The effect of sacroiliac joint manipulation on gluteus maximus muscle activity in asymptomatic participants.

By

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I, Kevin Worth, do declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate to the contrary)

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DEDICATION

To my family: Lynne, Brian and Kim. None of this would have been possible without you. I am deeply grateful for the sacrifices that you have all made for me to be able to complete this; I could not have come this far without you.

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ABSTRACT

Purpose: The effects of spinal manipulation are well documented; however there is a gap in the current literature regarding the exact mechanisms underlying the effectiveness of spinal manipulation. Further evidence is required to improve the understanding of the neurophysiological effects of spinal manipulative therapy and its effect on muscle activity. The objectives of this study were to investigate the effects of sacroiliac joint manipulation on gluteus maximus muscle activity in an asymptomatic sample group when compared to a placebo group

Methods: A randomized, controlled, pre-test, post-test repeated measures design allowed for 28 participants, aged 18-40 years old, with sacroiliac joint dysfunction to be allocated into either a sacroiliac joint manipulation or a placebo group. Muscle activity of the gluteus maximus was measured before intervention and again 10 minutes post intervention. IBM SPSS was used to analyse the data with significance set at ($p=0.05$). Repeated measures ANOVA testing was used to determine the significance within and between groups.

Results: There was evidence of an improvement in the intervention compared with the placebo group from pre to post for outcomes of Channel A mean and maximum values, and for Channel B maximum values. In the other measures there was a trend observed but insufficient evidence to conclude that it was a real effect. The partial eta squared values were relatively small for these non-significant effects and medium to large for the significant effects.

Conclusion: Analysis of the results revealed that there was evidence of an improvement in the intervention group when compared with the placebo group in some of the outcomes measured while other outcomes measured trended towards an improvement but lacked a sufficiently large sample size to conclude that it was a statistically significant effect.

Key indexing terms: Sacroiliac joint, electromyography, manipulation, muscle activity.

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LIST OF ABBREVIATIONS

ACH: - acetylcholine

ACHE - acetylcholinesterase

ADP: - adenine diphosphate

AP: - action potential

ASIS: - anterior superior iliac spine

ATP: - adenine triphosphate

BMI: - body mass index

Ca^{2+}: calcium ions

cm: - centimeters

CNS: – central nervous system

DUT: - Durban University of Technology

EMG: - electromyography

GTO: - golgi tendon organs

HVLA: - high velocity low amplitude

IVD: - intervertebral disc

IVF: - intervertebral foramen

kg: - kilogram

LBP: - low back pain

LMN: lower motor neuron

Max: - maximum

Min: - minimum

mm: - millimetre

ms: - millisecond

MS: - muscle spindle

mV: -millivolts

MVC: - maximum voluntary contraction

MVIC: - maximum voluntary isometric contraction

***n*:** - sample number

Na^+: - sodium ions

NMJ: - neuromuscular junction

PNS: - peripheral nervous system

PSIS: - posterior superior iliac spine

ROM: - range of motion

RMS: root mean square

SD: - standard deviation

SEMG: - surface electromyography

SI: - sacroiliac

SIJ: - sacroiliac joint

SM: - spinal manipulation

SMT: - spinal manipulative therapy

TLF: - thoracolumbar fascia

µm: micrometer

UMN: upper motor neuron

Definitions

Afferent nerve: A sensory nerve transmitting impulses to the central nervous system (CNS) (Taber's Cylopedic Medical Dictionary 2013).

Articulation: A joint; the site of close approximation of two or more bones. It may be immovable, slightly movable or freely movable (Taber's Cylopedic Medical Dictionary 2013).

Asymptomatic: Without symptoms (Taber's Cylopedic Medical Dictionary 2013).

Body mass index: An index for estimating obesity. This can be obtained by dividing weight in kilograms by height in meters squared (Taber's Cylopedic Medical Dictionary 2013).

Cavitation: An audible crack or pop following deep mobilization or joint manipulation (Bergmann and Peterson 2011).

Efferent nerve: A sensory nerve that transmits impulses from the brain or CNS towards the periphery (Taber's Cylopedic Medical Dictionary 2013).

Facilitation: The hastening of an action or process; the addition of the energy of a nerve impulse to that of other impulses activated at the same time (Taber's Cylopedic Medical Dictionary 2013).

Force closure: Forces acting across a joint to create stability (Takasaki *et al*).

Joint dysfunction: Joint mechanics showing disturbances of function without structural change resulting in affected quality and range of motion. This can be increased motion (hypermobility), decreased motion (hypomobility) or aberrant motion (instability) (Bergmann and Peterson 2011).

Joint fixation: The state whereby an articulation has become temporarily immobilized in a position that it may normally occupy during normal physiological movement (Bergmann and Peterson 2011).

Joint manipulation: A manual procedure that involves a directed thrust to move a joint past normal physiological range of motion without exceeding the anatomical limit. It is commonly associated with an audible crack or cavitation (Bergmann and Peterson 2011).

Mechanoreceptors: Mechanically sensitive neurons found within a joint's structure and surrounding tissues (Tortora and Derrickson 2009).

Motion palpation: A procedure using the hands to assess the active and passive range of motion of a joint segment (Bergmann and Peterson 2011).

Motor neuron: Neural structures that transfer impulses from the CNS to muscle tissue in order to stimulate contraction or glands for secretion (Taber's Cylopedic Medical Dictionary 2013).

Muscle strength: The maximum force that can be generated by a muscle or muscle group (Taber's Cylopedic Medical Dictionary 2013).

Placebo: A method used as an inactive control as a test of a treatment that is suspected of being useful in the treatment of a certain condition (Taber's Cylopedic Medical Dictionary 2013).

Proprioception: The awareness of posture, movement, and changes in equilibrium (Taber's Cylopedic Medical Dictionary 2013).

Sensory neuron: Neural structures capable of transmission of afferent information or sensation (Taber's Cylopedic Medical Dictionary 2013).

Surface electromyography: An electrical, non-invasive, method of recording electrical activity of selected muscle groups while at rest and during voluntary contraction (Taber's Cylopedic Medical Dictionary 2013).

CHAPTER ONE

Introduction

1.1 Introduction

Spinal manipulative therapy (SMT) is one of the most frequently used treatments for patients with low back pain (LBP) (Hancock *et al.* 2008). SMT is practiced by many practitioners including and specifically chiropractors and has been proven to be useful in the treatment and management of LBP (Ferreira *et al*. 2003; Bronfort *et al*. 2004; Potter, McCarthy and Oldham 2005; Goertz *et al*. 2012). It is a technique which is aimed at joints with reduced or restricted movement, known as joint restrictions, in order to return a joint to full range of motion (ROM). Joint restrictions may be as a result of muscle spasm at a segmental level, soft tissue fibrosis, intercapsular adhesions and intradiscal derangements (Bergmann and Peterson 2011:112). Altered biomechanics of the SIJ may result in pain and weakness resulting in further dysfunction of the joint and surrounding musculature (Cholewicki, McGills and Norman 1991). For the pelvis to function normally the SIJ requires stability and some movement to act as a shock absorber between the lower limbs and trunk, as well as a proprioceptive feedback mechanism to co-ordinate and control movement (Tucker 2011).

There is a poor understanding of the exact mechanism underlying the effectiveness of SMT (Herzog, Scheele and Conway 1999; Colloca and Keller 2001). Three main theories exist to explain the effect of SMT; biomechanical, neurophysiological and muscular reflexogenic theories (Potter, McCarthy and Oldham 2005). These suggest that SMT may have a physiological effect resulting in a change of flow of sensory feedback to the central nervous system (CNS), which in turn could affect the surrounding musculature (Pickar 2002).

The original theory used to describe the neurophysiological mechanism of SMT was proposed by Korr (1978), who suggested that when SMT is applied to a restricted spinal level, the surrounding hypertonic muscles are stretched, affecting their muscle fibres and causing a substantial increase of neurological impulses to the CNS. This in turn results in a decrease of gamma efferents leading to normal gamma gain and muscle tone by relaxing the muscle (Gatterman 2005; Leach 2004). While McCarthy, Potter and Oldham (2019) showed that a general thrust procedure was as effective in reducing low back pain in participants.

The gluteus maximus muscle originates at the ilium, posterior to the posterior gluteal line, the posterior surface of the sacrum and coccyx, and the sacrotuberous ligament. The distal fibres end in iliotibial tract; this inserts into the lateral condyle of the tibia. It is innervated by the inferior gluteal nerve (L5, S1, S2) and it is involved in thigh extension and lateral rotation (Moore, Dalley and Agur 2010: 564). The Sacroiliac Joint (SIJ) is innervated by the ventral rami of L4 and L5, the superior gluteal nerve, and the dorsal rami of L5, S1 and S2 (Forst *et al.*2006). The gluteus maximus fibres attach to the sacrum and assist in pulling the sacrum laterally into the ilium and have an important function in the force closure of the SIJ (Vleeming *et al*. 2012) through the posterior oblique sling (Vleeming *et al.* 2007*)*. It has also been suggested that malrecruitment of the motor units of gluteus maximus during weight bearing may be a possible cause of SIJ dysfunction (Hossain and Nokes 2005). Due to the intimate relationship, close proximity and shared neurological innervations the gluteus maximus shares with the SIJ, the gluteus maximus was chosen for this study.

Colloca and Keller (2000) have demonstrated that SMT has a significant effect on erector spinae maximum voluntary contraction (MVC) in participants with mechanical LBP compared to a placebo and a control group. This suggests that SMT may have an effect on sensory neurological response; this resulted in altered efferent pathways at that spinal level and therefore may affect muscle strength at the segmental level being manipulated. No study currently exists on the effects of SMT on the SIJ and its effects on the surrounding musculature in terms of SEMG readings, therefore this study was conducted.

1.2 The aim

The aim of this study is to determine the effect of manipulation applied to the sacroiliac joint, compared to a placebo intervention in terms of surface EMG readings of the associated gluteus maximus maximum voluntary contraction in asymptomatic participants.

1.3 The objectives

The objectives of this study are:

To determine the effect of sacroiliac joint manipulation on gluteus maximus muscle MVC in terms of maximum, minimum and mean values.

To determine the effect of placebo intervention of the sacroiliac joint on gluteus maximus muscle MVC in terms of maximum, minimum and mean values.

To compare the results between the two groups in terms of SEMG readings.

1.4 The hypotheses

1.4.1 Null hypothesis

The null hypothesis states that:

There will be no statistically significant improvement in pre- and post-SIJ manipulation in terms of maximum, minimum and mean values.

There will be no statistically significant improvement in pre- and post-placebo intervention in terms of maximum, minimum and mean values.

There will be no significant difference between the groups in terms of objective outcomes.

1.4.2 Alternate hypothesis

The alternate hypothesis states that:

The group receiving the sacroiliac joint manipulation will show a statistically significant

($p < 0.05$) improvement in gluteus maximus muscle activity in terms of maximum, minimum and mean values when compared to the placebo group.

1.5 Scope of the study

This study was a quantitative, randomised placebo controlled, single blinded, pre-test/post-test experimental design. Twenty-eight male participants asymptomatic for pain were randomly assigned to either the intervention group that received a manual SIJ manipulation, or the placebo group that received a sham manipulation. SEMG measurements were taken pre- and post-intervention. Participants were not excluded if they had known about or been exposed to chiropractic care. Data was captured in an Excel spreadsheet and analysed. A p value <0.05 was considered statistically significant.

1.6 Flow of dissertation

Chapter one introduces the reader to the study, as well as outlining the rationale for the study, together with the aims, objectives and study hypothesis.

Chapter two, the literature review, will provide an overview of the relevant anatomy, physiology, biomechanics and neurology related to the sacroiliac joint, as well as an overview of sacroiliac joint dysfunction, surface electromyography and chiropractic theories on manipulation.

Chapter three describes the methodology utilised in this study to achieve the aims and objectives. It also provides an outline for the study design, population and sampling strategy, methods, techniques and instruments used, as well as the data analysis and ethical issues.

Chapter four presents the results of the study. The demographic and characteristics of the sample, together with the SEMG data, are presented using figures and tables.

Chapter five provides an analysis and discussion of the results in this study as they relate to the current literature.

Chapter six concludes the study, discussing the study limitations and recommendations.

CHAPTER TWO:

LITERATURE REVIEW

2.1 Introduction

This chapter provides a review of the literature surrounding the anatomy, neurology, physiology and the biomechanics relevant to this study. This chapter also aims to familiarise the reader with theories explaining the effects of spinal manipulative therapy, as well as an understanding of the gluteal muscles and sacroiliac joint dysfunction.

2.2 An overview of the pelvis

The bony pelvis consists of the pelvic girdle; this is formed by two hip bones laterally and the sacrum posteriorly. These unite posteriorly to form the sacroiliac joints (SIJ) and anteriorly to form the pubic symphysis (Moore, Dalley and Agur 2010).For the purpose of this study only the SIJs will be discussed in depth. It is however important to mention the hip joint and pubic symphysis as they are relevant to the biomechanics of the SIJ as they allow for nutation and counternutation (Muscolini 2011: 275; Tortora and Derickson 2011).

2.3.1 Joints of the pelvis

2.3.1.1 The sacroiliac joint

The SIJs are formed through an articulation between the sacrum and its corresponding lateral ilia. These consist of a synovial joint anteriorly between the auricular surfaces, and a posterior syndesmosis between the tuberosities (Moore, Dalley and Agur 2010). The SIJs are true synovial joints as they share a joint cavity containing synovial fluid and are enclosed by a joint capsule (Bergmann and Peterson 2011).

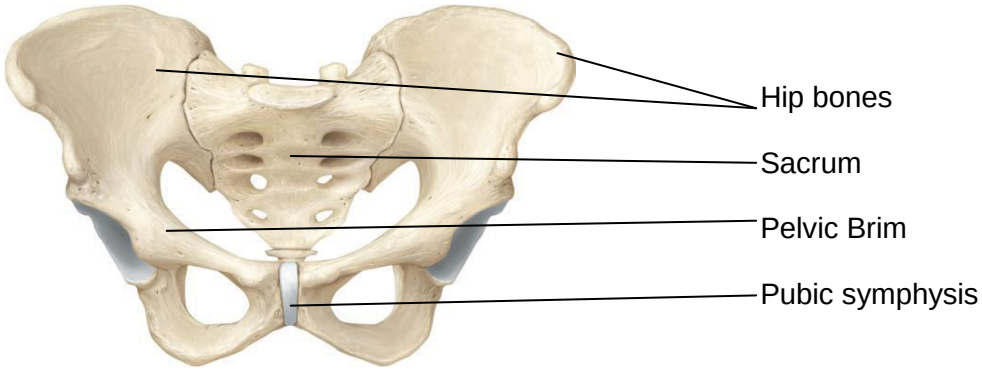

Figure 1: Illustration of a sacroiliac joint (Tortora and Derickson 2011)

There is very limited literature surrounding the joint capsule of the SIJ. Bogduk and Endres (2005) attributes this to the joint being so closely surrounded by a thick ligament, making it difficult to determine where the ligament ends, and the capsule begins. This has led to authors such as Bogduk and Endres reporting on the posterior capsule as being rudimentary or possibly absent, and that the anterior capsule thickens to form the anterior sacroiliac ligament.

The articulating surfaces of the SIJ are described as auricular in shape; this is unique and important in their function (Moore, Dalley and Agur 2010). These surfaces have dissimilar contours that allow an interlocking mechanism through alternating depressions and elevations (Bergmann and Peterson 2011). This interlocking mechanism stabilises the joint to aid in effective weight distribution to be transferred from the axial skeleton through the pelvic rim to the lower limbs while standing, and to the ischial tuberosities when sitting (Moore, Dalley and Agur 2010). Forces from the lower extremities are distributed posteriorly towards the spine and anteriorly to the pubic symphysis (Bergmann and Peterson 2011:263).

Despite acceptance that the SIJ is a mobile joint, there is some dispute as to how much movement occurs and where the axes of motion are located (Bergmann and Peterson 2011). Bogduk and Endres (2005) suggest that the average range of motion of the SIJ is about one degree, and that this movement helps to support its function as a stress-relieving joint.

During flexion of the hip the ipsilateral ilium glides backwards and downwards across the sacrum and compresses against it, rotating at the pubic symphysis. During hip extension the ilium glides forwards and flares away from the sacrum. These movements are produced by the mass of the trunk acting on the sacrum and tension exerted by the muscles of the lower limb on the ilium (Bogduk and Endres 2005).

Singular sagittal plane movements of the sacral base - referred to as nutation (movement anteriorly and inferiorly) and counternutation (movement posteriorly and inferiorly) - occur only during flexion and extension of the trunk, and when moving from the upright, seated and recumbent positions (Bergmann and Peterson 2011).

The sacroiliac joint is innervated by the L4 and L5 ventral rami, the superior gluteal nerve and the L5, S1 and S2 dorsal rami or from the sacral dorsal rami (Forst *et al.* 2006).

The SIJs function as strong, weight bearing joints and are restricted in mobility, this allows for their role in transferring weight from most of the body through the hip bones (Moore, Dalley and Agur 2010).

2.3.1.1.1 Sacroiliac joint dysfunction

Sacroiliac joint dysfunction is characterised by abnormal movement of the joint. This movement may be excessive, diminished, or malalignment of the joint. This abnormal movement results in excessive stress on the surrounding structures and often causes local or referred pain to the lumbar, pelvis or gluteal region. SIJ dysfunction often presents as sharp or shooting pain that radiates down the posterior thigh but typically does not extend past the knee; it is often worsened when lying on the affected side or climbing stairs. It is frequently misdiagnosed as radicular pain. (Poley and Borcher 2008; Raj and Varacallo 2019).

2.3.1.1.2 The posterior oblique sling

The posterior oblique sling (POS) is a group of muscles comprising of the gluteus maximus, latissimus dorsi and biceps femoris (Liebson 2004) and acts to stabilise the SIJ through force closure as well as transfer force during forward flexion (Page, Frank and Lardner 2010). Vleeming *et al*. (2007) showed that the SIJ may be affected by the functional relationship of the POS muscles. For this reason, it was of interest that the gluteus maximus muscle was selected for testing MVC.

2.3.1.1.3 The posterior muscle chain

The posterior muscle chain is comprised of the thoracic, lumbar and hip extensor muscles. Studies have reported that reduced muscle strength, endurance and diminished motor control in this chain has been noted, and subsequent studies have shown lower endurance times in those with low back pain (Ridder *et al.* 2013).

2.3.1.1.4 The thoracolumbar fascia

Fascia is a fibrous connective tissue that surrounds skeletal muscle that has historically been considered as a passive sheath with minimal significance on movement. More recently there has been an increase in research and understanding that has suggested that fascia may play a role in proprioception, pain perception, change In tone and movement (Wilke *et al*. 2017).

The thoracolumbar fascia (TLF) is made of several layers that separate the paraspinal muscles from the muscles of the posterior abdominal wall, quadratus lumborum and psoas major (Willard *et al*. 2012). Willard *et al.* (2012) noted that tension applied by the surrounding

muscles may be transmitted through the TLF resulting in a stiffening of the lumber spine and increased force-closure of the SIJ, this would aid in increasing stability of the pelvis. It was also noted that the TLF receives both proprioceptive and nociceptive innervation which suggests a possible role in back pain.

2.3.1.1.4 Form and force closure

The sacroiliac joint achieves stability through a complex mechanism. Form closure refers to the theoretical state of stability of a joint through close fitting articular forces that require no additional external forces to maintain this stability. However this would significantly reduce the mobility of the joint. The SIJ achieves this through interfacing joint surfaces, “wedging” of the sacrum into the ilia, corresponding ridges and grooves along the surface of the SIJ, and ligaments that bind the joint (Vleeming and Schuenke, 2019).

Force closure is the theoretical state where a joint achieves stability through lateral forces and friction leading to joint compression. This is achieved through force via ligaments, fascia, muscles and ground reaction force (Vleeming and Schuenke, 2019). These are extremely important as a change in the form and force closure of the SIJ will be as a result of a dysfunctional joint.

2.3.1.2 The pubic symphysis

The pubic symphysis is a secondary fibrocartilaginous joint that consists of the interpubic disc and its surrounding ligaments that unite the two pubic bones in the midline anteriorly (Moore, Dalley and Agur 2010). The pubic symphysis is innervated by branches of the iliohypogastric, ilioinguinal and pudendal nerves (Becker, Woodley and Stringer 2010).

2.3.1.2 The hip joint

The hip joint is a synovial ball and socket that is comprised of the acetabulum of the os coxae and the head of the femur. The joint is composed of the articular capsule which attaches from the acetabulum to the femur; and the iliofemoral ligament, that originates from the anterior inferior iliac spine and inserts in the intertrochanteric line of the femur (Tortora and Derickson 2011).

2.3.2 Ligaments of the pelvis

There are numerous ligaments related to the pelvic region. Only those relative to the SIJ will be discussed in the context of this research, as shown in Table 1. These ligaments are numerous and strong and play an important role in the stability of the SIJ via force closure (Vleeming *et al.* 2012).

Table 1: Attachments and functions of the ligaments of the sacroiliac joint.

Ligament name	Attachments	Function
Interosseous sacroiliac ligament	Between the sacrum and the ilium, dorsal to the joint. The superficial band attaches to the sacrum laterally at S1 and S2 to the medial portion of the iliac crest.	The strongest of the SIJ ligaments, this ligament functions to attach the ilium to the sacrum to stabilise the bony interlocking mechanism and provide multidirectional stability.
Posterior Sacroiliac ligament	Located posteriorly to the interosseous ligament. The long posterior SI ligament consists of long fibres that attach medially to the sacrum laterally at S3 and S4, and laterally to the posterior superior iliac spine (PSIS) and the posterior aspect of the inner lip of the iliac crest.	Connects the lateral aspects of the sacrum to the PSIS, and the posterior aspect of the iliac crest. The long posterior SI ligament tightens and prevents counternutation of the sacrum. The short posterior SI ligament prevents flaring or diastasis of the joint.
Anterior Sacroiliac ligament	Thickening of the anterior portion of the fibrous joint capsule. Consists of multiple transverse fibres that attach from the ala and anterior surface of the sacrum to the anterior surface of the ilium.	Connects the ilium to the sacrum and prevents anterior separation of the joint.
Sacrospinous ligament	Consists of a wide origin medially from the lateral edge of the sacrum below the SIJ. Its fibres join laterally on the ischial spine.	This ligament is orientated to prevent upward slanting of the inferior portion of the sacrum by anchoring it to the ischium. Aids in preventing nutation of the joint.
Sacrotuberous ligament	Arises from the PSIS to join with the long posterior SI ligaments; from the transverse tubercles of the lower sacral segments, and from the lateral margin of the sacrum, where it unites with the sacrospinous ligament. It narrows and broadens again before attaching to the medial aspect of the ischial tuberosity.	This ligament is orientated to prevent upward slanting of the inferior portion of the sacrum by anchoring it to the ischium. Aids in preventing nutation of the joint.

(Adapted from Bogduk and Endres 200; Moore, Dalley and Agur 2010; Vleeming *et al.* 2012)

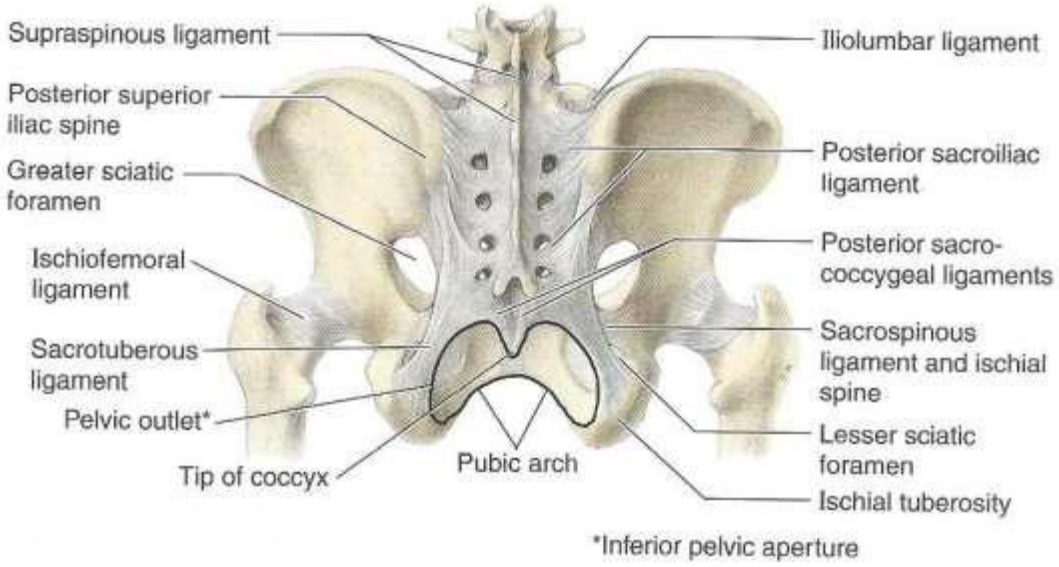

Figure 2: Ligaments of the posterior aspect of the pelvis (Moore, Daley and Agur 2010).

2.4 An overview of the musculature of the gluteal region

The musculature of the gluteal region are organised into two layers consisting of a superficial and deep layer. (Moore, Dalley and Agur 2010)

2.4.1.1 The superficial muscles of the gluteal region

The superficial layer is comprised of three overlapping gluteal muscles - the gluteus maximus, medius and minimus, and the tensor of fascia latae. These attach proximally to the lateral surface of the ilium, and act mainly as extensors, abductors and medial rotators of the hip (Moore, Dalley and Agur 2010). These are discussed in Table 2:

Table 2: Superficial Muscles of the gluteal region.

Muscle	Proximal attachment	Distal attachment	Innervation	Action
Gluteus maximus	Posterior iliac crest, posterolateral sacrum and coccyx.	Iliotibial band (ITB), and some fibres insert into gluteal tuberosity.	Inferior gluteal nerve (L5,S1,S2)	Extension and aids in lateral rotation of hip.
Gluteus medius	External ilium, inferior to the iliac crest and between the anterior and posterior gluteal lines.	Greater trochanter of femur.	Superior gluteal nerve (L5,S1)	Abducts and medially rotates hip. Aids in stabilising pelvis during weight bearing.
Gluteus minimus	External ilium between the anterior and inferior gluteal lines.	Greater trochanter of femur.	Superior gluteal nerve (L5,S1)	Abducts and medially rotates hip.
Tensor of fascia lata	Anterior superior iliac spine (ASIS); anterior iliac crest.	Iliotibial band.	Superior gluteal nerve (L5,S1)	Abducts and medially rotates hip.

(Adapted from Moore, Dalley and Agur 2010; Muscolini 2011)

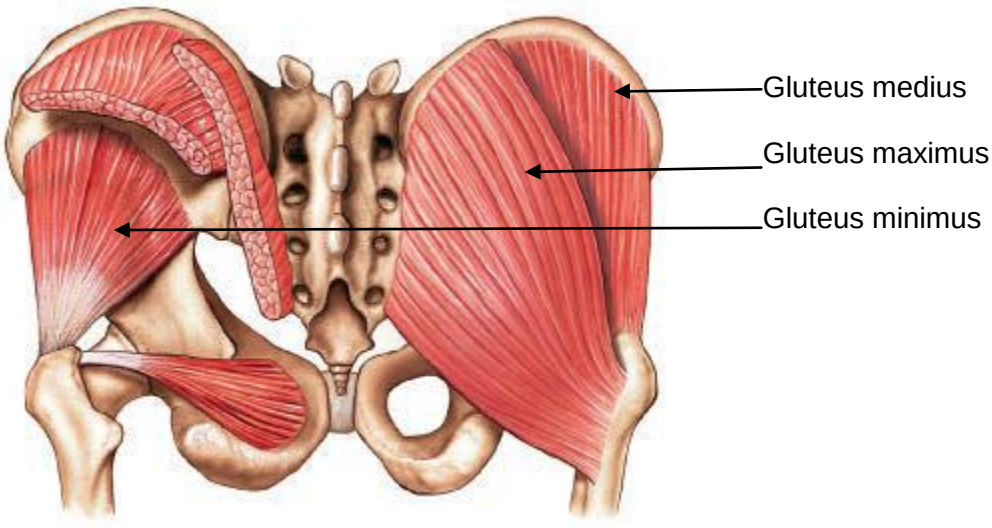

Figure 3: Superficial muscles of the gluteal region (Martini *et al.* 2018).

2.4.2 The deep muscles of the gluteal region

The deep layer is comprised of smaller muscles; these are: piriformis, obturator internus, superior and inferior gemelli and quadrates femoris. These muscles all distally attach to the intertrochanteric crest of the femur. The deep muscles of the gluteal region act to laterally rotate the thighs, as well as to stabilise the hip joint (Moore, Dalley and Agur 2010).

Due to the deep nature of these muscles SEMG would have been insufficient as fine-needle EMG would have been required, thus rendering these muscles unsuitable for this study (Crisswell 2011).

Table 3: Deep Muscles of the gluteal region.

Muscle	Proximal attachment	Distal attachment	Innervation	Action
Piriformis	Anterior surface of sacrum, and the sacrotuberous ligament.	Greater trochanter of the femur.	Branches of anterior rami of S1, S2.	Laterally rotate extended thigh and abduct flexed thigh.
Obturator internus	Pelvic surface of obturator membrane and surrounding bones.	Medial surface of greater trochanter of femur.	Nerve to obturator internus (L5, S1).	Laterally rotate extended thigh and abduct flexed thigh.
Superior and inferior gemeli	Superior: Ischial Spine Inferior: Ischial tuberosity	Medial surface of greater trochanter of femur.	Superior: Nerve to obturator internus (L5, S1). Inferior: Nerve to quadratus femoris(L5, S1).	Laterally rotate extended thigh and abduct flexed thigh.
Quadratus femoris	Lateral aspect of ischial tuberosity.	Quadrate tubercle on intertrochanteric crest of femur.	Nerve to quadratus femoris(L5, S1).	Laterally rotates thigh, Steadies femoral head.

(Adapted from Moore, Dalley and Agur 2010; Muscolini 2011)

2.5 An overview of the nervous system

The nervous system is comprised of two major divisions, the central nervous system (CNS) which comprises of the brain and spinal cord, and the peripheral nervous system (PNS) made up of the remaining nervous tissue outside of the CNS. The PNS can be further divided into the somatic nervous system (SNS), the autonomic nervous system (ANS), and the enteric nervous system (ENS) (Tortora and Derrickson 2009).The nervous system plays an important role in all body systems, and due to its relevance to muscle contraction it will be discussed (Tortora and Derrickson 2009).

2.5.1 The peripheral nervous system

The PNS contains of nervous tissue that exists outside of the CNS; it is responsible for conducting impulses to and from the CNS. The PNS consist of two types of nerves: the cranial and spinal. There are 12 pairs of cranial nerves that exit the cranial cavity, and 31 pairs of spinal nerves that exit the vertebral column. Spinal nerves are formed from a union of dorsal and ventral roots of the spinal cord. The dorsal roots consist of afferent fibres, while the ventral roots consist of efferent fibres. The spinal nerve exits the spinal column through the intervertebral foramen (IVF) where it then divides into dorsal (posterior) and ventral (anterior) rami (Tortora and Derrickson; Moore, Dalley and Agur 2010).

The dorsal rami innervate the synovial joints of the vertebral column and the skin and muscles of the back. The ventral rami innervate the structures and musculature of the upper and lower limbs, as well as the skin over the anterior and lateral areas of the trunk. The ventral rami unite with adjacent rami to form a plexus which supply nerves to a region. The major nexuses are the cervical, brachial, lumbar and sacral plexuses (Tortora and Derrickson 2009; Moore, Dalley and Agur 2010).

2.5.1.1 Sensory receptors

Sensory receptors are found at the distal ends of sensory neurons and respond to specific stimuli in order to provide the CNS with information of the body both internally and externally to provide a reflex action (Martini *et al.* 2018). A subtype of sensory receptor known as mechanoreceptors are thought to be affected as a result of manipulation (Pickar 2002).Sensory receptors can be divided into pain and mechanoreceptors as shown in Table 4.

Table 4: Sensory receptors of the nervous system

Receptor type		Location	Sensations	Adaption Rate
Mechanoreceptor	Meissner corpuscles	Hairless skin.	Fine touch, pressure, vibration.	Rapid
	Merkel discs	Stratum basale of the epidermis.	Fine touch, pressure.	Slow
	Type I: Ruffini corpuscles	Deep layers of the dermis, in ligaments and tendons.	Skin stretch, static joint position, active and passive joint motions.	Slow
	Type II: Paciniancorpuscles	Subcutaneous layer of the dermis, joint capsule, periosteum and some viscera.	Pressure, vibrations, active and passive joint motions.	Rapid
	Muscle spindles	Most striated muscle.	Muscle length.	Slow
	Type III: Golgi tendon organs	Ligaments and tendons.	Muscle tension.	Slow
Pain Receptors	Type IV	Free nerve endings located in all tissue excluding the brain.	Pain.	Non-adapting

(Adapted from Leach 2004; Moore, Dalley and Agur 2010; Bergmann and Peterson 2011; Martini 2018; Muscolini 2011).

2.5.1.2 Sensory nerve fibres

Nerve fibres can be classified into sensory, motor and interneurons. Sensory nerve fibres, as described in Table 5, are also known as afferent neurons, they transmit information to the CNS through cranial or spinal nerves.

Table 5: Classification of sensory nerve fibres.

Type	Fibre Diameter (µm) and conduction velocity (m/s)	Myelin	Location	Function
I	12-20; 80-120	Myelinated	Muscle	Proprioception, kinesthesia
II	6-12; 35-72	Myelinated	Muscle, joints, skin	Proprioception, mechanical

III	1-6; 4-36	Thin myelin layer	Muscle, joints, ligaments, skin	Mechanical, heat, cold, nociception
IV	0.2-1.5; 0.4-2	Unmyelinated	Muscle, joints, ligaments, skin	Mechanical, heat, cold, nociception

(Adapted from Pickar 2002; Leach 2004)

2.5.1.3 Motor neurons

Motor neurons are efferent fibres within the CNS that innervate and control muscle skeletal muscle function, as well as organs and organ systems. Skeletal muscle innervations are achieved through a union of motor neurons to form a motor neuron pool. This combined with the muscle work together as a unit to produce a contraction (Stifani 2014; Leach 2004). They can be classified into three types as shown in Table 6:

Table 6: Classification of motor neuron fibres.

Type	Size and conduction Velocity	Myelinated	Function
Alpha	Large: 8-20μm and 35-120m/sec	Yes	Innervate the force producing extrafusalmuscle fibres.
Beta	Medium size and conduction velocity	Yes	Innervate both extrafusal and intrafusal muscle fibres.
Gamma	Small: 2-8 μm and 10-50m/sec	Yes	Innervate the intrafusal muscle fibres and control muscle spindle sensitivity to stretch.

(Adapted from Leach 2004; and Stifani 2014)

2.5.1.4 The motor unit

The most basic level of nervous system organisation of the muscle is the motor unit and its alpha motor system. The alpha motor system comprises of the lower motor neuron, an axon, and the muscle fibres it innervates. The number of muscle fibres per motor unit varies greatly depending on the muscle, with those associated with fine motor tasks having significantly more motor units than strength producing muscles. The lower motor axon branches to allow it to attach to a muscle fibre at the motor end plate. This creates a neuromuscular synapse (Crisswell 2011).

2.6 Skeletal muscle

Skeletal muscles are voluntary somatic muscles that typically attach to bones. Their primary functions include movement and stabilisation of bones and other structures such as the digestive tract (Tortora and Derrickson 2009; Moore, Dalley and Agur 2010).The gluteus maximus muscle used for testing purposes in this study is a skeletal muscle.

The skeletal muscle fibre as illustrated in Figure 4consistsof three layers separated by connective tissue. This connective tissue extends beyond the muscle fibres to form tendons which attach the muscle to a bone, or an aponeurosis that connects to another muscle (Tortora and Derrickson 2009).

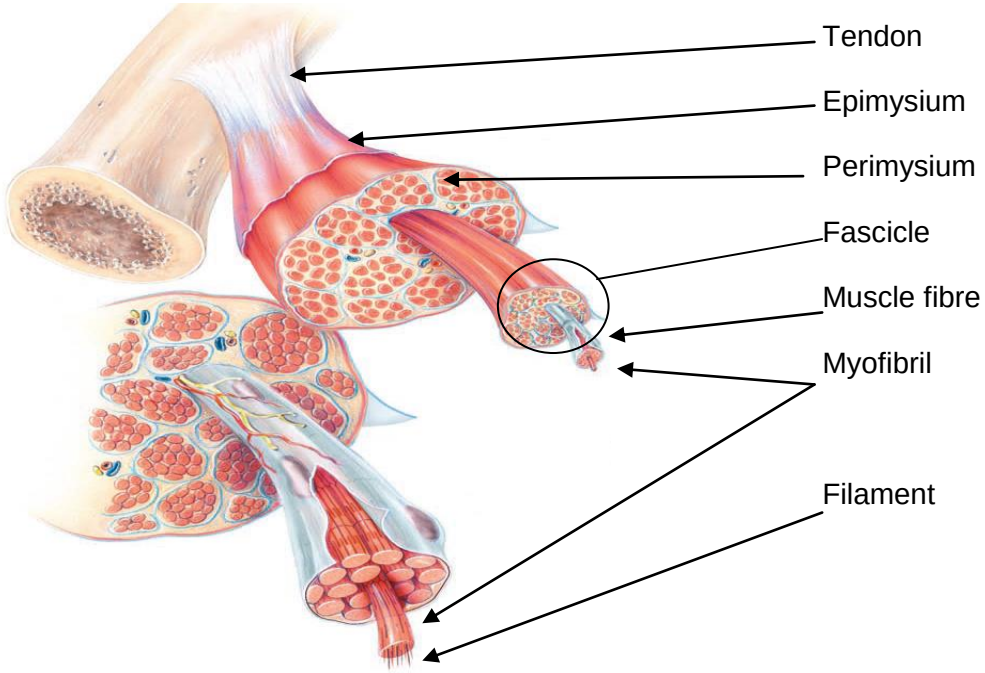

Figure 4: Components of a skeletal muscle (Tortorra and Derrickson 2009).

Each individual muscle skeletal fibre contains thousands of myofibrils; these are the organelles responsible for contraction of skeletal muscles and give skeletal muscles its striated appearance. Surrounding the myofibrils is a system of membranous sacs known as the sarcoplasmic reticulum. Within the myofibrils are bundles of smaller structures known as myofilaments. These are arranged into compartments known as sarcomeres which are the most basic contractile unit of a myofibril as illustrated in Figure 5 (Tortora and Derrickson 2009).

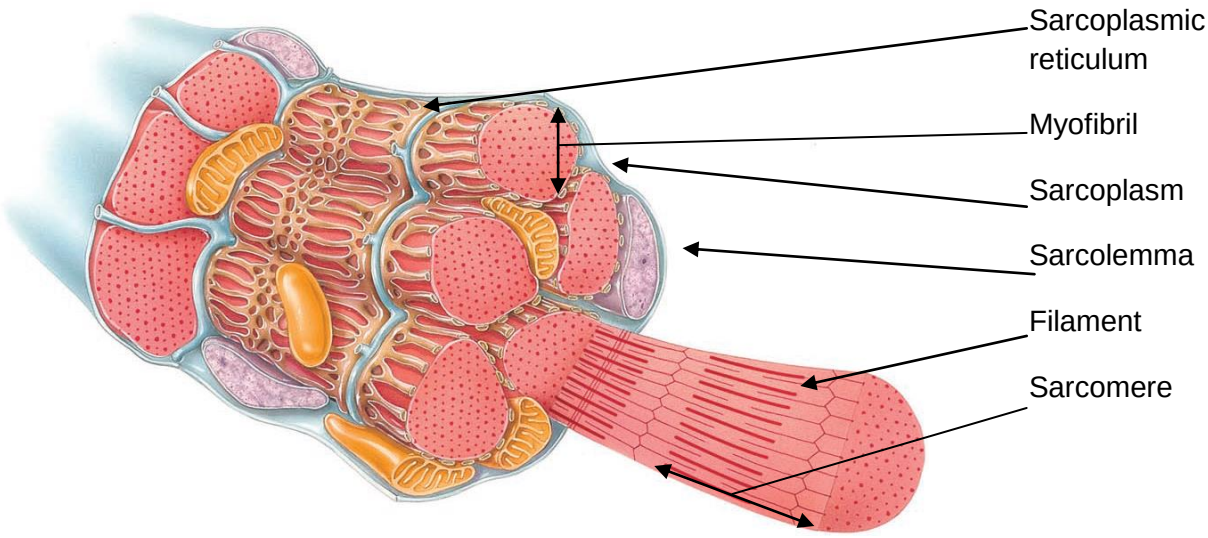

Figure 5: Microscopic organisation of a muscle fibre (Adapted from Tortora and Derrickson 2009).

2.6.1 Contraction of skeletal muscle

A muscle contraction begins with an action potential nerve impulse that travels along a motor nerve to the synapse at the neuromuscular junction (NMJ) of a skeletal muscle fibre. At the NMJ the nerve secretes the neurotransmitter acetylcholine (ACH) and this binds to a receptor on the muscle fibre membrane which opens the channel. Once this ACH channel opens it allows sodium ions (Na^{+}) to diffuse into the cell of the muscle fibre. The influx of positively charged ions depolarises the membrane, resulting in an action potential across the sarcomere which starts the contraction cycle (Martini *et al.* 2018).

The contraction cycle is a series of molecular events that permit muscle contraction. As contraction begins, calcium ions (Ca^{2+}) are released from the sarcoplasmic reticulum into the cytosol within the zone of overlap in a sarcomere. These ions then bind to tropinin which transports tropomyosin away from the myosin-binding sites on actin. Once these binding sites are free, the contraction cycle begins in several stages:

Adenosine triphosphate (ATP) hydrolysis. The myosin head includes an ATP binding site and an ATPase enzyme that hydrolyses ATP into adenosine diphosphate (ADP) and a phosphate group. This reaction energises the myosin head.

Myosin attaches to actin to form cross-bridges. The energised myosin head attaches to the myosin-binding site on actin, forming cross-bridges.

Power Stroke. After cross-bridges are formed the power stroke occurs. The energy stored in the resting state is released as the cross-bridges rotate and release the bound ADP and phosphate. The cross-bridge produces force while it rotates towards the centre of the sarcomere.

Myosin detaches from actin. At the end of the power stroke phase the cross-bridge remains attached to the actin. Another ATP binds to the myosin head and the link is broken. As ATP is hydrolysed into ADP the energy is used to reset the myosin head.

This contraction cycle repeats as so long as ATP is available and the Ca^{2+} levels are sufficiently high. During each power stroke the cross-bridges repeatedly rotate back and forth, this movement applies force shortening the sarcomere by about 0.5%. This results in a shortening of the entire contracted muscle at the same rate due to the sarcomeres contracting together (Tortora and Derrickson 2009; Martini *et al.* 2018).The energy produced during this contraction cycle can be recorded by an EMG reading (Crisswell 2011).

2.6.2 Muscle tone and length

Changes in muscle length and tension are monitored and maintained by the muscle spindles and Golgi tendon organs (Tortora and Derrickson 2009; Bergmann and Peterson 2011).

2.6.2.1 Muscle spindles

Muscle spindles are specialised proprioceptors located in skeletal muscles that are involved in the stretch reflex and monitoring changes in muscle length. Muscle spindles consist of several slow adapting sensory nerve endings, called intrafusal muscle fibres that are enclosed in a connective tissue capsule that contain from three to ten intrafusal muscle fibres. They are scattered among most skeletal muscles and are plentiful in muscles that produce finely controlled movement, while muscles involved in coarser forceful movements contain fewer (Tortora and Derrickson 2009).

When a muscle is stretched, the muscle spindle is also stretched and becomes stimulated, this leads to an impulse in a sensory neuron that alerts the CNS that the muscle has just been stretched. To prevent over stretching or tearing of a muscle, this impulse causes a reflex contraction of the muscle to cease excessive stretching that may damage the muscle. This is known as the stretch reflex (Muscolino 2011).

The terminal ends of intrafusal muscle fibres are stimulated by gamma motor neurons. These adjust the tension in a muscle spindle in response to the length of the muscle. When

a muscle contracts and shortens, these neurons stimulate the ends of the intrafusal fibres to contract, ensuring it is kept taut and more sensitive to stretch allowing it to be more easily trigger the stretch reflex. The sensitivity of the muscle spindle is determined by the gamma motor system; this system is comprised of upper motor neurons (UMNs) and lower motor neurons (LMNs). Sensitivity of the muscle spindle is controlled by UMNs exerting on LMNs subconsciously by processing factors, including previous and present traumas, the location of the muscle, the need for stability in the region and emotional and physical stress. The regions of the brain that primarily control gamma UMNs are the brainstem nuclei, the hypothalamus, the amygdala and the cerebellum (Tortora and Derrickson 2009; Muscolino 2011).

2.6.2.2 Golgi tendon organs

Golgi tendon organs (GTOs) are sensitive mechanoreceptors that are located within the musculotendinous junction and are stimulated by tension placed on the tendon. During contraction of a muscle, pulling forces are exerted on a tendon which stimulates the GTO, creating an impulse in a sensory neuron, alerting the CNS that the muscle has contracted and shortened. Pulling forces acting on a tendon may damage and tear the tendon; an impulse in the CNS results in a reflex relaxation of the muscle known as the tendon reflex (Muscolino 2011). Korr (1978) theorised that manipulation of a spinal segment will stretch and stimulate both muscle spindles and GTOs in surrounding musculature. This will in turn result in relaxation of hypertonic muscles.

2.6.3 Factors affecting muscle contraction

There are several factors that can affect the ability of a muscle to contract. These include the length-tension relationships, limbic system dysfunction, fatigue, and muscle fascicle length and diameter. These may all play a role in an individual's ability to maximally contract a specific muscle (Martini *et al.* 2018).

2.6.3.1 Length-tension relationships

The length-tension relationship of a muscle is the relationship between the length of a single sarcomere and the force it is able to produce. During a contraction the amount of tension generated is dependent on the number of power strokes performed by cross-bridges within a sarcomere. The number of cross-bridges that can form is dependent on the amount of overlap of thick and thin filaments (Martini *et al.* 2018).

When a sarcomere is at or close to its resting length, the zone of overlap is at an optimal position, and the muscle fibre can produce its maximum tension. When muscle fibres contract, only the myosin heads that are within the region of overlap can bind to active sites and produce tension in a muscle. As the sarcomere is stretched to a longer length this overlap zone shortens, resulting in a decrease in tension produced. As a muscle fibre is stretched to 170% of its optimal length there is no overlap of thick and thin filaments. This results in the muscle fibre not being able to contract and the tension drops to zero (Tortora and Derrickson 2009; Crisswell 2011; Martini *et al.* 2018).

2.6.3.2 Limbic system dysfunction

The limbic system is one of the areas of the brain that control gamma upper motor neurons. These are responsible for determining the sensitivity of the musculoskeletal system to stretch. Dysfunction of the limbic system has been linked to depression, anxiety and emotional and physical stress which may negatively affect muscle contraction and tension (Muscolino 2011).

2.6.3.3 Fatigue

During sustained muscle contraction the velocity at which conduction of the action potentials along the muscle fibres slow resulting in the muscle beginning to discharge. This can occur from between one to five minutes of continuous contraction. This effect is associated with depletion of energy stores, an increase in metabolites and a decrease in tissue perfusion (Crisswell 2011) For the purpose of this study, after measuring MVC, it was imperative to allow a rest period of 10 minutes before performing the second round of contraction. This was regarded as enough time to recover from fatigue as shown by Larivière *et al.* (2003).

2.6.3.4 Muscle fascicle length and diameter

Fasicular arrangement affects a muscle's power and ROM. The longer the fibres, the greater the ROM. The power of a muscle is dependent on the cross-sectional area of the fibre (Tortora and Derrickson 2009).

2.6.4 Classification of skeletal muscle fibres

Skeletal muscle fibres are classified into three variants, as shown in Table 7 -fast twitch (type II-B), slow twitch (type I) and intermediate twitch (type II-A) fibres. These fibres differ in size, contraction speed, mitochondria concentration and oxidative enzymes (Martini *et al.* 2018).

Table 7: Muscle fibre characteristics

Fibre classification	Cross-section diameter	Contraction speed	Number of mitochondria	Resistance to fatigue
Fast fibres (type II-B)	Large	Fast	Sparse	Low
Slow fibres (type I)	Small	Slow	Many	High
Intermediate fibres (type II-A)	Intermediate	Fast	Intermediate	Intermediate

(Adapted from Martini *et al.* 2018)

The predominant fibre type that the gluteus maximus muscle is comprised of has not been determined; therefore, this was not taken into consideration in the participant selection process of this study.

2.6.5 Muscle strength

Kell, Bell and Quinney (2001) defined muscle strength as being the maximal force that a specific muscle or muscle group can produce at a certain speed. They have shown that individuals with an increased level of muscular strength, as well as muscular endurance and flexibility, are associated with decreased levels of disability and injury, and an increase in ability to perform activities of daily life.

2.7 Measures of gluteus maximus maximum voluntary contraction

2.7.1 Maximum voluntary contraction and its clinical relevance

The evaluation of muscle strength is important to consider in the assessment and management of neuromuscular patients. The literature supports objective measurement and assessment of muscle strength in monitoring the progression of a disease, and in evaluating the efficacy of patient interventions (Meldrum *et al.* 2007). Maximum voluntary contraction (MVC) is utilised in various aspects of health care by numerous health care professionals in both clinical and research environments. MVC has been shown to have a high sensitivity which is important in monitoring small interval changes that can be used in the evaluation of a rehabilitation patient's progression, or in the deterioration of a patient's neuromuscular disease (Meldrum *et al.* 2007; Conable and Rosner 2011).

2.7.2 Hip extension test to isolate gluteus maximus

Hislop and Montgomery (2007) described this test in order to isolate the gluteus maximus muscle to test and grade its strength. The hip extension test involves positioning a participant prone on a table with the tested knee flexed to 90°. The researcher is positioned at the side being tested at the level of the pelvis and stabilises the posterior thigh above the knee. The participant then extends their hip through range of motion while maintaining knee flexion during which resistance is given in a downward direction towards the floor. The contraction is then graded from 0 to 5, with grade 0 being no palpable contraction and grade 5 being complete range of motion against resistance. A modification of this test involves using a resistance band placed around the participants' posterior thigh above the knee to allow for a maximum voluntary contraction to be performed as shown by Boren *et al*. (2011).

2.7.3 Electromyography

Surface electromyography (SEMG) is a safe and non-invasive technique that ensures unbiased and objective documentation of the electrical potentials produced by a muscle during contraction. This is done by recording the energy exchange that is produced by the motor unit of a muscle during depolarisation at the NMJ during muscle contraction (Crisswell 2011). EMG measurements are considered to be a quantitative measure of the maximum output produced by a muscle and is commonly used to assess the global function of muscles, muscle patterns and abnormal muscle activity. Multiple studies have shown SEMG to be a reliable and easily repeatable measure of muscle output during various tasks, including maximum voluntary contraction (Kent 1997; Suter 1999; Colloca and Keller 2000). Repeated MVC tests are frequently used to monitor the changes in the average frequency associated with fatigue. These protocols typically involve tests that require a short rest period between contractions, followed by a long duration of maximal contraction (Colloca and Keller 2000).

SEMG is frequently used in kinesiological studies that assess the function of muscles, and for abnormal muscle activity due to its non-invasive nature, the lack of tissue damage and the ability to easily replicate the location of surface electrodes for additional research studies (Kent 1997). Body mass index (BMI) is an important factor to consider when utilising SEMG as it must first pass through subcutaneous fat before reading the muscle electrical potential. This may affect the results of the output (Crisswell 2011).

An alternative to SEMG is intramuscular or fine-needle EMG. This is a more invasive technique as a needle electrode is inserted into the specific muscle that is being assessed,

which may result in tissue damage and injury. These electrodes have a smaller field of reading and are more appropriately used in monitoring a specific muscle. Replication of intramuscular EMG is less reliable due to difficulty in replicating the exact depth and location of the needles area of insertion (Kent 1997). Due to the invasive nature of fine-needle EMG, the use of surface EMG was selected.

2.8 Spinal manipulative therapy

Spinal manipulative therapy (SMT) is one of the most frequently used therapies in the conservative management of joint dysfunction that leads to pathologies such as low back and neck pain (Bronfort *et al.* 2004; Potter, McCarthy and Oldham 2005; Hancock *et al.* 2008). SMT is a technique which is aimed at joints with reduced or restricted movement, known as joint restrictions, in order to return a joint to full ROM (Bergmann and Peterson 2011). Manipulation is thought to achieve this through a process of reducing joint locking, releasing entrapped meniscoid/menisci (Gatterman 2005; Bergmann and Peterson 2011; Haldeman 2012) and by removing joint adhesions (Leach 2004). As a result, manipulation may allow for the optimisation of muscle function.

Joint fixations involve a partial or complete restriction of a joint's normal movement; this may occur in one or more directions and is usually referred to as a partial loss of joint movement or ROM. This is known as hypomobility of the joint (Bergmann and Peterson 2011: 112).Spinal manipulative therapy is aimed at joint fixations; these may occur as a result of physical factors such as segmental muscle spasm, soft tissue fibrosis, intercapsular adhesions and intradiscal derangements (Bergmann and Peterson 2011:112), as well as psychological and emotional factors such anxiety and depression (Muscolino 2011:). Joint fixations may lead to symptoms such as point tenderness and increased pain sensitivity over the spinous process as well as increased muscle tone and pain (Leach 2004).

Leach (2004) noted that there are three zones of movement within a synovial joint (see figure 6):

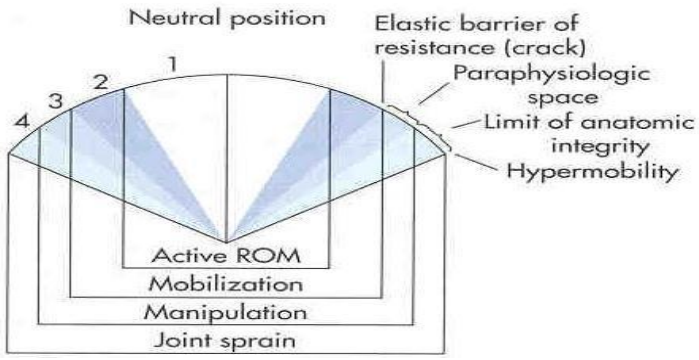

Figure 6: Physiological, paraphysiological and pathological zones of movement of a synovial joint (Gatterman 2005:).

Physiological movement: This is the zone in which normal passive and active ROM, as well as mobilisation occurs.

Paraphysiological movement: This is the zone in which high velocity, low amplitude thrusts separate articular surfaces of a joint by moving the joint past the elastic barrier of resistance, this produces an audible 'crack' known as a cavitation.

Pathological movement: Movement past the barrier of normal anatomical integrity moves into the pathological zone of movement. Movement into this zone will result in a sprain or dislocation of the joint; this can range from a simple elongation to a complete rupture of the joint capsule (Leach 2004).

2.8.1 Methods of delivering SMT

There are several ways that SMT can be delivered. This chapter will only discuss in depth the relevant methods used.

2.8.1.1 Mobilisation

Joint mobilisation can be defined as a passive movement of a joint or joint segment up to, but not exceeding, the physiological end ROM. It is a repetitive movement of the joint at the end of its' ROM with the goal of restoring optimal ROM and improving the quality of motion. Mobilisation can be applied through various grades from grade I to IV which ranges from very small amplitude movements at the beginning of the joint's ROM to movement that stretches to the very end of ROM (Bergmann and Peterson 2011). Since mobilisation would not serve the purpose of this study it was not selected as the method of intervention to be used.

2.8.1.2 High velocity low amplitude manipulation

The most commonly used spinal manipulation is the high velocity, low amplitude (HVLA) thrust, this is delivered with a controlled speed, depth and magnitude through a specific structure and is often associated with a gapping of the joint and a cavitation (Potter, McCarthy and Oldham 2005).

2.8.2 The effects of manipulation

There is a poor understanding of the exact mechanism underlying the effectiveness of SMT understood (Herzog, Scheele and Conway 1999; Colloca and Keller 2001). There are three main theories that exist to explain the effect of SMT; biomechanical, neurophysiological and muscular reflexogenic theories (Potter, McCarthy and Oldham 2005). These three components appear to all work on a neurophysiological basis (Bicalho *et al.* 2010), as SMT is thought to have a physiological effect on the movement of sensory information to the CNS and therefore will have an effect on the surrounding musculature (Pickar 2002). This chapter will briefly discuss the neurophysiological theories as they are the most relevant to this study.

Korr (1978) proposed a model in which he stated that normal neural impulse transmission within the CNS would be negatively affected due to any degree of interruption caused by a joint fixation. He suggested that a joint fixation causes the segmental muscles of the spine to increase their gamma gain in order to restore normal muscle spindle discharge. This increased gamma gain affects the activity of the alpha motor neuron which results in excessive contraction and restriction of the involved motion segment. This region becomes hypersensitive to input from the brain and body and may involve musculoskeletal tissues adjacent to the joint fixation. When SMT is applied to the fixated segment it results in a rapid stretch of extrafusal and intrafusal muscle fibres of the surrounding hypertonic muscles causing a bombardment of afferent impulses to the CNS, this in turn restores normal gamma gain and muscle tone (Korr 1978; Leach 2004).

In a study performed by Randoll *et al.* (2017) it was found that SMT provided hypoalgesic effects. This was theorised to be through three potential effects, firstly through inhibition of dorsal horn neurons' activity. Secondly, through activation of descending pathways that originate from various brain structures. Thirdly, through a non-specific cerebral process that helps to modulate pain perception.

Lewit (2009) and Korr (1978) have shown that manipulation has an effect on the efficient functioning of the neurological system that both directly and indirectly controls joint function

(Suter *et al*. 1999; Hillermann *et al*. 2006). The neurological effects caused by manipulation are thought to occur due to depolarisation of the motor neuron pools supplied by the level at which manipulation has been administered. This depolarisation occurs due to the manipulation's effect on the mechanoreceptors located within the manipulated joint. This leads to a massive increase in the afferent bombardment of the spinal nerve root and dorsal root ganglion, resulting in facilitation of the affected level. Facilitation of the segmental level occurs when axons are brought closer to threshold and thus are easier to depolarise (Beck 2011; Crossman and Neary 2015). This depolarisation may allow for the manipulated segment to normalise through homeostatic processes as the facilitated segments are restored to their physiological normal levels (Tortora and Derrickson 2008; Hall and Guyton 2011).

Suter *et al*. (2000) researched the effects of SMT on muscle inhibition in extremities. They concluded that following SMT there was an improvement in muscle function. They hypothesised that as a result of SMT there was restoration of motor neuron excitability which may have altered muscle inhibition.

A study performed by Colloca and Keller (2000), assessed the MVC of the erector spinae in 40 participants with mechanical LBP after instrument assisted SMT compared with a placebo and a control group. SEMG readings were taken pre- and post-intervention and the results showed a significant increase in SEMG readings of paraspinal MVC when compared to the placebo and control group. This study indicated that SMT may improve muscle function and recruitment and may be the basis for further research into the effects of SMT.

2.9 The placebo effect

The use of placebo in randomized control trials has been regarded as the gold standard for non-biased clinical research (Rothman and Michels 1994). Rothman and Michels (1994) also stated that placebo presents the opportunity for a researcher to determine the efficacy of an already tested treatment or intervention as a placebo offers a 'clear benchmark' from which to work.

The difficulty in using a sham manipulation is that it must meet the participant's perception of a "real" manipulation while ensuring that the sham manipulation is therapeutically inert so as not to affect the results. Participants should have no doubt that the intervention they are receiving is an active intervention (Vernon *et al.* 2005). Chaibi *et al*. (2015) made use of a placebo lumbar SMT that consisted of a non-specific contact over the lumbar area performed lateral to the spinal column. This manipulation was performed with a low velocity,

low amplitude push manoeuvre in a non-intentional and non-therapeutic direction with sufficient joint slack to prevent any joint cavitations from occurring as a cavitation may produce a neurological response. This was performed to provide no therapeutic effect, nor any stimulus to the SIJ that may evoke a neurological response. In a post-intervention questionnaire, participants were unable to determine whether they were placed in the intervention or placebo group.

The sham manipulation in this study consisted of participants in the same side-lying position as the intervention group with the bottom leg straightened and the top leg flexed with the ankle resting on the bottom legs knee, a non-thrust push move delivered to the gluteal region. This procedure was done in accordance with guidelines shown by Chaibi *et al*. (2015).

2.10 Conclusion

Research has suggested that SMT as an intervention may improve muscle recruitment and functional activity (Hillermann *et al*. 2006). Further investigation and research into manipulation and its effects on muscle strength and activity are important. This study endeavoured to achieve this by testing gluteus maximus activity before and after manipulation of the adjacent SIJ.

CHAPTER THREE:

METHODOLOGY

3.1 Introduction

This chapter outlines the procedures used to conduct this study, including the study design, and analysis procedures.

3.2 Study design

This study was designed as a quantitative randomised, placebo-controlled pre-test /post-test experimental design. This allowed for the random allocation of participants into two groups. All groups were tested prior to the administration of the intervention or placebo and following the intervention all groups were retested in order to determine any effect. The independent variable for this study was the chiropractic manipulation and the dependant variable was the muscle activity produced by the gluteus maximus.

The study was approved by the Institutional Research Ethics Committee (IREC 161/17: Appendix J) and was registered on the South African Clinical Trials register (registration number: DOH-27-0618-6064, Appendix M). The study was conducted at the Durban University of Technology Chiropractic Clinic, after a letter of permission was obtained from the Clinic Director (Appendix K)

3.3 Study population

The study population consisted of male participants recruited from the Greater Durban area.

3.4 Sampling procedure

3.4.1 Sample size

A sample size was done using G*Power version 3.1.9.2. The sample size was calculated using power of 80% and a significance level of 0.05 using repeated measures ANOVA analysis. From this a sample of 28 participants was required for this study, with 14 participants placed in each group (Tonya 2019).

3.4.2 Sample recruitment

Participants were recruited through advertisements (Appendix A) which were placed around the Durban University of Technology campus, places of communal gathering and through word of mouth. Permission was obtained to place advertisements prior to them being displayed.

Respondents to the advertisements were contacted telephonically and asked specific questions to determine whether they were eligible to partake in the research (Table 8).

Table 8: Appendix B: Questions and expected answers from respondents to qualify to participate in this study

Questions asked	Answers required.
Would you be willing to answer a few questions in order to determine your eligibility into the study?	Yes
In your opinion are you currently healthy?	Yes
Are you male?	Yes
Are you between the ages of 18 and 40 years old?	Yes
Have you experienced any low back pain in the past three months?	No
Can you tell me your weight and height? (This was done in order to determine the body mass index)	Calculated BMI: 18.5-24.9kg/ m^2
Have you had any major spinal trauma, surgeries or suffer from any chronic illnesses? (e.g. Diabetes, hypertension, heart failure.)	No

Respondents that did not meet the above criteria were thanked for their time. Those that fulfilled the requirement and were interested in participating in the research were scheduled for an appointment at the DUT Chiropractic Day Clinic at their earliest convenience. The participants were informed that they would be needed for two hours for the initial consult and research procedure. Participants were required to meet the following criteria in order to participate in the study.

3.4 Inclusion and exclusion criteria

3.4.1 Inclusion criteria

1. Met the criteria listed in Appendix B.
2. Participants had read, agreed to and signed the Letter of Information and Informed Consent (Appendix C).
3. Participants were between the ages of 18 and 40 years old. This excluded the need for parental consent (MRC of SA 2002-2004) while also reducing the likelihood of any degenerative changes being present in the participants (Berkow *et al*. 1997).
4. Participants were all male to allow for homogeneity of the sample group.
5. Participants had a BMI between 18.5 kg/m²and24.9 kg/m² to minimise excess body fat and ensure accurate resting SEMG readings (Crisswell 2011).
6. Participants were free of low back pain (LBP) for at least three months.
7. Participants had a sacroiliac joint flexion restriction of any degree present determined by motion palpation as outlined by the guidelines of Bergmann and Peterson (2011).
8. Participants were pain free and asymptomatic with the exception of SIJ flexion restriction.

3.4.2 Exclusion criteria

1. Failure to meet the criteria listed in Appendix B.
2. On-going treatment for LBP by other health care providers.
3. Chiropractic students or practitioners, to ensure participants were blinded to the study.
4. Participants were asked if they were familiar with manipulation of the lower back and pelvis, if they answered yes they were excluded.
5. The use of anti-inflammatory, muscle relaxants or analgesics within 72 hours prior to participation in the study. A washout period of 72 hours was suggested by Poul *et al*. (1993).

Chronic illnesses including, but not limited to: (Buffel du Vaure *et al*. 2016)

1. Coronary heart disease;
2. Hypertension;
3. Transient ischaemic attack;
4. Type 2 Diabetes;
5. Heart failure.

Contraindications to sacroiliac manipulation including, but not limited to: (Bergmann and Peterson 2011)

1. Traumatic injuries;
2. Abdominal aortic aneurysm;
3. Metabolic disorders;
4. Osteoarthritis;
5. Tumours;
6. Neurological complications;
7. Bone infections;
8. Surgery.

Contraindications to SEMG including, but not limited to: (Campbell 2013)

1. Electrical sensitivity;
2. Bleeding,
3. Skin irritation.

3.5 Measurement tools

3.5.1 Surface electromyography (SEMG)

The electrodes used in this study were Electrospyres 35mm round, pre-gelled Ag/AgCl disposable ECG electrodes. The placement areas on participants were wiped down with alcohol swabs before placement as shown in Figure 8 for the gluteus maximus.

Surface electromyography (SEMG) is a safe and non-invasive technique that ensures unbiased and objective documentation of the electrical potentials produced by a muscle during contraction This is done by recording the energy exchange produced by a muscle motor unit during depolarisation at the NMJ during muscle contraction (Crisswell 2011). EMG analysis is considered to be a quantitative measure of the maximum output produced by a muscle and is commonly used to assess the global function of muscles, muscle patterns and abnormal muscle activity. Multiple studies have shown SEMG to be a repeatable and reliable measure of muscle output during various tasks, including maximum voluntary contraction (Kent 1997; Colloca and Keller 2000; Chapman *et al*. 2010). Repeated MVC tests are frequently used to monitor the changes in the average frequency associated with fatigue. These protocols typically involve tests that require a short rest period between contractions, followed by a long duration of maximal contraction (Colloca and Keller 2000).

SEMG is frequently used in kinesiological studies that assess the function of muscles, and for abnormal muscle activity due to its non-invasive nature, the lack of tissue damage and the ability to easily replicate the location of surface electrodes for other research studies (Kent 1997). Body mass index (BMI) is an important factor to consider when utilising SEMG as it must first pass through subcutaneous fat before reading the muscle electrical potential and this may affect the results of the output (Crisswell 2011).It is recommended by multiple authors to best quantify the level of muscle activity by using the root mean square value (RMS) (Suter *et al.* 2000*;* Arabadzhiev *et al.* 2010; Farfan, Pollitti and Felice 2010; Fukuda *et al.* 2010).

The SEMG equipment used to conduct this study was the Biopac-Bionomadix complete wireless research system. This includes the MP150 Data Acquisition System, AcqKnowledge software and the Bionomadix Dual-channel Wireless EMG Transmitter and Receiver Pair (Biopac Systems Inc 2015).

3.6 Sample Allocation

Participants were randomly allocated into one of two groups using a draw from a randomised box kept at the clinic's front desk. Once the participant was determined to be eligible to participate in the study an independent research assistant would randomly select a folded piece of paper that "group one" or "group two" had printed on it, the participant was then allocated to this group. As the researcher was blinded to the group allocation, randomisation was done by an independent research assistant.

Group one – Sacroiliac joint manipulation group.

Group two – Placebo sacroiliac joint manipulation group.

If a participant dropped out of the study or was excluded, a new participant was recruited in his place.

3.7 Blinding

Double blinding was used in this study in order to minimise any potential bias and increase the validity of this study (Brink, Van der Walt and Van Rensburg 2006). Randomisation of participants was held by the Chiropractic clinic's front office. The research assistant, a chiropractic student registered for M.Tech: Chiropractic was responsible for randomisation of participants as well as administration of all interventions to the placebo and intervention group while the researcher had stepped out of the room. This ensured that the researcher was not aware of which group the participant belonged to. Participants were also blinded as

they were not informed of the group they were allocated, and a sham manipulation was used to ensure they believed they received intervention. Participants were requested not to discuss interventions with the researcher as the researcher was not involved in any aspect of the allocation of intervention to ensure blinding. The research assistant was not involved in data capturing and analysis in any way as they were not blinded in this study.

3.8 Participant informed consent

At the initial consultation, the respondents were given a Letter of Information and Informed consent (Appendix C) along with a verbal explanation of the research and what was expected of the participant to ensure they understood. The participant was informed that they were free to withdraw from the study at any point without any consequences to themselves. If the participant wished to withdraw from the study, they were thanked for their time and allowed to leave.

The participants were allowed to ask any questions regarding the study, which were answered by the researcher. Once all questions were answered and the participants were satisfied, they were required to complete and sign the Letter of Information and Informed Consent.

Those that agreed to participate underwent a case history (Appendix E), physical examination (Appendix F) and a lumbar and pelvic regional examination (Appendix G). Participant examination results were discussed with the on-duty clinician at the time of consultation. Participant details were recorded on the clinic record and then accordingly coded by front desk staff for anonymous data collection.

3.8.1 Intervention

The intervention applied to each participant was based on the group into which they had been randomly allocated:

Group one: The participants received a sacroiliac joint manipulation administered by the research assistant. The technique used involved placing the participant in side lying posture with the dysfunctional sacroiliac joint side up, the upper thigh was flexed between 60 and 80 degrees and contact was applied to the ilia and the leg to develop tension while the indifferent hand stabilises the participants shoulder before a flexion manipulation was applied (Bergmann and Peterson 2011). Every effort was made by the research assistant to ensure that the manipulation was specific and targeted to the SIJ, however there is the possibility that the L5 region may have been affected.

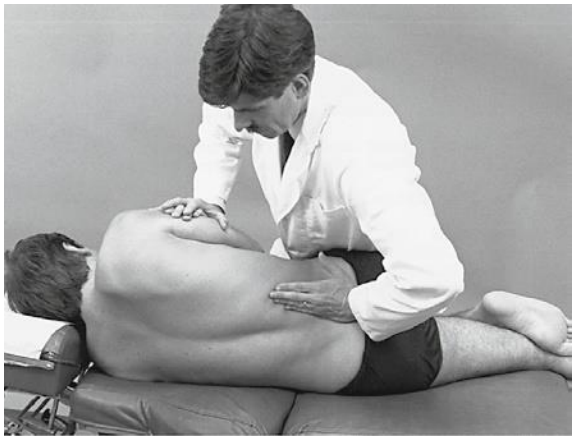

Figure 7: Sacroiliac joint flexion manipulation (Bergmann and Peterson 2011)

Group two: The participants received a placebo sacroiliac joint manipulation administered by the research assistant. This consisted of the same setup as the intervention group however; a non-thrust push manoeuvre was delivered to the gluteal region as done in accordance with guidelines shown by Chaibi *et al*. (2015) where a placebo lumbar SMT was used that consisted of a non-specific contact over the lumbar area performed lateral to the spinal column. This was performed using a low velocity, low amplitude push manoeuvre in a non-intentional and non-therapeutic direction with sufficient joint slack to prevent any joint cavitations from occurring. This group aided in a comparison to the intervention group to determine if the effects were due to the setup of the manipulation, and not due to the manipulation itself.

3.9 Full research procedure

Participants that fit the criteria for the telephonic interview presented to the Chiropractic Day Clinic for the initial consultation which all new patients of the DUT Chiropractic Day Clinic undergo. This consists of a case history, physical examination and lumbar regional examination (Appendices E, F and H). This was to ensure that each participant met the inclusion criteria.

The participant was then screened for SIJ restrictions bilaterally, using the sacral push and upper sacroiliac joint mobility test as described by (Bergmann and Peterson 2011).

The sacral push was performed by asking the participant to sit with their arms crossed over the front of their chest contacting their shoulders. The researcher then stood behind the participant and established bilateral thumb contact over the patient's SIJ and sacral ala. The

participant was then asked to extend their back and rotate to the right and then the left around the researcher's thumbs. Restriction in anterior gliding of the sacral base indicates a SIJ restriction (Bergmann and Peterson 2011). The sacral push test was chosen to help identify SIJ restrictions as it has been shown to have specificity and sensitivity of greater than 60% (Stuber 2007).

The upper sacroiliac joint mobility test was performed by asking the participant to stand and support themselves by contacting the wall, using both hands. The researcher sat behind the participant and established thumb contact over the participant's posterior superior iliac spine (PSIS) and the second sacral tubercle. The participant was then instructed to flex the ipsilateral hip to 90 degrees while keeping the knee bent, this induces flexion of the hip and SIJ. With normal movement in the joint, the researcher's thumbs should approximate as the PSIS moves posteriorly and inferiorly towards the second sacral tubercle. A SIJ flexion restriction was suspected when the thumbs did not approximate as the pelvis rotated obliquely around the opposite hip. This procedure was then repeated on the opposite side to determine if there is an SIJ restriction of the opposite SIJ (Bergmann and Peterson 2011).This was retested by the research assistant to validate the presence of a restriction and this information was recorded on the data collection sheet (Appendix D). If a restriction was noted bilaterally the one deemed most restricted received the intervention.

The placement areas for the electrodes were cleaned with alcohol swabs after which the electrodes were placed. The participant was placed in the prone position with two electrodes placed 3cms apart over the middle of the muscle, 2.5 to 5cms above the gluteal fold, and another two electrodes placed at the halfway point between the trochanter and the sacral vertebrae, at the level of the trochanter, as shown in Figure 8 (Crisswell 2011). Electrodes for Channel A were placed over the superior portion of the gluteus maximus, while the Channel B electrodes were placed inferior to Channel A.

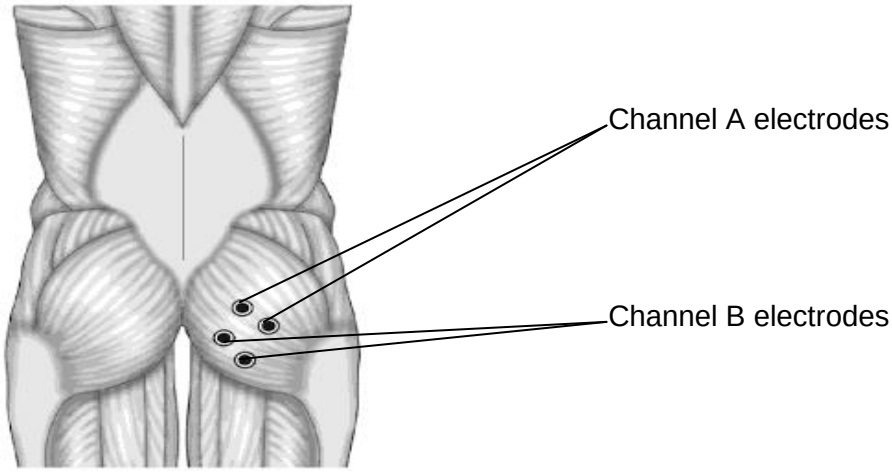

Figure 8: Electrode placement for the gluteus maximus muscle (Crisswell 2011)

The Biopac – Bionmadix complete wireless research system with four channel EMG recording (Biopac Systems Inc 2015) was switched on and baseline readings were taken for a one-minute period of inactivity while the participant remained motionless. The participant was then asked by the researcher to perform three maximal resisted hip extensions. Both the intervention group and the placebo group were asked to maximally contract and resist to their maximum ability without injuring themselves. This was performed by participants lying prone and the researcher requesting the participant starts flexing at the knee and extending their hip backwards, exerting the maximum amount of force possible against a black Theraband tied down with no room for slack as shown by Hislop and Montgomery (2007) each of five second duration, followed by one minute of rest as done by Boren *et al*. (2011).

Figure 9: Hip extension test to isolate gluteus maximus (Hislop and Montgomery 2007)

The participants were given 10 minutes to recover from any muscle fatigue as this was shown to be enough time by Larivière *et al*. (2003). This recovery was done while lying in the prone position and prior to intervention. Immediately post-intervention the participants of both groups were asked to repeat the maximum voluntary contractions of the gluteus maximus three times for a period of five seconds while SEMG readings were recorded. To help control for conditions the same room was used for every participant, the air-conditioning in the room was kept at 21° Celsius and the participant was asked to reduce any activity while they were recovering.

3.9.1 Flow diagram of full research procedure

Participant responds to the advertisement seen as well as by word of mouth. Four participants responded to the advert and the remainder through word of mouth.

↓

Telephonic interview in order to include or exclude participant based on answers to Table X.

↓

Appointment scheduled with participant at the DUT Chiropractic Day Clinic.

↓

Research procedure explained to the participant. Participants were given the opportunity for questions and were informed that they may withdraw from the study at any point before the Letter of Information and Informed Consent was read and signed by the participants (Appendix C).

↓

Case history (Appendix E), physical examination (Appendix F) and lumbar and pelvic regional examination (Appendix G) completed and BMI was calculated and recorded for each participant on the data collection sheet (Appendix D).

↓

SIJ restriction was tested for and confirmed by the research assistant.

↓

Participants were randomised by the research assistant and their assigned group recorded at the DUT clinic's front desk.

↓

Electrodes were placed as explained above and the participants were taught how to perform a maximum voluntary contraction of the gluteus maximus.

↓

Participants performed a maximum voluntary contraction of the gluteus maximus for a period of five seconds. This was repeated three times with a rest period of one minute between contractions.

↓

The participant received the intervention as allocated by their randomisation. This was performed by the research assistant in order to maintain blinding of the researcher. The participants received either a SIJ manipulation or a placebo SIJ manipulation.

↓

The participant remained prone for 10 minutes in order to recover from any muscle fatigue they may have experienced.

↓

The participant repeated maximum voluntary contraction of the gluteus maximus three times.

↓

On completion, the participants were thanked for their time before they left.

↓

All data was captured from the participant and then processed using BiopacAcqKnowledge to determine the root mean square of the captured data. This was then captured on an Excel spreadsheet by the researcher. 28 participants successfully completed the trial with no exclusions being made.

3.10 Ethical Considerations

Participants were asked to sign a letter of information and informed consent (Appendix C) at the initial consultation.

Participants had a 50% chance of being randomised into the placebo group, but as they were asymptomatic no treatment was withheld. However, if any illness or pathology was diagnosed at the initial consultation or during the research process the participant was referred accordingly.

Testing of gluteus maximus maximum voluntary contraction has no known risk factors and was performed under supervision of the researcher. If the participant developed pain, stiffness or discomfort during or within 24 hours of the study, they were examined and treated by the researcher as deemed appropriate by the researcher and clinician on duty.

The welfare of the participants was protected as the interventions and equipment utilised in this study were safe and registered.

If the participant wished to withdraw from the study, they were free to do so at any time without consequence.

All participant information was kept confidential and was stored securely in the Chiropractic Day Clinic. All data was collected in a manner that ensured participant information was kept confidential.

Permission to conduct this study on campus at the Chiropractic Day Clinic was obtained (Appendix K) prior to placement of advertisements in the above-mentioned locations (Appendix A). The DUT Institutional Research Ethics Committee granted full ethical approval prior to the commencement of the study (IREC 161/17: Appendix J).

3.11 Data Analysis

Data recorded from participants for the duration of this study was stored on a password encrypted laptop with the names of the participants coded in order to ensure confidentiality. Due to the variety of data produced during muscle contraction, raw SEMG data needed to be normalised through root mean square (RMS) calculation in order to compare pre- and post-intervention of that participant, as well as between the intervention and placebo group. Each RMS graph used three event markers for each contraction. At each event marker a focus area was created for the duration of the five second contraction. The BiopacAcqKnowledge

program generated mean, maximum and minimum values for these contractions and this was captured using Microsoft Excel.

The data was analysed using IBM SPSS Statistics version 25. Baseline measures as well as height, weight and BMI were compared between the two treatment groups by means of t-tests. Changes between pre-and post- were compared between groups using repeated measures ANOVA testing. The interaction between time (pre- to post-) and group (treatment group) was considered as the effect of the intervention. Where the p value was <0.05 for the interaction, a significant treatment effect was declared. The partial eta squared for this effect was calculated and reported as a measure of the standardized effect size which is more informative than the p value to allude to the magnitude of the intervention effect. Rules of thumb for partial eta squared effect sizes were used: small: 0.02, medium: 0.13, large: 0.26. Profile plots were generated to assess the direction of the effects.

CHAPTER FOUR:

STATISTICAL METHODS AND RESULTS

4.1 Introduction

This chapter presents the results. The data will be presented using tables, graphs and figures.

4.2 Sampling outcome

In total there were 28 participants between the ages of 18 and 40 years who presented asymptomatically with the presence of a sacroiliac joint fixation. There were no drop-outs in this study.

4.3 Height, weight and body mass index (BMI)

There was a statistically significant height difference between the groups (p=0.041) which was only equivalent to 5 cm on average, and no difference in weight or BMI between the groups.

Table 9: Height (m), weight (kg) and body mass index (BMI) (kg/m^2) per group

		Group			
		Placebo	Intervention	Total	P value
Height (meters)	Valid N	14	14	28	0.041
	Mean	1.80	1.75	1.77	
	Standard Deviation	.07	.05	.06	
Weight (Kg)	Valid N	14	14	28	0.261
	Mean	76.64	73.71	75.18	
	Standard Deviation	8.01	5.20	6.79	
BMI (Kg/m²)	Valid N	14	14	28	0.522
	Mean	23.67	23.94	23.81	
	Standard Deviation	1.21	.98	1.09	

4.4 Electromyography readings (mV)

4.4.1 Pre-intervention values by treatment group

The goal of randomisation is to ensure equivalence of the groups at baseline. The table below shows that there were no statistically significant differences between the groups at baseline although Channel B pre-intervention maximum values approached significance with a difference of 0.081 units between the group means.

Nevertheless, the analysis procedure to compare the interventions adjusted for any baseline imbalances.

Table 10: Pre-intervention values per treatment group

		Group			
		Placebo	Intervention	Total	P value
Channel A Pre-Test Mean	Mean	.08	.08	.08	0.906
	Standard Deviation	.06	.06	.06	
Channel B Pre-Test Mean	Mean	.10	.07	.08	0.145
	Standard Deviation	.05	.03	.04	
Channel A Pre- Test Max	Mean	.28	.22	.25	0.283
	Standard Deviation	.13	.15	.14	
Channel B Pre-Test Max	Mean	.26	.18	.22	0.068
	Standard Deviation	.14	.08	.12	
Channel A Pre-Test Min	Mean	.01	.02	.02	0.421
	Standard Deviation	.01	.02	.01	
Channel B Pre- Test Min	Mean	.03	.01	.02	0.339
	Standard Deviation	.06	.01	.05	

4.4.2 Channel A mean values

Table 11: Channel A pre- and post-intervention mean values

Group	Time	Mean	Std. Error	95% Confidence Interval		P Value
				Lower Bound	Upper Bound	
Placebo	Pre-intervention	.083	.016	.050	.116	0.002
	Post-intervention	.063	.020	.022	.103	
Intervention	Pre-intervention	.080	.016	.047	.113	
	Post-intervention	.100	.020	.059	.140	

Table 12: Multivariate tests for Channel A pre- and post-intervention mean values

Channel A mean values Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.
time * Group	Roy's Largest Root	.434	11.277[b]	1.000	26.000	.002
	Hotelling's Trace	.434	11.277[b]	1.000	26.000	.002
	Wilks' Lambda	.697	11.277[b]	1.000	26.000	.002
	Pillai's Trace	.303	11.277[b]	1.000	26.000	.002
time	Roy's Largest Root	.000	.001[b]	1.000	26.000	.978
	Hotelling's Trace	.000	.001[b]	1.000	26.000	.978
	Wilks' Lambda	1.000	.001[b]	1.000	26.000	.978
	Pillai's Trace	.000	.001[b]	1.000	26.000	.978
a. Design: Intercept + Group Within Subjects Design: time						
b. Exact statistic						

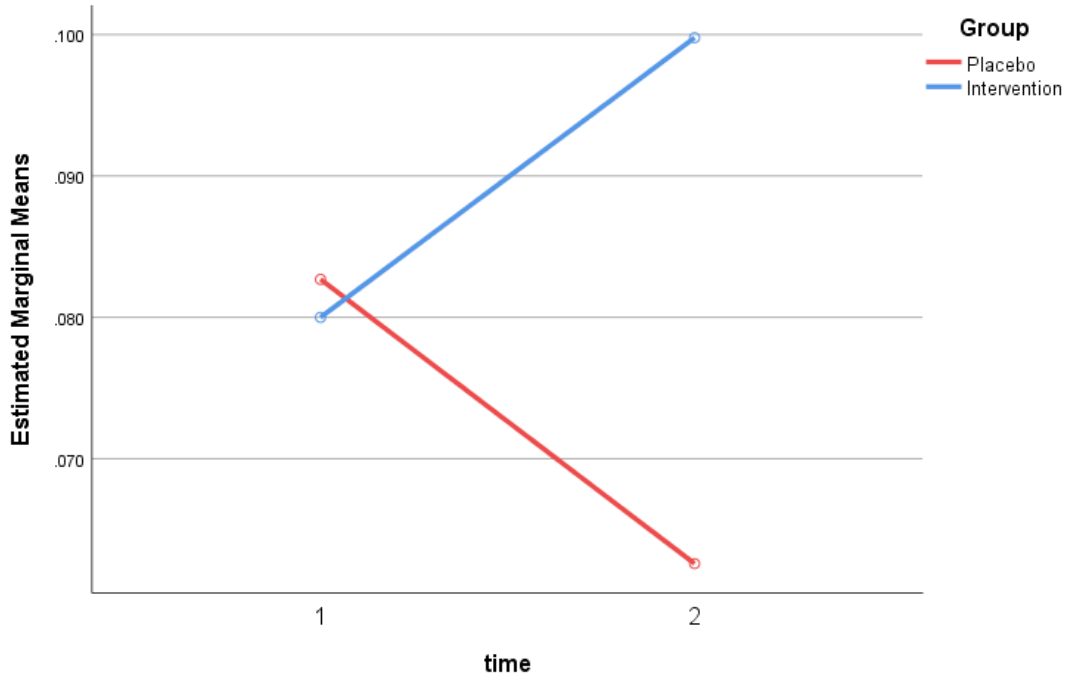

Figure 10: Graph showing the pre-intervention and post-intervention mean for Channel A mean values

There was a statistically significant treatment effect for channel A mean between the groups (p=0.002). The profile plot shows that there was a decrease in values from pre- to post- in the placebo group and a corresponding increase in the intervention group. This decrease in the placebo group may have occurred due to various factors including fatigue. The effect size measured by the partial eta squared was 0.303. This was classified as a large effect size.

4.4.3 Channel B mean values

Table 13: Channel B pre- and post-intervention mean values

Group	Time	Mean	Std. Error	95% Confidence Interval		P Value
				Lower Bound	Upper Bound	
Placebo	Pre-intervention	.095	.012	.071	.120	
	Post-intervention	.088	.018	.052	.125	
Intervention	Pre-intervention	.071	.012	.046	.095	0.066
	Post-intervention	.094	.018	.058	.131	

Table 14: Multivariate tests for Channel B pre- and post-intervention mean values

Channel B mean values Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.
time * Group	Roy's Largest Root	.141	3.672[b]	1.000	26.000	.066
	Hotelling's Trace	.141	3.672[b]	1.000	26.000	.066
	Wilks' Lambda	.876	3.672[b]	1.000	26.000	.066
	Pillai's Trace	.124	3.672[b]	1.000	26.000	.066
time	Roy's Largest Root	.038	1.001[b]	1.000	26.000	.326
	Hotelling's Trace	.038	1.001[b]	1.000	26.000	.326
	Wilks' Lambda	.963	1.001[b]	1.000	26.000	.326
	Pillai's Trace	.037	1.001[b]	1.000	26.000	.326
a. Design: Intercept + Group Within Subjects Design: time						
b. Exact statistic						

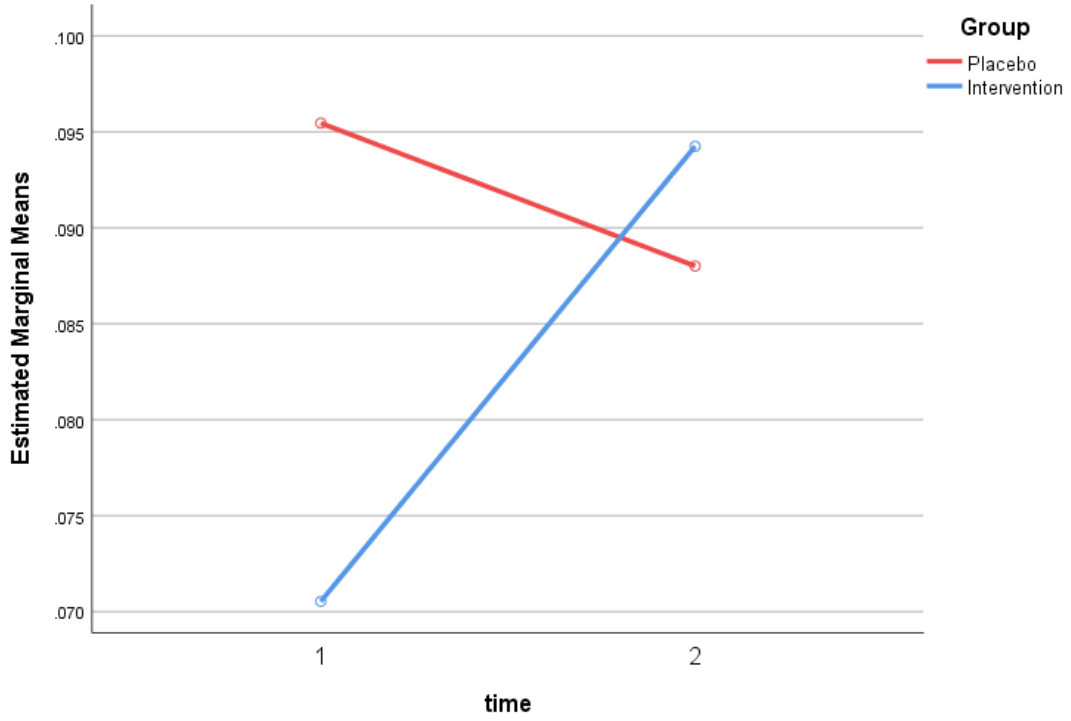

Figure 11: Graph showing the pre-intervention and post-intervention mean for Channel B mean values

There was a non-statistically significant treatment effect for channel B mean between the groups (p=0.066). The profile plot shows that there was a decrease in values from pre- to post- in the placebo group and a corresponding increase in the intervention group. The effect size measured by the partial eta squared was 0.124, a medium effect size.

4.4.4 Channel A maximum values

Table 15: Channel A pre- and post-intervention maximum values

Group	time	Mean	Std. Error	95% Confidence Interval		P Value
				Lower Bound	Upper Bound	
Placebo	Pre-intervention	.276	.038	.198	.355	0.169
	Post-intervention	.268	.053	.159	.376	
Intervention	Pre-intervention	.217	.038	.139	.296	
	Post-intervention	.269	.053	.161	.377	

Table 16: Multivariate tests for Channel A pre- and post-intervention maximum values

Channel A maximum values Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.
time * Group	Roy's Largest Root	.077	2.000[b]	1.000	26.000	.169
	Hotelling's Trace	.077	2.000[b]	1.000	26.000	.169
	Wilks' Lambda	.929	2.000[b]	1.000	26.000	.169
	Pillai's Trace	.071	2.000[b]	1.000	26.000	.169
time	Roy's Largest Root	.039	1.005[b]	1.000	26.000	.325
	Hotelling's Trace	.039	1.005[b]	1.000	26.000	.325
	Wilks' Lambda	.963	1.005[b]	1.000	26.000	.325
	Pillai's Trace	.037	1.005[b]	1.000	26.000	.325
a. Design: Intercept + Group Within Subjects Design: time						
b. Exact statistic						

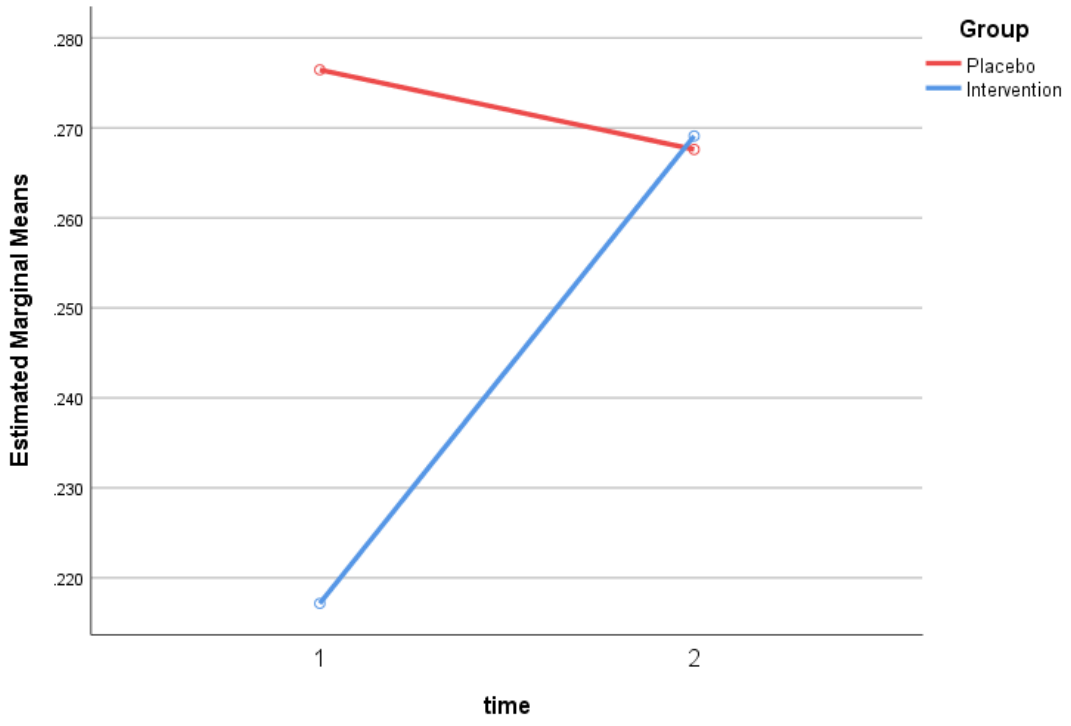

Figure 12: Graph showing the pre-intervention and post-intervention mean for Channel A maximum values

There was insufficient evidence of a treatment effect for channel A maximum values between the groups (p=0.169). The profile plot shows that there was a slight decrease in values from pre- to post- in the placebo group and a corresponding increase in the intervention group. The effect size measured by the partial eta squared was 0.071, a small effect size.

4.4.5 Channel B maximum values

Table 17: Channel B pre- and post-intervention maximum values

Group	Time	Mean	Std. Error	95% Confidence Interval		P Value
				Lower Bound	Upper Bound	
Placebo	Pre-intervention	.265	.030	.202	.327	0.010
	Post-intervention	.235	.036	.162	.308	
Intervention	Pre-intervention	.183	.030	.120	.245	
	Post-intervention	.217	.036	.144	.291	

Table 18: Multivariate tests for Channel B pre- and post-intervention maximum values

Channel B maximum values Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.
time * Group	Roy's Largest Root	.299	7.772[b]	1.000	26.000	.010
	Hotelling's Trace	.299	7.772[b]	1.000	26.000	.010
	Wilks' Lambda	.770	7.772[b]	1.000	26.000	.010
	Pillai's Trace	.230	7.772[b]	1.000	26.000	.010
time	Roy's Largest Root	.002	.051[b]	1.000	26.000	.823
	Hotelling's Trace	.002	.051[b]	1.000	26.000	.823
	Wilks' Lambda	.998	.051[b]	1.000	26.000	.823
	Pillai's Trace	.002	.051[b]	1.000	26.000	.823
a. Design: Intercept + Group Within Subjects Design: time						
b. Exact statistic						

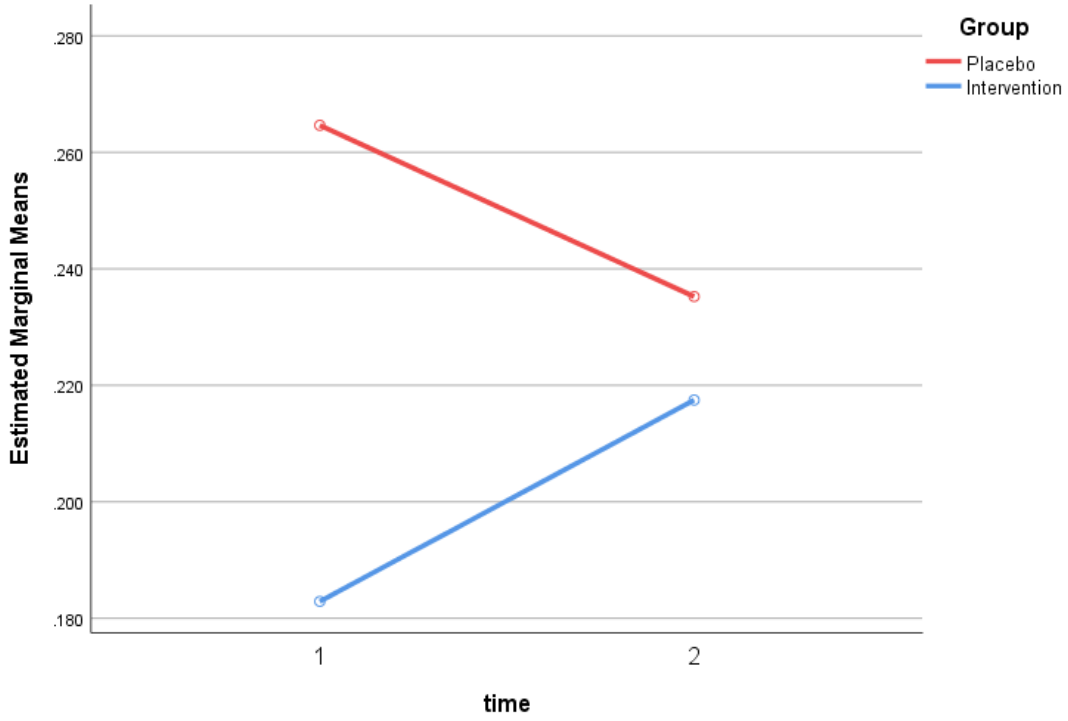

Figure 13: Graph showing the pre-intervention and post-intervention mean for Channel B maximum values

There was a statistically significant treatment effect for channel B maximum between the groups (p=0.010). The profile plot shows that there was a decrease in values from pre- to post- in the placebo group and a corresponding increase in the intervention group. The effect size measured by the partial eta squared was 0.230, a medium to large effect size.

4.4.6 Channel A minimum values

Table 19: Channel A pre- and post-intervention minimum values

Group	Time	Mean	Std. Error	95% Confidence Interval		P Value
				Lower Bound	Upper Bound	
Placebo	Pre-intervention	.013	.004	.005	.021	0.128
	Post-intervention	.011	.004	.004	.019	
Intervention	Pre-intervention	.018	.004	.010	.026	
	Post-intervention	.021	.004	.013	.029	

Table 20: Multivariate tests for Channel A pre- and post-intervention minimum values

Channel A minimum values Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.
time * Group	Roy's Largest Root	.095	2.467[b]	1.000	26.000	.128
	Hotelling's Trace	.095	2.467[b]	1.000	26.000	.128
	Wilks' Lambda	.913	2.467[b]	1.000	26.000	.128
	Pillai's Trace	.087	2.467[b]	1.000	26.000	.128
time	Roy's Largest Root	.005	.125[b]	1.000	26.000	.727
	Hotelling's Trace	.005	.125[b]	1.000	26.000	.727
	Wilks' Lambda	.995	.125[b]	1.000	26.000	.727
	Pillai's Trace	.005	.125[b]	1.000	26.000	.727
a. Design: Intercept + Group Within Subjects Design: time						
b. Exact statistic						

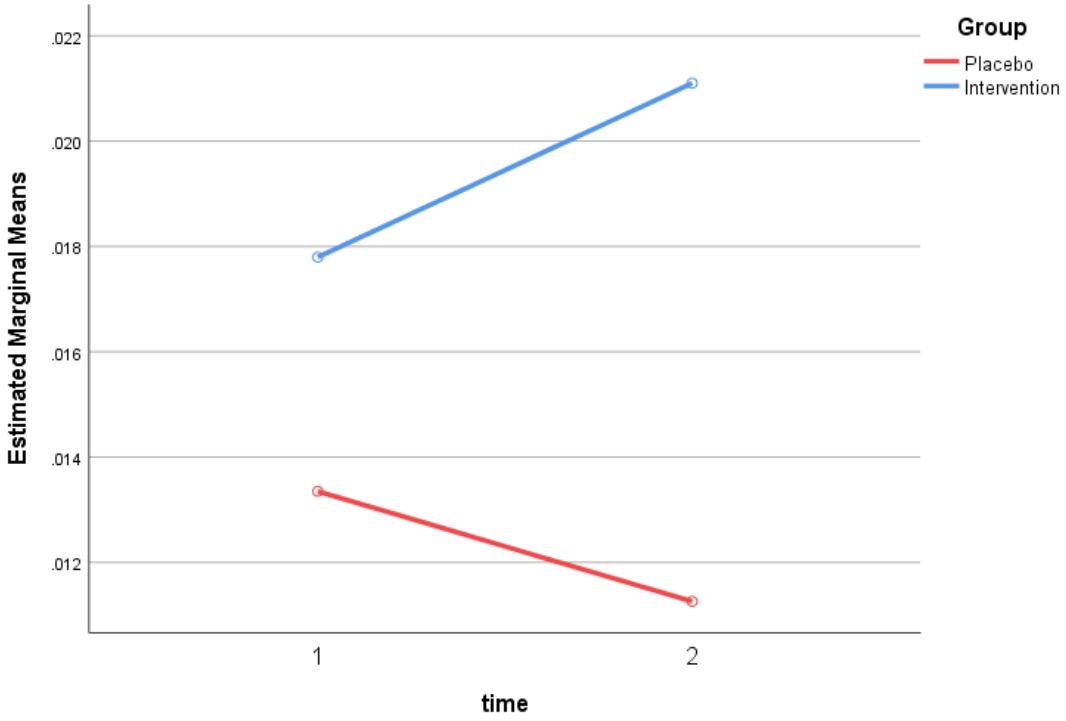

Figure 14: Graph showing the pre-intervention and post-intervention mean for Channel A minimum values.

There was insufficient evidence of a treatment effect for channel A minimum between the groups (p=0.128). The profile plot shows that there was a decrease in values from pre- to post- in the placebo group and a corresponding increase in the intervention group. The effect size measured by the partial eta squared was 0.087, a small effect size.

4.4.7 Channel B minimum values

Table 21: Channel B pre- and post-intervention minimum values

Group	time	Mean	Std. Error	95% Confidence Interval		P Value
				Lower Bound	Upper Bound	
Placebo	Pre-intervention	.031	.012	.006	.056	0.145
	Post-intervention	.011	.004	.004	.019	
Intervention	Pre-intervention	.015	.012	-.010	.040	
	Post-intervention	.021	.004	.013	.029	

Table 22: Multivariate tests for Channel B pre- and post-intervention minimum values

Channel B minimum values Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.
time * Group	Roy's Largest Root	.087	2.253[b]	1.000	26.000	.145
	Hotelling's Trace	.087	2.253[b]	1.000	26.000	.145
	Wilks' Lambda	.920	2.253[b]	1.000	26.000	.145
	Pillai's Trace	.080	2.253[b]	1.000	26.000	.145
time	Roy's Largest Root	.023	.605[b]	1.000	26.000	.444
	Hotelling's Trace	.023	.605[b]	1.000	26.000	.444
	Wilks' Lambda	.977	.605[b]	1.000	26.000	.444
	Pillai's Trace	.023	.605[b]	1.000	26.000	.444
a. Design: Intercept + Group Within Subjects Design: time						
b. Exact statistic						

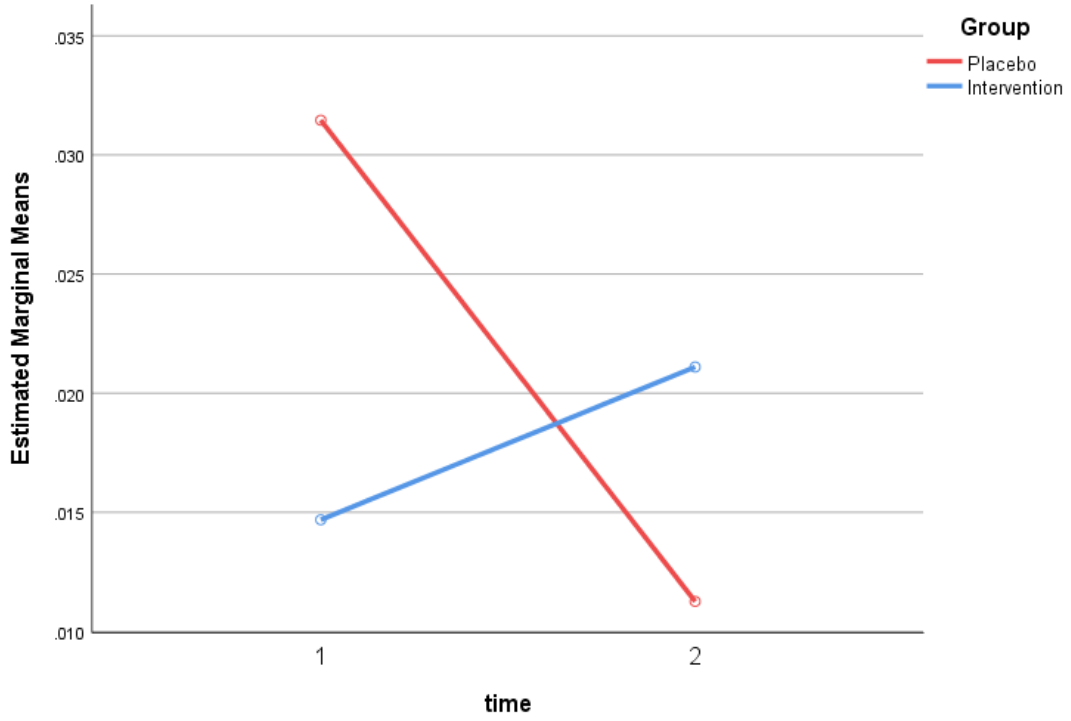

Figure 15: Graph showing the pre-intervention and post-intervention mean for Channel B minimum values.

There was insufficient evidence of a treatment effect for channel B minimum between the groups (p=0.145). The profile plot shows that there was a large decrease in values from pre- to post- in the placebo group and a corresponding increase in the intervention group. The effect size measured by the partial eta squared was 0.080, a small effect size.

4.5 Conclusion

There was evidence of an improvement in the intervention group when compared with the placebo group from pre- to post- for outcomes of Channel A mean and maximum values, and for Channel B maximum values. In the other measures there was a trend observed but insufficient evidence to conclude that it was a real effect. The partial eta squared values were relatively small for these non-significant effects and medium to large for the significant effects.

CHAPTER FIVE:

DISCUSSION

5.1 Introduction

This chapter will outline and discuss the results of this study within the context of the current literature.

5.2 Participant characteristics

5.2.1 Age, gender, body mass index and race.

The study population was limited to males between 18 and 40 years old. Age plays an important role in SEMG due to an increase in age being associated with a decrease in muscle mass and strength (Berkow *et al*. 1997: 225; Billot *et al.* 2010) and degenerative changes such as an increase in osteoarthritis which may impact the SIJ (Neogi and Zhang 2013).

Participants were only recruited if their BMI fell within the 'normal' BMI range of 18.5 kg/m² and 24.9 kg/m² in order to minimise subcutaneous fat. Crisswell (2011: 77) stated that there is an inverse correlation between skinfold thickness and the amplitude of SEMG readings; this is due to subcutaneous fat acting as an insulator between the muscle and the electrodes, the thicker the fat layer the smaller the signal that is picked up. There was no statistical difference in BMI (p=0.522) between the groups.

There is minimal reference to gender and race and their association with SEMG readings in the literature. However, the gender of participants was male to reduce variables.

5.3.1 Channel A and Channel B maximum values

The results of this study demonstrated no statistically significant change of muscle activity for Channel A maximum values (p=0.169). This result is not in line with the theory that SMT can have a neurological effect, resulting in a change in muscle activity. However, Herzog, Scheele and Conway (1999) noted a decrease in muscle activity post-SMT. They noted that there was unlikely to be any active muscle recruitment as a result of SMT due to the response (50 milliseconds) being too short for an active process and was likely reflexive and

transitory in nature. Similarly, Cardinale *et al.* (2014) suggested that any neuromuscular effects induced by SMT were negligible and transient in nature and compared their study to other studies such as Dishman and Bulbulian (2000) and Cunningham and Burke (2002) that showed similar short-term effects from manipulation.

Channel B (p=0.010) maximum values showed a statistically significant improvement when compared to the placebo group. The results from analysing this channel shows an increase in muscle activity. This is in line with the theory that SMT has a neurological effect by stimulating the joint capsule mechanoreceptors, resulting in an afferent bombardment of the shared spinal nerve roots (L5, S1 and S2) of the SIJ and gluteus maximus (Beck 2011; Crossman and Neary, 2015). In a similar study, Suter *et al.* (1999) presented a substantial reduction in quadriceps inhibition and a corresponding increase in muscle activity in symptomatic participants after SIJ manipulation. This was speculated to be related to either a reduction in referred pain or altered afferent feedback as a result of change to a dysfunctional SIJ. These results are also supported by Hillermann *et al.*(2006) who found significant increase (p =0.05) in quadriceps muscle strength post-SIJ SMT. This finding was attributed to SMT over the nerve root level of the tested muscle group, resulting in altered mechanoreceptor sensation in the motor neuron pool.

5.3.2 Channel A and Channel B minimum values

Both Channel A (p=0.128), and Channel B (p=0.145) minimum values did not produce statistically significant enough change to determine evidence of an effect. This indicates that SMT in this study did not increase the minimum activity produced by the gluteus maximus. This is in contrast with the theory that SMT has a positive neurological effect on the surrounding musculature. However, Lehman (2012) noted that there was a much larger effect in the change of muscle activity in the presence of muscle dysfunction, such as palpable tautness or pain prior to intervention. However, this study did not consider these effects as asymptomatic participants were used. It is possible that there was a diminished effect on the change in muscle activity due to the asymptomatic and pain-free nature of the participants, whereas symptomatic participants may have produced more notable results. Few other studies included minimum values in their results, and it was therefore difficult to draw comparisons to them.

Skin fold thickness may also have played a role in the minimal changes noted for this outcome. Crisswell (2011) has stated that there is a negative correlation between skin fold thickness and SEMG wave amplitude. This is due to subcutaneous fat acting as an insulator between the tested muscle and electrodes, resulting in a dampened signal. Although this

study controlled for participant BMI, it did not control for skin fold thickness which varied within the sample population and may have influenced the quality and magnitude of the data received. This may play an even more important role when trying to determine the minimum readings of a muscle.

It is also important to consider the effect of crosstalk in this study. Crosstalk occurs when the pick-up area of the electrodes overlaps, resulting in contamination of the muscle signals, impacting the quality of the data (Mogk and Keir 2003). In this study, efforts were made to reduce it through proper placement of the electrodes and keeping the room noise-free (Farina *et al.*2004). Although minimised, this may still contaminate results. In a study by Winter *et al.* (1994), it was shown that normal crosstalk can range from between 9% to 24% in muscles of the lower limb under regular SEMG conditions. It was noted that this crosstalk could be reduced through correct placement of the SEMG electrodes. Utilising a 1cm spacing between electrode pairs, crosstalk was as high as 49%, but this dropped to 13% with a 2cm spacing and 4% with a 3cm spacing.

5.3.3 Channel A and Channel B mean values

Results from this study showed a statistically significant improvement in the intervention group's mean values for Channel A (p=0.002), showing that SMT has influenced the activity of the gluteus maximus. Channel B showed a non-statistically significant (p=0.066) improvement when compared to the placebo group. These results once again are in line with other studies such as (Herzog, Scheele and Conway 1999; Suter *et al.* 1999; Hillermann *et al.* 2006 and Cardinale *et al.* 2014), suggesting that SMT may have a neurological effect on surrounding musculature. However, larger sample sizes and additional studies will be required to conclude this and to determine how much of an effect SMT has. The exact mechanisms underlying the neurophysiological effects of SMT are still unclear. It was noted that the intervention groups' baseline reading for Channel B was lower than that of the placebo group. This was possibly due to a difference in the group's ability to maximally contract, but was not found to be of statistical significance.

5.4 Conclusion

This study has shown varying results with some measurements determining a statistically significant increase in muscle activity, while other results tended towards an increase in muscle activity but lacked a large enough sample size to conclude whether this effect was real. These results correlate with other similar studies using SIJ manipulation but utilising different muscle groups.

Some contributing factors towards the diminished results in this study could be differing skinfold thickness, crosstalk and an overlooked dysfunction of the hip, knee and ankles.
It can be concluded from this study that chiropractic manipulation of the SIJ can have an effect of increasing muscle activity of the adjacent gluteus maximus muscle. Further studies with larger sample sizes are needed to determine whether these findings are consistent for maximum voluntary contraction minimum and mean measurements.

CHAPTER SIX:

CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter discusses and concludes the outcomes from this study. A conclusion is drawn from the results presented in Chapter 4 and discussions in Chapter 5. The limitations of this study are discussed, as well as recommendations made with regards to future research within the scope of this study.

6.2 Conclusion

This study proposed to determine the effect of sacroiliac joint manipulation on the gluteus muscle activity in asymptomatic participants. Analysis of the results revealed that there may have been of an improvement in the intervention group, compared with the placebo group in some of the outcomes measured. Other outcomes measured tended towards an improvement but lacked a sufficiently large sample size to conclude that it was a statistically significant effect.

6.3 Limitations

1. Although BMI was controlled in this study it was noted that subcutaneous fat layer thickness differed between participants. This may have affected SEMG readings as subcutaneous fat acts as an insulator between the electrodes and the muscle.
2. The small sample size (n=28) in this study may have limited the ability to obtain enough SEMG readings.
3. This study was conducted on asymptomatic participants; these results could differ from a sample of symptomatic individuals.
4. This study did not take into account individual participants' muscle tightness, which may have affected the participant's ability to maximally contract.

6.4 Recommendations

1. A measurement of skinfold thickness over the muscle being tested should be included in the participant inclusion criteria.
2. This study only evaluated the immediate effect of sacroiliac manipulation. Future studies should include a follow up measurement to determine the short- and long-term effects.
3. A larger sample size should be used in future studies.
4. The addition of a control group that receives no treatment would be useful to compare to the placebo and intervention groups in order to strengthen the outcome of a study.
5. Future studies should include motion palpation following the manipulation to reassess whether the joint manipulation was successful.
6. Future studies should include examinations of surrounding regions such as the hip, knee, foot and ankle, and the thoracic region to prevent an overlooked dysfunction that may have impacted the tested area.

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Appendices

Appendix A: Advertisement

RESEARCH PARTICIPANTS WANTED!

ARE YOU MALE AND BETWEEN 18 TO 40 YEARS OLD?

ARE YOU FREE FROM

LOW BACK/LEG PAIN?

INTERESTED IN PARTICIPATING IN RESEARCH THAT LOOKS INTO PREVENTATIVE TREATMENT OF LOW BACK PAIN?

AT

THE DURBAN UNIVERSITY OF TECHNOLOGY CHIROPRACTIC DAY CLINIC

THE PURPOSE OF THIS STUDY IS TO DETERMINE THE EFFECT OF JOINT MANIPULATION ON THE MUSCLE ACTIVITY OF THE GLUTEUS MAXIMUS.

CONTACT: KEVIN

0828943449

Appendix B: Questions and answers

Questions asked	Answers required.
Would you be willing to answer a few questions in order to determine your eligibility into the study?	Yes
Are you currently healthy?	Yes
Are you male?	Yes
Are you between the ages of 18 and 40 years old?	Yes
Have you experienced any low back pain in the past three months?	No
Can you tell me your weight and height? (This will be done in order to determine the body mass index)	Calculated BMI: 18.5-24.9kg/ m^2
Have you had any major spinal trauma, surgeries or suffer from any chronic illnesses?	No

Appendix C: Letter of information and informed consent

LETTER OF INFORMATION

Dear Participant,

Thank you for showing an interest in my research project.

Title of the Research Study: The effect of sacroiliac joint manipulation on gluteus maximus muscle activity in asymptomatic individuals.

Principal investigator/s/researcher: Kevin Worth, BTech Chiropractic

Co-investigator/s/supervisor/s: Dr H. Kretzmann, M.DIP: Chiropractic

Brief introduction and Purpose of the Study:

Outline of the Procedures: This research will take place at the Durban University of Technology Chiropractic Day Clinic. At the first consultation you will undergo a thorough examination. Following which you will be selected providing you meet the criteria for the research. Once accepted into the study, you will be randomly assigned into either a control or test group. The test group will receive one treatment involving a sacroiliac joint manipulation, while the control group will receive a placebo manipulation. Measurements will be taken before and after the treatment to determine the muscle activity of the gluteus maximus. **The total time commitment required for this research will be around 2 hours.**

Measurement tools:

Surface Electromyography (SEMG) is a safe and non-invasive technique used to measure the motor unit action potentials (MUAP) of muscle motor units during contraction. SEMG is most effectively used on superficial muscles as there is less tissue interference with the MUAP before they are picked up by the SEMG electrodes. Electrodes are attached to the skin overlying the muscle being observed, these are used to detect the MUAP. The MUAP that is picked up by the electrodes are filtered and amplified by the SEMG unit, this data is then processed and displayed in multiple ways.

This research will have approximately 60 participants

Risks or Discomforts to the Participant: You may experience some minor discomfort over the area that has been manipulated.

Benefits: This study will provide a better understanding as to what effect manipulation has on the muscular activity of the muscles surrounding the manipulated joint, enabling further research into the effectiveness of manipulation for pain management.

Reason/s why the Participant May Be Withdrawn from the Study:

- If you are uncomfortable and wish to withdraw at any point in the study you may do so with no adverse consequences for future treatment at this facility.
- If you experience any discomfort or pain during the study.

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

Costs of the Study: You will not be expected or required to cover any costs towards this study.

Confidentiality: All patient information will be made anonymous to ensure patient confidentiality. The results from this study will be used for research purposes only. Only the researcher and supervisor (DR. Kretzmann) will be allowed access to these records. All data will be securely destroyed after study (+5 years).

Research-related Injury: Should you experience unbearable pain or discomfort, the clinician on duty would be informed and an appropriate intervention(s) would be applied to help reduce the pain. The intervention(s) applied would depend on the clinical judgment of the researcher, the permission of the clinician on duty and the acceptance of the intervention by you. Such interventions may include: ice, stretching, ultrasound therapy and transcutaneous electrical nerve stimulation.

Persons to Contact in the Event of Any Problems or Queries:

Please contact the researcher Kevin Worth (082 8943449), my supervisor Dr Heidi Kretzmann (031 2055520) or the Institutional Research Ethics Administrator (031 3732375). Complaints can be reported to the Director: Research and Postgraduate Support, Prof C E Napier (031 3732577) or carinn@dut.ac.za

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, _____ (Name of Researcher), about the nature, conduct, benefits and risks of this study-Research Ethics Clearance Number:_____
- I have also received read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerized system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

_____	_____	_____	_____	
Full Name of Participant	**Date**	**Time**	**Signature**	**/ Right Thumbprint**

I, _____ (Name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

_____	_____	_____
Full Name of Researcher	**Date**	**Signature**
_____	_____	_____
Full Name of Witness (if applicable)	**Date**	**Signature**
_____	_____	_____
Full Name of Legal Guardian (if applicable)	**Date**	**Signature**

Please note the following:

Research details must be provided in a clear, simple and culturally appropriate manner and prospective participants should be helped to arrive at an informed decision by use of appropriate language (grade 10 level), selecting of a non-threatening environment for interaction and the availability of peer counseling (Department of Health,2004)

If the potential participant is unable to read/illiterate, then a right thumb print is required and an impartial witness, who is literate and knows the participant e.g. parent, sibling, friend, pastor, etc. should verify in writing, duly signed that informed verbal consent was obtained (Department of Health, 2004).

If anyone makes a mistake completing this document e.g. a wrong date or spelling mistake, a new document has to be completed. The incomplete original document has to be kept in the participant's file and not thrown away, and copies thereof must be issued to the participant.

References:

Department of Health: 2004.*Ethics in Health Research: Principles, Structures and Processes*
http://www.doh.gov.za/docs/factsheets/guidelines/ethnics/

Department of Health. 2006. *South African Good Clinical Practice Guidelines*. 2nd Ed.
Available at:
http://www.nhrec.org.za/?page_id=1

Appendix C: Letter of information and informed consent- IsiZulu

INCWADI YOLWAZI

Mbambiqhaza othandekayo,
Ngiyabonga ngokukhombisa kwakhoukulangazelela ukubamba iqhazakululu cwaningo lwami.

Isihloko socwaningo: Umthelela wokululwa kwelunga lsakhrollyakhi okubhudubezayo ekusebenzeni kemasela igluthlyasi makzimasi kubantu abangenazo izimpawu zesigulo/zezinhlungu.
Umcwaningi/umphenyi: Kevin Worth, BThekhiKhayirophrakthikhi

Umphathi: uDkt H. Kretzmann, M.DIP: Khayirophrakthikhi

Isingeniso kafushane kanye nenhloso yocwaningo:

Uhlaka lwenqubo yocwaningo: Lolu cwaningo luzokwenzelwa emtholampilo weKhayirophrakthikhi kwiNyuvesi yaseThekwini. Ngesikhathi sokuqala ubonwa, uzohlolwa/uzoxilongwa ngokuphelele. Okulandela lapho uzobe usuyakhethwangokwenqubo yocwaningo, uma kuwukuthi uyafaneleka ukuthi ubambe iqhaza kulolu cwaningo. Uma wamukelwe kucwaningo, uzobe usuyelashwakakodwa futhi ukwelashwa kwakho kuzobe kuhlanganisanokulungiswa noma ukwelulwa kwelunga lsakhrollyakhi okubhudubezayo. Ukukalwa/amamejamenti ayothathwa ngaphambili nangemuva kokwelashwa.
Isikhathi esiphelele esidengekayo ekuziphophezeleni kulolu cwaningo silinganiselwa emahoreni amabili.

Amathuluzlokumeja/ okukala:
Isafesi Elekthromayographi (SEMG) lyindlela ephephile futhi engalimazi esetshenziswa ukukala amamotho yunithi okusebenza kwemasela/imisipha. ISEMG ijwayele ukusetshenziswa ngempumelelo kumamasela/imisipha ekha phezulu ngoba kuba nezinga eliphansi lokuthi izicubu ziphazamise amamotho yunithi okusebenza kwemasela, ngaphambi kokuba athathwe ama elekthrodi eSEMG ukuze iwakale. Ama elekthrodi anamathiselwa kwisikhumbuza esemboze imasela noma umsipha ohlolwayo/oqaphiwe, wona asentshenziselwa ukuthola amamotho yunithi okusebenza kwemasela. Amamotho yunithi okusebenza kwemasela asuke ethathwe ama elekthrodi ayaye acwengwe futhi akhuliswe ISEMG yunithi, bese le mininingwane noma ulwazi luyasetshenzwa futhi lubonakaliswe ngezindlela eziningi.
Lolu cwaningo luzoba nababambiqhaza abalinganiselwa cishe kumashumi amane.

Ubungozi noma ukungaphatheki kahle kombambiqhazaokungadalwayilolu cwaningo: Ungazizwa unokungaphatheki kahle okuncanya nakulendawooluiwe kuyo.

Inzuzo: Lolu cwaningo luzoletha ukuqonda kangcono ukuthi ukululwa kwelunga kunamuthelela muni ekusebenzeni kwamamasela azungeze lelo lunga elilulwe, ukuze kugqugquzelwe ucwaningo olwengeziwe mayelana nokusebenza kokwelula/ukwelulwa ekulawuleni izinhlungu.

Izizathu ezingenza ukuthi umbambiqhaza asuswe/ahoxiswe kulolu cwaningo:

- Uma uzizwa ungaphathekile kahle futhi ufisa ukuhoxa kulolu cwaningo nganomayisiphi isikhathi ungahoxa, futhi angeke lokho kube nomthelela omubi ekulashweni kwakho kulesi sikhungo/kulo mtholampilo esikhathini esizayo.
- Uma uhlangabezana nokungazizwa kahle noma izinhlungu ngesikhathi ukululolu cwaningo.

ISAZISO: NJENGOMBAMBIQHAZA OZIKHETHELE UKUBA KULOLU CWANINGO, UVUMELEKILE UKUHOXA KUCWANINGO NGANOMA YISIPHI ISIKHATHI, NGAPHANDLE KOKUSHO/KOKUBEKA ISIZATHU.

Inani elikhokhwa umbambiqhaza ukuthi azibandakanye kulolu cwaningo: Umbambiqhaza akalindelekile noma akudingekile ukuthi akhokhe ukuze abe yingxenye yalolu cwaningo.

Ubumfihlo: Yonke imininingwane yesigulI angeke ivezwe ukuze kuqinisekiswe ubumfihlo besigulI. Imiphumela yalolu cwaningo izosetshenziselwa ucwaningo kuphela. Abantu abavumeleke ukufinyelela kulamarekhodi, umcwaningi nomphathi (Dr Kretzmann) kuphela.Yonke imininingwane/ idatha izobhujiswa ngokuyimfihlo emuva kocwaningo (eminyakeni engaphezu kwemihlanu).

Ukulimala okuphathelene nocwaningo: Uma umbambiqhaza ezwa izinhlungu ezingabekezelelekI noma ukungazizwa kahle, udokotela okhona emtholampilo ngaleso sikhathi uzokwaziswa ngalokhu futhi kuphinde kusetshenziswe izindlela ezifanelekile zokwelapha ezizosiza ngokudambisa izinhlungu. Lezo zindlela zokwelapha zizoncika ekwahlulelenI kukamcwaningI ngokwezinga lesigulo/lezinhlungu, imvume esuka kudokotela okhona emtholampilo ngalesosikhathi kanye nokuthi umbambiqhaza uyavuma yini ukuthi alashwe ngaleyo ndlela. Lezi zindlela zokwelapha zingabandakanya lokhu: iqhwa/ukubanda, ukweluIwa, I-aithrasawondI teraphi kanye nethranskhuthenIyasI elekthrikhalI nevu stimuleshinI.

Abantu ongaxhumana nabo uma kunezinkinga noma imibuzo:

Uyacelwa ukuthi uxhumanenomcwaningiuKevin Worth (081 046 3025), umphathi wophenyo uDkt Heidi Kretzmann (031 205 5520) nomaumlawuli wezimiso zokuhle kuCwaningo weSikhungo (031 373 2900). Izinkonondo zingadluiselwa futhi kumphathi/umqondisi: wezoCwaningo nesisekelo semfundo ephakeme,Solwazi S. Moyo (031 3732577) nomamoyos@dut.ac.za.

Ifomu lesivumelwano esicatshangisisiwe

Isitatimende semvumelwano yokuba umbambiqhaza kulolu cwaningo:

- Mina ngiyaqinisekisa ukuthi umphenyi ungazisile ngenkambo, uhlobo, izinzuzo kanye nobungozi balolu cwaningo- inombolo yophenyo: _____.
- Incwadi yolwazi olumayelana no cwaningo ngiyithole, ngayifunda futhi ngayiqondisisa.
- Ngiyaqonda ukuthi imiphumela yocwaningo, okubala imininingwane yami yobulili, iminyaka, usuku lokuzalwa, ama-initshiyali nokuthi ngiphethwe yini kuzosetshenzwa ngokungaziwa ukuze kwenziwe umbiko wocwaningo.
- Ngokubona izidingo zocwaningo, mina ngiyavuma ukuthi imininingwane yalolu cwaningo isetshenziwe ohlelweni lwekhompiyutha.
- Ngingakwazi, kunoma yisiphi isgaba ukuthi nginhoxise imvume nokubamba iqhaza kulolu cwaningo ngale kwengcindezi.
- Ngibe nethuba elanele lokubuza imibuzo futhi ngiyafunga ukuthi ngikulungele ubamba iqhaza kulolu cwaningo.
- Ngiyaqonda ukuthi lokho okusha, okubalulekile futhi okuthintana nokubamba kwami iqhaza ngenkathi kwenziwa lolu cwaningo ngizovumeleka ukukwazi.

_____	_____	_____	_____
Igama elipheleleIombambiqhaza sakesokudla	**Usuku**	**Isikhathi**	**Isiginisha/ Isithupha**

Mina, Kevin Worth ngiyaqinisekisa ukuthi lo mbambiqhaza ongenhla uchazelwe ngohlobo, inkambo nobungozi balolu cwaningo.

_____	_____	_____
Igama elipheleleIomphenyi	**Usuku**	**Isiginisha**
_____	_____	_____
Igama elipheleleIkafakazi (Uma kufanelekile)	**Usuku**	**Isiginisha**
_____	_____	_____
Igama elipheleleIomnakekelisemthethweni(Uma kufanelekile)		
_____		_____
Usuku		**Isiginisha**

Uyacelwa ukuthi wazi lokhu okulandelayo:

Imininingwane yocwaningo kumele inikezwe ngendlela ecacile, elula futhi efanelekile ngokosiko kanti futhi labo abazobamba iqhaza kumele basizwe ukuze bafinyelele kwisinqumo benolwazi olugcwele ngokuthi kusetshenziswe ulwimi olufanele noma abaluzwayo (lebanga leshumi), kukhethwe indawo ephephile futhi engasabeki yokwenzela lolu cwaningo kuphinde kutholakale nokwelulekwa ngabanye ontanga (Umkhandlu wezempilo, 2004).

Uma umbambiqhaza engakwazi ukufunda/engafundile, kudingeka ukuthi asebenzise isithupha sesandla sokudla kanti futhi nofakazilokwaziyo ukufunda noma ofundile futhi omazi kahlehle umbambiqhaza kungaba umzali, umuntu azalwa naye, umngani, umfundisi, njll. Kufanele aqinisekise ngokubhaliwe, ngokufanele asayine ukuthi itholakalile imvumelwano yolwazi exoxwayo (Umkhandlu wezempilo, 2004).

Uma kukhona owenza iphutha ngesikhathi egcwalisa le dokhumenti isib. abhale usuku olungeyilo noma abhale isipelingi esingesona, kumele aqale phansi agcwalise enye idokhumenti kabusha. Le dokhumenti yokuqala engagcwaliswanga ngokuphelele kumele ingalahlwa kepha igcinwe kwifayeli lombambiqhaza, bese kuthi amakhophi awo lamadokhumenti anikezwe umbambiqhaza.

Izinkomba:

Department ofHealth: 2004.*Ethics in HealthResearch:Principles, Structures and Processes* http://www.doh.gov.za/docs/factsheets/guidelines/ethnics/

Department ofHealth.2006.*SouthAfricanGood Clinical Practice Guidelines*. 2nd Ed.Available at:
http://www.nhrec.org.za/?page_id=1

Ngokwenjwayelo:

Umuntu okhombisa ukulangazelela ukubamba iqhaza kulolu cwaningo kumele aqinisekiswe ukuthi ukubamba iqhaza kungukuzithandela futhi inani labantu abadingekayo ukuthi babambe iqhaza kumele lingaphikwa. Ikhophi yencwadi yolwazi kumele inikezwe labo ababamba iqhaza kulolu cwaningo. Incwadi yolwazi kanye nefomu lesivumelwano esicatshangisisiwe kumele kuhunyushwe futhi kunikezelwe ngolwimi oluyinhloko/lwebele lukambambiqhaza isib. isiZulu.

Appendix D: Patient information sheet

Date: _____

Participant's code: _____

File no: _____

Height: _____m

Weight: _____kg

BMI (Body mass index): _____kg/m^2

Side chosen: _____

Objective measurements:

Measurements	Pre-intervention	Post-intervention
Mean SEMG readings (mV) Channel A		
Mean SEMG readings (mV) Channel B		
Maximum SEMG readings (mV) Channel A		
Maximum SEMG readings (mV) Channel B		
Minimum SEMG readings (mV) Channel A		
Minimum SEMG readings (mV) Channel B		

Appendix E: Chiropractic Day Clinic case history

Appendix E

CHIROPRACTIC PROGRAMME

CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient:_____ Date:_____

File #: _____ Age: _____

Sex: _____ Occupation: _____

Student:_____ 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:

Student's Case History:

1. **Source of History:**

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

3. **Present Illness:**

	Complaint 1(principle complaint)	Complaint 2 (additional or secondary complaint)
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:
Other (please list):

Tobacco
Alcohol
Social Drugs

7. Immediate Family Medical History:

Age of all family members
Health of all family members
Cause of Death of any family members

	Noted	Family member		Noted	Family member
Alcoholism			Headaches		
Anaemia			Heart Disease		
Arthritis			Kidney Disease		
CA			Mental Illness		
DM			Stroke		
Drug Addiction			Thyroid Disease		
Epilepsy			TB		
Other (list)					

8. Psychosocial history:

Home Situation and daily life
Important experiences
Religious Beliefs

9. Review of Systems (please highlight with an asterisk those areas that are a problem for the patient and require further investigation)

General

Skin

Head

Eyes

Ears

Nose/Sinuses

Mouth/Throat

Neck

Breasts

Respiratory

Cardiac

Gastro-intestinal

Urinary

Genital

Vascular

Musculoskeletal

Neurologic

Haematological

Endocrine

Psychiatric

Appendix F: Senior physical exam

Appendix F

DUT DURBAN UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

CHIROPRACTIC PROGRAMME

PHYSICAL EXAMINATION: SENIOR

Patient Name:			**File no:**	**Date:**	
Student:		**Signature:**			
VITALS:					
Pulse rate:			Respiratory rate:		
Blood pressure:	R	L	Medication if hypertensive:		
Temperature:			Height:		
Weight:	Any recent change!	Y / N	If Yes: How much gain/loss	Over what period	

GENERAL EXAMINATION:		
General Impression		
Skin		
Jaundice		
Pallor		
Clubbing		
Cyanosis (Central/Peripheral)		
Oedema		
Lymph nodes	Head and neck	
	Axillary	
	Epitrochlear	
	Inguinal	
Pulses		
Urinalysis		
SYSTEM SPECIFIC EXAMINATION:		
CARDIOVASCULAR EXAMINATION		
RESPIRATORY EXAMINATION		
ABDOMINAL EXAMINATION		
NEUROLOGICAL EXAMINATION		
COMMENTS		
Clinician:	**Signature:**	

Appendix G: Lumbar spine and pelvis regional exam

DUT DURBAN UNIVERSITY OF TECHNOLOGY — DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

CHIROPRACTIC PROGRAMME

REGIONAL EXAMINATION
LUMBAR SPINE AND PELVIS

Patient: _____ File#: _____ Date: _____

Student: _____ Clinician: _____

STANDING:

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

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

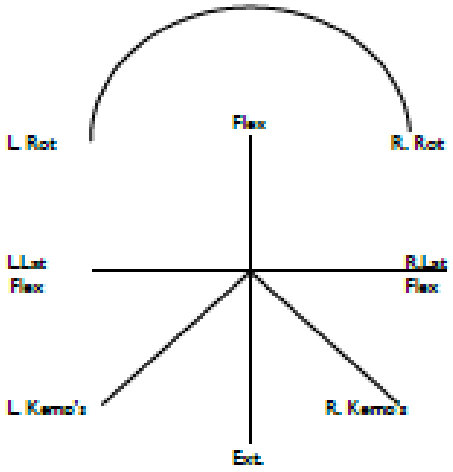
GAIT:

Normal walking
Toe walking
Heel Walking
Half squat

ROM:

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

Extension = 20-35°
L/R Rotation = 3-18°
L/R Lateral Flexion = 15-20°



Which movement reproduces the pain or is the worst?

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

SUPINE:

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

		Dermo	LBP!	Location	Loc pain	Buttock	Thigh	Calf	Heel	Foot	Brussard
SLR	L										
	R										

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

SITTING:

Soinous Percussion
Lhermitte

Valsalva

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

SLUMP / TEST											
	L										
	R										

LATERAL RECUMBENT:

	L	R
Ober's		
Femoral n. stretch		
SI Compression		

PRONE:

	L	R
Gluteal skrline		
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			
Iliocostal			
Rectus Abdominis			
Ext/Int Oblique muscles			

NON ORGANIC SIGNS:

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

NEUROLOGICAL EXAMINATION

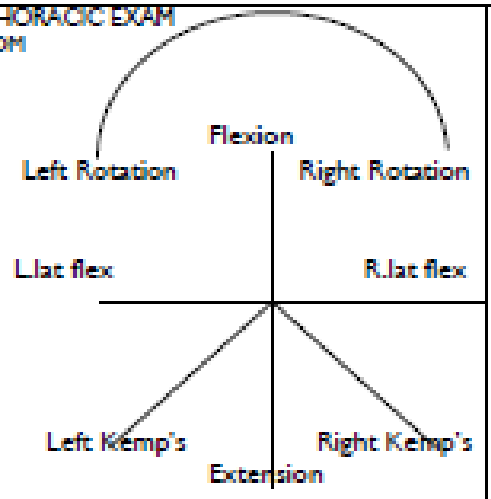
Fasciculations						
Plantar reflex						
level	Tender?	Dermatomes		DTR		
		L	R		L	R
T12				Patellar		
L1				Achilles		
L2						
L3				Proprioception		
L4						
L5						
S1						
S2						
S3						

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 rotation	Glutmed, min, TFL, adductors				3+ Weak against grav
Hip external rotation	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 plantarflexion	Gastrocnemius, soleus				
Ankle dorsiflexion	Tibialis anterior				
Inversion	Tibialis anterior				
Eversion	Peroneus longus				
Great toe extensor	EHL				

BASIC THORACIC EXAM

Passive ROM



Historr :

Orthopaedic assessment

BASIC HIP EXAM

Historr

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
Thoracic Spine		
Lumbar Spine		
Sacroiliac Joint		

Appendix H: SOAPE note

CHIROPRACTIC PROGRAMME Appendix H

Patient Name:		**File number:**	**Page:**
Date:	**Visit:**	**Student:**	
Attending Clinician:		**Signature:**	
S: Numerical Pain Rating Scale (Patient) Least 0 1 2 3 4 5 6 7 8 9 10 Worst	Student Rating ☐	**A:**	
O:		**P:**	
		E:	
Special attention to:		**Next appointment:**	
Date:	**Visit:**	**Student:**	
Attending Clinician:		**Signature:**	
S: Numerical Pain Rating Scale (Patient) Least 0 1 2 3 4 5 6 7 8 9 10 Worst	Student Rating ☐	**A:**	
O:		**P:**	
		E:	
Special attention to:		**Next appointment:**	
Date:	**Visit:**	**Student:**	
Attending Clinician:		**Signature**	
S: Numerical Pain Rating Scale (Patient) Least 0 1 2 3 4 5 6 7 8 9 10 Worst	Student Rating ☐	**A:**	
O:		**P:**	
		E:	
Special attention to:		**Next appointment:**	

Appendix I: Request for gatekeeper permission

Dear Director of Research and Postgraduate Studies,

My name is Kevin Worth and I am a chiropractic master's student at D.U.T. The title of my research is: **The effect of sacroiliac joint manipulation on gluteus maximus muscle activity in asymptomatic participants.** The study is a clinical trial that will require 60 participants and will take place on D.U.T property.

Due to the location and the research criteria of the study, some of the participants are very likely to be D.U.T students. As such I am requesting Gatekeeper permission so that any D.U.T students, who are interested and qualify as research participants, may participate in my study.

Study summary: This study aims to investigate the effect of manipulation on the gluteus maximus muscle in terms of muscle activity pre and post intervention. There is limited research looking at the effect manipulation has on surface EMG (SEMG) readings of the surrounding musculature and it is important that we increase our knowledge regarding the effect of manipulation on the surrounding musculature.

Proposed methodology: A randomized pre-test post-test using 60 asymptomatic participants. Participant's age range would be from 18-40 years. Measurement tools to be used: Surface electromyography (SEMG). Measurements will be taken prior to manipulation, and again post manipulation in order to determine the effect manipulation has on the surrounding musculature. Data will be analysed using MANOVA with a p value of less than 0.05 will be considered statistically significant.

Thank you for your time in considering my request.

Yours sincerely

Kevin Worth

21124607

Appendix J: IRIC approval

Directorate for Research and Postgraduate Support
Durban University of Technology
Tromso Annexe, Steve Biko Campus
P.O. Box 1334, Durban 4000
Tel.: 031-3732576/7
Fax: 031-3732946

05th June 2018

Mr Kevin John Kennedy Worth
c/o Department of Chiropractic and Somatology
Faculty of Health Sciences
Durban University of Technology

Dear Mr Worth

PERMISSION TO CONDUCT RESEARCH AT THE DUT

Your email correspondence in respect of the above refers. I am pleased to inform you that the Institutional Research and Innovation Committee (IRIC) has granted full permission for you to conduct your research "The effect of Sacroiliac join manipulation on gluteus maximus muscle activity in asymptomatic individuals" at the Durban University of Technology.

The DUT may impose any other condition it deems appropriate in the circumstances having regard to nature and extent of access to and use of information requested.

We would be grateful if a summary of your key research findings can be submitted to the IRIC on completion of your studies.

Kindest regards.
Yours sincerely

PROF CARIN NAPIER
DIRECTOR (ACTING): RESEARCH AND POSTGRADUATE SUPPORT DIRECORATE

Appendix K: Memorandum of permission

MEMORANDUM

To : Prof Adam
Chair: IREC

From : Prof A Ross
Deputy Dean: Faculty of Health Sciences

Dr Desiree Varatharajullu
Clinic Director: Chiropractic Day Clinic : Chiropractic and Somatology

Date : 29.05.2018

Re : Request for permission to use the Chiropractic Day Clinic for research purposes

---

Permission is hereby granted to:

Mr Kevin Worth (Student Number: 21124607)

Research title: " The effect of sacroiliac joint manipulation on gluteus maximus muscle activity in asymptomatic participants".

Mr Worth, is requested to submit a copy of his FRC / IREC approved proposal along with proof of his M.Tech:Chiropractic registration to the Clinic Administrators before he starts with his research in order that any special procedures with regards to his research can be implemented prior to the commencement of his seeing patients.

Thank you for your time.

Kind regards

Prof AHA Ross
Deputy Dean
Faculty of Health Sciences

Dr Desiree Varatharajullu
Clinic Director: Chiropractic Day Clinic
Chiropractic and Somatology

Cc: Mrs Linda Twiggs: Chiropractic Day Clinic
Dr L O'Connor: Research co-ordinator
Dr H.M.Kretzmann: Research supervisor

Appendix L: Trial Application

NHREC

South African Human Research Electronic Application System

TRIAL APPLICATION

Application ID:	5054	DOH Number	Pending	Page:	1/2

Applicant Details

Organisation :	Durban University of Technology
Applicant Type :	Academic Investigator
Contact Name :	Laura O'Connor
Address :	Chiropractic Programme Durban University of Technology PO Box 1334 Durban 4000
Telephone :	0313732923
Fax :	0865324209
E-mail :	lauraw@dut.ac.za
Responsible Contact person (for public)	L. O'Connor
Telephone :	03137372923
Research contact person	H.M. Kretzmann
Telephone :	0313732205

Trial Application Details

Issue Date :	2018/06/26
Sponsors :	Durban University of Technology
Primary Sponsor :	Durban University of Technology
FundingType :	Not Funded
Research Site Names :	Durban University of Technology Chiropractic Clinic
Primary Research Site Name :	Durban University of Technology Chiropractic Clinic
Total National Budget for Trial :	R R5962.00
Protocol / Grant Reference Number	REC161/17

Study Descriptive Information

Brief Title of Study :	The effect of sacroiliac joint manipulation on gluteus maximus muscle activity in asymptomatic participants.
Full Title of Study :	The effect of sacroiliac joint manipulation on gluteus maximus muscle activity in asymptomatic participants.
Anticipated Start Date :	2018/06/29
Anticipated End Date :	2018/10/31
Target Sample Size :	60
Study Phase :	Other
Study Scope :	Single Site
Study Type :	Interventional
Disease Type Heading :	Muscle, Bone and Cartilage Diseases
Disease Type Condition :	Musculoskeletal Diseases
Intervention Name (Generic) :	Spinal manipulation
Intervention Duration :	No. Type 5 Minutes

NHREC

South African Human Research Electronic Application System

TRIAL APPLICATION

Application ID:	5064	DOH Number	Pending	Page:	2/2

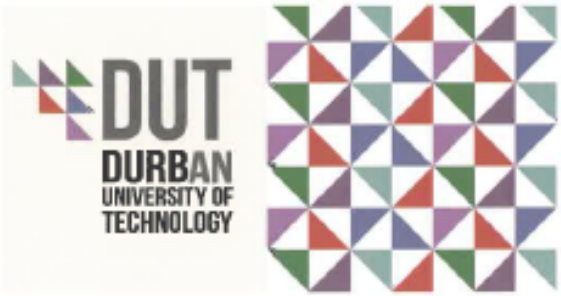
Interventional

Intervention Type :	Procedure
Purpose :	Treatment
Allocation :	Randomised
Masking :	Double Blind
Control :	Placebo
Assignment :	Parallel
Endpoints :	Efficacy

Study Descriptive Information

Recruitment Status as at Date:	2018/06/26
Recruitment Status :	Not Yet Recruiting
Gender :	Females
Ethnicity :	All
Age :	From 18 Years To 40 Years
Qualifying Disease Condition for Inclusion :	Healthy participants with a sacroiliac joint flexion restriction
Major Exclusion Criteria :	• On-going treatment for LBP by other health care providers. • Chiropractic students or practitioners, to ensure participants are blinded to the study. • The use of anti-inflammatory, muscle relaxants or analgesics within 72 hours prior to participation in the study. • Chronic illnesses • Contraindications to sacroiliac manipulation • Contraindications to SEMG
Key Primary Outcome :	Muscle activity
Key Secondary Outcomes :	

Appendix M: IREC approval



Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lawlorad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

25 July 2018

IREC Reference Number: **REC 161/17**

Mr K J K Worth
26 David Mclean Drive
Westville
Durban
3630

Dear Mr Worth

The effect of sacroiliac joint manipulation on gluteus maximus muscle activity in asymptomatic participants.

The Institutional Research Ethics Committee acknowledges receipt of your gatekeeper permission letters.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely,

Professor J K Adam
Chairperson: IREC

Appendix N: Application for approval of change of topic

APPLICATIONFORAPPROVALOF AMENDMENT	
To be completed electronically by the principal investigator/researcher in accordance with the Standard Operating Procedures of the IREC.	
Title of the study: The effect of sacroiliac joint manipulation on gluteus maximus muscle activity in asymptomatic participants.	
Institution: Durban University of Technology	Date: 12-03-2018
Name and qualification of principal investigator/researcher: Kevin Worth B:Tech Chiropractic	Name and qualification of supervisor(s):Dr H.M. Kretzmann MDIP: Chiropractic
Name of qualification: M:Tech Chiropractic	Student Number: 21124607
Ethical approval number: REC 161/17	Research site: DUT
Nature of amendment: Major amendment	
Effect on risk benefit profile of participants: Change in aims and objectives of the study from instrument assisted manipulation to manual manipulation. This change has been made due to the Impulse adjusting instrument not being a registered medical device in South Africa, and so will not pass approval with the Medical Devices Council. The proposal has been amended with minor changes to the literature review to discuss manual manipulation instead of instrument assisted manipulation, and the methodology updated to now use manual manipulation as the intervention. The focus of the study will instead look at the effects manual manipulation has on the gluteus maximus muscle, instead of the effects of the impulse adjusting instrument. These changes will result in no further risks for the participants, as instrument assisted	

manipulation and manual manipulation share the same risk factors.			
Please submit the following documentation: Amended proposal (changes to be underlined) Changes to letter of information and consent Any other relevant documentation			
Signature:	Date:		
Researcher:			
Supervisor:			
Head of Department:			
TO BE COMPLETED BY THE CHAIRPERSON OF THE IREC.			
Date received:	Review required:		
	Expedited		
TO BE COMPLETED BY THE CHAIRPERSON OF THE IREC			
The amendments:	Yes	No	N/A
Approved–there are no evident grounds for concern or further investigation.			
Approved subject to minor changes			
Needs to be re-submitted after recommendations are met			
Approved however a site inspection is recommended.			
Denied(please see attached)			
	Signature:	Date:	
Chairperson of FRC			
Chairperson of IREC			

Appendix O: Approval of change of topic

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

11 May 2018

Mr K J K Worth
26 David Mclean Drive
Westville
Durban
3630

Dear Mr Worth

The effort of sacroiliac joint manipulation on gluteus maximus muscle activity in asymptomatic participants.

I am pleased to inform you that your application to change the aims and objectives of the study from instrument assisted manipulation to manual manipulation has been approved.

Yours Sincerely

Professor J K Adam
Chairperson: IREC

DUT DURBAN UNIVERSITY OF TECHNOLOGY
2018 -05- 11
INSITUTUTIONAL RESEARCH ETHICS COMMITTEE
P O BOX 1334 DURBAN 4000 SOUTH AFRICA

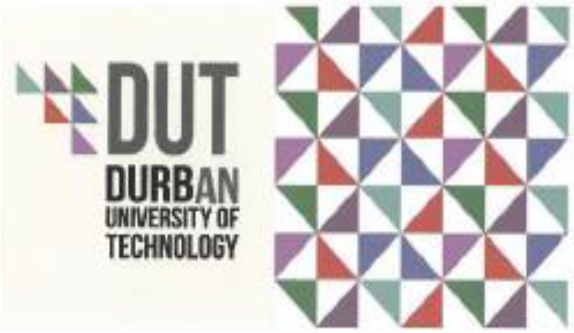
Appendix P: Request for change in sample size

APPLICATION FOR APPROVAL OF AMENDMENT	
To be completed electronically by the principal investigator/researcher in accordance with the Standard Operating Procedures of the IREC.	
Title of the study: The effect of sacroiliac joint manipulation on gluteus maximus muscle activity in asymptomatic participants.	
Institution: Durban University of Technology	Date: 26/03/2019
Name and qualification of principal investigator/researcher: Kevin Worth B:Tech Chiropractic	Name and qualification of supervisor(s):
Name of qualification: M:Tech Chiropractic	Student Number: 21124607
Ethical approval number: REC 161/17	Research site: DUT
Nature of amendment: Minor amendment	
Effect on risk benefit profile of participants: Change in sample size from 60 participants to 28 participants. This change has been made after consultation with the statistician, who has found after analyzing current data from research participants that 28 participants will have sufficient power to detect significant differences in the outcomes being tested.	
Please submit the following documentation: Amended proposal (changes to be underlined) Changes to letter of information and consent Any other relevant documentation	
Signature:	Date:
Researcher:	
Supervisor:	

Head of Department:			
TO BE COMPLETED BY THE CHAIRPERSON OF THE IREC.			
Date received:	Review required:		
	Expedited		
TO BE COMPLETED BY THE CHAIRPERSON OF THE IREC			
The amendments:	Yes	No	N/A
Approved–there are no evident grounds for concern or further investigation.			
Approved subject to minor changes			
Needs to be re-submitted after recommendations are met			
Approved however a site inspection is recommended.			
Denied(please see attached)			

	Signature:	Date:
Chairperson of FRC		
Chairperson of IREC		

Appendix Q: Approval of change of sample size



Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
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http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

2 May 2019

Mr K J K Worth
26 David Mclean Drive
Westville
Durban
3630

Dear Mr Worth

The effect of sacroiliac joint manipulation on gluteus maximus muscle activity in asymptomatic participants.

I am pleased to inform you that your application to change your sample size from 60 participants to 28 participants has been approved.

Yours Sincerely

Professor J K Adam
Chairperson: IREC

Appendix R: Research assistant contract

Statement of Agreement to Participate in the Research Study as a Research Assistant:

I ……..., ID number
…….. Voluntarily agree to participate in this study“ **The effect of manipulation on gluteus maximus muscle activity in asymptomatic participants.**” As a research assistant.

I will ensure that I maintain a level of confidentiality with regards to the research data that is collected.

Researcher assistant’s name (print)

……

Researcher assistant’s signature: ……

Date: ……

Researcher’s name (print) ……

Signature: …….

Date: ……..

Witness name (print) ……..

Signature: ……

Date: ……

Appendix S: Statistical data

Patient	Group	Side chos	A Pre test	A Pre Test	A Pre test	Channel A		B Pre Test	B Pre Test	B Pre Test	Channel B		A Post Tes	A Post Tes	A Post Tes	Channel A		B Post Tes	B Post Tes	B Post Tes	Channel B
1	A	Left	0.04215	0.02816	0.03244	0.03425		0.0734	0.05385	0.06343	0.06356		0.05652	0.05864	0.06471	0.059957		0.02885	0.03145	0.03164	0.030647
2	A	Right	0.03652	0.03797	0.03677	0.037087		0.03764	0.04639	0.05032	0.044783		0.03692	0.04719	0.04801	0.04404		0.03895	0.05678	0.05419	0.049973
3	B	Right	0.1016	0.10081	0.09279	0.0984		0.10829	0.10487	0.09401	0.10239		0.09513	0.11832	0.08945	0.100967		0.09557	0.12054	0.09279	0.102967
4	B	Left	0.07813	0.05619	0.06486	0.066393		0.0578	0.03847	0.0466	0.047623		0.0334	0.03531	0.04296	0.037223		0.02809	0.0291	0.03731	0.0315
5	A	Left	0.04499	0.05501	0.04296	0.047653		0.04216	0.05043	0.04209	0.044893		0.04392	0.04676	0.04332	0.044667		0.04987	0.05231	0.04847	0.050217
6	A	Left	0.06776	0.0891	0.10102	0.08596		0.10729	0.14478	0.1659	0.139323		0.13297	0.14772	0.16003	0.146907		0.18835	0.20862	0.22538	0.20745
7	A	Right	0.02598	0.03215	0.02753	0.028553		0.03508	0.04372	0.03567	0.038157		0.02785	0.02964	0.0271	0.028197		0.03779	0.04067	0.03765	0.038703
8	A	Left	0.06199	0.06848	0.09064	0.073703		0.08504	0.09499	0.1253	0.101777		0.06798	0.07762	0.09477	0.080123		0.09124	0.10418	0.12426	0.10656
9	B	Left	0.18103	0.19924	0.21605	0.198773		0.1636	0.18725	0.20185	0.184233		0.18694	0.21835	0.16228	0.18919		0.16484	0.18876	0.14478	0.166127
10	B	Left	0.17104	0.17993	0.187	0.179323		0.19862	0.2087	0.21737	0.20823		0.14224	0.17146	0.10079	0.138163		0.1755	0.20572	0.11319	0.164803
11	A	Right	0.05458	0.05312	0.04401	0.05057		0.06973	0.07006	0.0526	0.06413		0.06217	0.06664	0.05771	0.062173		0.06714	0.07389	0.06333	0.06812
12	A	Right	0.09986	0.07414	0.06895	0.080983		0.1211	0.09477	0.08874	0.101537		0.09627	0.06527	0.07585	0.07913		0.36489	0.29912	0.2829	0.315637
13	B	Left	0.0023	0.00141	0.00128	0.001663		0.08429	0.09368	0.0706	0.082857		0.00138	0.00124	0.00141	0.001343		0.08319	0.0964	0.08427	0.087953
14	B	Left	0.0016	0.00179	0.00151	0.001633		0.04076	0.03823	0.04713	0.04204		0.04921	0.04022	0.0249	0.03811		0.03874	0.03724	0.02632	0.0341
15	B	Left	0.06736	0.053	0.04108	0.053813		0.08193	0.06708	0.05253	0.06718		0.04947	0.04083	0.03754	0.042613		0.06858	0.05521	0.0507	0.058163
16	B	Left	0.06377	0.06467	0.06637	0.064937		0.0604	0.05921	0.0628	0.060803		0.00127	0.0013	0.00128	0.001283		0.03202	0.03155	0.04011	0.03456
17	B	Left	0.12388	0.09408	0.07987	0.099277		0.13494	0.10064	0.0847	0.10676		0.00147	0.00134	0.00144	0.001417		0.08345	0.10857	0.10431	0.098777
18	B	Right	0.05794	0.07528	0.07286	0.068693		0.05916	0.07581	0.07269	0.06922		0.00126	0.00145	0.00142	0.001377		0.10586	0.07747	0.08811	0.09048
19	B	Left	0.1536	0.14291	0.12046	0.13899		0.17859	0.16366	0.13593	0.159393		0.15813	0.15778	0.16068	0.158863		0.1736	0.16735	0.1685	0.169817
20	B	Left	0.11122	0.10028	0.07378	0.095093		0.1301	0.11559	0.08006	0.108583		0.09086	0.06077	0.10259	0.08474		0.11386	0.07437	0.13669	0.108307
21	B	Left	0.04439	0.03912	0.03306	0.038857		0.05664	0.04405	0.03648	0.045723		0.03759	0.03653	0.02695	0.03369		0.03887	0.0403	0.03418	0.037783
22	A	Left	0.05124	0.03603	0.03182	0.039697		0.06117	0.04495	0.02424	0.043453		0.03096	0.03123	0.03796	0.033383		0.04903	0.04568	0.05247	0.04906
23	A	Right	0.06207	0.06359	0.0689	0.064853		0.04753	0.04763	0.04989	0.04835		0.0815	0.08725	0.05737	0.075373		0.06487	0.06598	0.0464	0.059083
24	B	Right	0.05041	0.05	0.05489	0.051767		0.04773	0.05132	0.05477	0.051273		0.05182	0.04232	0.04724	0.047127		0.05116	0.04195	0.04707	0.046727

A Pre Test	A Pre Test	A Pre Test	Channel A		B Pre Test	B Pre Test	B Pre Test	Channel B		A Post Tes	A Post Tes	A Post Tes	Channel A		B Post Tes	B Post Tes	B Post Tes	Channel B
0.09793	0.06661	0.08036	0.081633		0.20308	0.13464	0.14066	0.15946		0.12946	0.15859	0.16006	0.14937		0.06307	0.08485	0.0846	0.077507
0.09326	0.1287	0.09253	0.10483		0.09582	0.12938	0.10328	0.109493		0.35399	0.12915	0.16238	0.215173		0.18939	0.1875	0.20886	0.19525
0.28236	0.26142	0.3261	0.28996		0.28396	0.2387	0.38901	0.30389		0.26043	0.40519	0.30985	0.325157		0.2851	0.42363	0.34094	0.34989
0.22922	0.21499	0.2429	0.229037		0.17122	0.13926	0.15866	0.15638		0.09272	0.10246	0.11301	0.10273		0.07084	0.07804	0.10223	0.083703
0.10809	0.12731	0.10203	0.112477		0.09136	0.1218	0.09863	0.10393		0.10193	0.10506	0.09542	0.100803		0.11679	0.11833	0.10762	0.114247
0.18175	0.25124	0.2285	0.220497		0.29441	0.34677	0.38945	0.343543		0.28303	0.34639	0.47017	0.36653		0.42187	0.50402	0.70943	0.545107
0.05931	0.0717	0.08068	0.070563		0.07119	0.09257	0.08274	0.082167		0.0652	0.07415	0.06819	0.06918		0.0652	0.07415	0.06819	0.06918
0.20814	0.1737	0.24773	0.209857		0.30531	0.27865	0.31282	0.298927		0.173	0.25057	0.32255	0.248707		0.23941	0.3293	0.42248	0.330397
0.54875	0.47536	0.63771	0.55394		0.48779	0.42428	0.58329	0.498453		0.44025	0.54063	0.34164	0.44084		0.3999	0.46493	0.32245	0.39576
0.43171	0.38665	0.42391	0.41409		0.51393	0.46582	0.48546	0.488403		0.35622	0.42033	0.29681	0.357787		0.40633	0.44303	0.30712	0.385493
0.12741	0.11205	0.09832	0.112593		0.209	0.25778	0.10974	0.192173		0.15511	0.15639	0.14533	0.152277		0.14693	0.2074	0.18069	0.17834
0.25828	0.21146	0.21595	0.228563		0.30734	0.26595	0.23092	0.26807		0.09627	0.06527	0.07585	0.07913		0.36489	0.29912	0.2829	0.315637
0.3479	0.42678	0.28533	0.353337		0.2411	0.2581	0.17128	0.223493		0.30319	0.46569	0.46981	0.412897		0.21532	0.28352	0.2054	0.234747
0.25054	0.20309	0.41946	0.29103		0.17844	0.12295	0.13462	0.145337		0.36989	0.19289	0.09039	0.217723		0.10377	0.10039	0.11042	0.10486
0.13561	0.14629	0.11342	0.131773		0.25785	0.17438	0.16005	0.197427		0.1446	0.10286	0.09201	0.113157		0.15269	0.18502	0.12717	0.15496
0.15139	0.28823	0.23528	0.224967		0.16294	0.16469	0.25914	0.19559		0.08344	0.11674	0.09591	0.098697		0.08344	0.11674	0.09591	0.098697
0.29517	0.23086	0.16607	0.2307		0.32753	0.24915	0.21355	0.26341		0.37261	0.54855	0.32775	0.416303		0.21674	0.28239	0.28594	0.26169
0.1657	0.18782	0.1831	0.178873		0.15789	0.17958	0.18543	0.1743		0.53466	0.35858	0.42205	0.43843		0.26596	0.18236	0.21489	0.22107
0.34806	0.39698	0.5559	0.433647		0.4762	0.37867	0.50974	0.45487		0.36148	0.35191	0.39727	0.37022		0.46552	0.45226	0.445	0.45426
0.34657	0.38695	0.21535	0.31629		0.44118	0.47324	0.22782	0.380747		0.30452	0.16238	0.28666	0.251187		0.3803	0.23658	0.38774	0.334873
0.10566	0.10316	0.08186	0.096893		0.13235	0.10686	0.07864	0.10595		0.08431	0.11081	0.06621	0.08711		0.08688	0.11521	0.09064	0.097577
0.21267	0.11861	0.35258	0.227953		0.18946	0.12831	0.07129	0.129687		0.08119	0.08764	0.30513	0.157987		0.12983	0.11292	0.17572	0.13949
0.15804	0.13088	0.37642	0.22178		0.12839	0.12596	0.20048	0.15161		0.1802	0.22963	0.14722	0.185683		0.14095	0.17997	0.13381	0.151577
0.11946	0.12885	0.12868	0.125663		0.11463	0.12062	0.11449	0.11658		0.11087	0.10299	0.12846	0.114107		0.11773	0.12438	0.10503	0.115713

c