac ligaments both play a crucial role in the self-locking mechanism of the sacroiliac joint. The sacrotuberous ligament connects the sacrum to the ischial tuberosity and its role is in restricting nutation. The long posterior sacroiliac ligament joins the posterior superior iliac spine to the sacrum and its lateral fibres are continuous with the sacrotuberous ligament. However, its function contrasts with that of the sacrotuberous in that tension is increased in the long posterior sacroiliac ligament during counter-nutation (Pool-Goudzwaard et al, 1998; Vleeming and Stoeckart, 2007).

Attachment of the biceps femoris tendon to the sacrotuberous ligament means that increased tension in the hamstring muscles can, in turn, load the sacrotuberous ligament and effectively cause counter-nutation. Other musculature that can be involved in the self-locking mechanism of the sacroiliac joint includes the effects of the thoracolumbar fascia, latissimus dorsi, erector spinae and gluteus maximus on the long posterior sacroiliac ligament. The erector spinae both pull the

sacrum forward, causing nutation, and pull the ilia together, compressing the cranial aspects of the sacroiliac joint in nutation. The gluteus maximus causes compression of the sacroiliac joint both directly, through its perpendicular orientation, and indirectly through its attachment to the sacrotuberous ligament. The latissimus dorsi contracts in conjunction with the gluteus maximus to compress the sacroiliac joint via the thoracolumbar fascia (Pool-Goudzwaard et al, 1998; Vleeming and Stoeckart, 2007).

2.3.2 Standing Biomechanics

DonTigny (2007a) described the structure of the sacroiliac joint as the reverse of a keystone, with the sacrum suspended between the ilia by the posterior interosseus ligaments and hanging more deeply with increased loading. The posterior superior iliac spines converge slightly with increased loading and the sacrum nutates, increasing tension on the posterior interosseus ligaments. This nutation of the sacrum also causes posterior movement of the sacral apex and transferring the weight of the torso through them and to the ilia. As the sacrum nutates its apex tilts posteriorly, increasing tension on the sacrotuberous and sacrospinous ligaments and thus employing the tensile strength of all the surrounding ligamenture to absorb stress. The biceps femoris and gluteus maximus provide further support to the pelvis by aiding to prevent further posterior movement of the sacral apex. The converging posterior superior iliac spines place increased pressure across the sacroiliac joint itself and protect the joint from shearing forces by increasing the friction across it (DonTigny, 2007a).

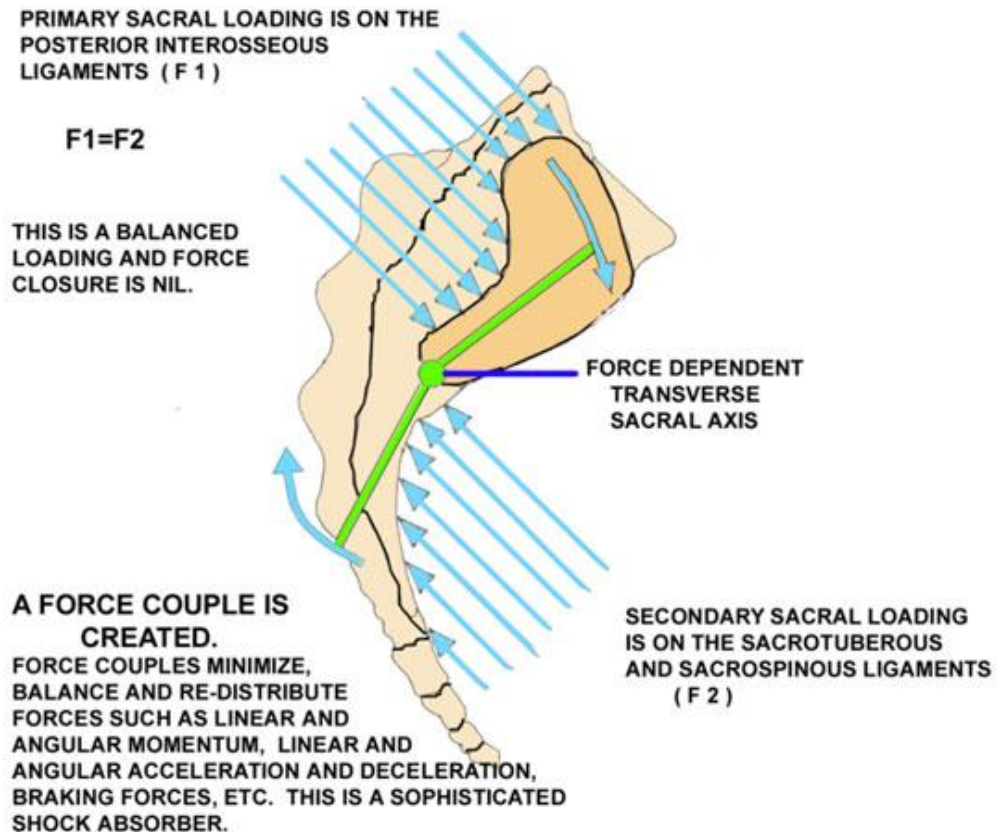


Figure 2.4: Diagram depicting loading of the sacroiliac joint (DonTigny, 2007b)

<http://thelowback.com>

2.3.3 Ambulatory Biomechanics

Humans have developed a unique bipedal gait that can be divided into a stance phase and a swing phase, and includes moments of both single and double leg support. Walking gait can be best described as the forward offsetting of the body's centre of gravity and the support of the body mass on one leg while the other leg is moved forward to stop the body from falling (Chaitow and DeLany, 2002; Sahrman, 2005). The pelvis plays an important role in all phases of gait and the sacroiliac joint serves as both a gyro for torso stability and a damper for axial forces (Schafer and Faye, 1990; Sahrman, 2005; Bergmann and Peterson, 2011).

2.3.3.1 Stance Phase

Stance phase accounts for sixty percent of the gait cycle and is the time during which the foot is in contact with the ground. It can be divided further into heel strike, loading response, mid-stance, terminal stance (heel lift) and toe-off

(DonTigny, 1997; Chaitow and DeLany, 2002). During this phase the foot makes contact with the ground and weight is transferred onto it. The role of the leg during stance phase is to provide stability for the ambulating body as the centre of gravity moves forward over the foot. This is a closed kinematic chain that must absorb much stress while remaining mobile (Chaitow and DeLany, 2002; Sahrman, 2005).

At heel strike, the quadriceps femoris function is to decelerate knee flexion and the hamstrings begin to extend the hip and pull the knee posteriorly (DonTigny, 1997). After heel strike the ipsilateral iliac bone begins to rotate anteriorly, creating counter-nutation within the sacroiliac joint and consequently unloading the supporting ligament. All weight bearing is transferred to the unilateral leg (single support phase) and the pelvis moves laterally to centre gravity over the stance leg (Chaitow and DeLany, 2002).

The gluteus maximus becomes active and begins to compress the sacroiliac joint and stabilise the pelvis during loading response (Vleeming and Stoeckart, 2007). The biceps femoris also serves to maintain self-locking in the ipsilateral sacroiliac joint through its attachment to the sacrotuberous ligament. This unilateral bracing of the sacroiliac joint serves to support the lumbosacral complex as it oscillates (DonTigny, 1997; Bergmann and Peterson, 2011).

Towards the final stage of the stance phase, the gluteus maximus serves to decelerate the anterior rotation of the pelvis and along with the hamstring muscle stabilises the ilium of the stance side. As the leg reaches terminal stance, the ipsilateral leg initiates heel strike and the double support phase begins. This period of double leg support decreases loading of the sacroiliac joint and the gluteus maximus can relax. Nutation in the sacroiliac joint is diminished, the joint is unloaded and the next swing phase can begin (Chaitow and DeLany, 2002; Vleeming and Stoeckart, 2007; Bergmann and Peterson, 2011).

2.3.3.2 Swing Phase

During swing phase the leg leaves the ground and moves forward in a complex orchestrated manoeuvre that can be subdivided into an initial swing, mid-swing and terminal swing. The initial swing begins as the foot leaves the ground and

ends when it is adjacent to the contralateral foot in mid-stance. Dorsiflexion of the ankle and flexion of the knee occur in order to produce ground clearance, and hip flexion occurs to advance the thigh. Mid-swing continues the actions of ankle dorsiflexion and hip flexion, and initiates knee extension. During terminal swing full knee extension occurs through the action of the quadriceps femoris, with the hamstring acting eccentrically to control the movement and counter the quadriceps femoris by providing deceleration of the extending knee prior to heel strike. It is at this point that maximal tension occurs in the hamstring muscle and the greatest risk of injury is present (Chaitow and DeLany, 2002; Sahrmann, 2005).

The forward movement of the leg during swing phase results in a posterior rotation of the ipsilateral iliac bone, and resultant nutation at the sacroiliac joint (Vleeming and Stoeckart, 2007; Bergmann and Peterson, 2011). This nutation increases the ligament tension in the pelvis and places the joint in a self-locked position, providing stability to the open kinematic chain. Nutation is maximal at terminal swing in preparation for heel strike and subsequent loading of the leg. Tension in the biceps femoris increases at this point due to nutation and transferred tension through the sacrotuberous ligament, and activation of the hamstrings to terminate knee extension. At heel strike a mechanism of loading occurs as the fibula moves caudally and further loads the already tensed biceps femoris due to their distal attachment to the fibular head (Vleeming and Stoeckart, 2007).

2.4 SACROILIAC JOINT DYSFUNCTION

Bergman and Peterson (2011) defines sacroiliac joint dysfunction as a state of relative hypomobility associated with possible altered positional relationships between the sacrum and the ilium.

Dreyfuss et al. (1996) uses the term sacroiliac joint dysfunction to describe pain from a sacroiliac joint that exhibits no demonstrable arthropathy, but is presumed to have some type of biomechanical disorder.

The International Association for the Study of Pain recognises sacroiliac joint pain as spinal and referred lower limb pain originating from the sacroiliac joint (Dreyfuss et al., 1996; Morris, 2006).

2.4.1 Epidemiology

Many authors have stated the prevalence of sacroiliac joint dysfunction as a common cause of low back pain (Bernard and Kirkaldy-Willis, 1987; Cibulka, 1992; Travell and Simons, 1993; Schwarzer et al, 1995; Mooney, 1997; Liebenson, 2007). Whether low back pain is a direct referral of sacroiliac joint dysfunction, or rather a result of biomechanical abnormalities that may reach up the spine, is a contentious issue (Bogduk, 2005).

Although there is a paucity of literature regarding the prevalence of sacroiliac joint dysfunctions in the general population, Cibulka (1992) found that 88% of patients with chronic low back pain demonstrated signs of sacroiliac joint dysfunction. Yet in the same year, Bernard and Kirkaldy-Willis (1992) found that 23% of patients treated at the Royal University Hospital Low Back Pain Clinic in Saskatoon, Canada were diagnosed with dysfunction of the sacroiliac joint. In a more current study, van der Wurff et al. (2006) found in their study on low back pain sufferers in the Netherlands, that 38% of the patients displayed a prevalence of sacroiliac joint origin.

Low back pain itself has been shown to have a high lifetime prevalence in numerous studies. Jin et al. (2004) found a lifetime prevalence of low back pain of 50-79% in a sample of the Chinese population. Walker (2004) found a lifetime prevalence of low back pain of 65% in Australian adults. An Ugandan study by Galukande et al. (2005) showed a national prevalence of low back pain of 62.3%, and Docrat (1999) found Indian and coloured populations in South Africa to have a prevalence of 26.6-78.2% for low back pain.

A study by Irwin et al. (2007) found a correlation between increased age and sacroiliac joint pain. Many authors describe an increase in sacroiliac joint pathology with increasing age, often due to joint deterioration (Schafer and Faye, 1990; Lippit, 1997; Morris, 2006; Paris and Viti, 2007).

2.4.2 Etiology

Lippit (1997) divides sacroiliac joint dysfunction into two categories: intra-articular and extra-articular dysfunctions. True intra-articular lesions are limited to fracture, infection, tumor, inflammatory spondylopathies, degenerative joint disease and

metabolic conditions. Extra-articular sacroiliac joint dysfunction describes lesions of the ligamentous structure that result in abnormal joint movement and alignment. In addition extra-articular dysfunctions can involve chronic inflammation of the joint while the joint itself is structurally normal.

The principal source of pain in the sacroiliac joint is the surrounding ligaments, particularly the deep posterior sacroiliac ligaments and the iliolumbar ligament, which can suffer from both chronic and acute strains or tears (Paris and Viti, 2007). These strains can result in ligament laxity and weakness which in turn will affect the movement and alignment of the sacroiliac joint. Hypermobility of the sacroiliac joint can occur as a result of these chronic ligamentous strains. As the primary function of the sacroiliac joint is to be a strong, stable weight-bearing joint, any hypermobility will lead to a decrease in stability, affected biomechanics, increased pain, and recruitment and imbalance of related musculature (Sahrmann, 2005). According to Lippitt (1997) and Paris and Viti (2007), muscles will attempt to compensate for incompetent ligaments, but are usually unsuccessful. The hamstring muscles, in particular the biceps femoris with its attachment to the sacrotuberous ligament, may be involved and affected by this process. Chronic hypermobility and instability can lead to a fixation of the joint in order to restore balance and stability (Lippitt, 1997; Paris and Viti, 2007).

Causes of ligamentous strains in the sacroiliac joint can include trauma such as motor vehicle accidents and falls onto the buttocks, and repetitive actions such as poor postural habits and even vigorous sexual positions whereby the thighs are repetitively forced onto the chest (Paris and Viti, 2007).

Unilateral stresses upon the pelvis and sacroiliac joint can result in pelvic torsion or lateral tilt. Schafer and Faye (1990) also list unilateral lower extremity insufficiency (short leg), muscle shortening or weakness, sacroiliac joint dysfunction, and hip or lower limb alignment problems, as causes of lateral pelvic tilt. The orientation of the pelvis in turn directs the lumbar curvature and as such, the hip muscles that play a role in pelvic inclination will also have an effect on lumbar lordosis. Short pelvic extensors (glutei and hamstring muscles) will cause posterior pelvic tilt and decreased lumbar curvature, and short pelvic flexors (iliopsoas and rectus femoris) will rotate the pelvis anteriorly and increase the

lumbar curvature. Cibulka et al (1986) describe a sacroiliac dysfunction as an anterior tilt of one ilium and a posterior tilt of the opposite ilium, and also found the anterior tilt occurring most commonly on the same side as hamstring injuries in their patients.

Schafer and Faye (1990) go on to describe sacroiliac fixations as shortening of the muscles or ligaments surrounding the sacroiliac joint, which result in a decreased mobility of the joint itself. Muscular fixations of the sacroiliac joint can involve shortened hamstring muscles fixing the ischium. Ligamentous fixations of the sacroiliac joint can involve shortening of the iliolumbar, sacrotuberous and sacroiliac ligaments. Shortening of these strong, supportive ligaments can force the sacroiliac joint into extremes of nutation or counter-nutation, or simply limit either movement(Schafer and Faye, 1990).

2.4.3 Clinical Presentation

Sacroiliac joint dysfunction can present as localized pain over the sacroiliac joint in the region of the posterior superior iliac spine, as diffuse low back pain, or even as distally referred pain (Bernard and Kirkaldy-Willis, 1987; Bernard and Kirkaldy-Willis, 1992; Cibulka, 1992; Travell and Simons, 1993; Schwarzer et al, 1995; Mooney, 1997; Liebenson, 2007).

Lee (2007) discusses 'Fortin's distribution of pain' that shows the sacroiliac joint to be capable only of causing pelvic girdle pain, between the iliac crest and gluteal fold. However, by virtue of the innervation of the sacroiliac joint, pain referral can be a common source of pain in the joint, related muscles and along the dermatomal paths of all the innervations, and the sacroiliac joint is accepted as a potential cause of lower limb pain (Moore and Dalley, 2006; Rupert et al., 2009; Bergmann and Peterson, 2011; Martini et al., 2012). Bernard and Kirkaldy-Willis (1992) specifically mention sacroiliac pain referral patterns that include the buttocks, posterior thigh and groin, which is also reiterated by Slipman et al. (2001).

2.4.4 Diagnosis

Diagnosis of sacroiliac joint dysfunction is commonly based on motion palpation and pain provocation techniques, however there is mixed opinion on the reliability

of these techniques (Bergmann and Peterson, 2011). Poor inter-examiner reliability can reduce the reliability of motion palpation techniques, while clinical tests for sacroiliac joint dysfunction based on manoeuvres intended to stress the sacroiliac joint and provoke familiar pain are seen to be more reliable (Laslett, 2007; Magee, 2007). While these provocation tests have shown reliability in identifying a sacroiliac joint dysfunction, they are unable to identify the specific structure that is causing the pain (Lee, 2007). The lack of a readily available reference standard for sacroiliac joint dysfunction limits the validity of most provocation tests despite their clinical significance (Laslett, 2008). Controlled local sacroiliac anaesthetic blocks can be considered the most reliable method for diagnosis of sacroiliac dysfunction as the source of pain (Rupert et al., 2009). Radiographic changes are not evident in the dysfunctional sacroiliac joint but radiographic studies can be utilized in order to exclude traumatic causes of sacroiliac pain (Kirkaldy-Willis et al., 1992). Radiographic examination can also be useful in excluding ankylosing spondylitis as a cause of sacroiliac joint pain (Skogsbergh and Cooperstein, 2005).

A differential diagnosis to true sacroiliac joint dysfunction includes (Wedge and Tchang, 1992; Dreyfuss et al., 1996; Laslett, 2008):

- Fractures of the sacrum or pelvis
- Diastasis from pregnancy or childbirth
- Spondyloarthropathy
- Crystal and pyogenic arthropathy
- Ankylosing spondylitis
- Diabetic neuropathy
- Nerve root tumours
- Osteoid osteoma
- Osteoporosis

Bergmann and Peterson (2011) set out a number of tests and techniques used for investigation of sacroiliac joint dysfunction, which, when used in conjunction, are effective in identifying the lesion. The evaluation of the sacroiliac joints includes palpation of the bony structures, muscle and ligaments surrounding the joint; assessment and provocation of joint play in both seated and prone positions; and

motion palpation of the joint while seated and standing (Bergmann and Peterson, 2011).

Gillet's test is an often cited orthopaedic test for sacroiliac dysfunction described by Dreyfuss et al. (1996) as involving the patient standing with his or her feet approximately 30cm apart, while the examiner sits behind the patient and palpates the S2 spinous process with one thumb and the posterior superior iliac spine with the other. The patient then flexes the knee and hip on the side to be tested and the test result is positive if the posterior superior iliac spine fails to move posteroinferiorly with respect to S2. While the test is commonly recommended it has been shown to have poor inter-examiner reliability (Dreyfuss et al., 1996; Laslett, 2008; Rupert et al., 2009).

Patrick's test stresses the sacroiliac joint by placing the hip in flexion, abduction and external rotation, and Gaenslen's test stresses the sacroiliac joint by flexing the contralateral hip of the supine patient while extending the ipsilateral hip (Dreyfuss et al., 1996; Mooney, 1997; Laslett, 2007). Both of these are commonly accepted as valid and reliable but scientific studies have found unfavourable results (Dreyfuss et al., 1996; Slipman et al., 2001; Laslett, 2008; Rupert et al., 2009).

2.4.5 Treatment

Treatment of sacroiliac joint dysfunction is often based on either mobilization or stabilization of the sacroiliac joint (Mooney, 1997). Mobilisation of the sacroiliac joint can include manipulation directed to the sacroiliac joints, while stabilization of the sacroiliac joint can involve the use of orthotic devices, stimulation of ligamentous repair, dynamic stabilization by enhanced motor function, or even surgical fusion (Mooney, 1997; Skogsbergh and Cooperstein, 2005). Pain originating from the sacroiliac joint can be controlled by intra-articular injection or neurolysis of the nerve supply (Slipman et al., 2001; Rupert et al., 2009).

Manipulation of the sacroiliac joints has been found to be effective in the treatment of sacroiliac joint dysfunction in a number of studies (Hendler et al., 1995; Haldeman, 2005). Paris and Viti (2007) and Bergmann and Peterson (2011) prescribe manipulation as the preferred treatment for fixated sacroiliac joints.

Laslett (2008) however states that there are no randomized trials of different treatments for patients with pain confirmed as arising from the sacroiliac joints. Manipulation as a treatment for sacroiliac pain is based on the presumption of a biomechanical dysfunction of the sacroiliac, which cannot always be reliably diagnosed (Laslett, 2008).

An anaesthetic injection can also be considered an effective treatment for pain originating in the sacroiliac joint (Kirkaldy-Willis et al., 1992).

2.5 THE HAMSTRING MUSCLES

2.5.1 Functional Anatomy

The hamstring is a collective term for the three muscles of the posterior thigh, namely the semitendinosus, semimembranosus and biceps femoris (Moore and Dalley, 2006). These muscles share the common properties of (Standring, 2008; Martini et al., 2012):

- (1) A proximal attachment to the ischial tuberosity.
- (2) Innervation by the sciatic nerves tibial division.
- (3) A span crossing both the hip and knee, and a main action causing extension of the hip and flexion of the knee.

The short head of the biceps femoris however, does not meet these conditions and is not considered a part of the true hamstring.

Collectively, the hamstring is important in maintaining standing posture and extending the hip during walking. They are most active, however, when eccentrically contracting in order to decelerate the leg in late swing phase.

a) The semitendinosus (Travell and Simons, 1993; Moore and Dalley, 2006; Standring, 2008; Martini et al., 2012)

The semitendinosus forms part of the medial hamstring, and the bulk of its fibres lie in the proximal half of the thigh. The fusiform belly of the muscle is intersected by a tendinous inscription, and about two thirds of the way down the thigh, its long cord-like tendon begins. This tendon bends posteromedially around the medial condyle of the tibia, and attaches to the medial tibia where it forms part of the pes anserinus alongside the distal attachments of the sartorius and gracilis.

The proximal attachment of the semitendinosus to the ischial tuberosity is by means of a common tendon with the long head of the biceps femoris. The main action of the semitendinosus is to extend the thigh, flex the knee and rotate the leg medially when the knee is flexed.

b) The semimembranosus (Travell and Simons, 1993; Moore and Dalley, 2006; Standring, 2008; Martini et al., 2012)

The broad semimembranous muscle lies deep to the semitendinosus in the medial aspect of the posterior thigh. Proximally, it attaches to the ischial tuberosity deep to the tendon of the semitendinosus and long head of biceps femoris. Distally, its tendon attaches to the posteromedial aspect of the medial condyle of the tibia. The main action of the semimembranosus is the same as that of the semitendinosus.

c) The biceps femoris (Travell and Simons, 1993; Moore and Dalley, 2006; Standring, 2008; Martini et al., 2012)

The biceps femoris forms the lateral portion of the hamstring muscle, and is, itself, composed of a long and short head. The short head of the biceps femoris is not considered a true hamstring muscle as it does not pass over both the hip and knee joint, rather attaching proximally to the lateral lip of the inferior third of the linea aspera of the femur, and distally to the posterolateral aspect of the fibular head. Whereas, the long head of the biceps femoris originates from the ischial tuberosity and joins the short head to form a common tendon at their distal attachment to the posterolateral fibular head. The long head of biceps femoris has also been shown to overshoot the ischial tuberosity and attach directly to the sacrotuberous ligament. The main action of the biceps femoris is to flex the knee and rotate the leg laterally when the knee is flexed.

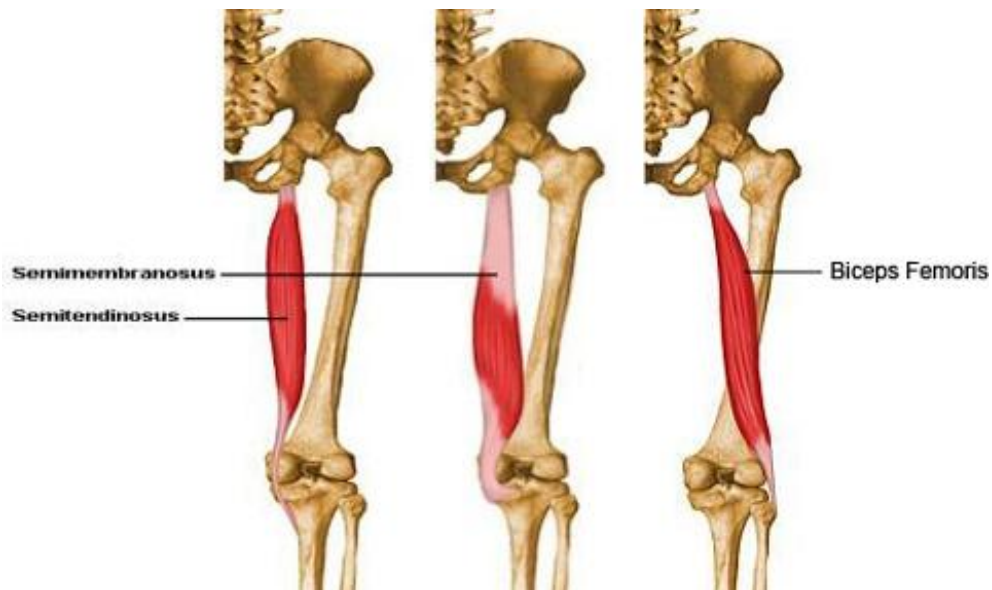


Figure 2.5: Diagram depicting hamstring muscles

(University of Florida, Department of Recreational Sports, Division of Student Affairs, <http://recsports.ufl.edu/fitness/fitness-assessment-center/corrective-exercises/hamstring-stretch>, 2010)

2.5.2 Innervation

The true hamstrings are innervated by the tibial division of the sciatic nerve, originating from L5, S1 and S2 spinal levels. The short head of the biceps femoris is innervated by the common fibular division of the sciatic nerve, originating from L5, S1 and S2 spinal levels. (Willard, 1997; Moore and Dalley, 2006; Standring, 2008; Martini et al., 2012).

2.6 HAMSTRING MUSCLE DYSFUNCTION

Hamstring muscle strains are common in most sports and have the highest prevalence of all muscle injuries in sports that involve high speed running and acceleration. These injuries also have a significant recurrence rate, with a previous hamstring injury being the greatest risk factor for strain of the hamstrings. (Verral et al., 2001; Orchard and Seward, 2002; Sherry and Best, 2004; Heiderscheit et al., 2005; Hoskins and Pollard, 2005a; Hoskins and Pollard, 2005b; Verral et al., 2006; Clark, 2008; Heiderscheit et al., 2010; Linklater et al., 2010; Elliot et al., 2011;)

Strains of the hamstrings most commonly occur at the musculotendinous junction during late swing phase while sprinting, as the muscle is at its longest and also

under the most tension as it decelerates the swinging leg (Connell et al., 2004; Heiderscheit et al., 2005). The biceps femoris portion of the hamstring is under the most tension during this terminal swing phase, which may relate to its increased tendency to become injured over the semimembranosus and semitendinosus portions (Thelen et al., 2005; Askling et al., 2007). Hamstring injuries can also occur in sports involving kicking, or other movements that include hip flexion and knee extension, due to the extreme stretch that these movements place upon the hamstring. These particular injuries are most common at the semimembranosus tendon (Askling et al., 2006; Askling et al., 2007).

The majority of hamstring injuries are first seen in the acute phase when the athlete experiences sudden pain in the posterior thigh during strenuous exercise, particularly sprinting or kicking (Reid, 1992; Askling et al., 2006; Askling et al., 2007). The transition from acute to chronic phase of injury in hamstring strains is largely dependent on injury severity, but generally the acute phase should last approximately 48 hours, or until inflammation settles (Brukner and Kahn, 2006). In many athletes the acute phase will develop into a chronic situation of recurring tightness in the involved hamstring, which may restrict performance (Reid, 1992; Askling et al., 2007). Orchard and Best (2002) consider the natural history of hamstring strains to last no more than 21 days, and define any injury persisting beyond this as chronic in nature.

Recurrence of hamstring injuries is a significant concern, with secondary injuries being more severe and often requiring twice the recovery time of the initial injury (Brookes et al., 2006; Koulouris et al., 2007). The risk of re-injury is most increased after an early return to sport by the athlete, after the initial injury (Koulouris et al., 2007; Orchard, 2001).

Reid (1992) explains muscle strains as a tearing or stretching of the fibres of the musculotendinous unit, most commonly occurring during sport. Muscle strains can occur as a result of either acute movements or repetitive stresses, and may present as acute or diffuse pain, palpable tightness, or spasm. Injured muscles can become inflexible and weakened, and any activity can exacerbate pain (Reid, 1992).

Muscle strains can be graded as follows (Reid, 1992; Gokaraju et al., 2008):

Grade I (Mild): This is a microscopic tear of the muscle fibres that may produce tightness in the posterior thigh and minimal swelling. The gait will not be affected and resisted knee flexion in the prone position would be unlikely to illicit significant pain.

Grade II (Moderate): This is a partial tear of the muscle fibres that will produce noticeable pain and swelling, and may affect gait, causing an antalgic limp. Activity will worsen pain and resisted knee flexion and full extension will illicit pain. Tenderness in the posterior thigh and weakness of the muscle are also normal for this injury. Subcutaneous bruising may appear for several days following the injury.

Grade III (Severe): This is a complete tear or rupture of the muscle. Pain will be severe and swelling and subcutaneous bruising will be immediate. Hip and knee movements will illicit severe pain and the patient will be unable to walk without aid. Surgical intervention is often required for injuries of this severity.

2.6.1 Epidemiology

Numerous studies have examined the epidemiology and prevalence of hamstring strains in a variety of sport settings. These are stated as follows:

Studies by Orchard and Seward (2002) and Feeley et al. (2008) reported similar findings and in all these studies a high incidence of re-injury was evident. A study by Brookes et al. (2006) on the prevalence of hamstring injuries in rugby players showed an injury rate of 5.6 per 1 000 with the majority being sustained during running (68%), and injuries as a result of kicking being the most severe. Elliott et al. (2011) carried out a 10 year review of injuries in American Football Players, including 1 716 hamstring injuries, and concluded that the majority of the injuries were suffered by sprinting players, with a remarkable 51.3% occurring pre-season.

A study by Roux et al. (1987) showing the incidence of injury in schoolboy rugby players in South Africa found muscle injuries to account for 17% of all injuries, with no further detail on site of injury. A South African study conducted on rugby injuries sustained by players during the 1995 Rugby World Cup games found

muscle injuries to account for 24% of all injuries, but no specific data on the hamstrings was obtained (Jakoet and Noakes, 1998). This result was repeated in a study of South African rugby players in the Super 12 tournament conducted by Holtzhausen et al. (2006), which found musculotendinous strains to account for 24% of injuries, and that a total of 11% of all injuries occurred in the thigh.

A number of studies were conducted on South African cricketers and their injuries and these include: Stretch (2001) found muscle injuries to be the most common (37.4%) and of the total number of injuries 49.7% occurred in the lower limbs. A more detailed study by Stretch (2003) found hamstring strains and tears to be the most common muscle injury in cricketers, accounting for 17% of all injuries. Milsom et al (2007) conducted a study on the incidence and nature of cricket injuries in South African schoolboy cricketers which found the incidence of hamstring injuries to be 4.5% of fielding injuries, and noted that 30% of batting injuries were strains of the quadriceps femoris and hamstrings.

Most recently Mtshali et al. (2009) conducted a study on female high school soccer players in a region of South Africa and found a one year prevalence of hamstring injuries to be 6% of all lower limb injuries and 26% of all lower limb muscle injuries.

2.6.2 Predisposing Factors

The most commonly reported risk factor for a hamstring injury is a history of previous injury to the hamstring muscles (Prior et al., 2009). Most studies found that if a person previously suffered from a hamstring injury they were 2 to 6 times more likely to suffer from a hamstring strain (Verral et al., 2001; Orchard, 2001; Gabbe et al., 2006; Hagglund et al., 2006; Engebretson et al., 2010). This may be related to a premature return to sports, possibly with insufficient rehabilitation (Gabbe et al., 2006; Hagglund et al., 2006). Verral et al. (2001) describe the formation of scar tissue during post injury remodelling of the musculotendinous junction, and the decreased functionality of this tissue that might lead to further injury when under stress. It has also been shown that other injuries to the lower limb can increase the risk of hamstring strain, emphasising the importance of a functional kinematic chain and normal biomechanics of the lower limb in minimizing the risk of hamstring injuries (Orchard, 2001; Verral et al., 2001).

Increased age has been marked as a risk factor for all muscle strains, including those of the hamstring muscles. Verral et al. (2001) associate as much as a 30% increase in risk of injury per annum. Studies by Orchard (2001) and Gabbe et al. (2006) show the most significant increase in risk occurring between the ages of 23 and 25. This increase in risk in older athletes may be associated with prolonged exposure over time within their risk activity (Murphy et al., 2003).

Ethnicity was seen in several studies to be a factor in the risk of hamstring injuries with professional black football players in the United Kingdom being at increased risk of injury, with no importance placed on specific nationality (Woods et al., 2004). In Australian Rules football aboriginal players had as much as 11 times greater risk of hamstring injury (Verral et al., 2001).

Decreased flexibility of the hamstring muscles has been proposed to be an important factor in hamstring injury (Pollard and Quodling, 1999) although most studies have failed to associate decreased flexibility with a higher incidence of hamstring injuries (Prior et al., 2009). Studies by Hartig and Henderson (1999) and Dadebo et al. (2004) both showed that stretching can reduce the risk of hamstring strains, suggesting that decreased flexibility may be associated with increased risk of injury. Prior et al. (2009) suggests that retrospective studies into hamstring flexibility cannot determine whether decreased flexibility is a predisposing factor to hamstring injury or simply a result of injury to this muscle. However muscle tightness can biomechanically predispose the hamstring to injury due to decreased stretch and force absorption before failure when required to lengthen, thus compromising the muscle (Prior et al., 2009).

A review of the literature by Prior et al. (2009) found conflicting evidence of hamstring strength as a risk factor. According to Rosene et al. (2001), strength balance between the hamstrings and quadriceps femoris has been considered important, with a ratio of between 50% and 80% being considered normal between the hamstrings and quadriceps femoris. However, the majority of modern literature fails to support this (Hoskins and Pollard, 2005a; Prior et al., 2009). But, studies by Yamamoto (1993) and Orchard et al. (1997) did show that a significantly weaker hamstring can be related to an increased risk of injury. The most common mechanism of injury to the hamstring muscles is during terminal

swing phase when the hamstring is acting eccentrically to decelerate the extending knee (Heiderscheit et al., 2005). Over-developed quadriceps femoris muscles will increase the force against which the hamstring is contracting and subsequently increase the chance of strains and tears within the muscle, suggesting that a comparative weakness can be a factor in risk of injury (Prior et al., 2009). Strength deficits found in patients with recurrent hamstring injuries can be a result of insufficient rehabilitation or uncorrected dysfunctions in the lumbar spine, pelvis or sacroiliac joint (Crosier et al., 2002).

Hamstring strains are more likely in higher levels of competition in sports, possibly due to greater effort by players and possible fatigue (Woods et al., 2004; Verral et al., 2001). Player position and activity is an important variable in the risk of hamstring injury, with mobile, running players found to be at greater risk (Elliott et al., 2011; Brookes et al., 2006). Conditioning is another important factor in the risk of injury, as shown by Elliott et al. (2011) in a study where over half of injuries occurred during pre-season training, further suggesting weakness as an increased risk of injury. Fatigue can be important in the pathogenesis of hamstring injury (Verral et al., 2001; Verral et al., 2006). Studies by Woods et al. (2004) and Dadebo et al. (2004) show a greater number of injuries occurring during the late stages of sports matches and practices.

Running technique can be responsible for an increased risk of hamstring injuries. A common mechanism of injury can occur when the body is leaning forward in an effort to achieve or maintain high speeds. This forward lean can place the hamstrings under an extra stretch, due to the biarticular nature of these muscles. This extra stretch may contribute to injury of the muscle (Hoskins and Pollard, 2005a).

Aberrant lumbo-pelvic biomechanics can be linked to hamstring muscle injuries. Posture abnormalities, leg length inequalities and pelvic tilt can all contribute to injuries of the lower limb. Increased lumbar lordosis has also been associated with an increase in hamstring strains and other thigh injuries (Hennessey and Watson, 1993; Watson, 2001). Cibulka et al. (1986) suggested a relationship between hamstring muscle strains and dysfunctional sacroiliac joints, through an anterior tilt of the pelvis. Woods et al. (2004) found increased incidence of anterior pelvic tilt in

black football players, who were shown to have significantly higher risk of hamstring injury.

2.6.3 Diagnosis

Diagnosis of hamstring injuries is based on a history of typical injury mechanism and clinical findings of localised pain and loss of function (Hoskins and Pollard, 2005a). Activity at the time of injury and the sequence of events leading up to the injury can be of vital importance in assessing the character of the injury, and level of immobility due to pain and weakness can assist in grading the severity of the injury (Gokaraju et al, 2008).

The purpose of a physical examination is to determine the location and severity of the hamstring injury (Heiderscheit et al., 2010). Palpation of the site is useful for finding the area of maximal pain and determining the length of the painful area, as well as assessing the presence or absence of a palpable defect in the musculotendinous unit. Strength can be tested through the use of resisted knee flexion, and passive straight leg raiser and active knee extension can be useful in assessing any loss of flexibility. (Heiderscheit et al, 2010)

A differential diagnosis for hamstring injuries includes a number of other causes of posterior thigh pain that need to be differentiated through careful examination.

Differential diagnosis includes (Travell and Simons, 1993; Hoskins and Pollard, 2005a; Heiderscheit et al., 2010):

- Adductor strain
- Adverse neural tension
- Referred posterior thigh pain
- Myofascial trigger points in gluteus medius and minimus
- Articular dysfunction of hip, knee, sacroiliac joint or lumbar spine
- Tenosynovitis of hamstring tendons
- Bursitis of biceps femoris superior bursa
- Pathological fracture of femur
- Local infections of muscle or bone
- Tumours of bone or muscle

Any suspected injury of the hamstring muscles must be differentiated from referred posterior thigh pain. Dysfunctional sacroiliac joints can be responsible for pain referred to the posterior thigh (Bernard and Kirkaldy-Willis, 1992; Slipman et al., 2001). Referred posterior thigh pain shows minimal tenderness on palpation and flexibility and strength changes should be insignificant. Gait should be unaffected in referred pain and lumbar and sacroiliac examinations may show abnormal neurological findings. Slump tests should be negative in hamstring muscle strains and may be positive in referred posterior thigh pain, and a history of back injury correlates with an increased risk of referred posterior thigh pain (Heiderscheit et al., 2010; Verral et al., 2001).

In some cases an imaging study may be required in order to make a definitive diagnosis. Ultrasound scans and Magnetic Resonance Imaging (MRI) can provide much information on the site and severity of the injury, and can help to assess the extent of haematomas as a result of severe hamstring muscle damage. These imaging techniques should be used 2-3 days post injury in order to allow inflammation to settle. MRI is more sensitive than ultrasound in assessing chronic or recurrent injuries and is most often used when assessing severe injuries for partial or complete rupture, and determining treatment or surgical options. Radiographs are only useful as imaging study in the case of suspected avulsion or apophyseal fracture (Gokaraju et al., 2008; Heiderscheit et al., 2010).

2.6.4 Management and Treatment

Treatment of hamstring muscle injuries is largely dependent on grading or severity of injury and the timeframe of the injury itself. Injuries in the acute phase, generally within 48-72 hours after the initial injury, are treated by following the principal of Rest, Ice, Compression and Elevation (RICE). The purpose of this treatment is to minimize inflammation and restrict the formation of haematomas (Kujala et al., 1997).

Less severe hamstring injuries are managed conservatively, while some Grade III tears may require surgical intervention (Kujala et al., 1997; Brukner and Kahn, 2006). Surgical intervention for both complete and partial proximal hamstring tendon rupture has a high success rate with a return to sport five to six months after diagnosis. The most important factor limiting success in surgical procedures

for severe hamstring injuries is a delay in diagnosis and referral (Klinge and Sallay, 2002; Lempainen et al., 2006).

Conservative care includes rest and immobilisation of the injured leg for 24-48 hours, before beginning mobilisation (Kujala et al., 1997; Gokaraju et al., 2008). Immobilisation should never exceed one week as this may promote atrophy and loss of flexibility (Hoskins and Pollard, 2005b). Cryotherapy can be used to control pain and inflammation related to a muscular strain, although no standards have been developed on the optimal mode or duration of treatment (Hoskins and Pollard, 2005b).

Clanton and Coupe (1998) prescribe the use of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) for the treatment of hamstring strains. While NSAIDs may be useful in controlling pain their long-term use can in fact hamper muscle recovery, and their use is not recommended in an evidence-based approach to hamstring injury management (Hoskins and Pollard, 2005b).

Although electrotherapeutic modalities such as therapeutic ultrasound, interferential current, transcutaneous electrical nerve stimulation and laser therapy are regular physiotherapeutic inclusions there is no evidence warranting their inclusion in the treatment and management of hamstring injuries other than for their anti-inflammatory and analgesic effects (Hoskins and Pollard, 2005b).

Mobilisation of the injured leg in a controlled, progressive and pain free manner is required to begin rehabilitation of the injury (Hoskins and Pollard, 2005b). Reid (1992) suggests gentle stretching during the subacute phase, leading to isometric exercises and proprioceptive neuromuscular facilitation (PNF) stretching when pain-free. Clanton and Coupe (1998) suggest starting mobilisation of the injured muscle one week after injury and advocate pain-free stretching and strengthening exercises that progress from isometric to isotonic and isokinetic. Feland et al. (2001) supports the use of PNF stretching in order to improve muscle mobility. Brukner and Kahn (2006) suggest beginning stretching and strengthening after inflammation has settled. Static stretches of the hamstring muscle performed regularly can be effective in improving flexibility of the hamstring muscle (Bandy and Irion, 1994; Anderson, 2000).

Traditional rehabilitation of hamstring injuries focuses predominantly on restoring mobility to the injured muscle and progressively strengthening the hamstring, and the primary goal is to return the patient to pre-morbid activities as soon as possible. The high rate of recurrence of these injuries, particularly in athletes, suggests that this return to sport may be premature in many cases, or that rehabilitation protocols are simply lacking in evidence-based research and development (Hoskins and Pollard, 2005b; Heiderscheit et al., 2010). Rehabilitation should aim to reduce the risk of re-injury, and factors that can contribute to this risk are reduced tensile strength of the scar tissue, reduced muscle strength due to atrophy or reflex inhibition, reduced flexibility of the muscle-tendon unit, and compensatory changes in biomechanical patterns (Orchard and Best, 2002).

Due to the nature of hamstring function and the mechanism of injury during eccentric loading of the hamstring muscles, eccentric strength training can play a role in restoring functional strength to the injured muscle and prevent recurrence of the initial injury (Heiderscheit et al., 2010). The Nordic hamstring exercise as utilised by Brookes et al. (2006) is a useful addition to any rehabilitation programme aimed at eccentrically strengthening the hamstring muscles.

Sherry and Best (2004) showed that a rehabilitation programme consisting of progressive agility and trunk stabilization exercises is more effective than a programme emphasizing isolated hamstring stretching and strengthening in promoting return to sports and preventing injury recurrence. This suggests that abnormal neuromuscular control of the trunk and pelvis could contribute and predispose to the initial injury (Hoskins and Pollard, 2005b).

Heiderscheit et al. (2010) advocate a three phased approach to rehabilitating hamstring injuries, beginning with cryotherapy, short term NSAID use, and therapeutic exercises within a protected range of motion. The next phase of care continues to include the use of ice post exercise, and includes therapeutic exercises with the emphasis on neuromuscular control, agility drills and trunk stabilizations, that are performed with a progressive increase in speed and intensity. Submaximal eccentric strengthening exercises are initiated in functional movements. The third phase of the programme is focused on full range of motion

exercises and sports specific drills. Eccentric loading exercises are expanded to end range of movement and increased in intensity.

This shift of focus from isolated hamstring treatment to dynamic stability and neuromuscular control highlights the possible involvement of pelvic and lumbar biomechanics in the pathogenesis of hamstring injuries (Sherry and Best, 2004; Heiderscheit et al., 2010)

2.7 SPINAL MANIPULATIVE THERAPY

Spinal manipulative therapy (SMT) of the sacroiliac joint was shown by Cibulka (1986), Fyfer (2005) and Fox (2006) to have beneficial effects on the strength and mobility of the hamstring muscles, however it is predominantly prescribed for the treatment of sacroiliac joint dysfunction and low back pain (Schafer and Faye, 1990; Magee, 2007; Bergmann and Peterson, 2011).

Manipulation has been found to be effective in the treatment of sacroiliac joint dysfunction (Hendler et al., 1995; Haldeman, 2005), and the primary goal of treatment for sacroiliac joint dysfunction is the restoration of normal lumbopelvic mechanics. Paris and Viti (2007) prescribe manipulation as the preferred treatment for fixated sacroiliac joints and Cibulka (1992) describes the successful use of sacroiliac joint manipulation in the treatment of low back pain.

Evans (2002) describes the mechanical theories behind the efficacy of High Velocity Low Amplitude Thrusts (HVLAT) in the treatment of low back pain. The four original theories are as follows (Shekelle, 1994; Leach, 2004; Bergmann and Peterson, 2011):

- 1) Release of entrapped synovial folds or plica,
- 2) Relaxation of hypertonic muscle by sudden stretching,
- 3) Disruption of articular or periarticular adhesions, and/or
- 4) Unbuckling of motion segments that have undergone disproportionate displacement.

Sturesson (2007) states that manipulation does not alter the position of the sacroiliac joint. This suggests that the effect that manipulation has on the sacroiliac joint may be other than a physical shifting of an immobile joint. The neurological effects of the manipulation were first described by Wyke (1985) as

giving rise to reflex changes in muscle tone due to the stimulation of articular mechanoreceptors. The sudden forceful stretching of hypertonic muscles surrounding a joint during manipulation can cause a release of afferent impulses that should reflexively regulate muscle tone (Cassidy and Kirkaldy-Willis, 1988). These reflexes are collectively known as the Arthrokinetic Reflexes, which are postulated to play a role in pain syndromes of the sacroiliac joint (Bernard, 1997).

2.8 CONCLUSION

There are two biomechanical models by which it is suggested the sacroiliac joint and hamstring may relate to one another. The first theory of sacroiliac joint dysfunction is an asymmetry between the two ilia, with an anterior tilt of one and posterior tilt of the other (Pool-Goudzwaard et al., 1998). This anterior tilt of the ileum moves the ischial tuberosity superiorly, thus increasing tension on the hamstring, while a posterior tilt shortens the hamstring (Travell and Simons, 1993). Either of these may predispose to injury of the hamstring. This effect can also occur inversely whereby myofascial changes in the injured muscles related to the pelvis affect the biomechanics of that region. This can involve the hamstrings acting on the position of the ilium (Prather and Hunt, 2004). It is, thus unknown, whether the sacroiliac joint dysfunction was as a result of the hamstring strain, or a contributing factor to the strain. A second theory of sacroiliac joint dysfunction is a loss of normal mobility of the sacroiliac joints. This is the subluxation complex as described by Gatterman (1990). In this subluxation complex, the joints motion is restricted, thus preventing normal mobility in that joint and affecting the surrounding structures. Cibulka et al. (1986) and Hoskins and Pollard (2005a and c) found a correlation in their subjects between pelvic asymmetry, sacroiliac joint dysfunction, and hamstring strains.

Cibulka et al. (1986) had proposed that anterior tilt of the pelvis increased risk of hamstring muscle strain and found the inclusion of manipulation directed to the dysfunctional SIJ to be beneficial in the restoration of hamstring strength. Fox (2006) showed sacroiliac manipulation combined with stretching to be beneficial in producing an increase in flexibility of uninjured hamstrings. A study conducted by Fyfer (2005) found manipulative therapy of the lumbar spine and/or sacroiliac joint to be of benefit in the treatment of hamstring injuries. Hoskins and Pollard (2005a,

b and c) advocate the use of spinal manipulative therapy in the treatment of certain cases of hamstring injury.

Arthrogenic muscle inhibition is a neurophysiological theory of presynaptic, reflex inhibition described by Hopkins and Ingersoll (2000) that may suggest a possible link between sacroiliac joint dysfunction and hamstring muscle strain. Dysfunctional joints may inhibit the strength and activation of their surrounding musculature through a common innervation. Correction of the joint dysfunction may counter the reflex, as demonstrated in the study by Suter et al. (2000), in which manipulation of sacroiliac joint dysfunction was shown to reduce reflex inhibition of the quadriceps femoris muscle. As the hamstring muscles share a common innervation with the sacroiliac joints (Moore and Dalley, 2006; Martini et al., 2012), it may be possible for sacroiliac joint dysfunction to reflexly inhibit the hamstring muscles, and as such alter the biomechanics of the muscle during gait and inhibit recovery of the muscle or predispose to injury.

In light of the above, this study aimed to examine the effect of sacroiliac manipulation in the treatment of hamstring muscle strains, when combined with and compared to, a rehabilitation regime including stretching and strengthening of the hamstring muscle.

CHAPTER THREE

3. METHODOLOGY

3.1 INTRODUCTION

This chapter details the procedures involved in carrying out this study, including study design, subject recruitment, data collection and analysis, and interventions used.

3.2 STUDY DESIGN

This study was a randomised controlled clinical trial, quantitative in nature conducted at Durban University of Technology. Based on this structure, the study was approved by the Faculty of Health Sciences Research and Ethics committee (Appendix A), indicating that the study complied with the requirements of the Declaration of Helsinki (Johnson, 2005).

3.2.1 Sampling Procedure

Randomised, non-probability based sampling was used on participants that responded to advertisements in the form of posters (Appendix B) placed on notice boards at local sports/athletic clubs, indoor sports arenas, around the Durban University of Technology and the University of Kwa-Zulu Natal. Advertisements were also placed in community newspapers that were circulated in and around the greater Durban area.

A telephonic or personal interview was conducted in which respondents were first asked whether they were willing to answer questions about themselves in order to access the study. Prospective participants were then asked questions about their age, their history and location of the injury, mechanism of injury and any previous treatment of the injury. Participants with acute injuries were recommended rest and ice for 72 hours (Reid, 1992) and included into study if the injury persisted for longer than 21 days and progressed to the chronic phase (Orchard and Best, 2002). Initial appointments were made at the Durban University of Technology Chiropractic Day Clinic for all suitable participants.

3.2.2 Sample Allocation

A total of 32 participants were selected and randomly allocated into two groups of 16, by the use of a numbered draw determining the treatment group (Cottrell and Mckenzie, 2005). All patients in Group one received treatment in the form of proprioceptive neuromuscular facilitation (PNF) stretching of the hamstring and resisted isometric exercises of the hamstring, as well as a series of static stretches of the hamstring to be performed at home. Group two participants received the same treatment as Group one but with the addition of sacroiliac manipulation performed during their visits. Concealed allocation was not possible due to the explanation of the research given to the participants in the Letter of Information and Consent (Appendix C).

3.2.3 Sample Characteristics

Inclusion Criteria:

- 1) Participants were accepted once they had given their informed consent in writing.
- 2) Participants had to be aged from 18 to 45 years of age (inclusive) to be accepted into this study, as patients younger than this are considered minors and prevalence of this injury increases with age (Verral et al., 2001), and patients older than 45 are more likely to have degenerative changes and fibrous ankylosis of the sacroiliac joints (Kirkaldy-Willis et al., 1992).
- 3) Grade I or II hamstring strains, in the chronic phase (Reid, 1992) as confirmed by palpatory tenderness and pain aggravated by resisted isometric testing of the hamstring muscle.
- 4) Participants had to have a sacroiliac joint dysfunction on the involved side, diagnosed through the technique outlined by Bergmann and Peterson (2011). Gaenslen's test, Patrick's test, Gillet's test, compression tests, static palpation, joint play tests, and motion palpation were all used to gain a clinical picture of sacroiliac dysfunction (Dreyfuss et al., 1996; Mooney, 1997; Slipman et al., 2001; Laslett, 2007; Laslett, 2008; Rupert et al., 2009; Bergmann and Peterson, 2011).

Exclusion Criteria:

- 1) Acute injuries of the hamstring of less than 21 days history (Reid, 1992; Orchard and Best, 2002).
- 2) Contraindications to spinal manipulative therapy including, but not limited to: atherosclerosis of major blood vessels, abdominal aortic aneurysm, tumors, bone infections, traumatic injuries such as fractures, arthritides, metabolic disorders, neurologic disorders, as screened through the case history, physical and regional examinations, with patients requiring further investigation being excluded (Gatterman, 1990).
- 3) Any patient with concomitant injuries and/or physical or biomechanical abnormalities to their lower limb, other than sacroiliac joint dysfunction, that might have affected their recovery (eg. knee or ankle pathology).
- 4) If the participant received any other treatment for their hamstring or sacroiliac joint dysfunction during the duration of the study.
- 5) Patients taking anti-inflammatory drugs for their condition. However, if no anti-inflammatory drugs had been ingested in the three days prior to application for the study, they were considered. Alternatively they had to endure a three day wash out period before being accepted for the study (Poul et al., 1993).

3.3 METHOD

At this initial visit the prospective participant was given a verbal explanation as well as a Letter of Information and Consent (Appendix C) which they were required to read and sign. They were given the opportunity to ask questions and made aware that they may withdraw from the study at any time.

Before the prospective participants were accepted into the study an initial examination was conducted. A case history (Appendix D), physical examination (Appendix E), lumbar regional examination (Appendix F), hip regional examination

(Appendix G) and knee regional examination (Appendix H) were done to determine inclusion and exclusion criteria. A SOAPE note (Appendix I) was included and completed on each visit.

Hamstring injuries were graded according to the criteria mentioned by Reid (1992) and those with suspected grade III injuries were excluded.

It was then determined whether the prospective participant either fulfilled or failed to fulfill all inclusion criteria and was either accepted into the study or rejected. Accepted participants then completed the Numerical Pain Rating Scale (Appendix J) and initial measurements were taken using the digital inclinometer and algometer and recorded on a measurement sheet (Appendix K). After these readings were recorded the researcher proceeded with the treatment of the participant according to their treatment group.

The treatment and data collection for both Group one and two was performed over a total of six visits. Visits were approximately twice weekly, for three consecutive weeks, with all six visits being completed within a timeframe of no longer than 21 days from initial visit. Subjective and objective measurements were conducted on visits 1, 3 and 6, and intervention took place on visits 1, 2, 3, 4 and 5.

3.4 INTERVENTION

3.4.1 Hamstring Directed Interventions

Both treatment groups received Proprioceptive Neuromuscular Facilitation (PNF) stretching of the hamstring during their visits, due to its effectiveness in improving muscle mobility (Feland et al., 2001). Participants in both groups were also taught a static hamstring stretch whereby one leg is stretched at a time by sitting with the leg extended in front of them, and then leaning over the leg until tension is felt (Anderson, 2000). This stretch was to be held for thirty seconds, repeated three times, and the entire regime performed three times daily (Bandy and Irion, 1994). Static stretching was used for the home regime due to its simplicity and ease of use.

Both treatment groups performed isometric hamstring exercises at visits one through five. These were performed while lying supine, at both 20 and 60 degrees of knee flexion, and repeated for ten sets lasting ten seconds each (Sherry and

Best, 2004). The researcher provided the appropriate resistance for sub-maximal hamstring contraction. The participants were also taught prone leg curls and standing hip extensions, both with resistance provided by strength-appropriate Thera-band® exercise bands attached to the ankle and anchored by a solid point, as adapted from the study by Sherry and Best (2004). These exercises were performed at home, twice a day, as three sets of ten repetitions. The participants were asked to keep a stretch and exercise diary of their home routine in order to maximise compliance (Appendix K).

3.4.2 Spinal Manipulative Therapy

Treatment Group two received a manipulation consisting of a high velocity, low amplitude thrust (HVLAT) directed to their sacroiliac joint. This sacroiliac manipulation was performed on the side of their sacroiliac joint dysfunction, as determined by motion palpation. This manipulation was performed in the side lying position and the sacroiliac joint was reassessed and manipulated at each visit (Schafer and Faye, 1990; Bergmann and Peterson, 2011).

3.4.2.1 Motion Palpation

Each patient had their sacroiliac joints motion palpated in order to test for joint restrictions. The technique described by Schafer and Faye (1990), also described as Gillet's test, was used. The researcher's right thumb was placed on the right posterior superior iliac spine of the participant, and the left thumb on the sacral base. The participant then raised their right knee to their chest. A normal finding would show a separation of the researcher's thumbs, a posterior and inferior movement of the posterior superior iliac spine, and a lesser inferior movement of the sacral contact. If this movement was absent, then a right-sided flexion restriction existed. The participant then raised the left knee while the researcher maintained the original thumb contacts and the normal movement would be an approximation of the thumb contacts and the same inferior movement of the sacral base contact. Absence of this movement would have demonstrated a right-sided extension restriction. Both tests were repeated on the left sacroiliac joint although only sacroiliac joint dysfunction occurring on the side of the hamstring injury were recorded and manipulated.

3.4.2.2 Sacroiliac Manipulation

Participants in Group two received manipulation of the sacroiliac joint on the same side as the hamstring injury, and according to the restriction that was palpated. The participant was placed in the side lying position with the lesion side up if a flexion fixation, and lesion side down if an extension fixation. The participant's torso was moderately rotated and the upper leg flexed at the hip and knee. The participant's arms were folded across the participant's chest.

The researcher stood alongside the participant in a fencer stance with his cephalic hand stabilising the participant's arms. The researcher's caudad hand was placed over the sacroiliac joint and the participant's upper leg was supported by the researcher's thighs.

While the researcher stabilised the participant and removed slack with his cephalic hand, a body drop was performed and a high velocity, low amplitude thrust was delivered by the caudad hand in an inferior line of drive (Schafer and Faye, 1990; Bergmann and Peterson, 2011).

3.5 DATA COLLECTION

3.5.1 Subjective Data

Subjective data was obtained using the Numerical Pain Rating Scale (NRS-101): established by Jensen et al. (1986) for its reliability. This questionnaire measures perception of pain intensity experienced (Hjermstad et al., 2011). The participant was asked to rate their hamstring pain from 0 to 100, with 0 being no pain and 100 being the worst pain ever experienced. This questionnaire was completed on the first, third and sixth visits, before intervention.

3.5.2 Objective Data

Objective data was obtained on the first, third and sixth visits, before intervention, using the:

1. Pressure Algometer: A Wagner FDK20 Force Dial (Wagner Instruments, P. O. Box 1217, Greenwich, CT, 06836, U. S. A) was used. A pressure algometer measures pain threshold in an area of tenderness (Fischer, 1997; Kinser et al., 2009; Park et al., 2011). Two areas were tested with the

algometer, firstly, the most tender area between the posterior superior iliac spine and posterior inferior iliac spine, in order to measure sacroiliac joint tenderness. Secondly, the most tender point in the affected hamstring muscle. These areas were marked with a gentian violet marker in the first visit, to ensure accuracy of subsequent readings. The algometer was placed on each of these areas and pressure applied until the patient experienced pain in that area. This indicated the pain threshold and the reading on the algometer was recorded.

2. Digital Inclinator: A Saunders Digital Inclinator is a device used to measure range of motion and for the purpose of this study it was used to measure Straight Leg Raiser test in participants. This was done with the participant lying supine and the knee extended. A line was visualised from the greater trochanter to the lateral femoral condyle, and the base of the inclinometer was placed on this line. A passive leg raise with the knee extended was then performed to the point of discomfort, at which point the reading was taken. This reading was repeated 3 times for accuracy. (Bierma-Zeinstra et al., 1998; Zinovieff and Harborrow, 1975).

3.6 ETHICAL CONSIDERATIONS

All the data obtained from this study was reduced to file numbers; therefore the participants' identity is not available. To further maintain confidentiality, only the researcher and his supervisor analysed the results and no files were removed from the confines of the Chiropractic Day Clinic at the Durban University of Technology.

3.7 STATISTICAL ANALYSIS

SPSS version 18.0 was used to analyse the data. A p value <0.05 was considered as statistically significant. Patient demographics (age and gender) were compared between the treatment groups using t-test and chi square test respectively. Baseline outcomes were compared between groups using t-test. Subjective and objective outcomes were measured quantitatively. The effect of the intervention was using repeated measures ANOVA testing. Missing data for one participant at the final time point were imputed by taking the mean for that group. The time versus treatment group interaction effect assessed whether the effect of the

different treatment over time is the same. If the p value was <0.05 then it was concluded that the effect was significant and that the intervention group responded differently over time to the control group. The effect was plotted using profile plots to assess the direction of the effect and to assess any trends which may have been missed statistically (Esterhuizen, 2011).

CHAPTER FOUR

4. RESULTS

4.1 INTRODUCTION

This chapter is concerned with the demographic data of all the participants included in this study. It also contains a detailed statistical analysis of the subjective and objective data collected throughout the duration of the study.

4.2 ABBREVIATIONS

A list of statistical abbreviations that will be used in this chapter are:

F: This is the F-statistic and is the variance of the group means / mean of the within group variances.

N: This is the number of participants

P value: Observed level of significance. The *P* value is the smallest level of significance that would lead to the rejection of the null hypothesis.

t-test: The t-test assesses whether the means of two groups are statistically different from each other.

Wilk's lambda: The proportion of the variance in the outcomes that is not explained by an effect.

4.3 PRIMARY DATA

The primary data collected and utilized in this study consisted of a full case history, physical examination and regional examinations of the lower back, hip and knee, collected from each participant on their initial appointment. A SOAPE note was completed on each appointment with data regarding the participant's progress. Objective measurements were recorded on the first, third and sixth visits using a Wagner pressure algometer and a Saunders digital inclinometer. Subjective measurements were recorded on the first, third and sixth visits using a Numerical Pain Rating Scale (NRS-101).

4.4 SECONDARY DATA

The secondary data collected and utilized in this study was gathered from various medical text books, articles published in peer-reviewed journals, available both

online and from the Durban University of Technology library, and from M.Tech: Chiropractic dissertations available online and from the Durban University of Technology library. Data regarding the statistical analysis was gathered from e-mail communications with a statistician.

4.5 PARTICIPANT LOSS DUE TO DROPOUT

A total of twelve participants dropped out between the initial visit and the final visit. Ten were from Group one and two from Group two, and the majority of these dropped out of the study between the first and second visits. These participants were excluded from the study and replaced, and they did not affect the results in any way. One participant who failed to complete his final set of measurements was included in the study and their results were imputed by taking the mean of the group.

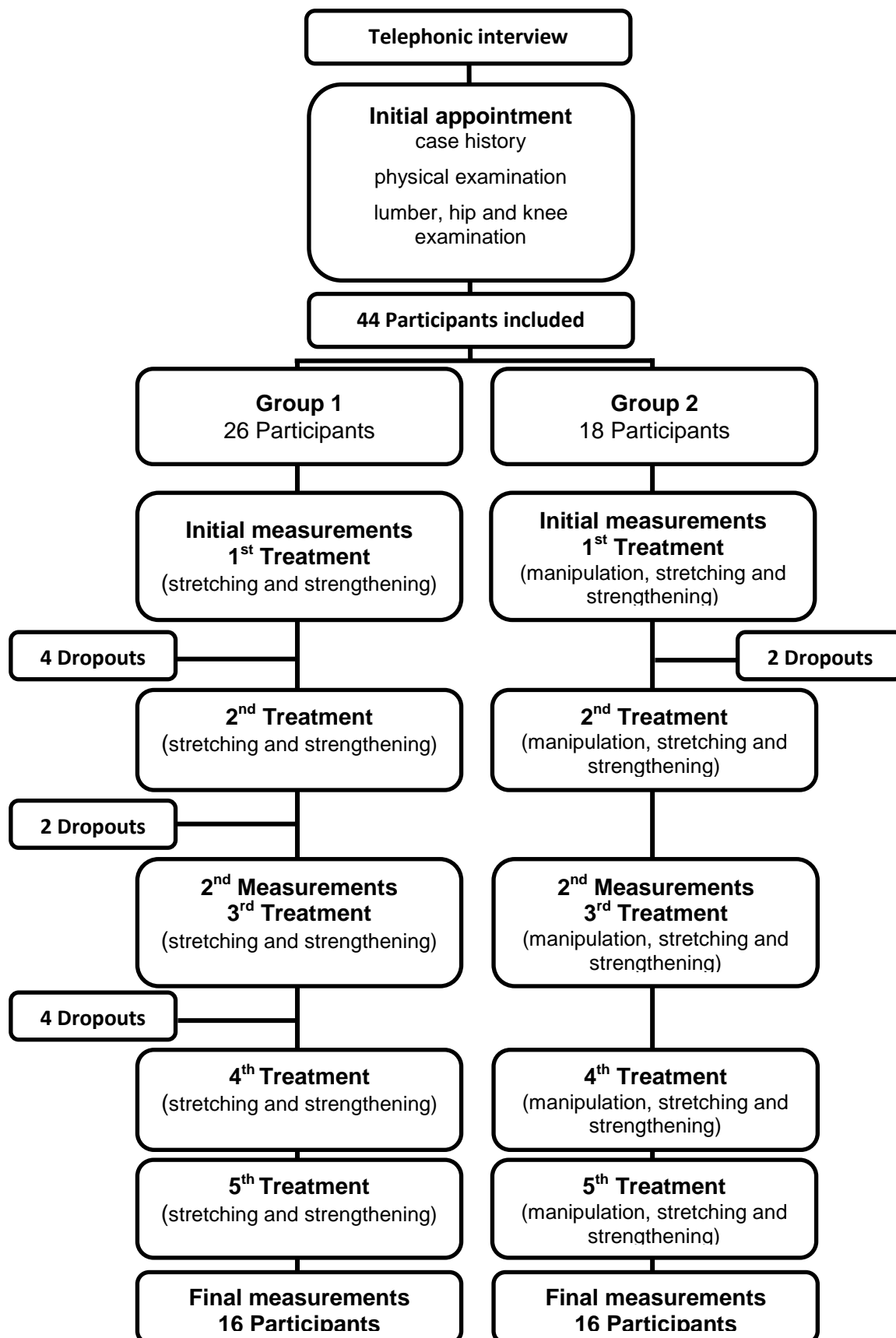


Figure 4.1: Consort diagram showing patient flow

4.6 RESULTS

4.6.1 Demographics

Comparison of demographics and baseline values between groups:

There was no difference between the two groups in terms of gender ($p=1.000$).

Table 4.1: Group by gender

			Gender		Total
			Female	Male	
Group	Group one (Control)	Count	3	13	16
		% within group	18.8%	81.3%	100.0%
	Group two (Manipulation)	Count	3	13	16
		% within group	18.8%	81.3%	100.0%
Total		Count	6	26	32
		% within group	18.8%	81.3%	100.0%

$p=1.000$

The two groups were also non-statistically significantly different according to age ($p=0.137$).

Table 4.2: Age by group

Group Statistics						p value
	Group	N	Mean	Standard Deviation	Standard Error Mean	
Age	Group one (Control)	16	31.69	6.509	1.627	0.137
	Group two (Manipulation)	16	35.75	8.410	2.103	

There were also no differences between the two groups in their baseline measurements (Table 4.3). Therefore the randomization process was complete and resulted in two equivalent group at baseline.

Table 4.3: Baseline outcome measurements by treatment group

Group Statistics						p value
	Group	N	Mean	Standard Deviation	Standard Error Mean	
(A) Digital Inclinator Straight leg raiser°	Group one (Control)	16	62.44	17.100	4.275	0.354
	Group two (Manipulation)	16	68.06	16.695	4.174	
(B) Hamstring Pressure Algometer (Kg/cm ²)	Group one (Control)	16	3.169	1.3951	0.3488	0.978
	Group two (Manipulation)	16	3.156	1.1719	0.2930	
(C) Sacroiliac Pressure Algometer (Kg/cm ²)	Group one (Control)	16	4.23	2.082	0.520	0.523
	Group two (Manipulation)	16	3.83	1.344	0.336	
(D) Pain at its Worst (out of 100)	Group one (Control)	16	70.63	12.093	3.023	0.747
	Group two (Manipulation)	16	68.69	20.516	5.129	
(E) Pain at its least (out of 100)	Group one (Control)	16	15.94	13.810	3.453	0.808
	Group two (Manipulation)	16	17.19	15.052	3.763	
Average NRS-101	Group one (Control)	16	43.2813	10.02990	2.50748	0.937
	Group two (Manipulation)	16	42.9375	14.01413	3.50353	

4.6.2 The Effect of the Manipulation

4.6.2.1 Digital Inclinator

There was a marginally non-significant treatment effect for this outcome ($p=0.079$). Figure 4.2 shows that the profiles overlapped at two points, one in the first half of the follow up period and one in the second. In the second half it appeared as if Group two (manipulation group) improved at a faster rate than Group one (control group), but this effect was not statistically significant.

Table 4.4: Within-subjects and between –subjects effects for digital inclinometer

Effect	Statistic	<i>p</i> value
Time	Wilk's lambda=0.245	< 0.001
Time*group	Wilk's lambda=0.839	0.079
Group	F=0.239	0.629

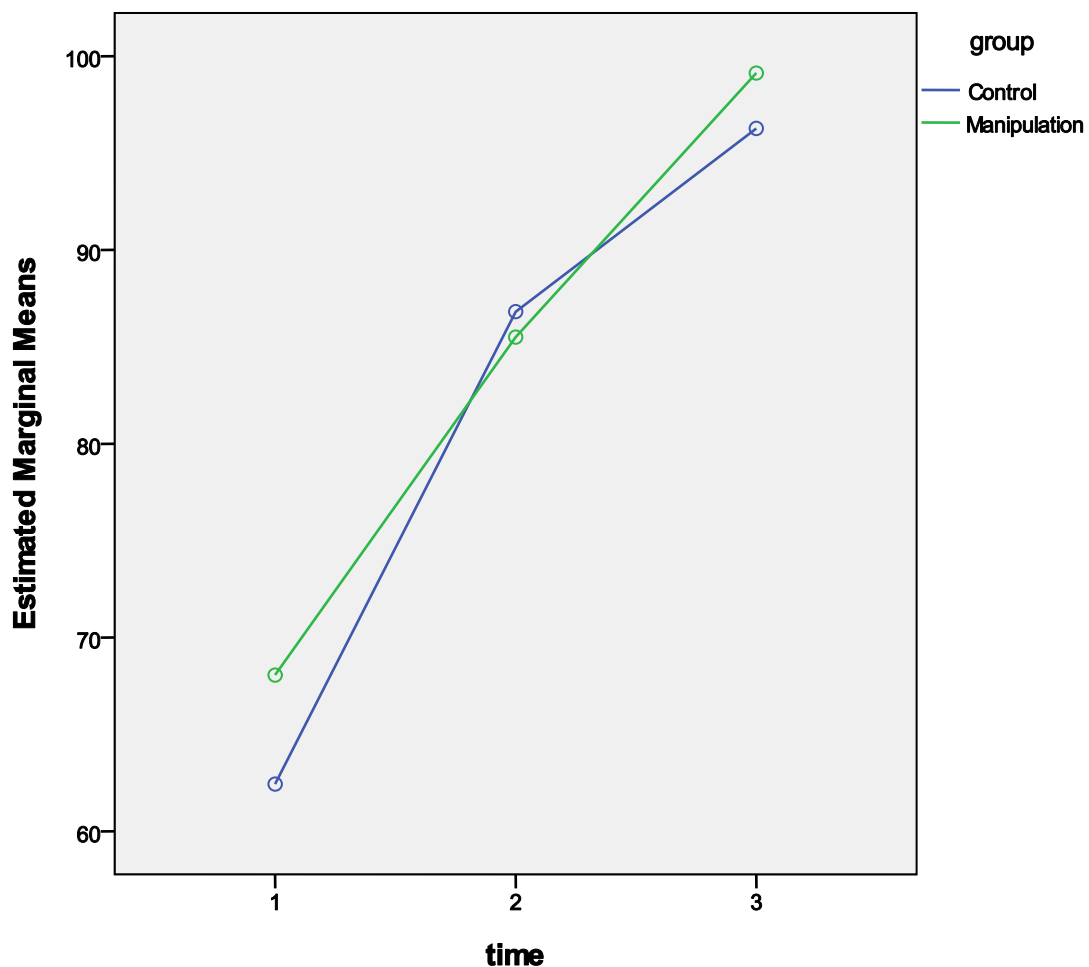


Figure 4.2: Profile plot of mean digital inclinometer measurement by group and time

4.6.2.2 Hamstring Pressure Algometer

There was no evidence of a treatment effect for this outcome ($p=0.377$).

Table 4.5: Within-subjects and between –subjects effects for hamstring pressure algometer

Effect	Statistic	<i>p</i> value
Time	Wilk's lambda=0.813	< 0.001
Time*group	Wilk's lambda=0.935	0.377
Group	F=0.380	0.542

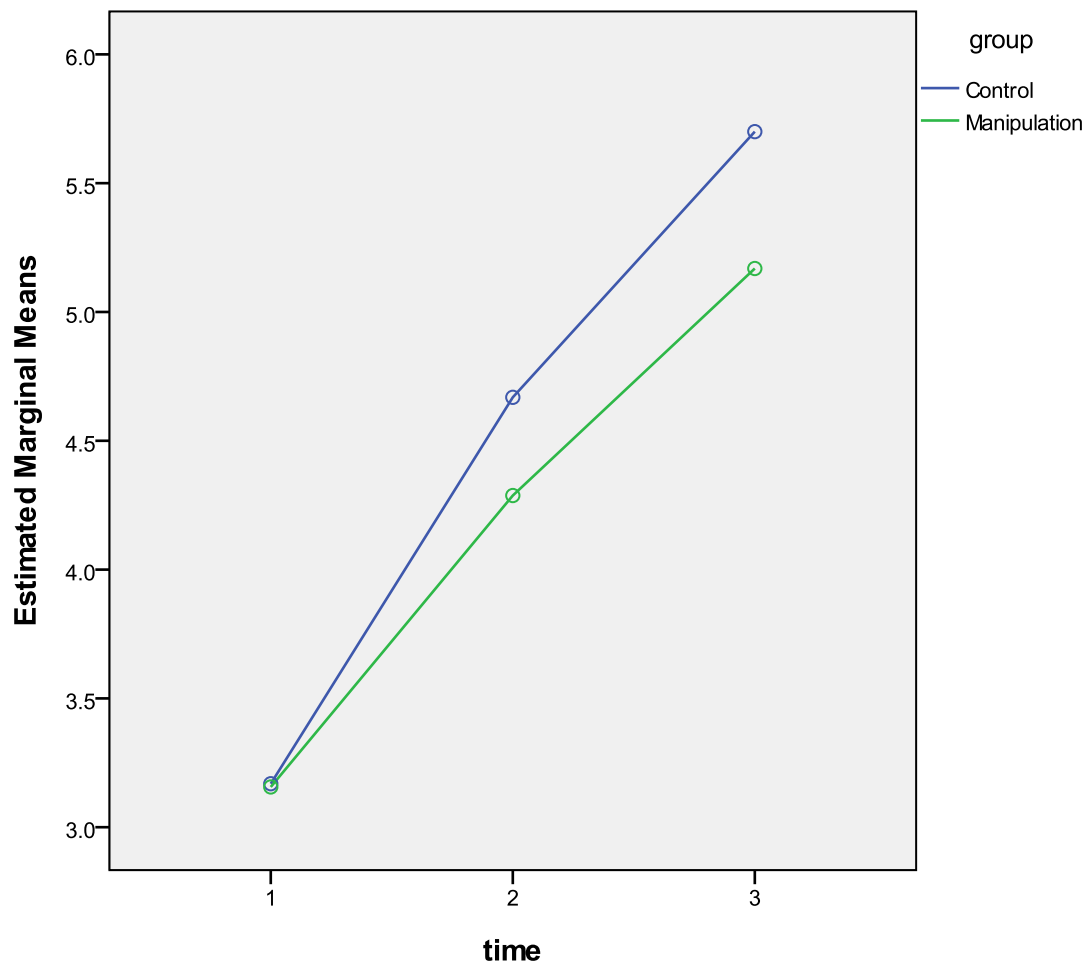


Figure 4.3: Profile plot of mean hamstring pressure algometer measurement by group and time

4.6.2.3 Sacroiliac Pressure Algometer

There was a marginally non-significant trend showing that Group two (manipulation group) performed better than Group one (control group) with regards to this outcome ($p=0.098$). This trend is reflected in Figure 4.4 which shows a crossing over of profiles and steeper rate of increase in Group one.

Table 4.6: Within-subjects and between –subjects effects for sacroiliac pressure algometer

Effect	Statistic	<i>p</i> value
Time	Wilk's lambda=0.323	< 0.001
Time*group	Wilk's lambda=0.852	0.098
Group	F=0.012	0.914

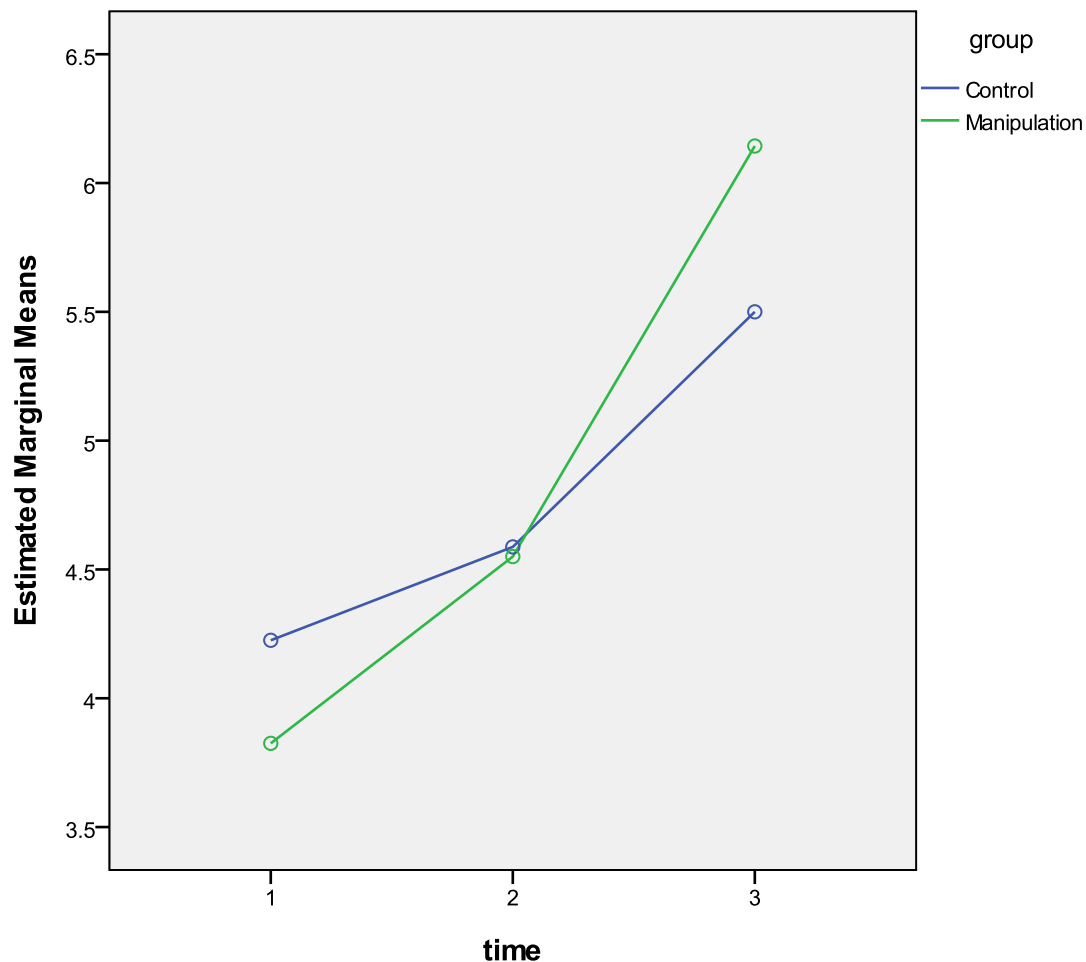


Figure 4.4: Profile plot of mean sacroiliac pressure algometer measurement by group and time

4.6.2.4 Numerical Pain Rating Scale (NRS-101)

There was no evidence of a treatment effect with regards to this outcome as both group improved to the same extent ($p=0.676$) as evidenced by almost parallel profiles in figure 4.5.

Table 4.7: Within-subjects and between –subjects effects for NRS-101

Effect	Statistic	<i>p</i> value
Time	Wilk's lambda=0.178	< 0.001
Time*group	Wilk's lambda=0.973	0.676
Group	F=0.046	0.831

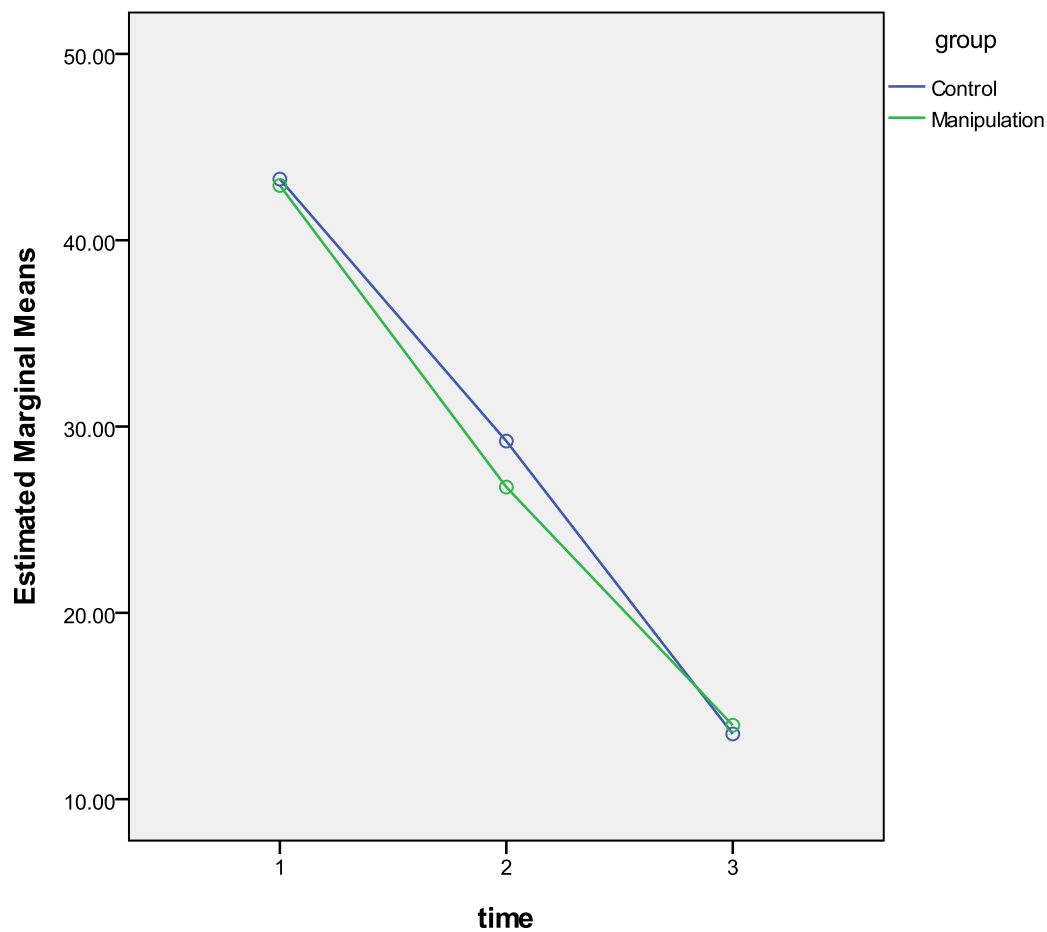


Figure 4.5: Profile plot of mean NRS-101 measurement by group and time

4.7 SUMMARY AND CONCLUSION

This study has not provided conclusive evidence that manipulation is of benefit. Where non-significant trends were shown, it is likely that this was due to lack of statistical power and that with a few more participants, the same effect size would have been statistically significant. Therefore, this study needs to be repeated with a larger sample size before definite conclusions can be made. Nevertheless, some of the results are encouraging and suggest that manipulation can be beneficial. For the Hamstring Pressure Algometer, the results may suggest that manipulation was less beneficial than control treatment but this needs to be verified with a larger sample.

4.8 HYPOTHESIS TESTING

Null hypothesis:

Manipulation combined with hamstring stretching and strengthening had no effect on chronic grade I or II hamstring injury recovery when compared to hamstring stretching and strengthening alone.

The null hypothesis was accepted for this study as there were no statistically significant results.

CHAPTER FIVE

5. DISCUSSION

5.1 INTRODUCTION

This chapter is concerned with the discussion and interpretation of the statistical results displayed in Chapter Four.

Objective data was obtained using a digital inclinometer and measuring passive straight leg raiser in a recumbent position, and using a pressure algometer to measure pain threshold at points of tenderness in the hamstring muscle and over the sacroiliac joint.

Subjective data was obtained using the numerical pain rating scale 101.

The first part of this chapter will analyse the data according to the demographics of the sample and the latter part will interpret the objective and subjective findings.

5.2 DEMOGRAPHICS

Of the 32 participants selected for the study, 6 were female and 26 male. The grouping demonstrated an even split with 13 male and 3 female in each of the two treatment groups. The predominance of male participants (81.3%) in this study may well be associated with the prevalence of hamstring injuries in the predominantly male sports of rugby and football (Roux et al., 1987; Jakoet and Noakes, 1998; Dadebo et al., 2004; Woods et al., 2004; Brookes et al., 2006; Holtzhausen et al., 2006). It is suggested that sporting data be included in future studies as this may also result in potential bias between the groups as a result of the likelihood of injury / re-injury.

The age of participants in this study ranged from 22 to 45 years, with a mean average of 31.69 years in Group one (control group) and 35.75 years in Group two (manipulation group). Orchard (2001), Verral et al (2001) and Gabbe et al. (2006) found increasing age to be a major risk factor in the occurrence of hamstring strains, and an average age of over 30 years in this study reinforces those findings.

The standard deviations between the two groups: Group one 31.69 +/- 6.509 (youngest 26 and oldest 38) and Group two 35.75 +/- 8.410 (youngest 28 and oldest 44), however, is greater and may be responsible for the lack of differences between the groups in terms of the outcomes of the study, with the older patients in Group one potentially negating the improvements in the younger participants in the same group. This is less likely in Group two which only has 12 years between its youngest and oldest participant. It is therefore suggested that even though randomization in this study seemed to achieve fairly comparable groups, that stratification according to gender, age and / or sport should be considered in future studies to determine the effect of these variables on the outcome of the studies.

Older patients would also have greater risk of sacroiliac dysfunction as a result of deterioration, with possible pain referral to the posterior thigh that may be complicate a hamstring injury (Schafer and Faye, 1990; Lippitt, 1997; Morris, 2006; Irwin et al. 2007; Paris and Viti, 2007). This may suggest that a greater number of Group two participants had a hamstring injury complicated by concomitant pain referral and, therefore, would not have responded as predicted.

5.3 BASELINE READINGS

There was no statistically significant difference between the baseline measurements of both groups, suggesting a well randomized sample selection. It was, however noted (Table 4.3 on page 43) that the Group one achieved consistently higher baseline readings with the sacroiliac algometer measures (indicating that they were able to sustain a greater kg/cm² for both readings as compared to the Group two). In contrast, the manipulation group seemed to record better inclinometer readings.

These baseline findings would seem to suggest that Group one had potentially lesser pain and dysfunction of the sacroiliac joint than Group two resulting in increased ability to sustain pressure. The increased inclinometer readings of Group two suggest a greater degree of hamstring disability in Group one than Group two. This might suggest a greater number of isolated hamstring injuries being included in Group one and a greater number of complicated hamstring injuries, or referred pain syndromes in addition to hamstring injuries, being

included in Group two. It may also be seen to suggest that some of the hamstring injuries included in Group two might be complicated by more severe sacroiliac dysfunctions.

These assertions would need to be revisited based on the outcomes of this study (as discussed in the next section) in order to determine their relevance.

5.4 INFERENCE ANALYSIS

5.4.1 Digital Inclinometry

Table 5.1 shows the average readings of passive straight leg raiser, as measured by digital inclinometer, for each group over the entire study.

Table 5.1: Digital Inclinometer straight leg raiser

Group		Reading 1	Reading 2	Reading 3	Mean Change (Reading 1 to 2)	Mean Change (Reading 2 to 3)	Overall Mean Change (Reading 1 to 3)
Group one (Control)	Mean	62.4375	86.8125	96.26667	24.375	9.45417	33.82917
	Standard Deviation	17.09959	17.10056	19.10298			
Group two (Manipulation)	Mean	68.0625	85.5	99.125	17.4375	13.625	31.0625
	Standard Deviation	16.69518	14.14685	13.0582			
Total	Mean	65.25	86.15625	97.74194	20.90625	11.58569	32.49194
	Standard Deviation	16.86761	15.45255	16.05193			

Group one had an improvement of 24.375 degrees over the first week of the study while Group two improved by 17.4375 degrees. This would concur with the assertions made from the baseline readings that Group one had less joint compromise and would thus respond more quickly to muscle related interventions (stretching and strengthening) in the early phase of the treatment after which they were likely to hit a plateau and only improve marginally thereafter. This agrees with the literature that shows that stretching programmes of the hamstring muscles increase mobility of the hamstring over time in the absence of serious sacroiliac

joint dysfunction and compromise (Bandy and Irion, 1994; Bandy et al, 1997; Hartig, 1999; Feland, 2001; Fox, 2006).

The early advantage of Group one was reversed in the second portion of the study when there was a 9.45417 degree improvement in flexibility of the control group and 13.625 degree improvement in Group two. This can be explained by Group two first requiring the removal of the arthrogenic muscle inhibition prior to responding to the muscle interventions (i.e. as muscle interventions would have been futile prior to sacroiliac joint manipulation), thus their inclinometer responses would have shown later. This is consistent with a study by Hoehler and Tobis (1982) that included manipulation and that showed a significant improvement in hamstring flexibility as a result of lumbosacral manipulation.

Despite the improvement in straight leg raiser being biased to Group one in the first week and to Group two in weeks 2 and 3, the overall improvement was statistically insignificant between the two groups, with 33.8297 degrees and 31.0625 degrees of improvement to Group one and Group two respectively. It is however noted that over time both groups improved significantly ($p < 0.001$) implying that both interventions had a significant effect on hamstring flexibility over the six week period.

Thus, the study shows that the results for inclinometry are inconclusive in this study's context, and suggestions for determining a more conclusive result are that:

- Future studies include a manipulation only group in order to determine when and to what extent an effect can be attributed to manipulation only. This concurs with Fox (2006), who suggests that any improvement in flexibility caused by manipulation might be overlooked and attributed to the concurrent stretching program (Fox, 2006).
- Further to this and based on a study conducted at the Technikon Witwatersrand by Fyfer (2005), it may be prudent to consider including distinct manipulation groups (viz. lumbar spine versus sacroiliac joint versus a combination of lumbar spine and sacroiliac joint manipulation) as his study seemed to indicate that sacroiliac joint manipulation alone demonstrated a statistically insignificant improvement in straight leg raiser over the course of his program.

- It should also be considered that future studies should perhaps run over a longer period as muscle strengthening is likely to show results after six – eight weeks, which was beyond the reaches of this study. Thus, intermediate and long term studies may show different results.

5.4.2 Pressure Algometry

Pressure algometry performed on tender points within the hamstring and over the sacroiliac joint showed contradictory results for the two groups.

Table 5.2 shows the average readings of pressure algometry performed over the sacroiliac joint for each group over the entire study. Table 5.3 shows the average readings of pressure algometry performed on the hamstring muscle for each group over the entire study.

Table 5.2: Hamstring pressure algometry

Group		Reading 1	Reading 2	Reading 3	Mean Change (Reading 1 to 2)	Mean Change (Reading 2 to 3)	Overall Mean Change (Reading 1 to 3)
Group one (Control)	Mean	3.16875	4.66875	5.7	1.5	1.03125	2.53125
	Standard Deviation	1.395096	1.892342	2.22486			
Group two (Manipulation)	Mean	3.15625	4.2875	5.16875	1.13125	0.88125	2.0125
	Standard Deviation	1.171875	1.30531	1.215302			
Totall	Mean	3.1625	4.478125	5.425806	1.315625	0.947681	2.26306
	Standard Deviation	1.267395	1.610797	1.766723			

Table 5.3: Sacroiliac pressure algometry

Group		Reading 1	Reading 2	Reading 3	Mean Change (Reading 1 to 2)	Mean Change (Reading 2 to 3)	Overall Mean Change (Reading 1 to 3)
Group one (Control)	Mean	4.225	4.5875	5.5	0.3625	0.9125	1.275
	Standard Deviation	2.081506	2.362731	2.654107			
Group two (Manipulation)	Mean	3.825	4.55	6.14375	0.725	1.59375	2.31875
	Standard Deviation	1.344371	1.487279	1.265422			
Total	Mean	4.025	4.56875	5.832258	0.54375	1.263508	1.807258
	Standard Deviation	1.735586	1.942137	2.048152			

Hamstring pain threshold, as demonstrated by hamstring pressure algometry, had identical baseline readings of 3.16875 / 3.15625 for both groups and Group one showed an overall improvement of 2.53125 compared to just 2.0125 for Group two. While statistically insignificant this result is easily distinguishable in Figure 4.2 on page 44. It is noted that while the baseline hamstring pain threshold readings were near identical, this did not necessarily suggest that there was an equal degree of injury of the hamstring muscles in both groups, as myofascial trigger points could have mimicked muscle strain in causing point tenderness.

The inversion of this result was seen in sacroiliac pain threshold, as demonstrated by sacroiliac pressure algometry, where Group one showed an overall improvement of 1.275 and Group two improved by 2.31875. This trend supports the assertion that Group two had increased sacroiliac dysfunction (may be an attribute of the increased older persons in this group) with greater severity than Group one. Nevertheless, this trend towards greater improvement in sacroiliac pain threshold in those who received manipulation can be related directly to the effects of the performed manipulation on the sacroiliac in question. Manipulation is the preferred method of treatment for sacroiliac joint dysfunction (Hendler et al, 1995; Haldeman, 2005) and this study shows a greater improvement in sacroiliac

pain threshold when manipulation is included in the treatment program. This difference may show clinical significance and further supports the effectiveness of manipulation in the treatment of sacroiliac pain and dysfunction.

This study shows an improvement in hamstring pain threshold for both groups, suggesting a degree of recovery of the hamstring injury in both groups as a result of the stretching and strengthening programme, although a control group who did not receive treatment was not included to rule out recovery over time. This could be improved upon in future studies by including a natural history group. Fyfer (2005) showed a statistically significant improvement in hamstring pain threshold as a result of sacroiliac manipulation alone, lumbar manipulation alone, and sacroiliac and lumbar manipulation combined, but this study failed to include a manipulation only group to examine the effects of manipulation when isolated from stretching or strengthening.

5.4.3 Summary

While both groups showed large improvements in terms of objective findings, there was no statistically significant difference between the two groups. The data showed the greatest difference between groups in the pressure algometry, although hamstring algometry favoured Group one and sacroiliac algometry favored Group two. Thus there was no overall statistically significant advantage to the inclusion of manipulation in a rehabilitation programme for hamstring strains in terms of objective measures but there was support for the use of stretching and strengthening programmes in hamstring injury rehabilitation and the use of manipulation in the treatment of sacroiliac pain and dysfunction. There was also cause to re-examine the design of the study as the inherent limitations become apparent. Diagnosis and examination for inclusion and exclusion factors was insufficient to rule out the inclusion of referred posterior thigh pain syndromes, particularly from the dysfunctional sacroiliac joint, and differential diagnoses for hamstring muscle injury such as myofascial trigger points.

5.5 SUBJECTIVE DATA

5.5.1 Numerical Pain Rating Scale 101

The numerical pain rating scale consisted of a rating from 0 to 100 for participants to rate their hamstring pain at its least (0) and worst (100), although this can be combined into a mean average of pain at the time of the measurement (as shown in Figure 4.4 and below). Overall the pain rating scale was almost identical in the two groups, showing no differences between control and intervention. Table 5.4 shows the mean NRS-101 readings for both groups throughout the study.

Table 5.4: Numerical Pain Rating Scale (NRS-101) (Average pain)

Group		Reading 1	Reading 2	Reading 3
Group one (Control)	Mean	43.125	29	13.46667
	Standard Deviation	10.01249	10.96054	11.18588
Group two (Manipulation)	Mean	42.8125	26.625	13.9375
	Standard Deviation	14.01532	13.55421	14.08767
Total	Mean	42.96875	27.8125	13.70968
	Standard Deviation	11.98247	12.18523	12.55705

What can be noted from the results in Table 5.4 is that while the mean readings between groups are very similar, the standard deviation of Group two's readings is far greater than that of the Group one. This demonstrates a greater variance in improvement of experienced pain within Group two, suggesting that some of the participants of this group had been much less responsive than others to the treatment. This supports the idea of more severe sacroiliac dysfunctions being present in some participants of Group two, possible due to the older patients shown to be in this group. This may have diluted the results supporting the use of sacroiliac manipulation.

5.5.2 Summary

The mean subjective ratings show no real difference between control and intervention groups, with a steady, even improvement in both groups over the course of the study. However if one analyses the standard deviation more closely it becomes apparent that Group two contains a much greater variance in readings,

demonstrating a greater improvement in some participants and a much lesser improvement in others. This result is clinically significant and can be the result of a number of different factors affecting the non- or minimally responsive patients. There may be factors affecting those participants that complicate the treatment of the hamstring injury, such as injuries with a greater level of chronicity which may require a longer period of treatment in order to achieve optimal results, or other injuries or abnormalities which may have been unrecognized, including myofascial pain syndromes or referred posterior thigh pain.

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

Both groups of this study showed improvements across the board over the three weeks. Inclinator readings of straight leg raiser improved by over 30 degrees between the first and sixth visit in both groups, but there was no statistical difference between Group one (control group) and Group two (manipulation group) that could indicate that the addition of sacroiliac manipulation was of any benefit. Pressure algometry of the injured hamstring muscle itself demonstrated a slight but statistically insignificant difference between the two groups, with the control performing better than the manipulation. Pressure algometry over the sacroiliac joint showed a greater improvement in the intervention group, but again the difference was statistically insignificant. The subjective measurements done by way of numerical pain rating scale (NRS-101) showed an even improvement in both groups with no statistically significant difference between control and manipulation, but a noticeable difference in the standard deviation of each groups readings, Group two showing far greater internal variance.

All of this information lends itself to the suggestion that the limitations of the study in excluding concomitant myofascial trigger points or referred posterior thigh pain may have resulted in some participants suffering from complicated muscle strains, possibly related to sacroiliac dysfunction.

Another factor is the broad nature of the hamstring injuries included, with no data gathered on chronicity, severity, recurrence or cause of injury. Injuries with a greater chronicity or severity may require a longer period of treatment in order to achieve optimal results. This would emphasise the need for ongoing assessment in the treatment of hamstring injuries, as well as demonstrate the importance of careful history taking and assessment to completely understand the pathogenesis of each specific injury. Of course there are many more factors that might have affected these few individuals and without a priori analysis at the outset of the study, it is difficult to conclusively state that these results would be applicable to all similar participants.

6.2 RECOMMENDATIONS

The following recommendations could increase the validity and improve the results of this study:

- The use of imaging techniques in the diagnosis and assessment of hamstring muscle strains would help to confirm and grade these injuries.
- More specific criteria in the inclusion of sacroiliac dysfunction would ensure consistency of participants.
- Collection of further demographic data including ethnicity and sport participation.
- Collection of further data on mechanics of injury, level of chronicity and specific grade of injury (I or II).
- More specific inclusion criteria with regards mechanics of injury, level of chronicity and grade of injury.
- A more comprehensive study including a greater number of objective and subjective measurements, including muscle strength and the bilateral measurements.
- A crossover study showing the result of manipulation at a later point in the study.
- A larger study involving increased number of participants may increase the significance of results.
- The addition of further subject groups, including a manipulation only group, lumbar manipulation groups, and placebo control/ natural history group.
- The involvement of an independent, blind observer to record measurements and eliminate researcher bias.

- The narrowing of variables such as age, gender, race or sport participation in order to increase validity.
- The inclusion of more comprehensive rehabilitation techniques including trunk stability.
- A longer study that followed participants' recovery in order to measure recurrence of chronic injuries in subsequent sports seasons and to ensure complete recovery of all injuries.
- A longer study that provided for injuries with greater levels of chronicity that may require a longer period of treatment.

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APPENDIX A



DURBAN
UNIVERSITY of
TECHNOLOGY

Faculty of Health Sciences

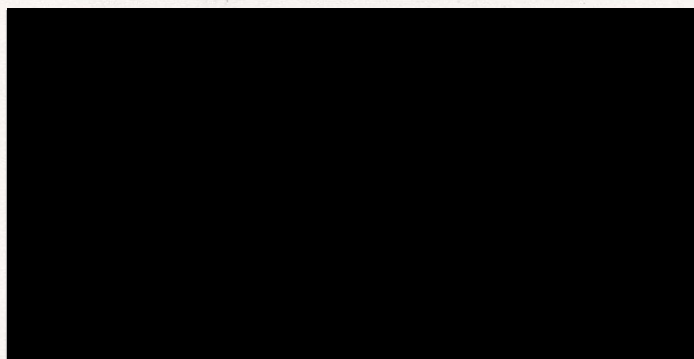
ETHICS CLEARANCE CERTIFICATE

Student Name	Brett Michael Allison	Student No	20300533
Ethics Reference Number	027/10	Date of FRC Approval	12/08/2010
Qualification	Mtech Chiropractic		
Research Title:	The effect of sacroiliac joint manipulation, when combined with conventional treatment, in the management of chronic hamstring strain.		

In terms of the ethical considerations for the conduct of research in the Faculty of Health Sciences, Durban University of Technology, this proposal meets with Institutional requirements and confirms the following ethical obligations:

1. The researcher has read and understood the research ethics policy and procedures as endorsed by the Durban University of Technology, has sufficiently answered all questions pertaining to ethics in the DUT 186 and agrees to comply with them.
2. The researcher will report any serious adverse events pertaining to the research to the Faculty of Health Sciences Research Ethics Committee.
3. The researcher will submit any major additions or changes to the research proposal after approval has been granted to the Faculty of Health Sciences Research Committee for consideration.
4. The researcher, with the supervisor and co-researchers will take full responsibility in ensuring that the protocol is adhered to.
5. **The following section must be completed if the research involves human participants:**

	YES	NO	N/A
❖ Provision has been made to obtain informed consent of the participants	x		
❖ Potential psychological and physical risks have been considered and minimised	x		
❖ Provision has been made to avoid undue intrusion with regard to participants and community	x		
❖ Rights of participants will be safe-guarded in relation to:	x		
- Measures for the protection of anonymity and the maintenance of Confidentiality.			
- Access to research information and findings.	x		
- Termination of involvement without compromise	x		
- Misleading promises regarding benefits of the research	x		



SIGNATURE: CHAIRPERSON OF RESEARCH ETHICS COMMITTEE

30/7/10
DATE

30/7/10
DATE

10/08/2010
DATE

10/08/10
DATE

APPENDIX B

Are you between the ages of

18 – 45?

And

Have an existing

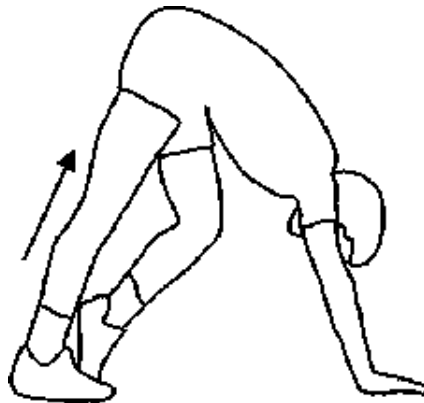
HAMSTRING INJURY?

Research is currently being done at the Chiropractic
Day Clinic at the Durban University of Technology

Should you qualify for the research, you will receive

FREE TREATMENT

This will include an assessment and treatment.



For more information, please contact

Brett

0845824008

(031) 373 2205 or (031) 373 2512

APPENDIX C

Letter of Information and Consent

Dear Participant,

Thank you for volunteering to be part of my study. I am a student currently pursuing my M. Tech: Chiropractic qualification at the Durban University of Technology

Research title: The effect of sacroiliac joint manipulation in the management of chronic hamstring strain when combined with conventional treatment.

Researcher: Brett Allison

Supervisor/s: Dr. Brian Kruger (supervisor) M. Tech: Chiropractic

The hamstring is one of the most common sites of muscle strain, with many strains becoming chronic over time. A chronic or recurrent hamstring strain can cause much disability in daily life, in particular in sport participation. The standard method of treatment for a chronic hamstring strain is to rehabilitate the injured muscle with stretching and strengthening protocols. Chiropractic manipulation of the sacroiliac joint has been shown to have positive effects on hamstring flexibility and injury, but very few studies have assessed the effectiveness of sacroiliac manipulation in conjunction with and comparison to standard rehabilitation. Therefore this study aims to determine the effectiveness of a sacroiliac manipulation when combined with conventional rehabilitation of a chronic hamstring strain.

Outline of procedure:

You will be required to have a case history, physical, lower back, hip and knee examination done at the chiropractic day clinic. The examination will determine your eligibility to join the study. Once accepted you will be required to sign an informed consent form after a full explanation of what the research involves. You will have the opportunity to ask questions about the procedures. This study consists of two groups, one receiving only a standard rehabilitation protocol and the other receiving this same protocol but with added sacroiliac manipulation. By partaking in the study you will be required to attend the clinic for a total of six appointments in three weeks, with two appointments evenly spaced per week. During all but the last of these appointments you will receive treatment. You will also need to perform a stretching and strengthening regime three times per day for the duration of the study.

Please ensure that while you are on this study that you do not receive any other treatment for your injured hamstring. In order for the research results to be accurate you are asked to follow the instructions given to you in terms of the treatments.

Benefits: This study will help health care practitioners determine the most effective means of treating and rehabilitating a strained hamstring muscle.

Risks/Discomforts to the Subject and Product info: It is possible for one to feel stiffness and tenderness post manipulation, although this does not suggest damage to the area. If this post manipulation stiffness occurs simply inform the researcher at your next visit.

Reason/s why the Subject May Be Withdrawn from the Study: You are free to withdraw at any time and it will not affect future treatments at the chiropractic clinic should you return.

Remuneration: By participating in this study there will be no cost to you nor will you receive any remuneration except for the free treatment.

Confidentiality: This will be maintained as only the researcher and supervisor will have access to the patient files, in the dissertation no personal information will be disclosed only the demographics and results of each group will be discussed.

Should you have any questions regarding the research please contact the researcher (Brett Allison) on 031 3732205 or 0845824008. If the researcher cannot be contacted please contact the supervisor (Dr Kruger) on 031 5649091 or the Mr V. Singh the faculty research coordinator at the Faculty of Health Sciences on 031 3732701.

Statement of Agreement to Participate in the Research Study:

I,..... (Full name)
.....(I.D), have read this document in its entirety and understand its contents. Where I have had any questions or queries, Brett Allison has explained these to me to my satisfaction. Furthermore, I fully understand that I may withdraw from this study at any stage without any adverse consequences and my future health care will not be compromised. I, therefore, voluntarily agree to participate in this study.

Subject's name:..... Subject's
signature.....

Date.....

Researcher's name:..... Researcher's
signature.....

Date.....

Witness name..... Witness
signature.....

Date.....

Thank you for your participation.

APPENDIX D
DURBAN UNIVERSITY OF TECHNOLOGY
CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient: _____ Date: _____

File # : _____ Age: _____

Sex : _____ Occupation: _____

Intern : _____ Signature: _____

FOR CLINICIANS USE ONLY:

Initial visit

Clinician: _____ Signature : _____

Case History:

Examination:

Previous:

Current:

X-Ray Studies:

Previous:

Current:

Clinical Path. lab:

Previous:

Current:

CASE STATUS:

PTT:

Signature:

Date:

CONDITIONAL:

Reason for Conditional:

Signature:

Date:

Conditions met in Visit No:

Signed into PTT:

Date:

Case Summary signed off:

Date:

Intern's Case History:

1. Source of History:

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

3. Present Illness:

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

4. Other Complaints:

5. Past Medical History:

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

6. Current health status and life-style:

- < Allergies
- < Immunizations
- < Screening Tests incl. x-rays
- < Environmental Hazards (Home, School, Work)
- < Exercise and Leisure
- < Sleep Patterns
- < Diet
- < Current Medication
- < Analgesics/week:
- < Tobacco
- < Alcohol
- < Social Drugs

7. Immediate Family Medical History:

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



8. Psychosocial history:

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

9. Review of Systems:

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

APPENDIX E

 D U R B A N UNIVERSITY of TECHNOLOGY		Durban University of Technology		 D U R B A N UNIVERSITY of TECHNOLOGY	
Patient Name :			File no :		Date :
Student :			Signature :		
VITALS:					
Pulse rate:			Respiratory rate:		
Blood pressure:	R	L	Medication if hypertensive:		
Temperature:			Height:		
Weight:	Any recent change? Y / N		If Yes: How much gain/loss	Over what period	
GENERAL EXAMINATION:					
General Impression					
Skin					
Jaundice					
Pallor					
Clubbing					
Cyanosis (Central/Peripheral)					
Oedema					
Lymph nodes	Head and neck				
	Axillary				
	Epitrochlear				
	Inguinal				
Pulses					
Urinalysis					
SYSTEM SPECIFIC EXAMINATION:					
CARDIOVASCULAR EXAMINATION					
RESPIRATORY EXAMINATION					
ABDOMINAL EXAMINATION					
NEUROLOGICAL EXAMINATION					
COMMENTS					
Clinician:			Signature :		

APPENDIX F

REGIONAL EXAMINATION - LUMBAR SPINE AND PELVIS



Patient: _____ File#: _____ Date: ____/____/____

Intern/Resident: _____ Clinician: _____

STANDING:

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

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

GAIT:

Normal walking
Toe walking
Heel Walking
Half squat

R. Rot

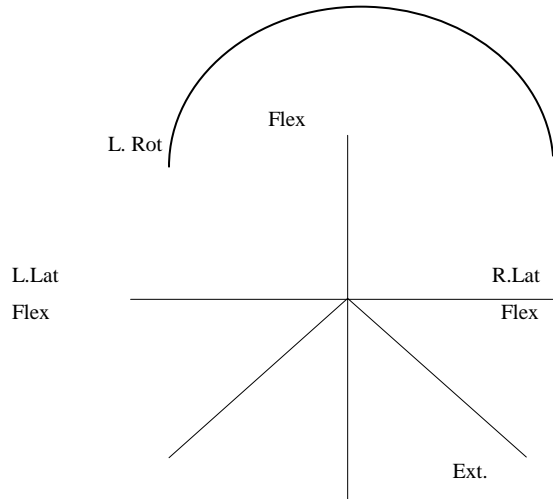
ROM:

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

Extension = 20-35°

L/R Rotation = 3-18°

L/R Lateral Flexion = 15-20°



Which movt. reproduces the pain or is the worst?

- Location of pain
- Supported Adams: Relief? (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

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

Slump 7 test	L										
	R										

LATERAL RECUMBENT:

	L	R
Ober's		
Femoral n. stretch		
SI Compression		

PRONE:

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

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

NON ORGANIC SIGNS:

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

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

NEUROLOGICAL EXAMINATION

Fasciculations

Plantar reflex

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

MYOTOMES

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

BASIC THORACIC EXAM

History
Passive ROM
Orthopedic

BASIC HIP EXAM

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

MOTION PALPATION AND JOINT PLAY

L

R

Upper Thoracics		
Lumbar Spine		
Sacroiliac Joint		

FEB 2007

DURBAN
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Patient: _____ File no: _____ Date: _____

Student: _____ Signature: _____

Clinician: _____ Signature: _____

Hip with complaint: Right ☐ Left: ☐

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

- **Anterior aspect**

Anterior aspect			Right	Left
1.	Iliac crests			
2.	Greater trochanter			
3.	Pubic symphysis and tubercle			
4.	Femoral head			
5.	Femoral Δ	Femoral artery		
		Lymph nodes		
6.	ASIS's			
7.	Inguinal ligament			
8.	Inguinal hernia			
9.	Muscles -	Quadriceps		
		Adductors		
		Abductors		
		Psoas		

Right	Left
-------	------

1.	Iliac crests posteriorly			
2.	Ischial tuberosity			
3.	Muscles	Piriformis		
		Gluteals		
		Hamstrings		
4.	PSIS's			
5.	Sciatic notch			
6.	SI joints			
7.	Lumbar Spine			
8.	Sacrum + coccyx			

Right		Left
-------	--	------

1.	Flexion (110-120°)		
2.	Extension (10-15°)		
3.	Adduction (30°)		
4.	Abduction (30-50°)		
5.	Medial rotation (30-40°)		
6.	Lateral rotation (40-60°)		

PASSIVE MOVEMENTS (<i>note end-feel, rom and pain</i>)		Right	Left
1.	Flexion (tissue stretch or approximation)		
2.	Extension (tissue stretch)		
3.	Adduction (tissue stretch or approximation)		
4.	Abduction (tissue stretch)		
5.	Medial rotation (tissue stretch)		
6.	Lateral rotation (tissue stretch)		
RESISTED ISOMETRIC MOVEMENTS (<i>note strength and pain</i>)		Right	Left
1.	Hip Flexion		
2.	Hip Extension		
3.	Adduction		
4.	Abduction		
5.	Medial rotation		
6.	Lateral rotation		
7.	Knee flexion		
8.	Knee extension		
REFLEXES		Right	Left
1.	Patella		
2.	Achilles		
DERMATOMES (<i>indicate deficits by level & location</i>)			
1.	Level		
2.	Location		
JOINT PLAY MOVEMENTS		Right	Left
1.	Caudal glide (long axis traction superior – inferior)		
2.	Compression @ 90° (inferior – superior)		
3.	Medial > lateral @ 180° / @ 90°		
4.	Lateral > medial @ 180° / @ 90°		
5.	Internal rotation		
6.	External rotation		
7.	Anterior > posterior		
8.	Posterior > anterior		
9.	Quadrant (scouring) test		
SPECIAL TESTS		Right	Left
1.	Patrick FABER Test		
2.	Trendelenberg Test		
3.	Craig's Test		
4.	Leg Length	Actual	
		Apparent	
5.	Sign of the Buttock		
6.	Thomas Test (hip flexion contracture)		
7.	Rectus Femoris Contracture Test		
8.	Iliopsoas contracture Test		
9.	Ely's Test (rectus femoris hypertonicity)		
10.	Ober's Test (ITB contracture)		
11.	Noble Compression Test (ITB Friction Syndrome)		
12.	Piriformis Test		
13.	Hamstrings	Hamstring Contracture Test	
		Tripod Test	

APPENDIX H

DURBAN UNIVERSITY OF TECHNOLOGY

KNEE REGIONAL EXAMINATION

Patient: _____ File: _____ Date: _____
 Intern: _____ Signature: _____
 Clinician: _____ Signature: _____

! **OBSERVATION** (Standing, Seated and during gait cycle).

A. Anterior view

Genu Varum: _____
 Genu Valgum: _____
 Patellar position: _____
 Tibial Torsion: _____
 Skin: _____
 Swelling: _____

B. Lateral view

Genu Recurvatum: _____
 Patella Alta: _____
 Patella Baja: _____
 Skin: _____

C. Posterior view

Swelling: _____
 Skin: _____

D. General

Movement symmetry: _____
 Structures symmetry: _____

! **ACTIVE MOVEMENTS**

Flexion (0 - 135E) _____
 Extension (0 - 15E) _____
 Medial Rotation (20 - 30E) _____
 Lateral rotation (30 - 40E) _____

! **PASSIVE MOVEMENTS**

Tissue approx _____
 Bone-bone _____
 Tissue stretch _____
 Tissue stretch _____
 Patellar movement _____

! **RESISTED ISOMETRIC MOVEMENTS**

Knee: Flexion: _____ Ankle: Plantarflexion _____
 Extension: _____ Dorsiflexion _____
 Internal rotation: _____
 External rotation: _____

! **LIGAMENTOUS ASSESSMENT**

One-Plane Medial Instability

Valgus stress (abduction) _____
 Extended _____
 Resting Position _____

One-Plane Lateral Instability

Varus stress (adduction) _____
 Extended _____
 Resting Position _____

One-Plane Anterior Instability

Lachman Test (0-30°) _____
 Anterior Drawer Sign _____

One-Plane Posterior Instability

Posterior "sag" Sign _____
 Posterior Drawer Test _____

Anterolateral Rotatory Instability

Slocum Test _____
 Macintosh Test _____

Anteromedial Rotatory Instability

Slocum Test _____

Posterolateral Rotatory Instability

Jacob _____
 Hughston's Drawer Sign _____
 Reverse pivot shift test _____

Posteromedial Rotatory Instability

Hughston's Drawer Sign _____

! **TESTS FOR MENISCUS INJURY**

McMurray _____
"Bounce Home" _____

Anderson med-lat grind _____
Apley=s _____

! **PLICA TESTS**

Mediopatellar Plica _____
Plica "Stutter" _____

Hughston's Plica _____

! **TESTS FOR SWELLING**

Brush/Stroke Test _____

Patellar Tap Test _____

! **TESTS FOR PATELLA FEMORAL PAIN SYNDROME**

Clarke's Sign _____
Waldron test _____

Passive patella tilt test _____

! **OTHER TESTS**

Wilson's _____
Fairbank's _____
Noble Compression _____

Quadriceps Contusion Test _____
Leg Length Discrepancy _____

! **JOINT PLAY**

Movement of the tibia on the femur
Translation of the tibia on the femur
Long axis distraction of the tibiofemoral joint
Inf, sup, lat, + med glide of the patella
Movement of the inf. tibiofibular joint
Movement of the sup. tibiofibular joint
Movement of the sup. tibiofibular joint

P | A: _____ A | P: _____
M | L: _____ L | M: _____

A | P: _____ P | A: _____
A | P: _____ P | A: _____
S | I: _____ I | S: _____

! **PALPATION**

Tenderness _____ Swelling _____
Joint line _____ Nodules/exostoses _____
Ligaments _____ Muscles: thigh: _____
Patella: _____ Leg: _____
Patella tendon: _____ Popliteal artery: _____
Bursae: _____

! **REFLEXES AND CUTANEOUS DISTRIBUTION**

	R	L
Patellar Reflex (L3,L4)		
Medial Hamstring Reflex (L5,S1)		

! **DERMATOMES**

	R	L		R	L
L2			S1		
L3			S2		
L4			S3		
L5					

07/02/2007

Patient Name:		File #:		Page:	
Date:		Visit:		Intern:	
Attending Clinician:		Signature:			
<div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> S: Numerical Pain Rating Scale (Patient) Least 0 1 2 3 4 5 6 7 8 9 10 Worst </div> <div style="width: 20%; text-align: center;"> Intern Rating <input style="width: 40px; height: 20px;" type="text"/> </div> <div style="width: 30%; text-align: right;"> A: </div> </div> <div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> O: </div> <div style="width: 30%; text-align: center;"> P: </div> <div style="width: 30%; text-align: right;"> E: </div> </div> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> Special attention to: </div> <div style="width: 45%; text-align: right;"> Next appointment: </div> </div>					
Date:		Visit:		Intern:	
Attending Clinician:		Signature:			
<div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> S: Numerical Pain Rating Scale (Patient) Least 0 1 2 3 4 5 6 7 8 9 10 Worst </div> <div style="width: 20%; text-align: center;"> Intern Rating <input style="width: 40px; height: 20px;" type="text"/> </div> <div style="width: 30%; text-align: right;"> A: </div> </div> <div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> O: </div> <div style="width: 30%; text-align: center;"> P: </div> <div style="width: 30%; text-align: right;"> E: </div> </div> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> Special attention to: </div> <div style="width: 45%; text-align: right;"> Next appointment: </div> </div>					
Date:		Visit:		Intern:	
Attending Clinician:		Signature			
<div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> S: Numerical Pain Rating Scale (Patient) Least 0 1 2 3 4 5 6 7 8 9 10 Worst </div> <div style="width: 20%; text-align: center;"> Intern Rating <input style="width: 40px; height: 20px;" type="text"/> </div> <div style="width: 30%; text-align: right;"> A: </div> </div> <div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> O: </div> <div style="width: 30%; text-align: center;"> P: </div> <div style="width: 30%; text-align: right;"> E: </div> </div> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> Special attention to: </div> <div style="width: 45%; text-align: right;"> Next appointment: </div> </div>					

APPENDIX J

Numerical Rating Scale - 101 Questionnaire

Date: _____ File no: _____ Visit no: _____

Patient name: _____

Please indicate on the line below, the number between 0 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 **one** number.

0 _____ 100

Please indicate on the line below, the number between 0 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 **one** number.

0 _____ 100

APPENDIX K

Patient name:

File number:

Treatment group:

Theraband strength:

	Digital Inclinator SLR	Hamstring Pressure Algometer	SI Pressure Algometer
Visit 1			
Visit 3			
Visit 6			

APPENDIX L

Stretching and Exercise Diary

In order to recover from your hamstring injury the following stretches and exercises must be done each day for the entire duration of the research study.

Static stretch - Sit on the floor with one leg bent and the leg to be stretched extended in front of you, then reach over this leg towards your toes. Hold this stretch for 30 seconds then relax. The stretch should be repeated 3 times in a row. Do 3 of these stretches 3 times a day (3 in the morning, 3 at lunch and 3 in the evening)

Prone leg curl - Attach the Theraband™ to a solid, safe object at ground level. Attach the other end to your ankle. Then once lying flat on your stomach bend your knee while keeping your thigh on the ground. The Theraband™ must provide resistance for the exercise. Perform 10 repetitions of the exercise then rest. Repeat the entire exercise 3 times, twice a day (3 sets in the morning and 3 sets in the evening).

Standing hip extension – Attach the Theraband™ to a solid, safe object at ground level. Attach the other end to your ankle. Then stand facing the object. Extend your leg behind you, keeping the knee straight. The Theraband™ must provide resistance for the exercise. Perform 10 repetitions of the exercise then rest. Repeat the entire exercise 3 times, twice a day (3 sets in the morning and 3 sets in the evening).

	Morning Stretch	Morning Exercises	Midday Stretch	Evening Stretch	Evening Exercises
Day 1					
Day 2					
Day 3					
Day 4					
Day 5					
Day 6					
Day 7					
Day 8					
Day 9					
Day 10					
Day 11					
Day 12					
Day 13					
Day 14					
Day 15					
Day 16					
Day 17					
Day 18					
Day 19					
Day 20					
Day 21					