

THE EFFECT OF LOW BACK MANIPULATION COMPARED TO COMBINED LOW BACK AND HIP MANIPULATION FOR THE TREATMENT OF CHRONIC NON-SPECIFIC LOW BACK PAIN

By

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*I, Jesse Bruins Roberts, 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

“Nobody trips over mountains. It is the small pebble that causes you to stumble.
Pass all the pebbles in your path and you will find that you have crossed the
mountain.”

— Unknown

For their support, sacrifice, patience, inspiration and belief, I dedicate the final
milestone of this mountainous chapter in my life to my mother, and father.
To my family, your motivation and love have seen me through to the end, and to my
friends, without whom I may have finished a year or two earlier, but with whom I
have gained invaluable experiences that are instrumental to my character.
To my future patients and the chiropractic profession, you have given me the means
to fulfil my expectations in primary health care and I shall do so with integrity,
compassion and principle.

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ABSTRACT

Background: Chronic non-specific low back pain (CNSLBP) is a common ailment treated by chiropractors. Most chiropractors focus on the localised lumbar area of pain. Other chiropractors focus on restoring function to compensating articulations in the 'full kinematic chain' by assessing and treating the lower extremity in conjunction to the low back. Patients with LBP often exhibit decreased hip-related ranges of motion that may result in future LBP, relapse and a prolonged recovery time. Studies investigating the effect of treating the kinematic chain in relation to LBP are limited and the literature, although widely taught and practiced, is largely anecdotal. Chiropractic manipulation has shown to be effective in the treatment of LBP and many lower extremity conditions.

Objectives: This study set out to determine if a combination of low back and hip manipulation would result in a more beneficial outcome for the participant, suffering with CNSLBP, than low back manipulation alone in terms of objective and subjective outcomes.

Method: The study was a randomised controlled clinical trial which, through purposive sampling, consisted of 50 participants with CNSLBP and hip joint dysfunction. The participants were randomly divided into two groups of 25 each [A and B]. Group A received low back manipulation alone and Group B received combined low back and hip manipulation. Subjective data was obtained through the Oswestry Low Back Pain Disability Index (ODI) and the Numerical Pain Rating Scale (NPRS). Objective data was obtained through the use of a Force Dial Algometer and an Inclinometer. Data collection occurred at the first, third and fifth consultations and was coded and analysed using IBM SPSS version 24.0. A *p*-value value of less than 0.05 was considered to be statistically relevant.

Results: Intra-group testing showed that there was a significant difference over time, within both groups, with regards to internal rotation and external rotation of the hip, flexion of the lumbar spine, increased pain tolerance in Algometer tests, decreased NPRS values and decreased ODI scores. Within Group A, the mean scores for hip flexion reflected a more significant increase over time than those of Group B. Within

Group B, the mean scores for left and right rotation of the lumbar spine reflected a more significant change over time than those of Group A. Inter-group testing showed no significantly differential treatment effect for any of the subjective and objective outcomes. This means that both treatments were equally effective and the hypothesis, that suggested that Group B would improve more than Group A, was incorrect.

Conclusion: Both treatment groups improved subjectively and objectively with regards to CNSLBP. Inter-group testing showed that statistically, and for all outcome measurements, there were no significant differences between the two treatment group's results. This suggested that there was no additional benefit in combining hip joint manipulation with low back manipulation in the treatment of CNSLBP.

Key Indexing Terms: *Chronic nonspecific low back pain, hip dysfunction, randomised controlled clinical trial, manipulation*

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LIST OF DEFINITIONS

Chronic Low Back Pain (CLBP)

One practice guideline defined CLBP as low back pain (LBP) of more than six weeks duration (Thorson *et al.*, 2008), which was the definition used for the purpose of this study.

Compensation

This term defines changes in structural and functional biomechanics of the human body in order to preserve balance following disturbance or dysfunction (Haldeman, 2005), for example: in the case of leg length discrepancies, compensatory external rotation occurs to increase stability in the shorter leg (Subotnick, 1999).

Drop-Out

A research participant who was unable to attend all five appointments for their manipulation treatments at the Chiropractic Day Clinic within the allocated two week time period due to personal reasons.

Gait (walking) cycle

The time a person takes, when they walk normally, between two heel strikes of the same foot (Magee, 2006).

Incidence

Incidence is the rate that new cases of a specific disease occur, over a specific time period and describes the risk of contracting a disease within a population (Dorland, 2011).

Joint Dysfunction

A joint dysfunction is a change in the function of a joint without structural change, for example: changes to stability, mobility, alignment and quality of movement in the joint (Bergmann and Peterson, 2011).

Joint Restriction

This refers to a temporary restriction of an articulation, within its normal physiological ROM (ROM), associated with shortened ligaments, muscular spasms or intra-articular origins (Haldeman, 2005).

Kinematic chain

This term describes a group of articulations or joints in the human body that are intrinsically connected and functioning as a whole, for example: The lower kinematic chain comprises of the foot, ankle, knee, hip, pelvis and lumbar spine (Bergmann and Peterson, 2011).

Low Back

For the purpose of this research, the low back will refer to a region in the human body that constitutes the vertebral units, intervertebral discs, nerve roots and the soft tissue surrounding the 1st to the 5th lumbar vertebra and the sacroiliac joints (McIntosh and Hall, 2011).

Low Back Pain (LBP)

This describes a local pain, ache, stiffness or discomfort between the lower costal margin and the gluteal fold. This is also known as 'lower back pain' (Galukande *et al.*, 2005).

Lower-cross Syndrome

This syndrome is characterised by weak/lengthened gluteal and abdominal muscles and concomitant strong/short hip flexors and erector spinae muscles (Chaitow *et al.*, 2001).

Manipulation

This describes a treatment protocol in which a brief, high velocity/low amplitude (HVLA) impulse is directed at a dysfunctional synovial joint in order to carry it past its normal physiological ROM but within its anatomical ROM (Bergman and Peterson, 2011).

Mechanoreceptor

These receptors are proprioceptive sensory nerve cells responsible for the perception of touch, movement, sound and vibration (Redwood, 1997).

Motion Palpation

A chiropractic procedure involving various hand-palpation techniques used to assess the integrity, mobility and general functionality of a person's joint or anatomical structure in terms of tenderness, shape, size, consistency, position and ROM (Gatterman and Hansen, 1994).

Motor neuron Pool

This term refers to the motor nerves innervating a specific muscle group (Hopkins and Ingersoll, 2000).

Myofascial Trigger Point

A myofascial trigger point occurs when a band of skeletal muscle becomes taut and symptomatically painful to compression. When active, it may refer and radiate pain to specific regions in the body (Simons, Travell and Simons 1999).

Nociception

The term explains the sensory function of specialized nerve cells that perceive pain in response to physical, mechanical or chemical tissue damage (Redwood, 1997).

Non-specific Low Back Pain (NSLBP)

'Non-specific' refers to LBP that is not related to a specific diagnosed pathology such as a tumour, infectious disease, rheumatoid arthritis or osteoporosis (Balagué *et al.*, 2012).

Prevalence

The percentage of a population with a specific disease at a specific time, not to be confused with incidence, which is the rate of occurrence of new cases of a specific disease (Dorland, 2011).

Primary restriction

This term defines the primary source of a biomechanically dysfunctional joint in a kinematic chain (Bergman and Peterson, 2011).

Secondary restriction

The secondary, compensatory restriction of a joint that is distal to the initial biomechanically dysfunctional joint (primary restriction) in a kinematic chain (Bergman and Peterson, 2011).

Syndesmosis

A syndesmosis joins two adjacent bones with fibrous connective tissue and allows for minimal movement, for example: the radioulnar joint (Moore, Dalley and Agur, 2013).

LIST OF ABBREVIATIONS

CLBP	Chronic low back pain
CNSLBP	Chronic non-specific low back pain
HVLA	High velocity/ low amplitude
LBP	Low back pain
NPRS	Numerical Pain Rating Scale
ODI	Oswestry Low Back Pain Disability Index
ROM	Range of motion
SIJ	Sacroiliac joint
TVP	Transverse process

CHAPTER ONE

INTRODUCTION

1.1 THE PROBLEM AND ITS SETTING

Chronic non-specific low back pain refers to pain, discomfort, stiffness and/or ache felt between the costal margin and the gluteal fold of more than six weeks duration (Thorson *et al.*, 2008). Airaksinen *et al.*, (2006) identified six low back pain (LBP) systematic reviews (Balagué *et al.* 1999, Bressler *et al.*, 1999, Ebbelhøj *et al.*, 2002, Hestbaek *et al.*, 2003, Pengel *et al.*, 2003 and Walker, 2000) and noted that the condition affects 84 percent of individuals, world-wide, at some point in their lives and is often chronically disabling. McIntosh and Hall conducted a systematic review in 2011 and found that, on average, after one year, 33 percent of people suffered from chronic, moderate pain and 15 percent from chronic, severe pain in resource-rich countries

According to Stewart, Ricci and Chee (2003) and Maniadakis and Gray (2000), people with LBP frequently take time off work and with such a loss in productivity, Katz (2006) estimated that, in the United States, 100 billion dollars is lost per annum. In Africa, it is the most prevalent musculoskeletal condition and cause of disability (Louw *et al.*, 2007). The condition is most common between the working ages of 35-55, resulting in a large economic burden in a disabled workforce (Louw *et al.*, 2007).

LBP and hip joint dysfunction often occur concomitantly (Liebenson, 2007). This may be because the low back and hip joint form part of an intrinsically connected kinematic chain (Bergman and Peterson, 2011). The resultant kinematic decrease in pelvic-thoracic co-ordination and hip ROM is believed to subtly predispose a person to future LBP, relapse and a prolonged recovery time (McGill *et al.*, 2003). Studies investigating the kinematic relationship between the hip joint and LBP are limited and the literature, although widely taught and practiced, is largely anecdotal (Dananberg and Guiliano, 1999).

Due to extensive clinical research, chiropractic is now highly respected as an alternative to conservative medical management of low back pain (Manga, Angus and Swan, 1993; Globe *et al.*, 2008; Lawrence *et al.*, 2008; Triano, 2009 and Weber and He, 2010). When treating LBP many chiropractors focus on the localised, lumbosacral area of pain (Morris, 2007). Others focus on restoring function to compensating articulations in the 'full kinematic chain' by assessing and treating the lower extremity in conjunction with the low back (De Luca *et al.*, 2010). Evidence based practice is essential in order to validate the most effective treatment protocols and achieving a level of concurrence between these two management styles would be beneficial to the chiropractic profession.

1.2 AIMS AND OBJECTIVES

Aim: The aim of this study was to determine the effect of low back manipulation alone compared to combined low back and hip manipulation in the treatment of chronic non-specific low back pain (CNSLBP).

Objective One: To determine the effect of low back manipulation alone (Group A) compared to combined low back and hip manipulation (Group B) in the treatment of CNSLBP in terms of **subjective** clinical findings. (Numerical Pain Rating Scale, Oswestry Low Back Pain Disability Index).

Objective Two: To determine the effect of low back manipulation alone (Group A) compared to combined low back and hip manipulation (Group B) in the treatment of CNSLBP in terms of **objective** clinical findings. (Force Dial Algometry, Inclinator ROM tests).

Hypothesis: The hypothesis indicated that there would be a significant difference between Group A and Group B in terms of the subjective and objective findings in the study.

Null Hypothesis: The null hypothesis indicated that there would be no significant difference between Group A and Group B in terms of the subjective and objective findings in the study.

1.3 PURPOSE AND BENEFIT OF THE STUDY

LBP is often chronically disabling in terms of work-loss, social aspects and general quality of life (Bergman and Peterson, 2011). In a study consisting of 6 systematic reviews, the prevalence of LBP related disability was found to be 11-12 percent (Airaksinen *et al.*, 2006) and after one year, 33 percent of people suffered from moderate pain, and 15 percent from severe pain in resource rich countries (McIntosh and Hall, 2011).

Wieser *et al.*, (2011) conducted a questionnaire type study on a sample of 2,507 German-speaking respondents in Switzerland in 2005, of whom 1,253 had suffered from LBP in the last 4 weeks, and noted that only 22.8 percent of patients suffering with LBP had consulted their physician within four weeks of the onset of their pain and only six percent of these patients had consulted a specialist. This may suggest that the lack of early management could be an important factor in an acute condition progressing to chronic.

There have always been multiple, varying practice styles within the chiropractic profession that tend to lean towards either a pain-centred/local approach, a biomechanical/global approach or a holistic combination of the two (Good, 2016). These varying styles will impact on the specific treatment offered when treating a complex condition such as low back pain. As such, a practitioner needs to view the

spine intrinsically as a dynamic part of the body and a whole and look to other concomitant areas of dysfunction in the lower kinematic chain (McGreggor and Hukins, 2009). Therefore, this research would assist in a better patient management strategy if the findings show that the hip joint's functionality is shown to play a primary or secondary role in the perpetuation of CNSLBP. Going forward, chiropractors could substantiate a more holistic approach to the management thereof by placing emphasis on assessment and directing treatment to the hip joint dysfunction.

1.4 LIMITATIONS OF THE STUDY

1. To date, there have been no other studies in which the hip was manipulated in the treatment of CNSLBP to compare this study with.
2. This was a small sample size, completed in Durban, over seven months, between 2016 and 2017. Thus, the results may not be generalised (Weber and He, 2010).
3. When conducting research using survey type questionnaires, it cannot be assumed that the participants interpreted the questions equally (Weber and He 2010).
4. The study was limited by the inclusion criteria to participants who were between 18 and 45 years of age.
5. There was no long-term follow up to assess the chronicity of the condition.

1.5 OUTLINE OF CHAPTERS

Chapter One outlined the rationale, aims and objectives of the study. The following chapters review the relevant and existing literature surrounding the study (Chapter Two), describe the quantitative methodology used to carry out the study (Chapter Three), present the resultant statistics (Chapter Four) and discussion (Chapter Five) as such, as well as conclude and lay out any recommendations for future related topics of investigation (Chapter Six).

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The following chapter provides a discussion of the current literature relevant to the epidemiology and pathology of CNSLBP. This review will also highlight the appropriate anatomy pertaining to the low back and hip joint and the biomechanical relationship between the two. Current theories describing this kinematic relationship and potential links between LBP and hip joint dysfunction are then discussed as well as the manipulative management thereof.

2.2 CHRONIC NON-SPECIFIC LOW BACK PAIN

The term, 'non-specific' low back pain refers to LBP that does not relate to a diagnosed pathology, for example: neoplasms; infections or rheumatoid arthritis, but is believed to be of a mechanical origin (Balagué *et al.*, 2012). CNSLBP refers to 'non-specific' pain, discomfort, stiffness and/or ache felt between the costal margin and the gluteal fold of more than six weeks duration (Thorson *et al.*, 2008).

A report by Diamond and Borenstein (2006) indicated that 90 percent of LBP has a mechanical origin but, according to a systematic review conducted by McIntosh and Hall (2011), LBP is multifactorial in nature and therefore there are many aetiologies and risk factors, and so the anatomical origin is non-specific 80 percent of the time.

2.3 INCIDENCE AND PREVALENCE OF CNSLBP

Airaksinen *et al.*, (2006) identified 6 systematic reviews, noting that LBP is one of the most widespread public health care problems of the 20th century world-wide and affects up to 84 percent of all individuals at some point in their life. Louw (2007) indicated that, in Africa, LBP had a one year prevalence of 50% percent, a point prevalence of 15 percent and a lifetime prevalence of 62%. Systematic reviews showed that this prevalence rate is similar to studies done in developed countries (Hoy *et al.*, 2012; Manek and MacGregor, 2005 and Picavet and Schouten, 2002).

LBP is often chronically disabling in terms of work-loss, social aspects and general quality of life (Bergman and Peterson, 2011). In a study consisting of 6 systematic reviews, the prevalence of LBP related disability was 11-12 percent (Airaksinen *et al.*, 2006) and on average, after one year, 33 percent of people suffered from moderate pain, and 15 percent from severe pain in resource-rich countries (McIntosh and Hall, 2011). Wieser *et al.*, (2011) conducted a questionnaire type study on a

sample of 2,507 German-speaking respondents in Switzerland in 2005, of whom 1,253 had suffered from LBP in the last 4 weeks, and noted that only 22.8 percent of patients suffering with LBP had consulted their physician within four weeks of the onset of their pain and only six percent of these patients had consulted a specialist. This may suggest that the lack of early management could be an important factor in an acute condition progressing to chronic.

Kirkaldy-Willis and Bernard (1999) described three phases of degeneration that occur in a person's spine and that symptoms initially present during their 20s and / or 30s. This they refer to as the dysfunctional phase. This phase occurs when the initial biomechanical abnormality presents and progresses through the instability phase to the stabilizing phase, when their body tries to stabilize the abnormal biomechanics, resulting in muscle spasms and abnormal bony growth patterns (Kirkaldy-Willis and Bernard, 1999). The condition increases in recurrence, chronicity and severity as the patient ages and progresses from stage one to three (Kirkaldy-Willis and Bernard, 1999) and then decreases respectively after 65 years of age (Andersson, 1999).

In a data analysis conducted in 2006, Deyo, Mirza and Martin (2006) concluded that while the number of physician visits, in the United States of America (US), related to LBP had remained constant over the previous 10 years, the economic liability had increased substantially. Palmer *et al.*, (2000) believed that a shift of this nature is the result of a change in the understanding of LBP by both the physicians treating it and the patients seeking treatment. Deyo, Mirza and Martin (2006) and Davies *et al.*, (2009) also noted that education and higher income levels were inversely proportional to LBP prevalence.

According to Louw *et al.*, (2007), LBP is the most prevalent musculoskeletal condition and cause of disability in Africa. Louw *et al.*, (2007) points out that LBP affects most people between the ages 35 – 55 often causing them to be absent from work. As such, time off work creates an economic burden that negatively affects the country's financial status. There is a positive relationship between poverty and disease/disability (Deyo, Mirza and Martin, 2006 and Davies *et al.*, 2009) and with Africa being the poorest continent, its' population is largely predisposed to the condition (Bloom and Canning, 2000). This socio-economic liability is of particular concern in developing African countries where limited healthcare resources are already directed towards diseases such as HIV and AIDS (Walker, 2000).

In South Africa, the lifetime incidence of LBP in the Indian, coloured and black Durban population was 78.2 percent, 76.6 percent (Docrat, 1999) and 57.6 percent (Van Der Meulen, 1997) respectively. The prevalence of LBP in the aforementioned populations was 45 percent, 32.6 percent (Docrat, 1999) and 53.1 percent (Van Der Meulen, 1997) respectively. To date, no demographic reviews have been done in relation to the incidence and prevalence of low back pain amongst other ethnicities in South Africa, but according to the aforementioned prevalence rates, it appears that LBP affects all ethnicities (Docrat, 1999).

2.4 AETIOLOGY OF CHRONIC NON-SPECIFIC LOW BACK PAIN

Due to the multifactorial nature of CNSLBP, it is challenging to differentiate between primary or secondary causes, perpetuators and results of the syndrome (Garland, 2012 and Smart *et al.*, 2012).

Common causes of acute LBP include trauma, anatomical deformity and strain affecting the various innervated/nociceptive structures in the lumbopelvic region (Balagué *et al.*, 2012). These structures include the lumbar facet joints, paravertebral musculature/fascia, ligaments, thoracolumbar fascia, periosteum, vertebral endplates, annulus fibrosis of the intervertebral disc, dura mater, nerve roots, cauda equina, sacroiliac joints (SIJs) and blood vessels (Bogduk, 1997).

Structures commonly related to chronic LBP include the lumbar facet joints, the lumbar intervertebral discs and the SIJ (Bogduk, 1997 and Sakamoto *et al.*, 2001). The lumbar facet joints account for up to 30 percent of chronic low back pain (CLBP) cases (van Kleef *et al.*, 2010). This pain is believed to arise from the synovial membrane, the hyaline cartilage, the bone and/or the fibrous capsule of the facet joint (Cohen and Raja, 2007). According to Cramer and Darby (1996), when articular cartilage degenerates in the chronically dysfunctional facet joint, painful nociception of the inflammatory agents affecting the innervated joint and capsule results.

A chart audit of 677 SIJ patient reports from 75 different private physiotherapy practices were analysed and the prevalence of CLBP arising from the SIJ was shown to be between 13 and 30 percent by (Franke Jr., 2003). Dreyfuss (2004) suggests that the SIJ pain arises from ligament and capsular tension, compression of the joint, shearing forces on the joint, hypermobility, abnormal biomechanics, myofascial components and/or dysfunction of the lower kinematic chain. A study utilizing intra-articular analgesic nerve blocks in the SIJ highlighted a 15-21 percent relationship between LBP and the SIJ (Schwarzer *et al.*, 1995 and Maigne *et al.*, 1996).

LBP is common in manual labourers who repetitively bend, lift, twist, and carry (Linton, Hellsing and Hellden, 1998), but the progression from an acute condition to chronic is believed to be largely influenced by psychosocial factors (Balagué *et al.*, 2012). Lack of exercise and a sedentary lifestyle have also been shown to cause and perpetuate CLBP (Haslett *et al.*, 2002 and Linton, Hellsing and Hellden, 1998), with obesity being the highest cause of individuals seeking treatment for the condition (Shiri *et al.*, 2010). Occupations which involve awkward postures, extended periods of sitting and exposure to high vibration levels correlate with increased levels of LBP occurrence (Bernard *et al.*, 2011; Leelavathy *et al.*, 2011).

Psychosocial factors include job dissatisfaction, perceived low income, depression, anxiety, drug/alcohol/cigarette abuse and the individual's inability to seek care (Bensen, Young and perception (Reimann *et al.*, 2010) and structural deformities such as leg length and scoliosis (Kovacs *et al.*, 2003). Intervertebral disc degeneration, with subsequent loss of disc height, is another genetic factor that is associated with chronic LBP (de Schepper *et al.*, 2010).

2.5 ANATOMY OF THE LUMBAR SPINE, SACRUM AND HIP

The following sections will give an overview of the anatomy of the low back and hip in order to motivate the possible kinematic relationship between the two.

The low back, or lumbosacral spine, is an intricate musculoskeletal structure consisting of the five lumbar vertebrae (L1, L2, L3, L4 and L5), the sacrum (S1-S5), the coccyx (4 coccygeal fused vertebrae) and the SIJs (Moore, Dalley and Agur, 2013). The hip is a synovial ball-and-socket-type articulation involving the head of the femur and the acetabulum of the hip bone which consists of the ilium, ischium and pubis (Moore, Dalley and Agur, 2013).

2.5.1 THE LUMBAR SPINE

The vertebrae in the lumbar spine consist of a kidney-shaped body, a vertebral arch and seven vertebral processes (Moore, Dalley and Agur, 2013). The vertebra increase in size from L1 to L5 as the load increases and, unlike other segments of the thoracic spine, lumbar vertebrae do not have costal facets to articulate with the ribs (Moore, Dalley and Agur, 2013).

The posterior aspect of the vertebrae is called the vertebral arch and consists of the laminae and pedicles (Moore, Dalley and Agur, 2013). The lumbar vertebrae have differentially stronger laminae than that of the thoracic/cervical vertebra (Moore, Dalley and Agur, 2013). There are seven processes found at the arch, and they are: the spinous and two transverse processes (TVPs) for ligament and muscle attachment; the two superior articular processes and the two inferior articular processes (Moore, Dalley and Agur, 2013).

2.5.1.2 THE FACET JOINTS

The lumbar facet joints of the low back, also known as the zygapophyseal joints, are synovial planar joints and result from the articulation between the superior and inferior articular processes on the vertebral arches of two adjacent vertebra (Moore, Dalley and Agur, 2013). The superior articular processes face posteromedially and are concave, and the inferior articular processes face

anterolaterally and are convex (Magee, 2006). This arrangement helps to stabilize the joint along with the thick fibrous articular capsule (posterolateral to the joint), the ligament flavum (anteromedial to the joint) and the accessory ligaments which bond the laminae, TVPs and spinous processes (Moore, Dalley and Agur, 2013).

The anatomy of the zygapophyseal joints stabilises the spine during motion by resisting torsion (twisting motion) and translation (sliding motion) as well as facilitating flexion and extension movements (Moore, Dalley and Agur, 2013). These joints also carry up to 25 percent of the axial load (Magee, 2006).

2.5.1.2.1 FACET JOINT INNERVATION

The facet joint is innervated by the dorsal ramus which originates from the spinal nerve and divides into medial and lateral branches outside the intervertebral foramen (IVF). Each medial branch supplies two adjacent facet joints resulting in each joint being supplied by two nerves (Moore, Dalley and Agur, 2013).

2.5.1.3 INTERVERTEBRAL DISCS

Fibrocartilage intervertebral discs (IVDs) unite adjacent vertebrae from the second cervical vertebra to the sacrum and are thickest in the cervical and lumbar spine which enables a person to move readily and easily (Snell, 2012). The discs make up a quarter of the spines length and are responsible for increasing elasticity in the vertebral column to allow for movement and shock absorption (Snell, 2012). The IVDs differ in shape, resulting in the kyphotic and lordotic curves of the spine, particularly lumbar lordosis in the lumbar spine (Moore, Dalley and Agur, 2013).

Peripherally, IVDs are made up of a fibrocartilagenous annulus fibrosus, and centrally, a gelataneous nucleus pulposus (Snell, 2012). With advancing age, the annulus fibrosis loses its resilience and may rupture with large compressive forces, resulting in the nucleus pulposus herniating into the vertebral canal or intervertebral foramina and compressing spinal nerves, nerve roots and/or the spinal cord (Snell, 2012). Kuslich, Ulstran and Michael (1991) indicated that the outer annulus fibrosis is a likely cause of low back pain, this the demonstrated through their research by injecting saline fluid into the disc and applying external mechanical forces.

2.5.2 THE SACRUM

The sacrum is the triangular foundation at the base of the spine formed by the fusion of five sacral vertebral segments (Moore, Dalley and Agur, 2013 and Lee, 2004). The first sacral segment, S1,

articulates with the last lumbar vertebrae, L5, via two superior facet joints (Moore, Dalley and Agur, 2013). The last sacral segment articulates with the coccyx via a disc and bilaterally, with the ilia via the SIJs (Moore, Dalley and Agur, 2013). This sacral foundation provides strength and stability for the vertebral column by transferring the load from the thorax and abdomen to the pelvis and hips (Moore, Dalley and Agur, 2013).

2.5.2.1 THE SACROILIAC JOINT

A synovial joint consists of a joint cavity, articular cartilage and an articular capsule, and a syndesmosis type joint consists of fibrous tissue forming an interosseous membrane (Moore, Dalley and Agur, 2013). The SIJs are part synovial and part syndesmosis (Walker, 1986), articulating bilaterally between the sacrum and the ilia to form the base of the spine. This provides the strength and stability necessary for weight transmission to the hips and lower limbs (Vleeming *et al.*, 2012 and Hendler *et al.*, 1995).

Fibrocartilage covers the iliac surface of the joint and the sacral surface is covered by hyaline cartilage (Kirkaldy-Willis and Bernard, 1999). The joint surface in males is rougher and larger than in females. This provides the female SIJ with more mobility during labour (Vleeming *et al.*, 2012 and Harrison, Harrison and Troyanovich, 1997).

2.5.2.2 INNERVATION OF THE SACROILIAC JOINT

The SIJ and joint capsule are richly supplied by a wide range of sensory nerve fibres (Maitland *et al.*, 2001). These fibres originate from lumbar nerve root level 2 to the sacral nerve root level 4 (Maitland *et al.*, 2001).

This provides the central nervous system (CNS) with sensitivity to pressure and joint proprioception as well as further increasing stability at the base of the spine (Ombregt, Bisschop and Ter Veer, 2013).

2.5.3 THE HIP JOINT

The hip joint comprises a spherical femoral head (half of which sits in a horse-shoe shaped acetabular fossa), the acetabular labrum, the joint capsule and four stabilizing ligaments (Moore, Dalley and Agur, 2013). The femoral head is 66 percent hyaline cartilage and wider superiorly for weight bearing purposes, such as walking/standing (Moore, Dalley and Agur, 2013).

The acetabular labrum is fibrocartilage and attaches to the bony rim of the fossa to increase the depth of the joint complex and therefore increase the stability of the joint (Moore, Dalley and Agur, 2013). The joint capsule is also made of thick fibrous tissue, which functions to reinforce the joint and to keep the femoral head in the acetabular fossa (Moore, Dalley and Agur, 2013).

2.5.3.1 HIP JOINT INNERVATION

The region of the hip joint is supplied by the sciatic, femoral and obturator nerves (Snell, 2012). The sciatic nerve supplies the posterior compartment of the thigh and originates from a branch of the sacral plexus (L4, 5 + S1, 2, 3). The femoral nerve supplies the anterior compartment of the thigh and is the largest branch of the lumbar plexus (L2, 3, 4) and the obturator nerve supplies the medial compartment of the thigh, which also originates from the lumbar plexus (L2, 3, 4) (Snell, 2012).

2.5.4 MUSCLES AND MOVEMENTS OF THE LUMBAR SPINE AND HIP JOINT

2.5.4.1 MUSCLES AND MOVEMENTS OF THE LUMBAR SPINE

The muscles of the lumbar spine are responsible for global motion and stability during static and dynamic load bearing (Quint *et al.*, 1998). These muscles can be grouped into those which lie anterior to the vertebral body, those which lie posterior to the vertebral body (which are intrinsic) and the extrinsic muscles (White and Panjabi, 1990).

The anterior muscles include the rectus abdominus, transversus abdominus and abdominal oblique muscles. The extrinsic muscles include the quadratus lumborum, psoas and latissimus dorsi muscles and the posterior/intrinsic muscles are further classified into superficial, intermediate and deep muscles (White and Panjabi, 1990).

The posterior, intrinsic muscles are situated in the depressions bilaterally to the spinous processes and are responsible for intrinsic postural endurance (Snell, 2012). Superficially, erector spinae muscles run from the sacrum to the rib angles, TVPs and spinous processes of the upper vertebrae and include the iliocostilis, longissimus and spinalis muscles (Snell, 2012). Intermedially, oblique transversospinalis muscles run from the TVPs to the spinous processes and include the semispinalis, multifidus and rotatores muscles (Snell, 2012). Deep intrinsic muscles run between the TVPs and between the spinous processes of adjacent vertebrae and include the interspinalis and intertransversarii muscles (Snell, 2012).

Movements and normal ROM in the lumbar spine include flexion (anterior movement) of 60 degrees which is produced by the rectus abdominus and the psoas muscles, extension of 25 degrees (posterior movement) which is produced by the posterior vertebral, oblique abdominal and quadratus lumborum muscles (Magee, 2006 and Snell, 2012). Lateral flexion of 25 degrees (side bending movement) is produced by the intertransversarii and quadratus lumborum muscles and rotation of 18 degrees (twisting movement) is produced by the rotatores and oblique abdominal muscles (Magee, 2006 and Snell, 2012).

2.5.4.2 MUSCLES AND MOVEMENTS OF THE HIP JOINT

The normally functioning hip joints' ROM includes flexion, extension, abduction, adduction, internal rotation and external rotation (Moore, Dalley and Agur, 2013). The muscles that allow these movements to occur are listed as follows:

Flexion: On average, an individual is able to flex their hip 140 degrees with their knee in flexion (this is limited by the thigh and abdomen) and 90 degrees with their knee in extension (this is limited by the hip extensor muscle stretch) (Reid, 1992). An individual can generate maximum contractive forces at 30-35 degrees (Reid, 1992). The primary muscles responsible for this movement at the hip joint include the iliopsoas, rectus femoris and the tensor fascia lata (TFL) which are supplied by lumbar segmental nerves L1/2/3, L4/5 and L2/3/4 respectively (Moore, Dalley and Agur, 2013).

Extension: On average, an individual is able to extend their hip 40-45 degrees, any further exertion is limited by the iliofemoral ligaments, the ischiofemoral ligaments and the iliopsoas muscle (Reid, 1992). The primary muscles responsible for extension of the hip joint are gluteus maximus, semi-tendinosus, biceps femoris and semi-membranosus. These muscles are supplied by the fifth lumbar nerve and the first and second sacral nerves (Moore, Dalley and Agur, 2013).

Abduction: On average, an individual is able to abduct their hip 50 degrees in the neutral position and 90 degrees in the laterally rotated position (Reid, 1992). This movement is limited by the pubofemoral ligament, the iliofemoral ligament and the adductor muscles (Reid, 1992). Maximum contractive forces occur at 40-45 degrees (Reid, 1992). The gluteus medius and gluteus minimus muscles are primarily responsible for abduction of the hip joint and are supplied by the fifth lumbar and first sacral nerves (Moore, Dalley and Agur, 2013).

Adduction: On average, an individual is able to abduct their hip 40 degrees when the opposite hip is flexed. The movement is limited by the ligament of the head of the femur and the iliofemoral ligament (Reid, 1992). The adductor magnus, adductor longus and adductor brevis muscles are primarily

responsible for adduction of the hip joint and are supplied by the second, third and fourth segmental lumbar nerves (Moore, Dalley and Agur, 2013).

2.6 BIOMECHANICS THE LUMBAR SPINE, PELVIS AND HIP

2.6.1 THE LUMBAR SPINE BIOMECHANICS

The low back is responsible for a person's mobility and flexibility. It provides a passage for the spinal cord (Wong and Transfeldt, 2006) and it supports the upper body while transmitting weight through the pelvis and hips and to lower limbs (Magee, 2006).

The functional spinal unit (FSU) is a motion segment of the spine that displays similar biomechanical properties to the rest of the spine and affects every other FSU in the spine (White and Panjabi, 1990). This motion segment of the lumbar spine allows for combinations of flexion, extension, rotation and lateral flexion (Andersson, 1992) and consists of two adjacent vertebrae and the intervertebral disc (IVD) that separates them (Magee, 2006). ROM is subject to the direction that the articular processes of the vertebral body face and the thickness of the intervertebral disc (IVD) (Snell, 2012).

The IVD functions as a shock absorber (Magee, 2006) in axial compression, flexion, lateral flexion and posterior shearing during everyday load bearing activities (Wong and Transfeldt, 2006). The IVDs separate the vertebrae, allowing space for nerve roots to exit at the intervertebral foramina (Magee, 2006) which increases spinal mobility (Borenstein *et al.*, 1995). The IVDs differ in shape, resulting in the kyphotic and lordotic curves of the spine, particularly lumbar lordosis in the lumbar spine (Moore, Dalley and Agur, 2013).

Vertebral ligaments allow for limited movement at individual motion segmental levels but when moving together, as a kinematic chain, the result is a wide range of functional mobility in flexion, extension, lateral flexion and rotation (Snell, 2012).

The lordotic curve in the lumbar spine also protects it from compressive forces, reducing the axial transmission of force through the vertebral bodies and IVDs (Moore, Dalley and Agur, 2013). This lordotic curve is greater in females (White and Panjabi, 1990).

2.6.2 THE PELVIS AND SACROILIAC JOINT (SIJ) BIOMECHANICS

The pelvis forms the connection, via the hip joints, between the lumbar spine and lower extremities (Vleeming, 2012). The SIJs and pubic symphysis transmit weight and provide shock absorption during the walking gait by increasing pelvic elasticity (Lee, 2004). The pelvis and SIJ do not have direct

muscular control, however, they are influenced by the muscles that control the lower limb and lumbar spine which attach directly to them (Magee, 2006).

According to Snijders, Vleeming and Stoeckhart (1993), the SIJ is said to have a self-bracing mechanism that relies on compression of the joint, a high friction co-efficient and the wedge-angle of the articulation when standing straight. The high friction co-efficient is achieved by the rough nature of the articular surfaces in the joint and the compression mechanism occurs due to surrounding muscles and ligaments (Snijders, Vleeming and Stoeckhart, 1993).. This mechanism allows for bending movements and resists shearing forces but it can be hindered due to ligament laxity and muscle weakness (Snijders, Vleeming and Stoeckhart, 1993).

2.6.3 HIP JOINT BIOMECHANICS

The hip joint, like the shoulder joint, is a ball-and-socket type joint (Bergman and Peterson, 2011). However, unlike the shoulder, its' movements are more restricted due to the depth of the acetabular socket (Bergman and Peterson, 2011). When viewing an individual from the front, the femur deviates medially in order to place the knee below the hip and when viewed from the side, the femur bends anteriorly (Bergman and Peterson, 2011). These anatomical structural patterns accommodate strain from the forces of weight transmission (Bergman and Peterson, 2011).

Flexion of the hip results in the iliofemoral and ischiofemoral ligaments 'unwinding' about the femoral neck as the pelvis rotates anteriorly (Kapandji, 2008). Such flexion places the joint in the loose-packed position, which is restricted by the hamstrings (Kapandji, 2008). Hip extension causes the pelvis to rotate posteriorly, and is therefore limited by the iliofemoral and ischiofemoral ligaments which twist about the femoral neck (Kapandji, 2008). This posterior pelvic tilt, and resultant ligamentous resistance is responsible for endurance during the erect posture by causing the articulation to tighten into a closed-packed position (Kapandji, 2008). This closed-packed position is most emphasized during hip extension, abduction and internal rotation (Bergmann and Peterson, 2011).

Hip abduction and adduction are a combination of rolling and gliding movements away and towards the midline respectively (Bergmann and Peterson, 2011). Abduction is restricted by the inferior hip joint capsule and iliofemoral ligament and hip adduction is restricted by the pubofemoral and ischiofemoral ligaments (Bergmann and Peterson, 2011).

Stabilization of the pelvis in the coronal plane is an antagonistic relationship between the adductors and abductors of both hips. During the single-leg-standing test, the ipsilateral gluteus medius abductor muscles stabilize the pelvis but, when weak, result in an abnormal pelvic tilt to the opposite side

(Bergmann and Peterson, 2011). This suggests that biomechanical dysfunction is present and that further investigation into the cause is necessary (Bergmann and Peterson, 2011).

Internal and external rotation of an individual's hip results in their knee rotating medially and laterally respectively, with internal rotation being restricted by the anterior ligament and external rotation being restricted by the posterior ligament (Bergmann and Peterson, 2011).

2.7 MOTOR CONTROL (LOCAL AND GLOBAL)

Co-ordinated motor control through precise activation and deactivation of global and local muscles in the lumbopelvic area results in stable, efficient postural control and movements with minimal restriction or rigidity (Hodges, 2003 and Lee, 2004).

2.7.1 LOCAL MUSCLES

Before movement of the trunk and extremities occurs on a global scale, local muscles in the low back and pelvis provide anticipatory stability through early activation, thus preventing excess shearing during load bearing activities (Richardson *et al.*, 2002). As the load is transferred to the pelvis, the diaphragm (or 'roof' of the local muscle system) acts as local trunk stabilizer and maintains respiratory function while the pelvic 'floor' muscles support the pelvic organs (Lee, 2004).

Research conducted by Moseley, Hodges and Gandevia (2002) showed that when a load is predictable, like lifting and carrying, the local multifidus muscles are recruited prior to any movement of the upper extremity. Bromitt, Matheson and Meira (2013) and Hodges and Richardson (1997) state that the transversus abdominus muscle is also recruited to locally stabilize the low back in anticipation of extremity movements in healthy individuals. In individuals with LBP however, this was delayed, inefficient or absent (Hodges and Richardson, 1997).

2.7.2 GLOBAL MUSCLES

The global muscle system comprises of four muscle slings that function together to stabilize the pelvis and hip joints between the thorax and the lower limb (Vleeming *et al.*, 1995).

- The 'Posterior Oblique sling' forms a connection from the latissimus dorsi to the gluteus maximus muscles via the thoracodorsal fascia (Lee, 2004).
- The 'Anterior Oblique sling' connects the anterior abdominal fascia, the external oblique muscles, the adductor muscles of the hip and the opposite internal oblique muscles (Lee, 2004).

- The 'Longitudinal sling' joins the biceps femoris, peronei and erector spinae muscles to the sacrotuberous ligament and deep lamina of the thoracodorsal fascia (Lee, 2004).
- The 'Lateral sling' is known to be a primary stabilizer of the hip joint and comprises the TFL, the gluteus medius and minimus muscles and the lateral stabilizers of the thoracopelvis (Lee, 2004).

2.8 THE FASCIAL LINK

Fascia envelopes and links the neuromuscular skeletal system as a continuous sheet of proprioceptive tissue that provides the CNS with sensory input in order to carry out an efficient, efferent muscular response to movements, loads or change in posture (Dellito *et al.*, 2012). Therefore, any tensile changes in the fascial tissue will stimulate receptors throughout the kinematic chain, optimizing efficient kinetic energy (Dellito *et al.*, 2012 and Swinkels and Dolan, 1998).

2.8.1 THE THORACOLUMBAR FASCIA

The thoracolumbar fascia physically links the low back to the lower extremity (Vleeming *et al.*, 1995). Therefore it plays a vital role in load transmission, via the pelvis and hips, between the two (Vleeming *et al.*, 1995).

The fascia consists of anterior, middle, and posterior layers of which the posterior layer is most significant to this study. The posterior layer runs from the latissimus dorsi and trapezius muscles in the thorax to the gluteus maximus muscle inferiorly, forming the link to the pelvis (Vleeming *et al.*, 1995). Forces are then transmitted to the lower extremity via the iliotibial band (ITB), which runs from the gluteus maximus muscle to the lateral epicondyle of the tibia (Snell, 2000).

Certain muscles, responsible for pelvic stability, attach directly to the thoracolumbar fascia and result in proprioceptive, tensile changes in the fascia when active/contracting. These include the internal oblique, transversus abdominus, gluteus maximus, multifidus, erector spinae, and biceps femoris muscles (Lee, 2004).

2.8.2 THE LOWER EXTREMITY FASCIA

The lower extremity fascia is actively involved in the function or dysfunction of the pelvic girdle (Lee, 2004). This fascia attaches to the iliac crest, sacrum, coccyx, inguinal ligament, ischial ramus, superior pubic ramus, inferior pubic ramus, sacrotuberous ligament and the ischial tuberosity (Lee, 2004).

The fascia merges superiorly with the abdominal and thoracolumbar fascia of the trunk and inferiorly with the iliac crest and gluteus maximus muscle as two bands, inserting into the iliotibial tract with the TFL (Lee, 2004). The iliotibial tract blends with the aponeurosis of the quadriceps femoris muscle and attaches to the head of the fibula, the femoral condyles and the tibial condyles (Lee, 2004).

2.9 ARTHROGENIC MUSCLE INHIBITION

Arthrogenic muscle inhibition refers to the presynaptic, protective, reflex inhibition of muscles surrounding a damaged, painful, distended or dysfunctional joint (Rice and McNair, 2010 and Hopkins and Ingersoll, 2000). This inhibition results in the failure of muscle groups within a common motor-neuron pool to recruit all motor units and therefore, abnormal muscle function (Ingersoll, Palmieri and Hopkins, 2003 Rice and McNair, 2010 and Suter *et al.*, 2000).

When joint receptors receive excitatory stimulation through pain, capsule compression, ligamentous stretching or irritation, interneurons transmit inhibitory impulses to the muscle to prevent movement and further damage to the joint (Rice and McNair, 2010 and Crossman and Neary, 1995). Clinically, this is seen as a perceived or actual weakness in the muscle (Suter *et al.*, 2000).

Prolonged, constant decreased activity affects the joint at a muscular, bone and neural level with resultant type-1 muscle atrophy, peri/subperiosteal bone resorption, elongation/stiffening of ligaments with resultant reduction in tensile strength (White and Panjabi, 1990), decreased action potentials across muscle fibre motor endplates and decreased levels of potassium and sodium transport (Ingersoll, Palmieri and Hopkins, 2003). This alteration in the proprioceptive and motor control systems of the muscle groups, results in changes in load transfer patterns, inefficient movement, increased degenerative change, delayed rehabilitation and an increased risk for re-injury (Lee, 2004). Therefore, with regards to this study, arthrogenic muscle inhibition in relation to the hip joint and its surrounding musculature could be a major factor in the perpetuation of CNSLBP (Kirkaldy-Willis and Bernard, 1999).

Ingersoll, Palmieri and Hopkins (2003) argue that arthrogenic muscle inhibition is a natural protective mechanism which, if removed, could leave the joint prone to re-injury or further damage. They do agree that recovery can be accelerated by eliminating the arthrogenic inhibitory process, but suggest a

controlled environment, with predictable loads and movement patterns, for rehabilitation in such circumstances.

Treatment protocols for the elimination of the arthrogenic inhibitory reflex include transcutaneous electrical nerve stimulation (TENS), the injection of lidocaine into the joint and cryotherapy, which is the use of low temperatures for pain management and circulatory benefits (Hopkins and Ingersoll, 2000).

According to Tullberg *et al.* (1998), manipulation restores kinematic function to a joint and its' surrounding musculature by normalizing the arthrogenic inhibitory reflex and interrupting the nociceptive pain cycle.

The SIJ has a rich supply of nociceptive mechanoreceptors which can lead to arthrogenic inhibition of muscles within its common motor neuron pool, specifically the hip joint (Sakamoto *et al.*, 2001). Suter *et al.*, (2000) describes that, through the excitation of joint receptors, SIJ manipulation may alter afferent input to the motor neuron pool which supply the muscles of the hip. This process decreases arthrogenic inhibition and restores normal function to the joint (Suter *et al.*, 2000).

According to Arokoski *et al.*, (2002), most of the studies carried out on the subject of arthrogenic muscle inhibition have focussed on the knee joint and its effect on the quadriceps femorus muscle. There has yet to be a CNSLBP related study on arthrogenic muscle inhibition in relation to the hip joint, which is situated anatomically at the more proximal end of the quadriceps femoral muscle.

2.10 THE KINEMATIC CHAIN

A 'kinematic chain,' as described by Bergmann and Peterson (2011), is a group of articulations which are intrinsically connected to function as a whole. When an individual places weight on a foot during their normal walking gait, the foot is considered to be load bearing. In this state the 'lower' kinematic chain, which constitutes all the interdependent articulations from the lumbar spine to the load bearing foot, is considered to be 'closed.' In this state, any change in the biomechanics of one joint will have immediate and lasting effects on the other joints in the kinematic chain (Bergmann and Peterson, 2011). Therefore a dysfunctional joint distal to the low back, yet within a common kinematic chain, could predispose an individual to future LBP, relapse and a prolonged recovery time (McGill *et al.*, 2003). In a study conducted by De Luca *et al.*, (2010), subjects previously diagnosed with hip osteoarthritis benefited from chiropractic treatment of the full lower kinematic chain in terms of hip ROM and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) hip disorder questionnaire which focusses on patient perception and functional activities. This motivates a possible

relationship between the low back and the hip joint and warrants further research into the link (De Luca *et al.*, 2010).

The hip joint connects the axial skeleton with the lower extremity at the articulation of the pelvis and femur, where it supports multidirectional, gravitational and muscular forces up to four times an individual's body weight (Vleeming, 2012). It plays a vital role in maintaining the body's centre of gravity and stabilising the spine by orientating the femur to ensure correct weight transmission during every day activities (Bergmann and Peterson, 2011). The hip's ability to shift in the sagittal and coronal plane allows for flexion/extension and lateral bending movements respectively (Mcgreggor and Hukins, 2009).

The kinematic interdependence between the hip and the lumbar spine described above is further emphasized in the development of the child's spinal curves during their first three years of life. Initially, the child's gait differs from that of an adult, but, with the rotary ability of the hips, the trunk is able to translate in the sagittal plane, allowing for the formation of the secondary cervical, thoracic and lumbar curves. This is referred to as 'the lumbo-pelvic click-clack movement' (Snijders *et al.*, 2004).

The hips provide a high level of mobility as well as muscular stability, co-ordination and balance for a functional gait and, if hindered, can affect activities such as walking, bending forward and lifting (Hendrick *et al.*, 2011). Therefore, identification and treatment of hip dysfunction is imperative, yet is often overlooked (Bergmann and Peterson, 2011).

The hips account for most of trunk flexion after 60 degrees in the healthy spine (Bergmann and Peterson, 2011). One of the most important predictors of LBP, with regards to hip joint ROM, results from a change in the hip's strength and stability in the sagittal plane (i.e. in flexion and extension) (McGill *et al.*, 2003).

This change was observed in LBP patients by Vogt *et al.*, (2003) and Liebenson (2007), who noted weakness in hip extensors with a resultant early and prolonged activation of the erector spinae muscles. Similarly, Van Dillen *et al.*, (2000), noted tightness in the iliopsoas muscles with resultant, restricted extension and lengthened extensors. Hussein *et al.*, (1999) showed a decrease in stride length and Lamothe *et al.*, (2002) reported a more rigid/uncoordinated pelvic-thoracic gait with a slower velocity in patients with LBP. An increase in waist hinging and a decrease in hip hinging were also evident in the LBP patient's lifting strategy (Sparto *et al.*, 1997), and a decrease in hip movement was noted during sit-to-stand activities (Etnyre *et al.*, 1999).

This pattern of change is present in 'lower crossed syndrome,' characterised by weak/lengthened gluteal and abdominal muscles and concomitant strong/short hip flexors and erector spinae muscles which leads to a 'sway-back' posture that exposes the lumbar spine to excess load/strain (Chaitow *et al.*, 2001). Possible habitual causes of iliopsoas shortening include 'foetal position sleeping,' repetitive

flexion at the waist, prolonged sitting and a sedentary lifestyle that may predispose or be a result of LBP or both (Vleeming, 2012). If hypertonic, the CNS lowers the nociception threshold in the iliopsoas resulting in increased inflammatory neuropeptides, decreased movement of the muscle and a compensatory increase in lateral bending of the lumbar spine (Vleeming, 2012). Repetitive stress from increased lateral bending patterns results in instability and fragility in the lumbo-sacral spine and according to Vleeming (2012), in this state, any movement can cause injury. Ellison *et al.*, (1990) also noted that any decrease in hip ROM (especially external rotation) could subject the lumbar spine to similar cumulative strain.

Walking is a repetitive daily activity, which, under normal biomechanical circumstances, is a highly efficient action (Vleeming, 2012). On average, a person completes 2 500 gait cycles per day and by the age of 30 will have completed 30 000 000 cycles (this number can be tripled depending on the individual's person's job and lifestyle) (Vleeming, 2012).

The iliopsoas muscle, which flexes the hip during walking, attaches directly to the lateral vertebral and intervertebral disc borders of T12 and L1-5, and biceps femoris, which extends the hip during walking, continues as the lumbar intermuscular aponeurosis to attach to the lumbar vertebral TVPs (Vleeming, 2012). If an individual's lower limb weighs 15 percent of their body weight and the iliopsoas muscle flexes 2 500 times a day, the lumbar spine of a person weighing 70kg experiences 26 250kg per limb per day of force during the hip flexion movement alone (Vleeming, 2012).

From the above mentioned information, one can expect that a hip related abnormal gait, trauma, abnormal posture, developmental anomaly or degenerative joint disease (or a combination of these) with consequential cumulative strain, could result in a chronic biomechanical syndrome, in this case LBP (Vleeming, 2012). This leads us to "The Gait Theory".

2.11 GAIT THEORY

Many of the symptoms related to CNSLBP have been linked to the kinematic strain of an abnormal gait cycle rather than structural defects in the spine itself which is in accordance with the frequency of recurrence and patient history associated with the condition (Dananberg and Guiliano, 1999).

The gait cycle is described as 'the time interval and sequence of motion occurring between two consecutive initial contacts of the same foot' (Magee 2006). The lower kinematic chain is considered to be closed from the time that the heel initially touches the ground, through the stance phase, to the toe-off of the same foot (Magee, 2006). All movements and forces during this phase of the gait cycle are absorbed throughout the lower extremity and joints constituting the chain (Magee, 2006).

The iliopsoas muscle, which is attached to the iliac crests; lumbar spine; vertebral septa and lumbar discs, is the primary flexor of the hip joint during the swing phase (Bergmann and Peterson, 2011). Failure of full extension at the hip joint during this phase due to a shortened iliopsoas muscle could place abnormal strain on the lumbar spine. This failure could therefore be a major aetiological factor in the chronicity of LBP (Dananberg and Guiliano, 1999).

Gradually the automatic, synchronicity of hip extension is diminished resulting in inefficient kinematics during the toe-off, pre-swing and swing phases of the gait cycle and compensatory lateral bending of the trunk towards the contralateral side occurs (Vleeming, 2012). The contralateral quadratus lumborum and hip extensor muscles are then recruited as a compensatory mechanism to bring the following lower extremity into motion (Dananberg and Guiliano, 1999).

It has been shown that CLBP patients suffer from symptoms presenting on the same side as the sagittal restriction. These include concomitant SIJ syndrome, greater trochanteric bursitis, tight quadratus lumborum muscles and tight, weak gluteal muscles. A dysfunctionally tight quadratus lumborum muscle can cause overuse and rotational strain to the fifth lumbar vertebrae due to the muscles direct attachment to the iliac crest and iliolumbar ligament (Moore, Dalley and Agur, 2013).

Cibulka *et al.*, (1998) noted that patients with CLBP in the SIJ region showed signs of increased external hip rotation on the same side as the restricted SIJ, but CLBP patients without SIJ dysfunction showed increased external hip rotation bilaterally. Lee (2004) indicated that postural asymmetry can be present without pelvic girdle dysfunction but the inverse is not true, pelvic girdle dysfunction is always indicative of postural asymmetry.

If the kinematic gait cycle is not assessed when dealing with LBP, it could become a perpetuating cause of instability in the lumbar spine. This would explain the high levels of chronicity and recurrence of the condition.

2.12 POSTURAL-BALANCE COMPLEX

The postural-balance complex results from the combined vestibular, visual, somatosensory and proprioceptive afferent information processed by the CNS for functional neuromuscular control (Lephart *et al.*, 1997).

CLBP results in changes in postural alignment and balance (Nies and Sinnott, 1991; Sung, Yoon and Lee, 2010 and Ham *et al.*, 2010). According to Gill and Callaghan (1998), this could be related to the proprioceptors in the lumbar spine which are affected by the biomechanical dysfunction. In a study undertaken by Jo *et al.* (2011) to compare the stability of the lower extremities in patients with and

without low back pain it was shown that, during the single leg standing test, those with low back pain had a significantly shorter endurance time.

In order for functional movement to occur in the upper and lower extremities, it is necessary to have a stable base from which to move, which in this case refers to the individual's trunk and pelvis (Willson *et al.*, 2005 and Bouisset, 1991). Changes in balance and the stability of the lumbo-pelvic region directly affect movement patterns of the lower limb and more specifically the hip joint, which could therefore be considered as a part of the spine in terms of a kinematic chain (McGreggor and Hukins, (2009).

2.13 LEG LENGTH INEQUALITY

Anatomical leg length inequality originates from osseous or structural differences, whereas functional leg length inequality occurs due to compensatory positioning mechanisms and is a sign of pelvic dysfunction (Magee, 2006). Discrepancies between leg lengths can result in pelvic obliquity, which is the abnormal inclination of the pelvis and sacrum laterally, when standing neutrally on both legs (Cooperstein and Lew, 2009 and Morscher, 1977). This increases the compensatory workload of the hip joint abductors (Inman, Ralston and Todd, 1981) and lumbar paraspinal muscles to maintain balance in the pelvis, resulting in spinal ligamentous strain and biomechanical dysfunction (Friberg, 1983).

Manello (1992) argues that spinal joint dysfunction results in asymmetrical changes to the SIJ, pelvis and lower extremity through muscle imbalances. This can result in torsional abnormalities, affecting the flexors, extensors and femoral head position in the hip joints, thus causing leg length inequality (Cooperstein and Lew, 2009). This results in compensatory external rotation to increase stability in the shorter leg (Subotnick, 1999).

It has been shown that sacroiliac syndrome results in pelvic obliquity (Cibulka, Dellito and Koldehoff, 1988) and that pelvic obliquity results in hip joint dysfunction (Friberg, 1983). Although the studies done on LBP in relation to leg length inequality are limited, Giles (1981) and Rowe (1971) have shown an association and it is suggested that, when dealing with sacroiliac dysfunction, a practitioner should assess the patient for functional or anatomical leg length discrepancies (Magee, 2006).

2.14 PAIN THEORY

The pain theory refers to the physical, motor dysfunction that occurs in patients suffering with pain or the fear of pain in relation to psychosocial factors such as anxiety, past experiences, cultural beliefs, barbiturate drugs, alcohol abuse and caffeine (Butler and Mosley, 2003). The presence or fear of pain

has an effect on motor control (Hodges and Mosley, 2003), and can lead to changes in muscle bulk, fibre type and recruitment patterns which could affect the lower extremities and hip joints (Hodges and Richardson, 1996).

Addressing the psychosocial aspects of a patient suffering from CLBP is essential as sustained emotional states lead to changes in muscle tone (Holstage, Bandler and Saper, 1996). Chronically hypertonic muscles cause prolonged increases in joint pressure and strain as seen in the SIJs with hypertonia of the pelvic muscles (Richardson *et al.*, 2002). It is possible to alter dysfunctional motor patterns by simply restoring the patient's motivation through awareness and education (Hodges and Mosley, 2003).

2.15 FEAR AVOIDANCE

Fear avoidance refers to the psychosocial behavioural patterns of someone with LBP who avoids activity due to fear of pain or causing further damage, resulting in neuromuskuloskeletal disuse syndromes which could affect the lower extremities and hip joints, depression and disability (Vlaeyen and Linton, 2000). Fear avoidance is seen as a major risk factor for chronicity in LBP sufferers and is more of an accurate predictor of disability than pain intensity (Crombez *et al.*, 1999).

Some factors associated with individual fear avoidance behaviours include education, social factors, vitality, drug use, perceived disability, the physician's role and pain intensity (Crombez *et al.*, 1999). Physicians have varying personal behavioural patterns with regards to fear avoidance and these habits are often transferred to the patient they are managing, for example: a physician who believes that pain causing activities should be avoided when experiencing low back pain may advise their LBP patients to be inactive (Poiraudreau *et al.*, 2006). It has been shown that patients advised to rest in bed as a management strategy for LBP have scored higher in future fear avoidance behaviour questionnaires with regards to physical activity (Fujii, Matsudaira and Oka, 2013).

According to recent CNSLBP management guidelines, physicians play an important role in the development of fear avoidance and chronicity with regards to LBP and should encourage normal activity and discourage bed rest (Koes *et al.*, 2010).

2.16 MANIPULATIVE THERAPY

Chiropractic manipulation was used in this study as it has been shown to be a favourable treatment option in the treatment of LBP and a variety of lower extremity conditions (Globe *et al.*, 2008 and Manga *et al.*, 1993; Vernon, 2000; Bronfort, 2007 and Van Tulder, Furnan and Gagnier, 2005). Seventy six percent of chiropractors in the United States stated that they often incorporated extremity

manipulation into spinal condition treatment protocols (Christensen *et al.*, 2005). Manipulation involves a brief, high velocity/low amplitude (HVLA) impulse directed at a dysfunctional synovial joint to carry it past its normal physiological ROM but within its anatomical ROM (Bergman and Peterson, 2011). This releases the joint restriction, enabling it to move in its normal ROM, thereby restoring function to the joint (Di Fabio, 1992).

Research highlights that manipulation of the spine has been subjected to more clinical trials than any other form of treatment (Van Tulder *et al.*, 2006) and its resultant positive effect on reducing pain and disability has been clinically documented thoroughly (Kirkaldy-Willis and Cassidy, 1985; Roberts *et al.*, 1989; Schaefer and Faye, 1990; DiFabio, 1992; Vicenzino *et al.*, 1998; Kirkaldy-Willis and Bernard, 1999; Vernon, 2000; Descarreaux, 2004; Van Tulder, Furnan and Gagnier, 2005; Haldeman, 2005; Bronfort, 2007 and Elleuch, 2009). Random clinical trials have shown that manipulation is a highly effective long-term method of treatment for CLBP of a mechanical origin (DiFabio, 1992) and has demonstrated better results when compared to medical, physiotherapy and out-patient hospital management over a 12 month period (Koes, Bouter and Van Mameren, 1992).

DiFabio (1992) states that the evidence motivating manipulation as a management strategy for lumbar facet syndrome is clear and similarly, Gatterman (1990) highlights that it should be the treatment method of choice when managing SIJ syndrome. Clinical trials support Gatterman's (1990) observation, presenting a 90% success rate (Van Tulder, Furnan and Gagnier, 2005). The most effective postural method of patient positioning for manipulation of the SIJ has been shown to be the side-lying posture, which was the posture utilized for this study (Cassidy and Mierau, 1992).

Various theories exist surrounding the mechanism of manipulative therapy with regards to mechanical (physical) and neurophysiological (reflex) responses (Bergmann and Peterson, 2011), but the central theory implies the presence of a lesion (Gatterman, 1995) that affects the biomechanical function of a joint resulting in proximal and distal dysfunction and symptoms (Triano, 2000). This lesion is then reduced through manipulation which, in relation to this study, involves the restoration of balance to the joints and muscles composing the kinematic chain (Haldeman, 2005). This has a positive effect on the arthrogenic inhibitory reflex and breaks the pain cycle by stretching the surrounding muscle tissue and causing reflex relaxation (Van Tulder, Furnan and Gagnier, 2005).

This study involved low back (lumbar spine and SIJ) and hip joint manipulative therapy specific to dysfunctional restrictions found. Manipulative procedures were standardized as far as possible with regards to technique and a clinician was present to advise the most effective method of manipulation through motion palpation. All low back manipulations were carried out in the side lying posture (Bergmann and Peterson, 2011). Hip joint manipulation involved the general long-axis distraction, which has also been shown to be the most effective method in restoring hip joint mobility in all movement patterns (Cibulka and Dellito, 1993).

2.17 CONCLUSION

This study aimed to contribute to and support the body of knowledge surrounding the hip joint's kinematic relationship to the low back and the associated dysfunctional relationship that may occur between the two in a patient suffering from CNSLBP. This, in turn, would stimulate further investigation into hip joint dysfunction, as well as other aspects of the lower kinematic chain's functionality, leading to a more effective management strategy and shorter recovery time for patients with CNSLBP.

It is evident that the lower limb (especially the hip articulation) is involved in spinal function and LBP (McGreggor and Hukins, 2009). Magee (2006) described the importance of examining the pelvis, especially the hip and sacro-iliac joints when investigating LBP. Leibenson (2007) describes the importance of joint mobilisation in the sacro-iliac, anterior hip capsule and lumbar spine when treating LBP and Brantingham *et al.*, (2012) suggested more research is necessary with regards to manipulation of the lower extremity due to a lack of supporting clinical trials. All muscular hip joint motion is supplied by the lumbar spine and in turn, the muscles that move the hip have a large effect on lumbar lordosis, pelvic tilt and lumbar spine movement with regards to flexion, extension, lateral flexion and contra-lateral rotation (Reid, 1992).

Therefore, an imbalance or dysfunction in the lumbar spine could perpetuate dysfunction in the hip joint and visa-versa, resulting in a dysfunctional lower kinematic cycle. Research has shown that hip joint manipulation results in increased muscle strength as well as decreased muscle spasm and, as such, improves muscle performance regardless of the presence or nature of the muscular and/or joint dysfunction (Yerys *et al.*, 2002).

Forbes (2009) investigated the distal articulations in the kinematic chain by studying the ankle joint's effect on LBP. Although the ankle does play a large role in the functional kinematic chain, Vleeming (2012) states that spinal motion would be the same if an individual walked on their knees and therefore, any joint below the knee can be considered to be secondary. This study, therefore, focussed on more proximal articulations in the kinematic chain pertaining to the hip joint's effect on LBP by including hip joint manipulation with a low back manipulation treatment protocol. This supports the knowledge surrounding this kinematic link and signifies a more holistic treatment protocol for LBP.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The following chapter reviews the research methodology followed during this study. This includes the design, participant recruitment and evaluation procedure, and the measurement tools used to obtain the data. The statistical procedures used to analyse the data obtained are also discussed.

3.2 DESIGN

This study used a randomised controlled clinical design in the quantitative paradigm to determine the beneficial effect of hip manipulation in the case of CNSLBP with concomitant hip joint dysfunction.

3.3 RESEARCH TOPIC APPROVAL

Full approval of the research proposal was granted by the Research Higher Degrees Committee (RHDC) on the 26th of April 2016 (Appendix O) and the Institutional Research Ethics Committee (IREC) on the 16th of August 2016 (Appendix N). IREC reference number: REC 60/16.

3.3 METHOD

3.3.1 SAMPLE

3.3.1.1 SAMPLE RECRUITMENT

Posters and flyers (Appendix K), with appropriate authoritative permission, advertised the study around the Durban University of Technology (DUT) campus, at all DUT clinics, health stores, hospitals, schools, sports clubs, gyms, occasional sporting events, private chiropractic practices and other health care facilities. Active recruitment was done through word of mouth, and new patients visiting the DUT Chiropractic Day Clinic (CDC).

3.3.1.2 SAMPLE SIZE

It was agreed that 50 participants with CNSLBP and hip joint dysfunction would be sufficient for this study (Esterhuizen, 2015). This was an increased population as per recommendations by similar and comparable, yet unpublished, research (Matkovich, 2004; Campbell, 2007 and Forbes 2009).

3.3.1.3 SAMPLE CHARACTERISTICS

Participants were recruited from Durban and surrounding areas. The participants were of any ethnic group or gender and between the ages of 18 to 45 years. Participants had CNSLBP and hip joint dysfunction. The measurement tools utilized in this study had not been validated in isiZulu and the researcher was not able to speak isiZulu therefore all documents, questionnaires, recruitment posters and telephonic screenings were in English to avoid negatively affecting the data.

Anyone responding to the posters/flyers underwent a brief telephonic screening (Appendix L) consisting of the relevant inclusion/exclusion criteria. This determined if they were provisionally appropriate for the study. Those who had provisionally qualified for the study, were then booked for their first consultation.

The initial consultation included a thorough case history, physical examination and the relevant low back and hip regional examinations. Participants, who met the inclusion criteria and qualified for the study, signed a Letter of Informed Consent (Appendix A) and were divided equally and randomly into two groups of 25 each (Group A and B).

3.3.1.4 SAMPLE ALLOCATION

Random allocation was carried out by the use of a large envelope containing 70 small pieces of paper. On 35 pieces, Group A was written and on the other 35, Group B was written. "Blind" selection of a letter (A or B) was carried out by the researcher and clinician on duty. The participant was then allocated according to the letter chosen.

3.3.1.5 INCLUSION AND EXCLUSION CRITERIA

3.3.1.5.1 INCLUSION CRITERIA

- Participants had to sign a Letter of Informed Consent (Appendix A). This stated that they understood and agreed to the research procedures and that they could withdraw from the study at any stage.
- Participants had to be older than 18 years in order to ensure no issues regarding parental consent occurred and under 45 years to reduce the risk of sacroiliac and/or spinal ankylosis (Kirkaldy-Willis and Bernard, 1999).

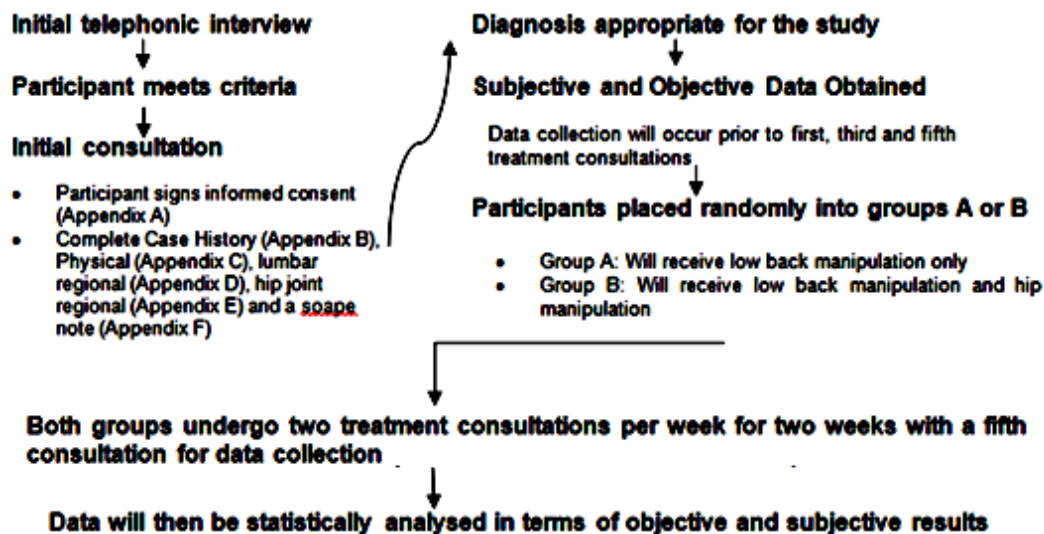
- Participants had to present with a clinical history, signs and symptoms of posterior facet syndrome and/or SIJ syndrome. Orthopaedic tests were performed for facet syndrome and SIJ syndrome, of which three out of four needed to have been positive.
- Participants had to present with unilateral or bilateral hip joint dysfunction in terms of end-feel and ROM. This was assessed for by the researcher using motion palpation techniques and was confirmed by the clinician on duty at the time. An inclinometer was used to objectively quantify the changes in ROM.

3.3.1.5.2 EXCLUSION CRITERIA:

- Potential participants were excluded if they had contraindications to lumbar spine and hip manipulation, for example, but not limited to: disc herniation with neurological deficits, fractures and tumours (Bergmann and Peterson, 2011).
- Potential participants who had previous hip or spinal surgeries.
- Potential participants who had received any treatment or medical intervention within 48 hours prior to the onset of the study were required to wait three days without further treatment before joining the study (Poul *et al.*, 1993). There were no incidences as such.
- Potential participants who required further diagnostic procedures to confirm a diagnosis were referred.
- Potential participants who were unable to attend the appropriate appointments at the DUT CDC.

3.4 CLINICAL PROCEDURE

3.4.1 SUMMARY



3.4.2 INITIAL CONSULTATION AND ORTHOPAEDIC TESTS

Potential participants who passed the telephonic screening (Appendix L) were then booked for an initial consultation at the DUT CDC. A thorough case history (Appendix B) and physical examination (Appendix C) was then performed to rule out any excluding factors, followed by the significant regional examinations of the low back (Appendix D) and hip joints (Appendix E).

In order to assess the potential participant for the presence of posterior facet syndrome and/or sacroiliac syndrome, the following orthopaedic tests were performed by the researcher and the clinician on duty. Three out of four of the tests for both posterior facet syndrome and sacroiliac syndrome were required to be positive. These tests, combined with the relevant clinical history, signs and symptoms enabled the researcher to make the respective diagnoses. (Kirkaldy-Willis and Bernard, 1999).

3.4.2.1 POSTERIOR FACET JOINT ORTHOPAEDIC TESTS

- **Kemp's Test:** The participant was asked to sit upright on the plinth with their arms crossed over their chest. They were then laterally flexed, extended and rotated over the facet being tested while a posterior to anterior (P-A) force was applied by the practitioner. A positive result was discomfort at the facet joint (Magee, 2006).

- **Spinous Percussion Test:** The participant was asked to lie in the prone position while the practitioner utilized a reflex hammer to lightly percuss the spinous processes. A positive sign was a mild discomfort (Bergmann and Peterson, 2011).
- **Palpatory Tenderness Test:** The participant was asked to lie in the prone position while the practitioner palpated the spinous processes, interspaces and facet joints (2.5cm lateral to the spinous process) for tenderness, muscle spasm or any other sign or symptom of pathology (Magee, 2006).
- **Facet Joint Challenge:** The participant was asked to lie in the prone position while the practitioner used the spinous processes of two adjacent vertebrae as levers to apply horizontal forces in opposing directions and stress the respective facet joint. A positive result was pain or discomfort at the facet joint (Gatterman, 1990).

3.4.2.2 SIJ ORTHOPAEDIC TESTS

Laslett (2008) stated that 3 or more positive pain provocation tests for sacroiliac syndrome, as listed below, had up to 91 percent sensitivity and 78 percent specificity.

- **Gaenslen's Test:** The participant was asked to lie in the supine position while the practitioner flexed the knee and hip on the suspected dysfunctional side with the opposite hip and knee in extension. A downward force was applied to reach end ROM resulting in posterior rotation of the ipsilateral ilium on the sacrum. A positive result was pain at the ipsilateral SIJ (Magee, 2006).
- **Erichsen's Test:** The participant was asked to lie in the prone position while the practitioner flexed the knee on the suspected dysfunctional side to 90 degrees and extended the ipsilateral side at the hip joint. This was done by applying a stabilizing force at the iliac crest and pulling the participants leg up into extension with a thigh contact, superior to the knee. A positive result was pain at the ipsilateral SIJ (Magee, 2006).
- **Patrick Faber's Test:** The participant was asked to lie in the supine position while the practitioner flexed the knee and flexed, abducted and externally rotated the hip joint on the side of suspected dysfunction, while the opposite hip was left in extension. A downward force towards the ground was then applied on the ipsilateral knee, while the opposite side was stabilized at the hemi-pelvis. A positive result was discomfort felt at the ipsilateral SIJ (Magee, 2006). Broadhurst and Bond (1998) demonstrated this test to be 77% sensitive and 100% specific.

- **Lateral recumbent sacroiliac joint compression Test:** The participant was asked to lie in the side-lying position, on any side, while the practitioner applied a downward force to the iliac crest. A positive result was discomfort felt at the SIJ (Magee, 2006).

3.4.2.3 HIP JOINT MOTION PALPATION

Motion palpation was performed by the researcher and the clinician on duty to detect hip joint restrictions in at least one of the participant's hips during any ROM test. The following motion palpation techniques were performed (Bergmann and Peterson, 2011):

- **Long axis Distraction:** The participant was asked to lie in the supine position while the practitioner straddled the participant's thigh, placing the epicondyles of the limb being tested between his knees to stabilize the limb. While palpating the ipsilateral iliofemoral joint with outer hand at the greater trochanter and stabilizing the pelvis at the anterior superior iliac spine (ASIS) with the other, the practitioner straightened his/her legs to produce a distracting force on the limb being tested. A lack of a 'springy' joint feel at the end ROM would indicate restriction (Bergmann and Peterson, 2011).
- **Internal and External Rotation:** With the participant in the supine position, the practitioner flexes the knee and hip of the limb being tested to 90 degrees. While palpating the iliofemoral joint with one hand, the other hand holds the calf which is used to induce rotation until discomfort is reported by the participant or restriction is perceived by the practitioner (Bergmann and Peterson, 2011).
- **Flexion:** With the participant in the supine position, the limb being tested is flexed at the knee and hip until discomfort is reported by the participant or restriction is perceived by the practitioner (Bergmann and Peterson, 2011).

3.4.3 INTERVENTION AND FREQUENCY

Joint restrictions in the low back and hip were identified by means of motion palpation by the researcher and confirmed by the clinician on duty. These techniques were carried out to determine the most effective method of manipulation in terms of the spinal level and hip joint sidedness, and spinal and hip joint plane and direction of restriction (Schaefer and Faye, 1990). A diagnosis was then noted in the SOAPE note (Appendix F), thereafter, a clinician on duty reviewed the diagnostic procedure, the participant was randomly allocated into Group A or Group B as mentioned previously and, finally, the participant was approved and signed off.

Group A: received low back manipulation alone

Group B: received combined low back and hip manipulation.

According to Globe *et al.* (2008), CLBP treatment should follow a protocol of two to three treatments per week, for two to four weeks with a re-evaluation at two to four weeks from initial consultation. For the purpose of this study, participants were scheduled for five consultations within two weeks with data collection occurring prior to the intervention at the first, third and fifth consultations.

3.4.3.1 INTERVENTION PROCEDURE

All low back manipulations were carried out by the researcher in the side lying posture (Bergmann and Peterson, 2011). Hip joint manipulation, in the supine position, consisted of a general long-axis distraction, which has been shown to be the most effective in manipulative technique in restoring general hip joint mobility (Cibulka and Dellito, 1993). The manipulated joints were then re-assessed in terms of mobility to ensure that the manipulation was effective.

3.4.3.1.1 LUMBAR SPINE MANIPULATION AND SACROILIAC JOINT MANIPULATION.

The participant was asked to face the researcher in the side lying position with the affected side up and their arms were crossed over their chest. The researcher then flexed the ipsilateral hip to the point of joint tension in the low back (Byfield, 2005).

The researcher used their cephalad hand to stabilize the participant at the shoulder while the participants' hip was adducted and flexed to the point of joint tension in the low back (Byfield, 2005). Simultaneously, the researcher used their caudal hand to motion palpate the restricted joint to the point of elastic restriction at which time a HVLA thrust was delivered to this joint with an inferior vector and body drop technique (Byfield, 2005).

3.4.3.1.2 THE HIP JOINT

To perform a long axis distraction manipulation of the hip joint, the patient was asked to lie in the supine position. The researcher placed the epicondyles of the limb being manipulated between their bent knees and firmly gripped the thigh with their hands. The participant was asked to stabilise themselves by holding the sides of the bed and the researcher straightened their legs with a HVLA

thrust to produce a long-axis distracting force on the limb and iliofemoral joint (Bergmann and Peterson, 2011).

3.5 MEASUREMENT TOOLS

3.5.1 SUBJECTIVE DATA

3.5.1.1 NUMERICAL PAIN RATING SCALE (APPENDIX G) (Jenson *et al.*, 1986)

A Numerical Pain Rating Scale is a reliable tool used to subjectively quantify the degree of effectiveness of a treatment protocol in terms of a decreased patient perception of pain on a numerical scale (Bolton and Wilkinson, 1998). The participant was asked to numerically rate their level of pain from 0-10, with 0 being no pain at all and 10 being the worst pain imaginable. This was repeated as part of four separate questions relating to the pain they felt at the time, their usual level of pain over the past week, their lowest level of pain over the past week and their worst level of pain over the past week. The current level of pain was noted (NPRSc) as well as an average of the four pain ratings (NPRSav).

3.5.1.2 OSWESTRY LOW BACK DISABILITY QUESTIONNAIRE (APPENDIX H) (Fairbank and Pynsent, 2000)

This scale is considered to be more accurate than other disability scales in relation to CLBP (Davidson and Keating, 2002). This survey consisted of ten questions and was used to acquire subjective data relating to the participant's functional ability to perform normal everyday activities associated with LBP. Each question scored zero to five, with a total possible score of 50. An average percentage was then calculated providing a functional disability rating from zero to 100. If the participant left out a question, the percentage was calculated from the adapted total possible score. The interpretations of scores are listed as follows (Fairbank and Pynsent, 2000).

3.5.1.3 INTERPRETATION OF OSWESTRY LOW BACK PAIN DISABILITY INDEX SCORE

- | | |
|---------------------------------------|--|
| 0% to 20%: minimal disability: | The participant can cope with most activities of daily living. Usually no treatment is indicated apart from advice on lifting sitting and exercise. |
| 21%-40%: moderate disability: | The participant experiences more pain and difficulty with sitting, lifting and standing. Travel and social life are more difficult and they may have difficulty functioning at work. Personal care, general activity and sleeping are not grossly affected and the patient can usually be managed by conservative means. |

41%-60%: severe disability:	The participant complains of pain and, as such, activities of daily living are affected. These participants require a detailed investigation.
61%-80%: crippled:	Back pain impinges on all aspects of the participant's life. Positive intervention is required.
81%-100%:	These patients are either bed-bound or exaggerating their symptoms.

3.5.2 OBJECTIVE DATA:

3.5.2.1 FORCE DIAL ALGOMETRY (APPENDIX I)

Algometry pain tolerance readings have shown excellent reliability and can therefore be used for objective medico-legal documentation of pain intensity (Livingston *et al.*, 1998). The Wagner Force Dial Pressure Algometer FDK20 (Wagner Instruments, P. O. Box 1217, Greenwich, CT, 06836, U.S.A) is able to measure forces applied to it in kilograms per square centimetre. The tool was used to objectively quantify the participant's response to treatment in terms of pain tolerance to force applied by the examiner.

Before taking a measurement, the researcher explained the procedure to the participant and advised that some discomfort would be felt and on feeling such, to inform them. The algometer was set to 0. The area of measurement was localised by palpation in the quadratus lumborum myofascial trigger points bilateral to the superior border of the fourth lumbar vertebrae. The researcher then applied force at one kilogram per square centimetre, per second, perpendicular to the skin. When the participant first perceived discomfort, they notified the examiner and an average of three readings was noted as their current pain threshold bilaterally.

3.5.2.2 INCLINOMETER (APPENDIX J)

The 'Saunders' digital handheld inclinometer' was used to measure hip joint and lumbar ROM. Both intra and inter examiner reliability have proved excellent for the inclinometer which has been shown to be highly reliable when measuring trunk ROM (Saur *et al.*, 1996) and a valuable tool in detecting hip joint ROM in children (Herrero *et al.*, 2011). Hand-held inclinometer measurements were shown to be highly accurate when compared to digital inclinometer and goniometer measurements (Boyd, 2012).

Anatomical landmarks were noted to standardize the placement of the inclinometer. For low back ROM measurements this landmark was at the level of the first lumbar vertebrae during flexion tests

(with the inclinometer vertically along the lumbar spine inferior to this landmark) and at L3 during rotation tests.

For hip joint ROM, the landmark was at the greater trochanter for the flexion test and at the tibial tuberosity for internal and external rotation tests. Low back ROM was measured in flexion, left rotation and right rotation with the participant in the seated position. Hip ROM tests were done in the supine position, for flexion, and in the seated position for internal and external rotation.

In order to standardize the hip rotation ROM tests, participants sat in a neutral position with their knees at the edge of the bed. An average of three measurements was captured for each ROM test.

3.5.2.3 MEASUREMENT FREQUENCY

The objective and subjective measurements were completed prior to treatment at the initial, third and fifth consultations.

3.6 ETHICAL CONSIDERATIONS

All participants had to have read the informed consent (Appendix A) and signed a statement of agreement to participate in the study which informed them of the following:

- All information and data collected would be strictly confidential, and their name would not appear in any research publication or replication thereof.
- All the data collected would be stored for 5 years, and thereafter it would be destroyed.
- The participant would not be charged for any treatment, services or consumables rendered by the researcher and no financial gain was awarded to the participant or the researcher.
- Should there have been a research-related injury or adverse reaction, the participant would not have received compensation and they may have been excluded from the research and referred for appropriate care.
- If the participant did not comply with the required treatment consultations within the required time, became ill, was found to fulfil an exclusion criterion or had an adverse reaction to treatment, they were withdrawn from the study.

- The participant was allowed to withdraw from the study at any time for any reason what so ever and this withdrawal did not affect their relationship with the researcher, the supervisor, DUT or any other affiliations associated with this research.

Potential participants were screened for contra-indications to manipulation and excluded from the study if necessary. According to Triano and Shultz (1997), the loads experienced in lumbar spine and pelvic manipulations were safe and serious complications to treatment were extremely low (Terret and Kleynhans, 1992).

Those participants who had not received manipulation before were informed with regards to the procedure and the potential side-effects. There were no coercive factors involved in patient recruitment and a maximum of 10% (N=50) of the participants were allowed to be DUT students to prevent bias.

3.7 STATISTICAL METHODOLOGY

IBM SPSS version 24.0 (manufactured by SPSS Inc., 444N. Michigan Ave, Chicago, Illinois, 60611, US) was used to analyse the data. A p value <0.05 was considered as statistically significant. Normal distribution testing was completed using the One-Sample Kolmogorov-Smirnov Test. This was done to justify the use of parametric testing. Frequency tables were computed in the case of the demographic variables. Demographics were compared between the two treatment groups using t-tests for quantitative normally distributed variables and Pearson's chi square tests for categorical nominal or ordinal variables. Baseline (pre-manipulation) quantitative outcomes were compared between the two groups using t-tests. To determine the effect of the low back and low back and hip manipulations separately, Intra-Group comparisons of outcomes over time were achieved using repeated measured ANOVA generalized linear models. To compare the effect of the low back and low back and hip manipulations, repeated measures ANOVA generalized linear models were used with Inter-Group comparisons. A significant time*group interaction effect indicated a statistically significant differential treatment effect. Profile plots were generated to compare the trends visually.

CHAPTER FOUR

RESULTS

4.1.1 INTRODUCTION

This chapter will present and analyse the demographic, subjective and objective statistical findings collated through the course of this study. Fifty participants were randomized into two equal treatment groups (A and B). Group A included 25 subjects who had low back manipulation only. Group B included 25 subjects who had a combined low back and hip manipulation. Subjective and objective data was recorded before treatments at consultations one, three and five and then transcribed to the data sheet (Appendix P) for statistical analysis by the statistician (Esterhuizen, 2017).

Abbreviations used in Chapter Four:

%	Percentage
=	Equals
<	Smaller than
>	Greater than
Ext Hip	External Hip Rotation
Flx L/S	Lumbar Spine Flexion
Flx Hip	Hip Flexion
Group A	Treatment group received low back manipulation alone
Group B	Treatment group received low back and hip manipulation
Int Hip	Internal Hip Rotation
Lrot L/S	Lumbar Spine Left Rotation
mean	Mean Value
N	Sample size
NPRSc	Numerical Pain Rating Scale (Current Value)
NPRSav	Numerical Pain Rating Scale (Average Value)
ODI	Oswestry Low Back Pain Disability Index Value
<i>p</i> -value	Level of Significance
Rrot L/S	Lumbar Spine Right Rotation
sd	Standard Deviation
SIG	Significance
SIJ	Sacroiliac Joint Manipulation

t	t-value for independent samples t-test
TP1	Algometer Average at Trigger Point 1 (left)
TP2	Algometer Average at Trigger Point 2 (right)

4.1.2 RESPONSE RATE

Over the course of the study, 75 potential participants showed an interest in the study. 61 of these potential participants were included in the study, 11 dropped out and the remaining 14 were excluded.

The 61 participants were divided by random allocation into groups A and B:

- Group A had a total of 25 participants at the end of the study
- Group B had a total of 25 participants at the end of the study

A total of 50 participants completed the study from Group A and Group B

The drop out participants withdrew for various reasons including, but not limited to, work commitments and personal reasons. Dropouts were replaced so as to achieve a 100% completion rate.

4.2 DEMOGRAPHICS

4.2.1 Age, Gender, Ethnicity

Table 4.1: DISTRIBUTION OF SAMPLE ACCORDING TO DEMOGRAPHIC CHARACTERISTICS

		N	Column N %
Group	A	25	50.0%
	B	25	50.0%
Gender	Male	24	48.0%
	Female	26	52.0%
Ethnicity	Black	10	20.0%
	Coloured	2	4.0%
	Indian	8	16%
	White	30	60.0%
Age: mean (sd)		28.4 (7.6) years	

Table 4.1 shows that 52% of the sample (n=50) were female (n=26), 60% were white (n=30) and the average age was 28.4 years.

Table 4.2: ONE-SAMPLE KOLMOGOROV-SMIRNOV AND SHAPIRO-WILK TEST FOR NORMALITY ON BASELINE DATA

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Flx Hip	0.093	50	0.200 [*]	0.978	50	0.455
Int Hip	0.085	50	0.200 [*]	0.975	50	0.356
Ext Hip	0.087	50	0.200 [*]	0.915	50	0.002
Flx L/S	0.060	50	0.200 [*]	0.988	50	0.904
Lrot L/S	0.094	50	0.200 [*]	0.871	50	<0.001
Rrot L/S	0.226	50	<0.001	0.768	50	<0.001
TP1	0.097	50	0.200 [*]	0.964	50	0.135
TP2	0.105	50	0.200 [*]	0.969	50	0.211
NPRSc	0.161	50	0.002	0.948	50	0.029
NPRSav	0.105	50	0.200 [*]	0.973	50	0.295
ODI	0.187	50	<0.001	0.877	50	<0.001
*. This is a lower bound of the true significance.						
a. Lilliefors Significance Correction						

The data in Table 4.2 reflects that the baseline data follow an approximately normal distribution for most variables except for Rrot L/S L/S, NPRSc and ODI ($p < 0.001$).

4.3 Comparison of Demographics between Treatment Groups

The demographics and baseline (pre-manipulation) outcomes were checked for consistency between the two groups to ensure that the randomization process was complete and that the two groups were equivalent at the beginning of the study. Thus, any changes found at the endpoints would then reflect the intervention's effect only and that any changes in the participant's condition did not come about by chance or coincidence.

Table 4.3: COMPARISON BETWEEN TREATMENT GROUPS IN TERMS OF AGE

Group Statistics							
	Group	N	Mean	sd	Std. Error Mean	<i>p</i> - value	
Age	A	25	29.52	7.506	1.501	0.308	
	B	25	27.32	7.598	1.520		

Table 4.3 reflects that there were no statistical differences in terms of mean Age between the treatment groups ($p=0.308$).

Table 4.4: COMPARISON BETWEEN TREATMENT GROUPS IN TERMS OF ETHNICITY, GENDER AND SI SIDEDNESS

		Group						<i>p</i> -value
		A		B		Total		
		N	Column N %	N	Column N %	N	Column N %	
Gender	Male	11	44.0%	13	52.0%	24	48.0%	0.571
	Female	14	56.0%	12	48.0%	26	52.0%	
Ethnicity	Black	6	24.0%	4	16.0%	10	20.0%	0.387
	White	16	64.0%	14	56.0%	30	60.0%	
	Indian	3	12.0%	5	20.0%	8	16.0%	
	Coloured	0	0.0%	2	8.0%	2	4.0%	
	Other	0	0.0%	0	0.0%	0	0.0%	
SI Sidedness	none	4	16.0%	2	8.0%	6	12.0%	0.588
	right	13	52.0%	11	44.0%	24	48.0%	
	left	5	20.0%	6	24.0%	11	22.0%	
	both	3	12.0%	6	24.0%	9	18.0%	

Table 4.4 reflects that there were no statistical differences in terms of gender between the treatment groups ($p=0.571$). Neither ethnicity nor the side of SIJ restriction (SI Sidedness) differed either ($p=0.387$ and 0.588 respectively).

4.4 Comparison of Baseline Outcomes between Treatment Groups

Table 4.5: COMPARISON OF PRE-MANIPULATION READINGS BETWEEN THE TREATMENT GROUPS: PARAMETRIC TESTS

	Group	<i>p</i>
Flx Hip	A	0.679
	B	
Int Hip	A	0.469
	B	
Ext Hip	A	0.327
	B	
Flx L/S	A	0.070
	B	
Lrot L/S	A	0.348
	B	
TP1	A	0.619
	B	
TP2	A	0.532
	B	
NPRSav	A	0.198
	B	

The results in Table 4.5 reflect that the pre-manipulation readings were not significantly different between treatment groups ($p>0.05$)

Table 4.6: COMPARISON OF PRE-MANIPULATION READINGS BETWEEN THE TREATMENT GROUPS: NON PARAMETRIC TESTS

Null Hypothesis	Test	Sig	Decision
The distribution of Rrot is the same across all categories of the Group	Independent Samples: Mann-Whitney Test	0.705	Retain the null Hypothesis
The distribution of Rrot is the same across all categories of the Group	Independent Samples: Mann-Whitney Test	0.393	Retain the null Hypothesis
The distribution of Rrot is the same across all categories of the Group	Independent Samples: Mann-Whitney Test	0.961	Retain the null Hypothesis

The results in Table 4.6 reflect that the pre-manipulation readings were not significantly different between treatment groups ($p > 0.05$).

4.5 Assessment of the Treatment Effect

4.5.1 Intra-Group Analysis

4.5.1.1 Objective Outcomes

4.5.1.1.1 Inclinator ROM Tests

Table 4.7: HIP FLEXION INTRA-GROUP ANALYSIS

Group	Effect		Value	Sig.
A	Time	Pillai's Trace	0.440	0.001
		Wilks' Lambda	0.560	0.001
		Hotelling's Trace	0.787	0.001
		Roy's Largest Root	0.787	0.001
B	Time	Pillai's Trace	0.176	0.107
		Wilks' Lambda	0.824	0.107
		Hotelling's Trace	0.214	0.107
		Roy's Largest Root	0.214	0.107

The information from Table 4.7 showed that there was a highly statistically significant change in this outcome over time in Group A ($p=0.001$) but not in Group B ($p=0.107$). As can be seen in the figures 4.1 and 4.2, Group A increased linearly over time while Group B increased steeply and then decreased.

FIGURE 4.1: MEAN HIP FLEXION BY TIME IN GROUP A

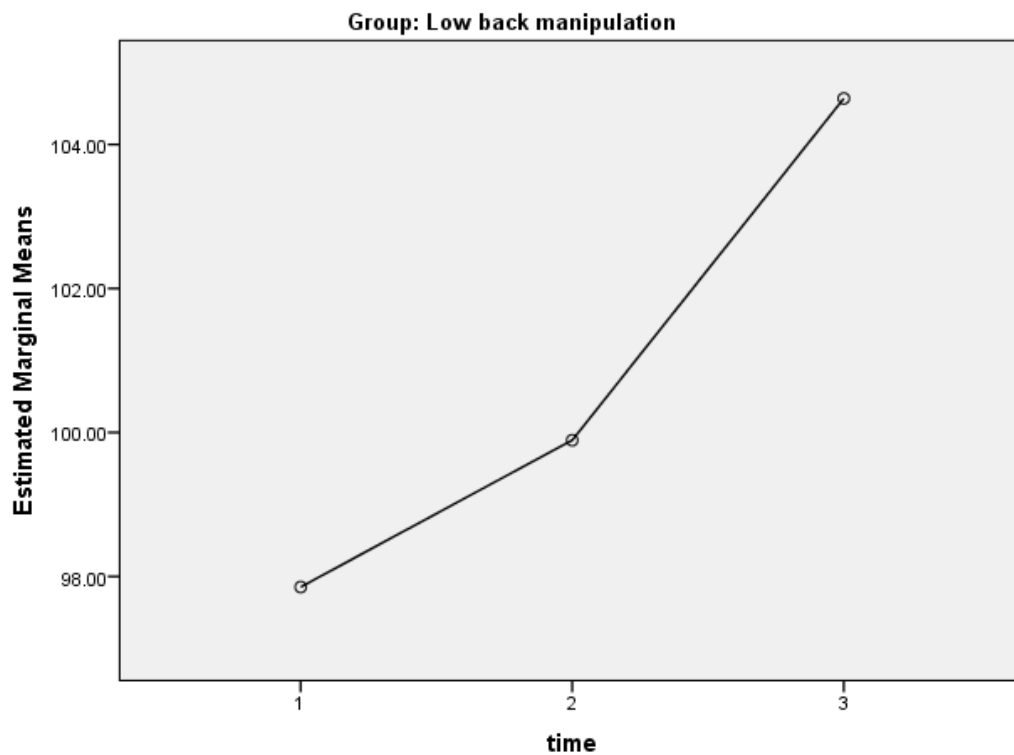


FIGURE 4.2: MEAN HIP FLEXION BY TIME IN GROUP B

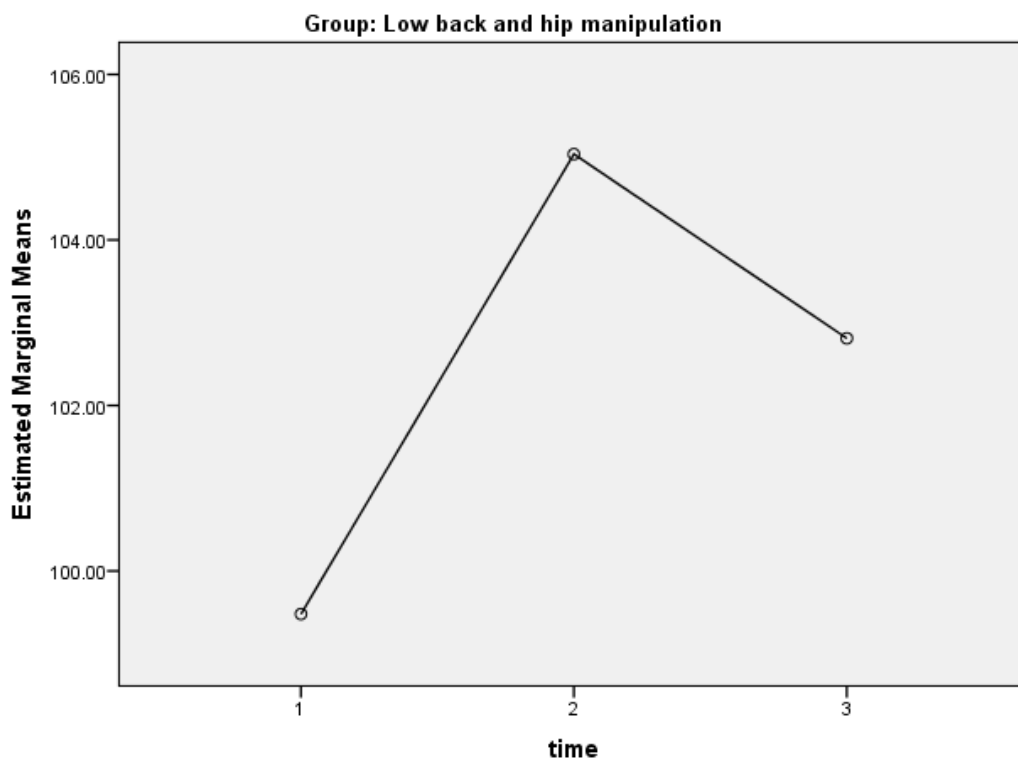


Table 4.8: HIP INTERNAL ROTATION INTRA-GROUP ANALYSIS

Group	Effect		Value	Sig.
A	Time	Pillai's Trace	0.293	0.019
		Wilks' Lambda	0.707	0.019
		Hotelling's Trace	0.415	0.019
		Roy's Largest Root	0.415	0.019
B	Time	Pillai's Trace	0.418	0.002
		Wilks' Lambda	0.582	0.002
		Hotelling's Trace	0.719	0.002
		Roy's Largest Root	0.719	0.002

The information in Table 4.8 showed that both groups ROM increased significantly over time ($p < 0.05$).

Table 4.9: HIP EXTERNAL ROTATION INTRA-GROUP ANALYSIS

Group	Effect		Value	Sig.
A	Time	Pillai's Trace	0.292	0.019
		Wilks' Lambda	0.708	0.019
		Hotelling's Trace	0.413	0.019
		Roy's Largest Root	0.413	0.019
B	Time	Pillai's Trace	0.306	0.015
		Wilks' Lambda	0.694	0.015
		Hotelling's Trace	0.440	0.015
		Roy's Largest Root	0.440	0.015

The information in table 4.9 showed a statistically significant increase in ROM in both groups ($p < 0.05$).

Table 4.10: LUMBAR FLEXION INTRA-GROUP ANALYSIS

Group	Effect		Value	Sig.
A	Time	Pillai's Trace	0.334	0.009
		Wilks' Lambda	0.666	0.009
		Hotelling's Trace	0.501	0.009
		Roy's Largest Root	0.501	0.009
B	Time	Pillai's Trace	0.279	0.023
		Wilks' Lambda	0.721	0.023
		Hotelling's Trace	0.387	0.023
		Roy's Largest Root	0.387	0.023

The information in Table 4.10 showed a statistically significant increase in ROM in both groups ($p < 0.05$).

Table 4.11: LUMBAR LEFT ROTATION INTRA-GROUP ANALYSIS

Group	Effect		Value	Sig.
A	Time	Pillai's Trace	0.224	0.054
		Wilks' Lambda	0.776	0.054
		Hotelling's Trace	0.288	0.054
		Roy's Largest Root	0.288	0.054
B	Time	Pillai's Trace	0.229	0.050
		Wilks' Lambda	0.771	0.050
		Hotelling's Trace	0.297	0.050
		Roy's Largest Root	0.297	0.050

The information in Table 4.11 showed a non-significant increase in ROM in Group A (Figure 4.3; $p > 0.05$) and a marginally significant increase in ROM in Group B (Figure 4.4; $p < 0.05$).

FIGURE 4.3: MEAN LUMBAR LEFT ROTATION BY TIME IN GROUP A

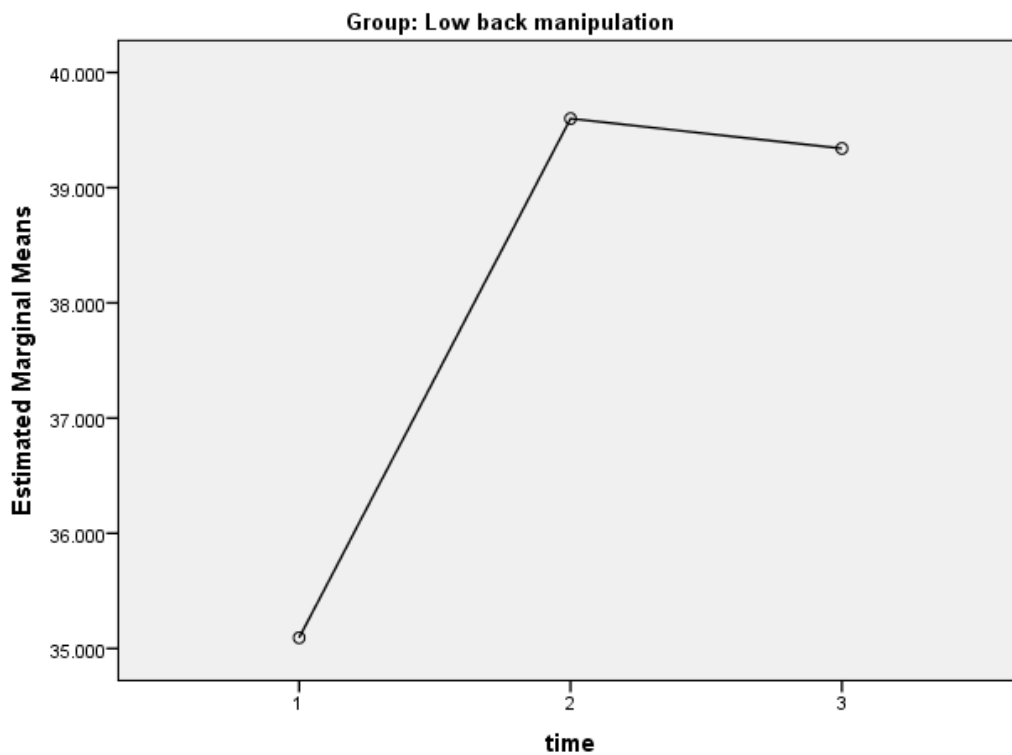


FIGURE 4.4: MEAN LUMBAR LEFT ROTATION BY TIME IN GROUP B

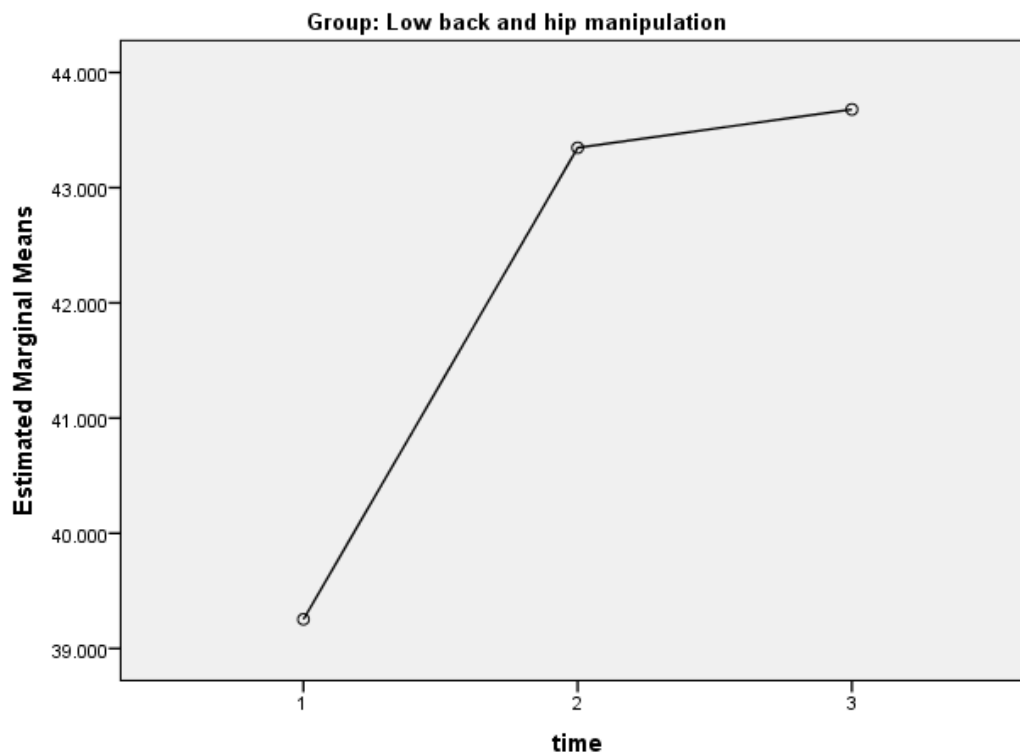


Table 4.12: LUMBAR RIGHT ROTATION INTRA-GROUP ANALYSIS

Group	Effect		Value	Sig.
A	Time	Pillai's Trace	0.046	0.579
		Wilks' Lambda	0.954	0.579
		Hotelling's Trace	0.049	0.579
		Roy's Largest Root	0.049	0.579
B	Time	Pillai's Trace	0.436	0.001
		Wilks' Lambda	0.564	0.001
		Hotelling's Trace	0.772	0.001
		Roy's Largest Root	0.772	0.001

The information in Table 4.12 showed very little change in ROM in Group A ($p>0.05$), following an initial decrease and a significant increase in ROM in Group B ($p<0.05$) as seen in Figures 4.5 and 4.6, respectively.

FIGURE 4.5: MEAN LUMBAR RIGHT ROTATION BY TIME IN GROUP A

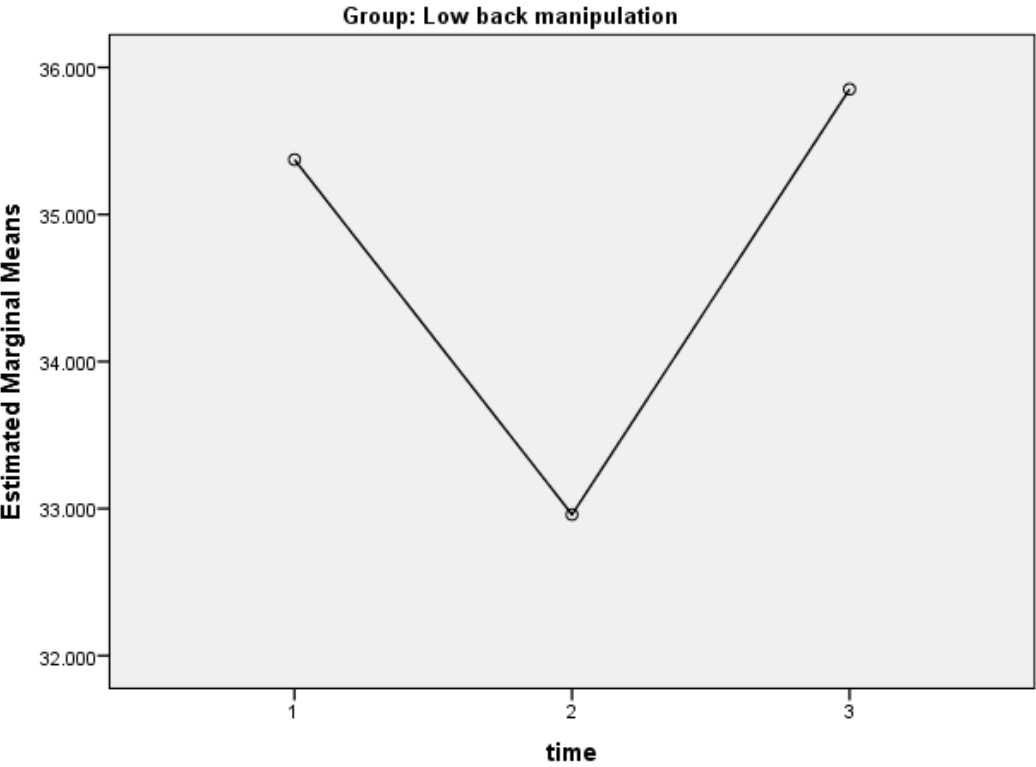
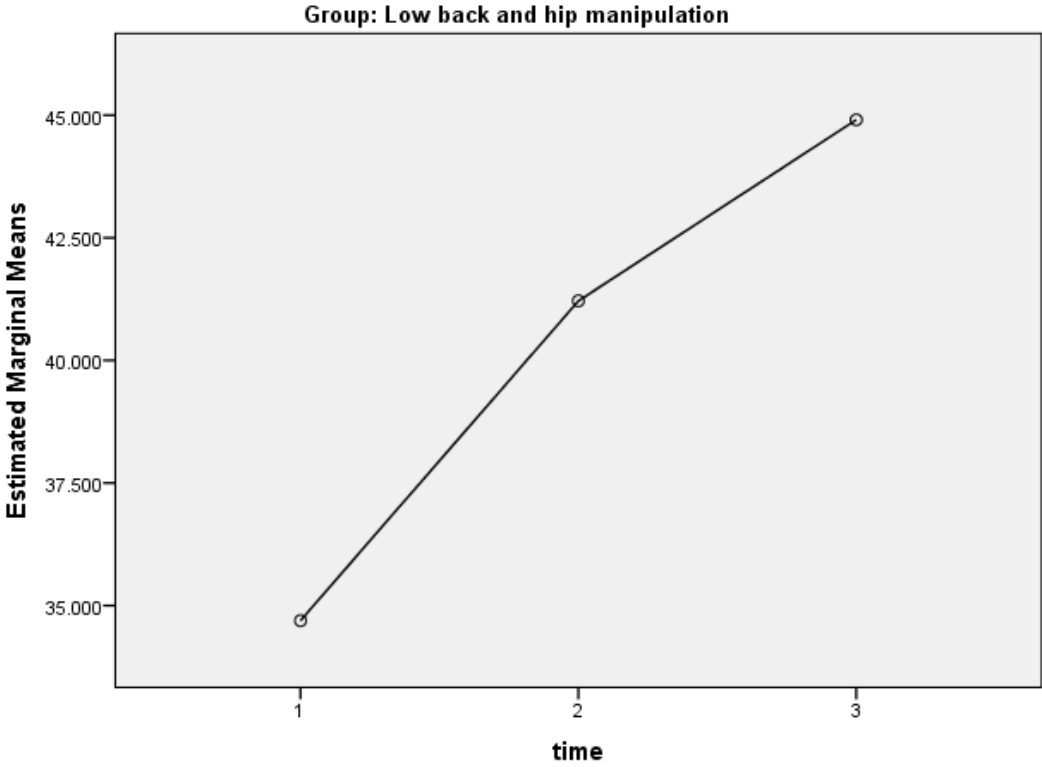


FIGURE 4.6: MEAN LUMBAR RIGHT ROTATION BY TIME IN GROUP B



4.5.1.1..2 Force Dial Algometry Tests

Table 4.13: TP1 INTRA-GROUP ANALYSIS

Group	Effect		Value	Sig.
A	Time	Pillai's Trace	0.596	<0.001
		Wilks' Lambda	0.404	<0.001
		Hotelling's Trace	1.477	<0.001
		Roy's Largest Root	1.477	<0.001
B	Time	Pillai's Trace	0.394	0.003
		Wilks' Lambda	0.606	0.003
		Hotelling's Trace	0.651	0.003
		Roy's Largest Root	0.651	0.003

The information from TP1 Intra-Group Analysis showed a statistically significant increase in ROM in both groups ($p < 0.05$). Figure 4.7 shows a uniform increase in Group A over time, where-as Figure 4.8 shows an initial increase and then decrease over time in Group B.

FIGURE 4.7: MEAN TP 1 BY TIME IN GROUP A

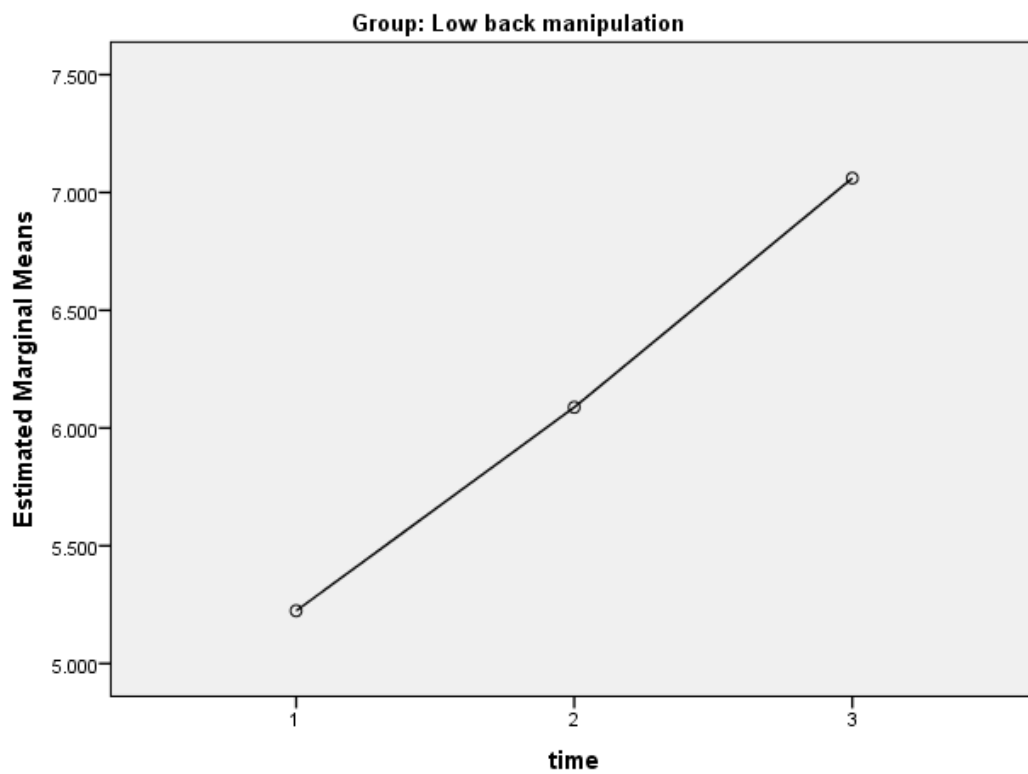


FIGURE 4.8: MEAN TP 1 BY TIME IN GROUP B

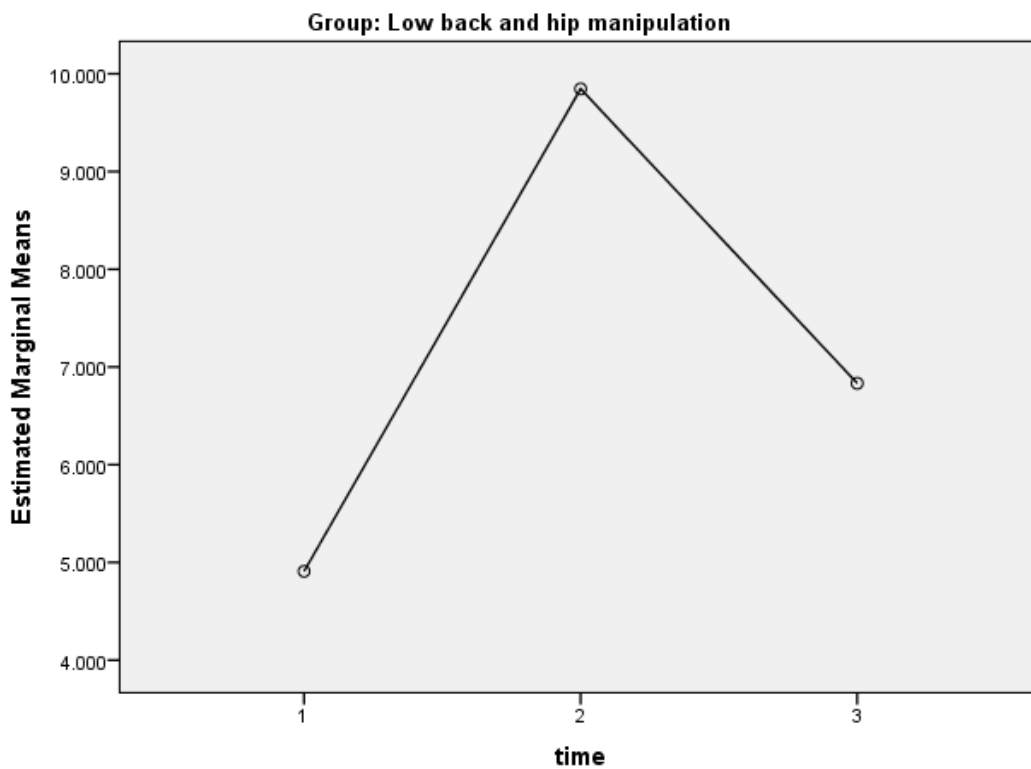


Table 4.14: TP2 INTRA-GROUP ANALYSIS

Group	Effect		Value	Sig.
A	Time	Pillai's Trace	0.440	0.001
		Wilks' Lambda	0.560	0.001
		Hotelling's Trace	0.785	0.001
		Roy's Largest Root	0.785	0.001
B	Time	Pillai's Trace	0.407	0.002
		Wilks' Lambda	0.593	0.002
		Hotelling's Trace	0.687	0.002
		Roy's Largest Root	0.687	0.002

The information from TP1 Intra-Group Analysis table showed a statistically significant increase in ROM in both groups ($p < 0.05$).

4.5.1.2 Subjective Outcomes

4.5.1.2.1 Oswestry Low Back Pain Disability Index

Table 4.15: OSWESTRY LOW BACK PAIN DISABILITY INDEX

Group	Effect		Value	Sig.
A	Time	Pillai's Trace	0.618	<0.001
		Wilks' Lambda	0.382	<0.001
		Hotelling's Trace	1.615	<0.001
		Roy's Largest Root	1.615	<0.001
B	Time	Pillai's Trace	0.679	<0.001
		Wilks' Lambda	0.321	<0.001
		Hotelling's Trace	2.116	<0.001
		Roy's Largest Root	2.116	<0.001

The information in Table 4.15 showed a highly significant decrease in both group ($p < 0.001$)

4.5.1.2.2 Numerical Pain Rating Scale

TABLE 4.16: NUMERICAL PAIN RATING SCALE (CURRENT)

Group	Effect		Value	Sig.
A	Time	Pillai's Trace	0.636	<0.001
		Wilks' Lambda	0.364	<0.001
		Hotelling's Trace	1.749	<0.001
		Roy's Largest Root	1.749	<0.001
B	Time	Pillai's Trace	0.578	<0.001
		Wilks' Lambda	0.422	<0.001
		Hotelling's Trace	1.368	<0.001
		Roy's Largest Root	1.368	<0.001

The information in Table 4.16 indicates a highly significant decrease in current pain for both groups ($p < 0.001$).

TABLE 4.17: NUMERICAL PAIN RATING SCALE (AVERAGE)

Group	Effect		Value	Sig.
A	Time	Pillai's Trace	0.667	<0.001
		Wilks' Lambda	0.333	<0.001
		Hotelling's Trace	2.007	<0.001
		Roy's Largest Root	2.007	<0.001
B	Time	Pillai's Trace	0.536	<0.001
		Wilks' Lambda	0.464	<0.001
		Hotelling's Trace	1.154	<0.001
		Roy's Largest Root	1.154	<0.001

The information in Table 4.17 reflects a highly significant decrease in pain for both groups ($p < 0.001$).

4.5.2 Inter-Group Analysis

4.5.2.1 Objective Outcomes

4.1.2.1.1 Inclinator ROM Tests

Table 4.18: HIP FLEXION INTER-GROUP ANALYSIS

Effect		Value	p
Time	Wilks' Lambda	0.874	0.043
Time*Group	Wilks' Lambda	0.960	0.382
Group	F	0.265	0.609

The information in Table 4.18 showed that for hip flexion, there was no evidence of a differential treatment effect in the two groups ($p=0.382$). The information supplied in Figure 4.9 highlights that the profiles of both treatments groups appeared to intersect after the 2nd time point. However, this trend was not statistically significant

FIGURE 4.9: MEAN HIP FLEXION BY TIME IN GROUPS A AND B

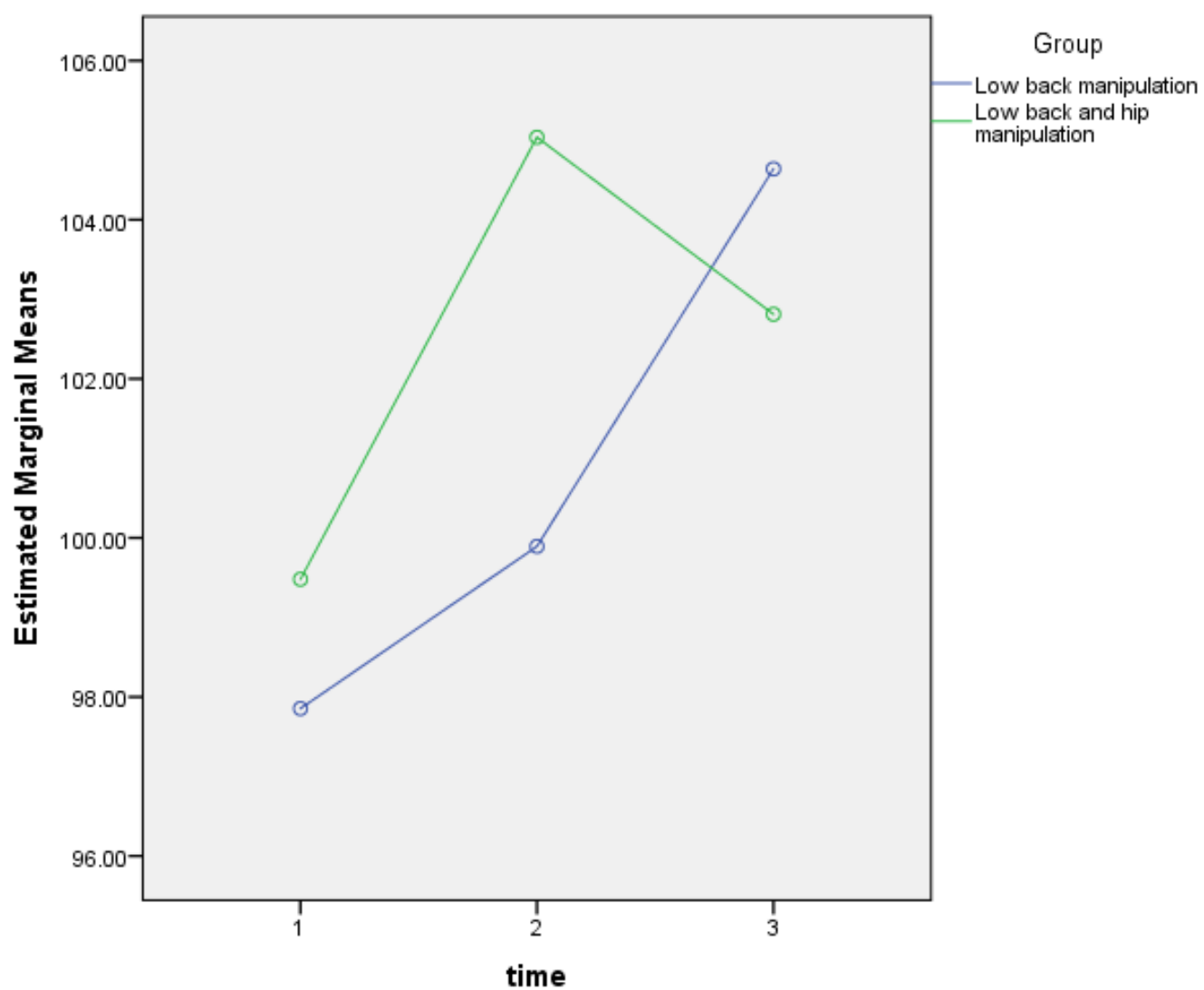


Table 4.19: HIP INTERNAL ROTATION INTER-GROUP ANALYSIS

Effect		Value	<i>p</i>
Time	Wilks' Lambda	0.649	<0.001
Time*Group	Wilks' Lambda	0.984	0.690
Group	F	2.31	0.135

The information in Table 4.19 showed that for hip internal rotation, there was no evidence of a differential treatment effect in the two groups ($p=0.690$). The information supplied in Figure 4.10 shows that the profiles of both treatments groups appeared to be relatively parallel over time. This indicating that the outcome was not influenced by which treatment group the participant was in.

FIGURE 4.10: MEAN HIP INTERNAL ROTATION BY TIME IN GROUPS A AND B

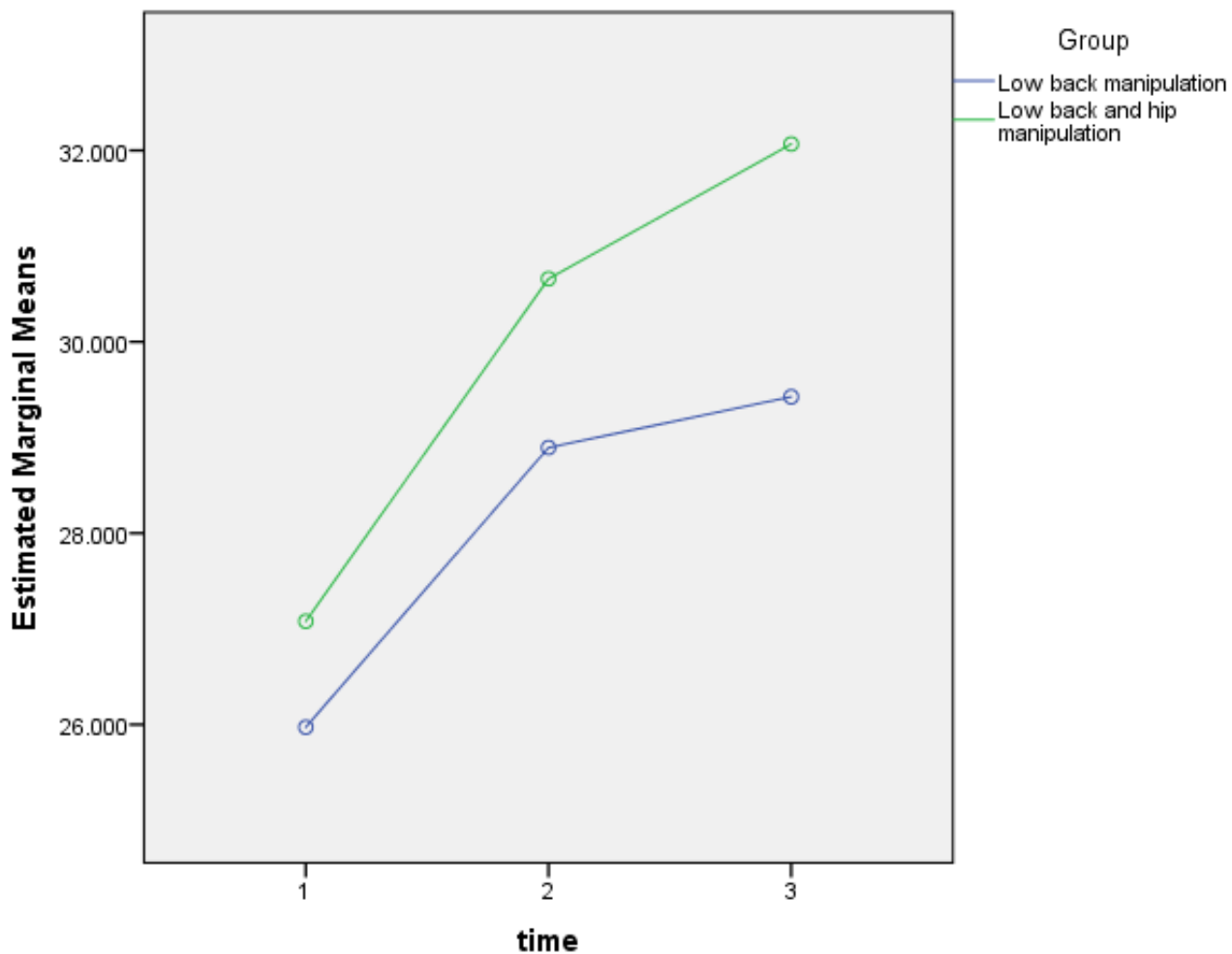


Table 4.20: HIP EXTERNAL ROTATION INTER-GROUP ANALYSIS

Effect		Value	p
Time	Wilks' Lambda	0.719	<0.001
Time*Group	Wilks' Lambda	0.993	0.855
Group	F	2.13	0.151

The information in Table 4.20 showed that for hip external rotation, there was no evidence of a differential treatment effect in the two groups ($p=0.855$). The information supplied in Figure 4.11 highlights that profiles of both treatments groups appeared to be relatively parallel over time. This indicating that the outcome was not influenced by which treatment group the participant was in.

FIGURE 4.11: MEAN HIP EXTERNAL ROTATION BY TIME IN GROUPS A AND B

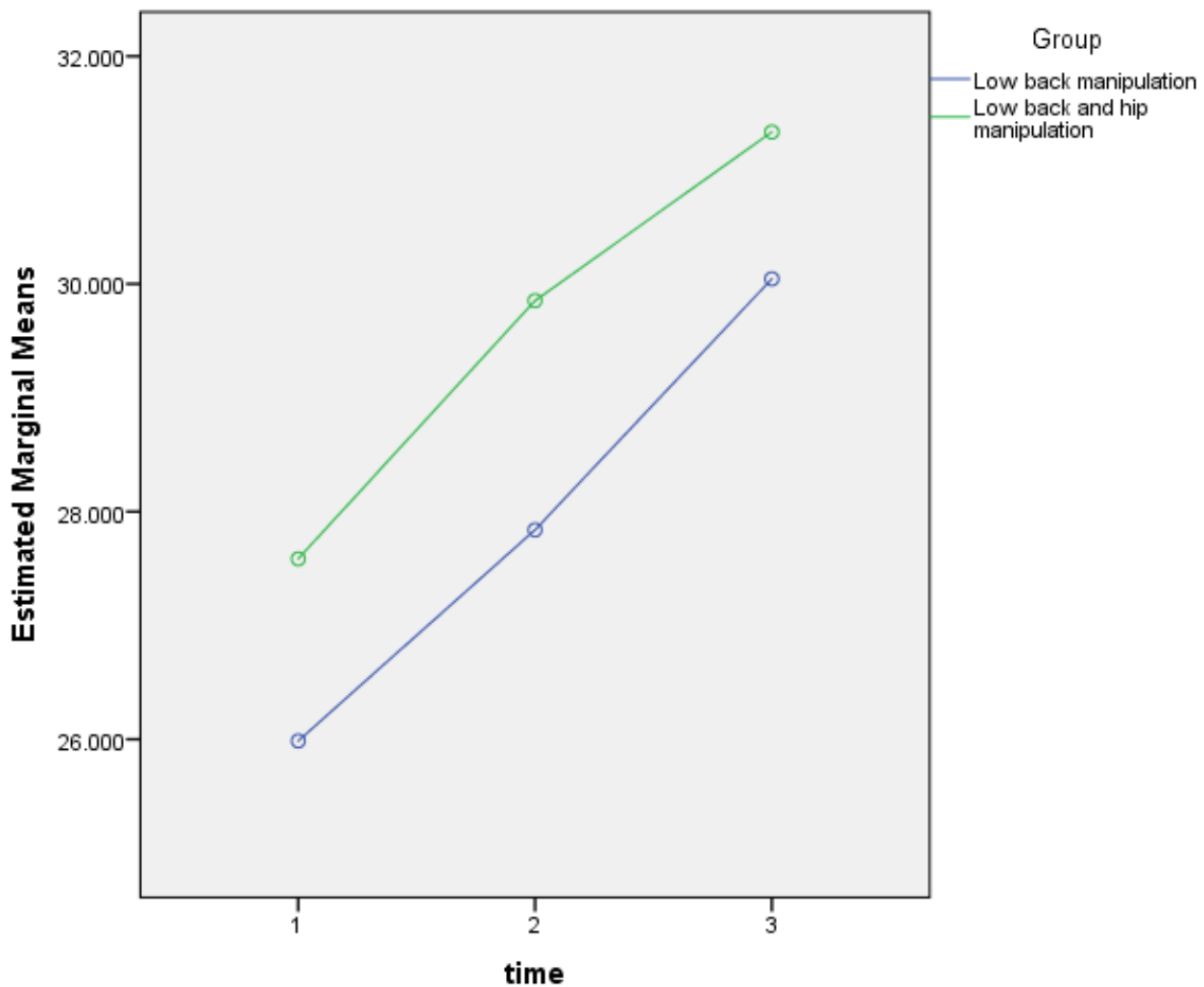


Table 4.21: LUMBAR FLEXION INTER-GROUP ANALYSIS

Effect		Value	<i>p</i>
Time	Wilks' Lambda	0.702	<0.001
Time*Group	Wilks' Lambda	0.955	0.336
Group	F	2.72	0.106

The
informa
tion in
Table
4.21

showed that for lumbar flexion, there was no evidence of a differential treatment effect in the two groups ($p=0.336$). The information supplied in Figure 4.12 indicates that profiles of both treatments groups appeared to be relatively parallel over time. This also indicating that the outcome was not influenced by which treatment group the participant was in.

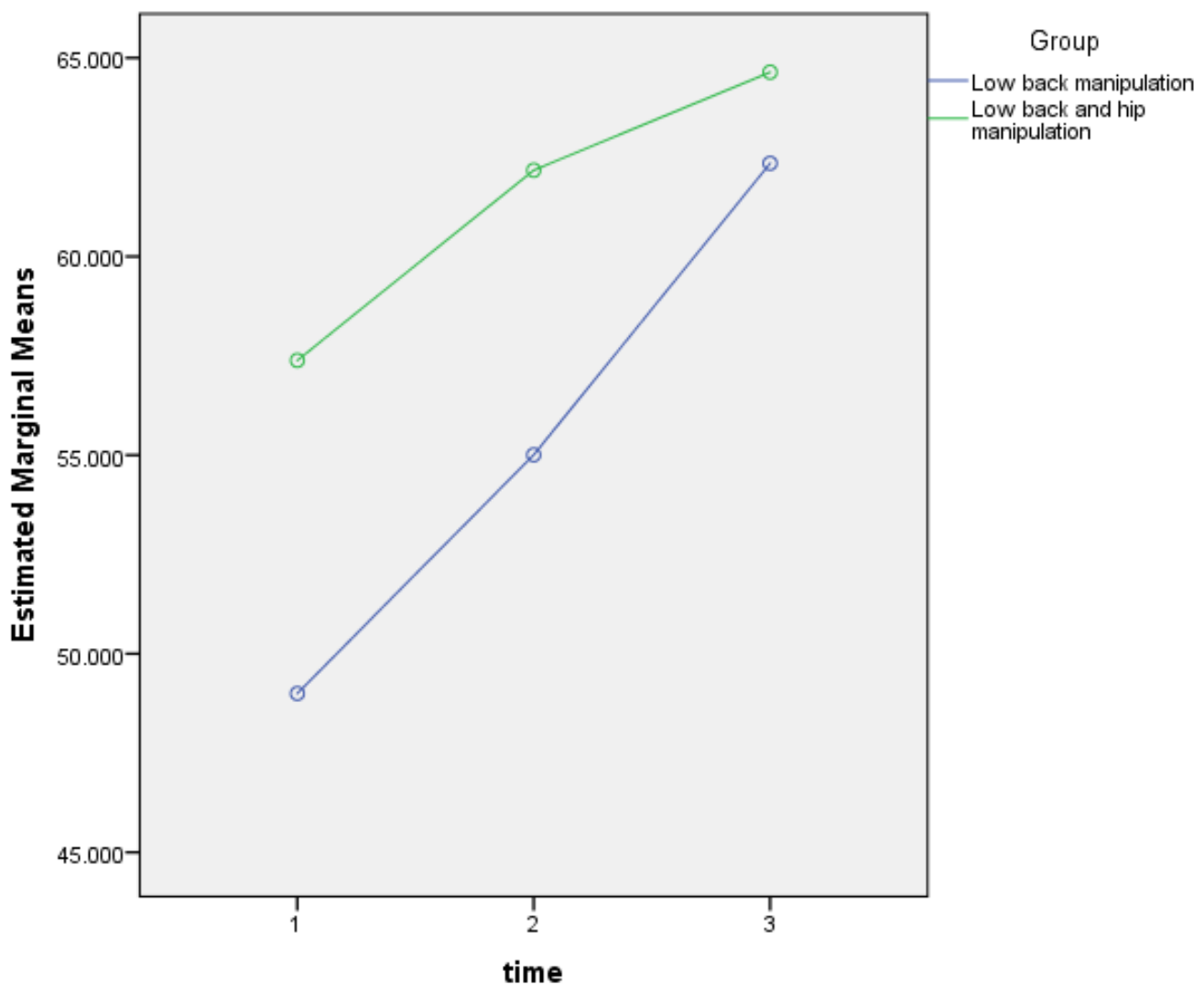
FIGURE 4.12: MEAN LUMBAR FLEXION BY TIME IN GROUPS A AND B

Table 4.22: LUMBAR LEFT ROTATION INTER-GROUP ANALYSIS

Effect		Value	<i>p</i>
Time	Wilks' Lambda	0.796	0.005
Time*Group	Wilks' Lambda	0.999	0.982
Group	F	0.991	0.324

The information in Table 4.22 showed that for lumbar left rotation, there was no evidence of a differential treatment effect in the two groups ($p=0.982$). The information supplied in Figure 4.13 highlights that the profiles of both treatments groups appeared to be relatively parallel over time. This indicating that the outcome was not influenced by which treatment group the participant was in.

FIGURE 4.13: MEAN LUMBAR LEFT ROTATION BY TIME IN GROUPS A AND B

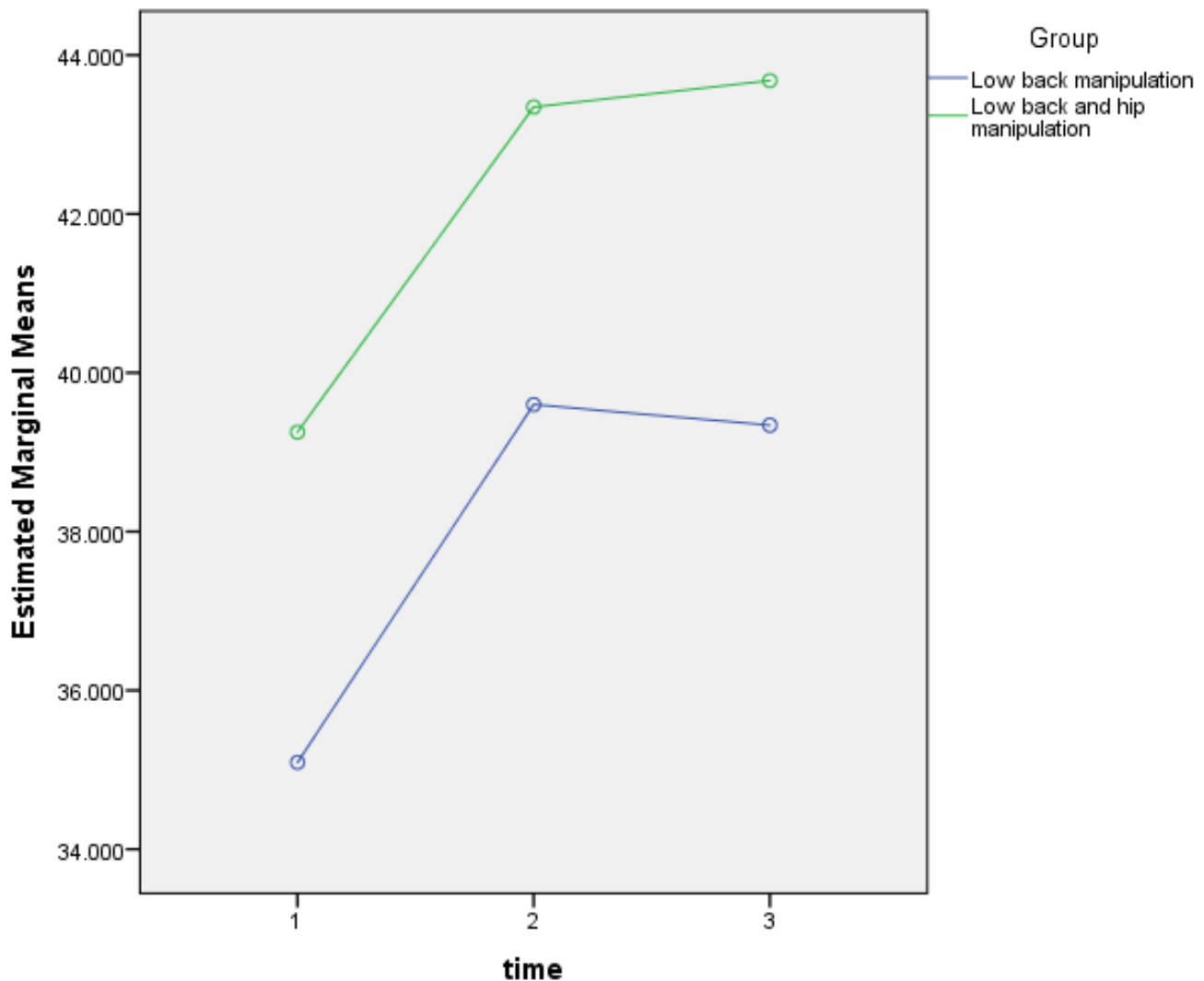
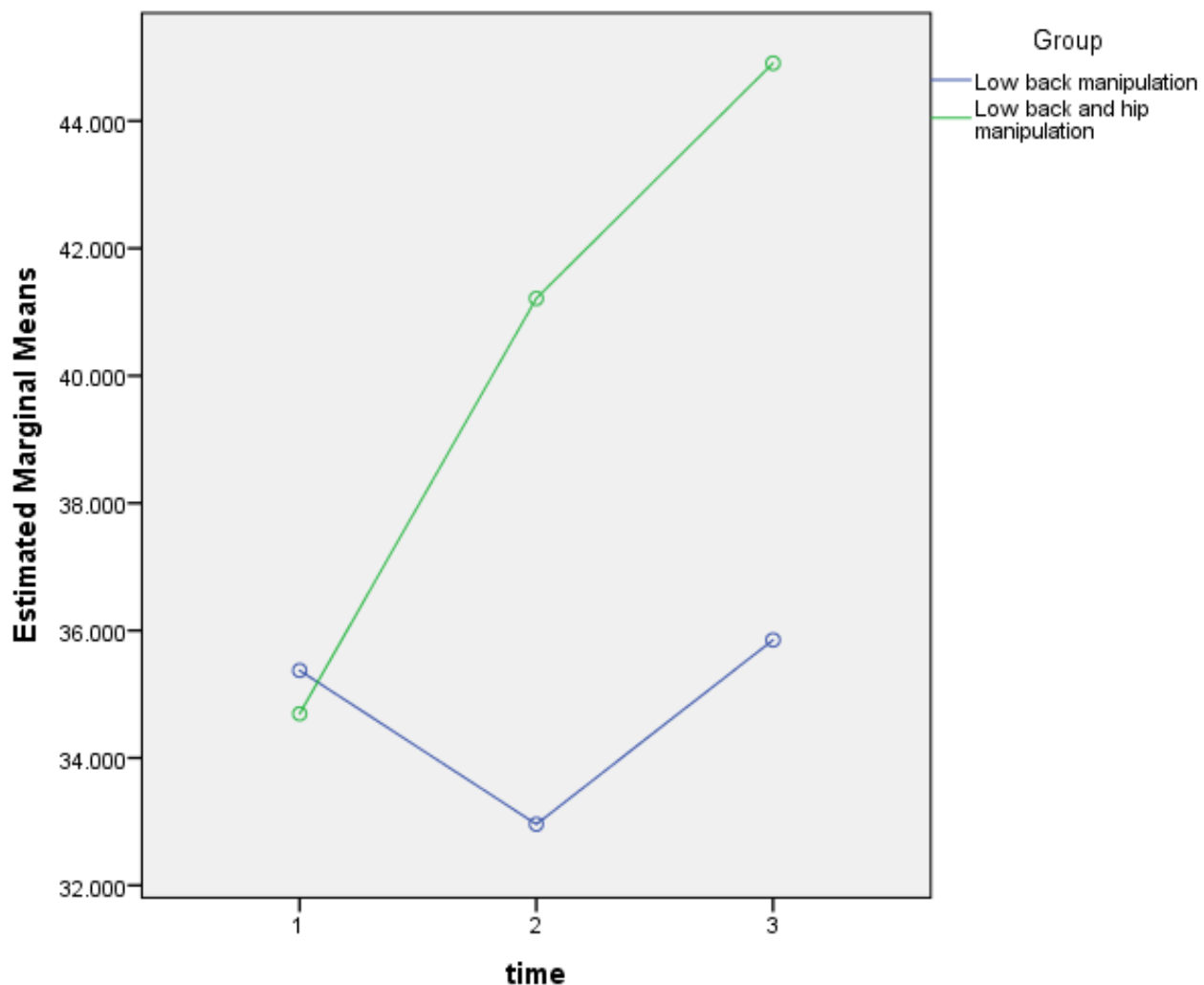


Table 4.23: LUMBAR RIGHT ROTATION INTER-GROUP ANALYSIS

Effect		Value	<i>p</i>
Time	Wilks' Lambda	0.855	0.025
Time*Group	Wilks' Lambda	0.917	0.130
Group	F	1.88	0.176

The information in Table 4.23 showed that for lumbar right rotation, there was no evidence of a differential treatment effect in the two groups ($p=0.130$). However, the information supplied in Figure 4.14 shows completely different profiles over time. Group B's lumbar range of motion in right rotation appeared to decrease between the first and second time point while Group A increased steadily throughout. The trend is, however, not statistically significant.

FIGURE 4.14: MEAN LUMBAR RIGHT ROTATION BY TIME IN GROUPS A AND B



4.5.2.1.2 Force Dial Algometry Tests

Table 4.24: TP1 INTER-GROUP ANALYSIS

Effect		Value	p
Time	Wilks' Lambda	0.525	<0.001
Time*Group	Wilks' Lambda	0.977	0.585
Group	F	0.470	0.496

The information in Table 4.24 showed that for the first Trigger Point area (TP1), there was no evidence of a differential treatment effect in the two groups ($p=0.130$). However, the information supplied in Figure 4.15 shows completely different profiles over time. Group B's pain tolerance appeared to increase steadily over time while Group A increased between the initial and third treatment consultations and then decreased. The trend was not statistically significant.

FIGURE 4.15: MEAN TP1 VALUES BY TIME IN GROUP A AND B

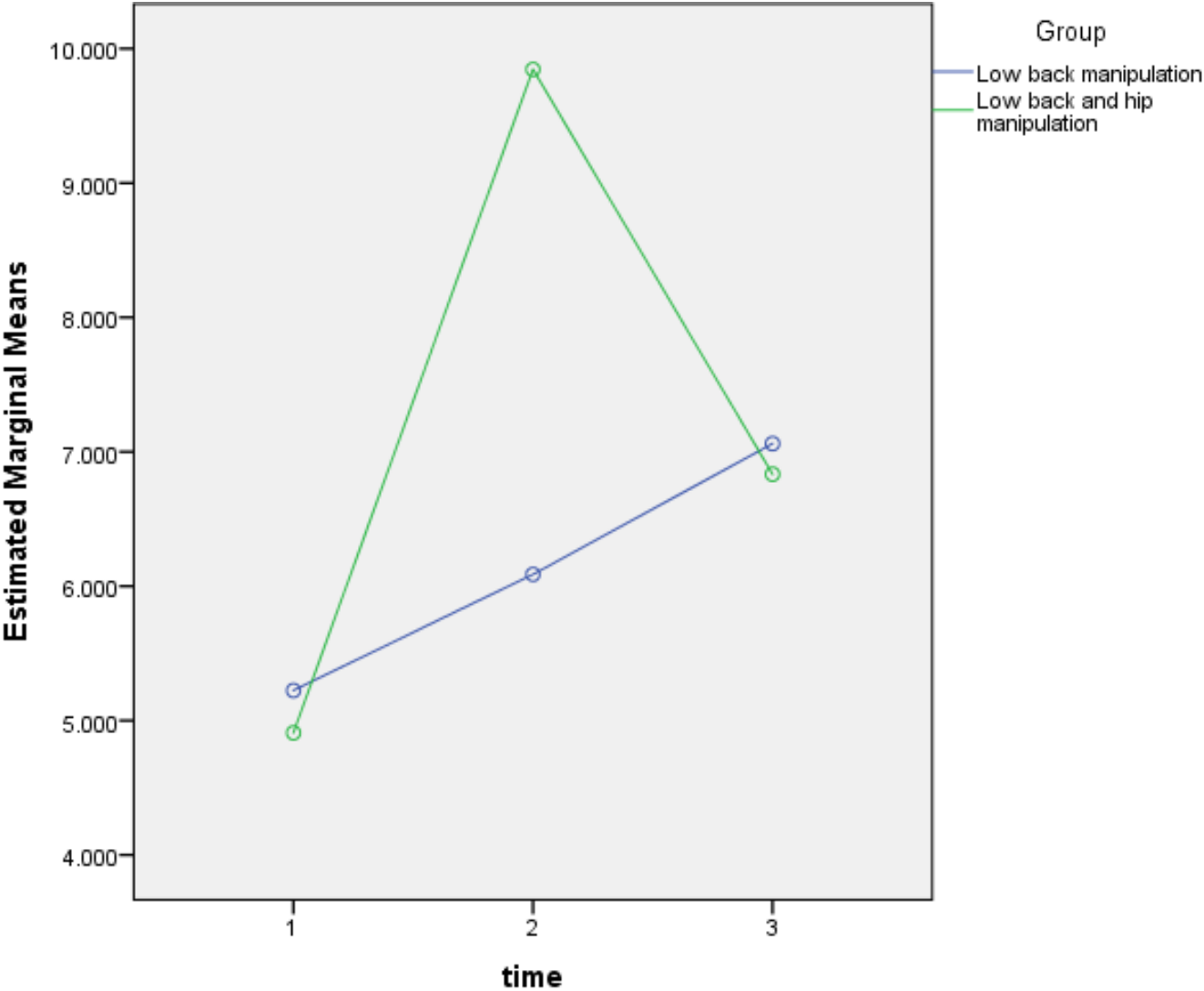
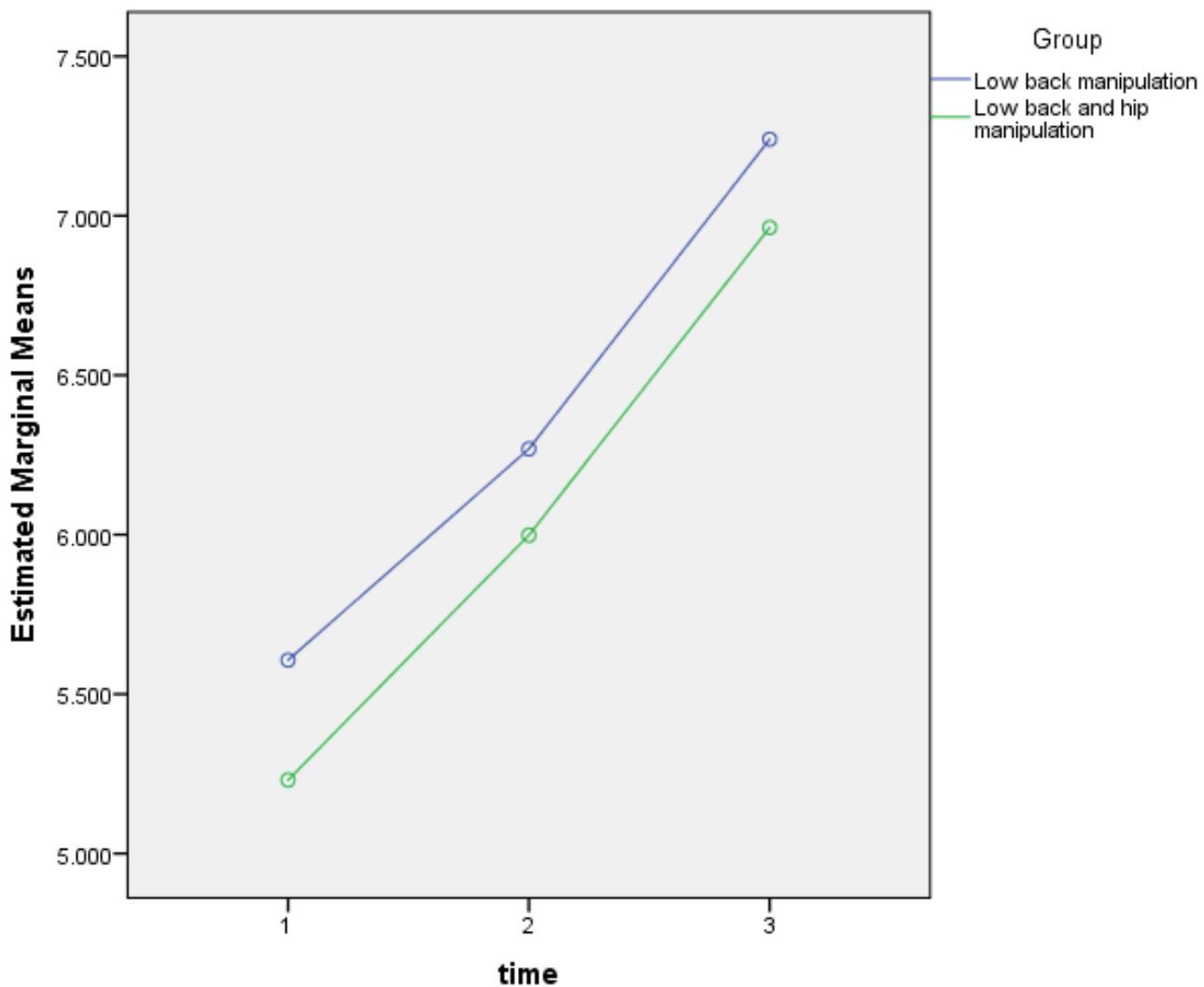


Table 4.25: TP2 INTER-GROUP ANALYSIS

Effect		Value	<i>p</i>
Time	Wilks' Lambda	0.581	<0.001
Time*Group	Wilks' Lambda	0.999	0.978
Group	F	0.244	0.623

The information in Table 4.25 showed that for TP2, there was no evidence of a differential treatment effect in the two groups ($p=0.978$). The information supplied in Figure 4.16 shows almost parallel profiles over time.

FIGURE 4.16: MEAN TP2 VALUES BY TIME IN GROUP A AND B



4.5.2.2 Subjective Outcomes

4.5.2.2.1 NPRSc and NPRSav

Table 4.26: NPRSc INTER-GROUP ANALYSIS

Effect		Value	p
Time	Wilks' Lambda	0.397	<0.001
Time*G	Wilks' Lambda	0.999	0.966
Group	F	1.52	0.224

The information in Table 4.26 showed that for NPRSc, there was no evidence of a differential treatment effect in the two groups ($p=0.966$). The information supplied in Figure 4.17 points to almost parallel profiles over time.

FIGURE 4.17: MEAN NPRSC VALUES BY TIME IN GROUP A AND B

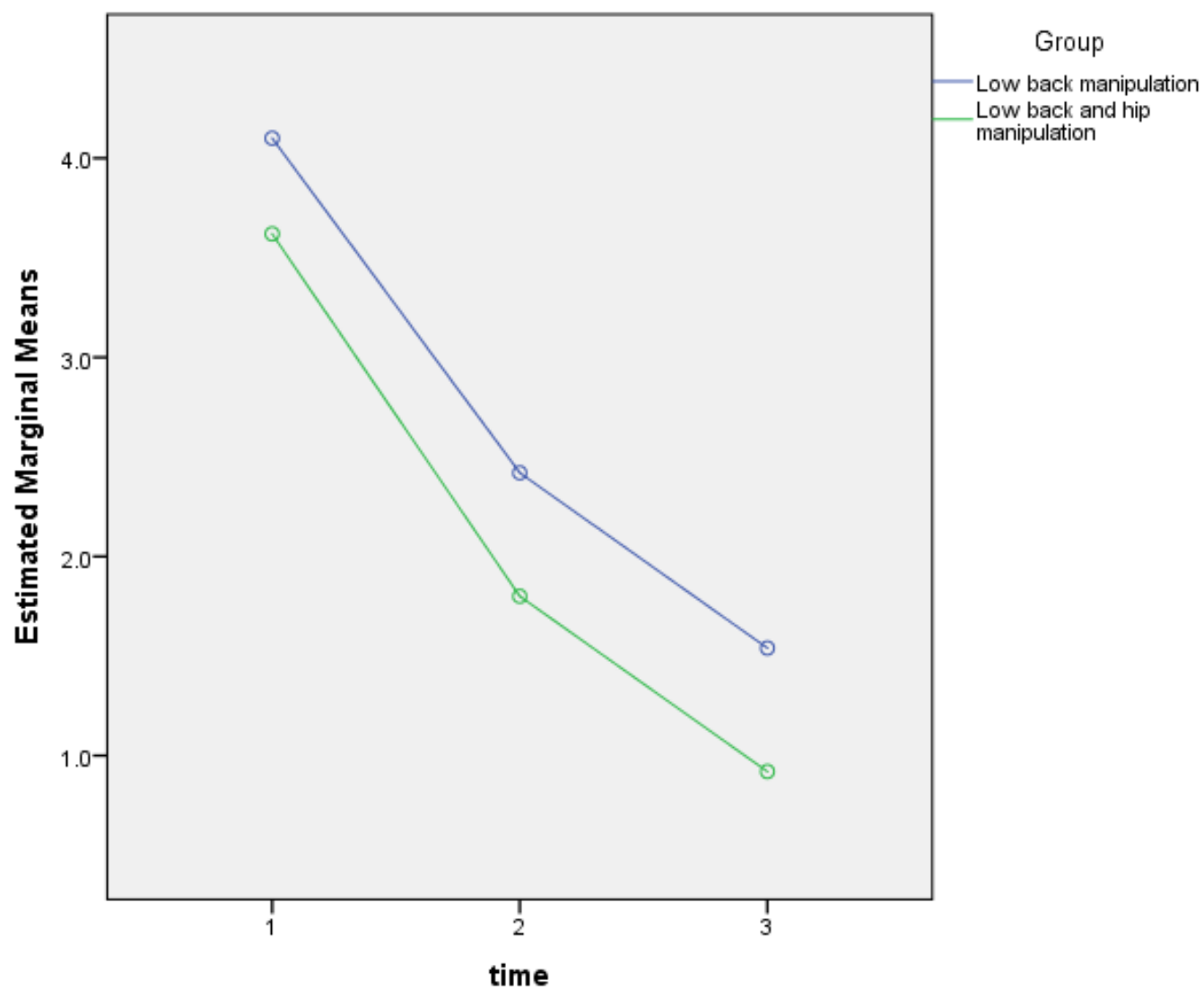
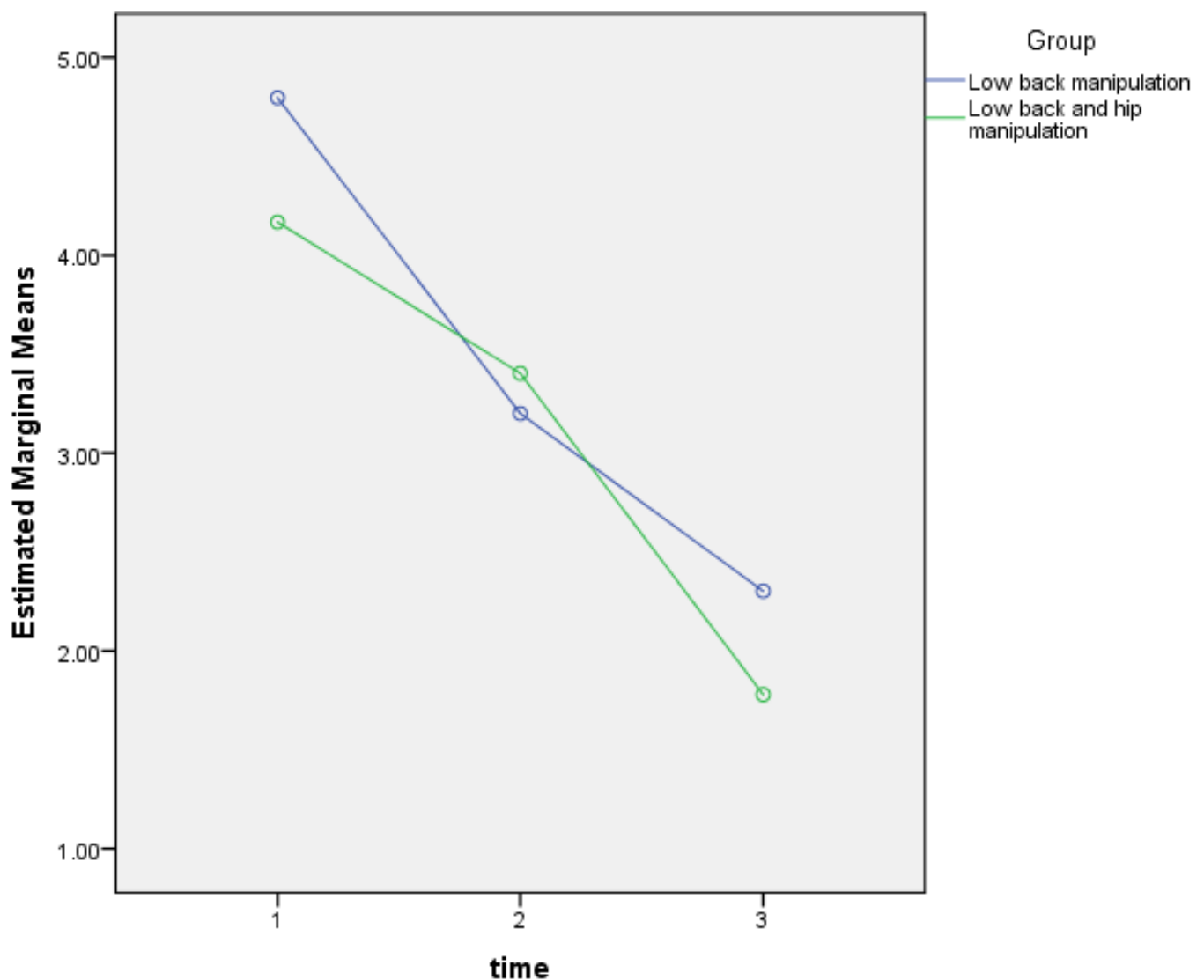


Table 4.27: NPRSav INTER-GROUP ANALYSIS

Effect		Value	<i>p</i>
Time	Wilks' Lambda	0.415	<0.001
Time*Group	Wilks' Lambda	0.985	0.702
Group	F	0.345	0.559

The information in Table 4.27 showed that for NPRSav, there was no evidence of a differential treatment effect in the two groups ($p=0.702$). The information supplied in Figure 4.18 indicates almost parallel profiles over time.

FIGURE 4.18: MEAN NPRSAV VALUES BY TIME IN GROUPS A AND B



4.5.2.2.2 Oswestry Low Back Pain Disability Index

Table 4.28: ODI INTER-GROUP ANALYSIS

Effect		Value	<i>p</i>
Time	Wilks' Lambda	0.352	<0.001
Time*Group	Wilks' Lambda	0.946	0.418
Group	F	1.31	0.258

The information in Table 4.28 showed that for the Oswestry Low Back Pain Disability Index scores (ODI), there was no evidence of a differential treatment effect in the two groups ($p=0.418$). The information supplied in Figure 4.19 highlights almost parallel profiles over time.

FIGURE 4.19: MEAN ODI VALUES BY TIME IN GROUP A AND B

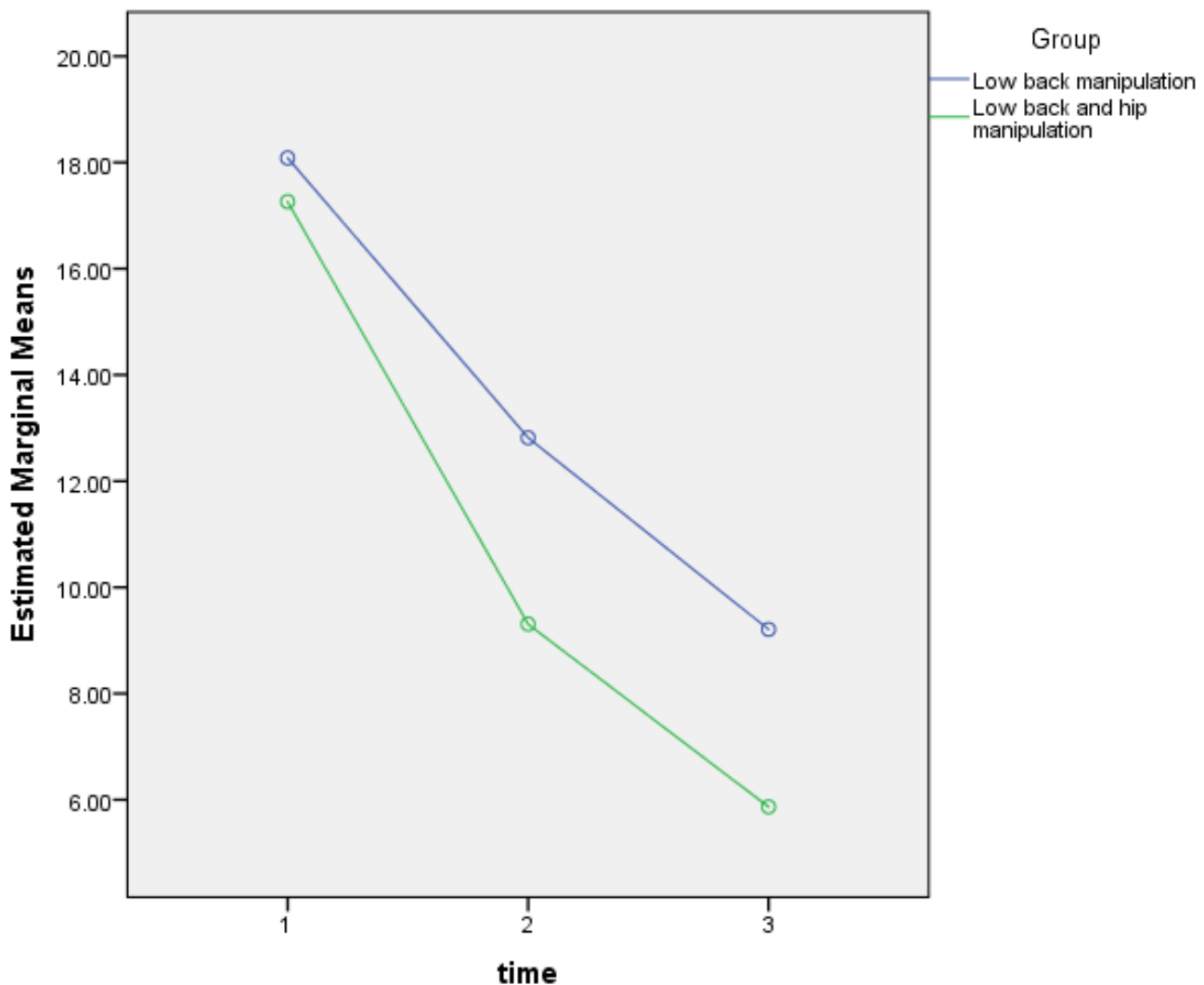


Table 4.29: MEANS FOR VARIABLES BY TREATMENT GROUP OVER TIME

	Group			
	A		B	
	Mean	Standard Deviation	Mean	Standard Deviation
Flx Hip	97.85	10.99	99.48	16.15
Flx Hip	99.893	12.020	105.037	10.743
Flx Hip	104.639	9.502	102.812	24.034
Int Hip	25.973	5.445	27.080	5.285
Int Hip	28.894	5.408	30.660	5.211
Int Hip	29.425	4.628	32.066	6.000
Ext Hip	25.986	5.369	27.585	6.028
Ext Hip	27.84	4.57	29.85	4.86
Ext Hip	30.045	4.532	31.335	5.087
Flx L/S	48.999	15.939	57.386	16.069
Flx L/S	55.01	18.50	62.17	13.06
Flx L/S	62.35	15.67	64.64	13.68
Lrot	35.093	11.024	39.253	18.973
Lrot	39.60	14.50	43.35	19.23
Lrot	39.340	10.268	43.679	17.708
Rrot L/S	35.373	21.177	34.693	15.138
Rrot L/S	32.960	14.673	41.214	18.073
Rrot L/S	35.852	12.416	44.907	18.068
TP1	5.224	2.472	4.909	1.952
TP1	6.088	2.701	9.846	20.970
TP1	7.061	2.757	6.833	2.730
TP2	5.607	2.401	5.231	1.776
TP2	6.269	2.761	5.998	1.925
TP2	7.240	2.900	6.963	2.649
NPRSc	4.1	2.2	3.6	1.9
NPRSc	2.4	2.1	1.8	2.1
NPRSc	1.5	1.8	0.9	1.7
NPRSav	4.80	1.75	4.17	1.65
NPRSav	3.20	2.14	3.40	4.72
NPRSav	2.30	1.94	1.78	1.97
ODI	18.08	10.33	17.26	9.94
ODI	12.818	8.791	9.306	8.816
ODI	9.209	8.426	5.866	6.152

4.6 SUMMARY AND REVIEW OF OBJECTIVES

Comparison between pre-manipulation scores between the two treatment groups did not indicate significant differences. The groups were not different in terms of age, ethnicity, and gender. Further, comparison between treatment groups in terms of subjective and objective baseline outcomes were not significantly different (Table 4.5 and 4.6).

Intra-Group testing showed that there was a significant difference over time with regards to internal rotation of the hip, external rotation of the hip, flexion of the lumbar spine, algometer average at TP1, algometer average at TP2, NPRSc values, NPRSav values and ODI scores within both groups.

NPRSc and NPRSav values significantly decreased over time within both treatment groups.

Within Group A, the mean scores for hip flexion reflected an increase over time.

Within Group B, the mean scores for left and right rotation of the lumbar spine reflect a significant change over time.

Inter-Group testing over time showed no significantly differential treatment effect for any of the outcomes. This means that both manipulations were equally effective.

CHAPTER FIVE

DISCUSSION

5.1 INTRODUCTION

This chapter discusses the demographic, subjective and objective statistics presented in Chapter Four. It will also compare the outcomes to previous similar studies and literature. This research was carried out over an eight month period. 61 participants with low back pain and hip joint restrictions were recruited from the Durban area and surrounds. Of the 61 participants, 11 dropped out due to work related and personal reasons. The participants consisted of males and females, ranging from ages 18 to 45 years and were from various ethnic groups. The participants reported LBP that had been present for more than six weeks. Pain levels were between 1.5 and 4.8 out of 10 on presentation, with moderate levels of disability according to the Oswestry Low Back Pain Disability Index. The participants were divided randomly and equally into two groups (A and B) of 25 each with differing treatment protocols. Throughout the research process there were 11 'drop-outs' who, for various reasons, could not attend all 5 consultations within the limited two week time period.

5.2 Demographic Data

5.2.1 Age

Table 4.1 indicates that the mean age of the participants in the study was 28.4 years. The standard deviation (sd) of the sample was 7.6 years. This is the extent of the deviation of ages of the sample as a whole and reflects that the age distribution was relatively even. There was no significant difference in the mean age between Groups A and B. This age range was chosen as Kirkaldy-Willis and Bernard (1999) stated that there is a higher likelihood of degenerative changes in individuals over 45 years of age.

Louw *et al.*, (2007) indicated that low back pain is most common between the ages 35 to 55 years. A more recent global prevalence study of low back pain that included 165 general population studies from 54 different countries, published between 1980 and 2009 was conducted by Hoy *et al.*, (2012) and suggested it is most common between 40 to 80 years of age. Kirkaldy-Willis and Bernard (1999) described three phases of degeneration in the spine and stated that symptomatic low back pain initially presents during the second decade (between 20 to 30 years of age), in the dysfunctional phase. This phase occurs when the initial biomechanical abnormality presents and progresses through the instability phase to the stabilizing phase, when the body tries to stabilize the abnormal biomechanics, resulting in muscle spasms and abnormal bony growth patterns (Kirkaldy-Willis and

Bernard, 1999). The condition increases in recurrence, chronicity and severity as the patient ages and progresses from stage one to three (Kirkaldy-Willis and Bernard, 1999) and then decreases respectively after 65 years of age (Andersson, 1999).

The mean age of the sample recruited in this study reflects participants that are between the dysfunctional and instability phases of chronic low back pain (Kirkaldy-Willis and Bernard, 1999). Participants at this age have more time and energy to manage their condition and, with it being a more recent development than in the case of older potential participants, they may be more motivated to try and treat it (Jegan *et al.*, 2017). Older potential participants may have accepted the chronicity of the condition and learnt to deal with it

The Durban Metro Census (1999) stated that the majority of the Durban population (61.5%) was of working age (25-45 years) and a more recent census (2011) placed 70 percent of the population in the '15 to 60 years of age' category. This may have prohibited possible participants of the working age category from joining the study as the consultations were only available during working hours from Monday to Friday. This was reflected by the high occurrence of 'dropouts', all related to their inability to attend the five consultations within two weeks due to unforeseen work commitments.

Another possible factor for the participants' overall low mean age may relate to the study being conducted at a university. Most students are between the ages of 18 to 25 years (Blauth *et al.*, 2011) and, as they regularly have to attend daily classes, they have better access to the research premises in terms of exposure and convenience. Therefore, they would be more likely to respond to the recruitment process and be able to continue with the consultations.

Regardless of the limitations mentioned above, both groups were equally limited with respect to the mean population age and reflected a statistically insignificant p -value of 0.308 (Table 4.3). Thus, the groups were homogenous and the age affect was negligible (Mouton, 1996).

5.2.2 Gender

As indicated in Table 4.1, overall, 48% of the participants (N=50) were male and 52% were female. This represents an evenly distributed sample with a statistically insignificant p -value between groups of 0.571 (Table 4.4).

Andersson (1999) indicated that the prevalence of low back pain is equal amongst males and females which is in accordance with the gender distribution in this study. However, other studies are contradictory, some suggesting that low back pain prevalence is higher among women than men (Fillingim, 2009; Bailey, 2009; Leveille *et al.*, 2001) and others have suggested that the condition is

marginally more prevalent in males (Forbes, 2009; Roncarti and McMullen, 1998; and Burton *et al.*, 1995).

5.2.3 Ethnicity

In terms of ethnic distribution, Table 4.1 reflects that most of the total sample population (N=50) were white (60%), followed by black (20%), Indian (16%) and coloured (4%). Between the two groups, the ethnic distribution was relatively even with a statistically insignificant *p*-value of 0.387.

Docrat (1999) stated that low back pain had a higher prevalence in the Indian population (78.2%) than the black population (57.7%) which is dissimilar to this study population, however according to the Durban Metro census (2011), the Durban population has a black majority (51.12%), then Indian (24.03%), then white (15.33%), then coloured (8.59%) and other ethnicity (0.93%). Therefore, due to the black population being greater than the Indian and the coloured population, the higher occurrence of black participants in this study is normal.

Unfortunately, there are no studies to date that represent the epidemiology of low back pain in South Africa amongst the white population.

A study conducted by Yelverton (2012) suggested that the awareness of chiropractic was low amongst the black culture and showed that as few as 17.1% (N=250) of the black population in Eastrand, Johannesburg, South Africa, knew what chiropractic is. This lack of awareness could explain the low number of black participants in the study (Yelverton, 2012), despite the higher prevalence of CNSLBP amongst the black ethnicity. It is possible that the chiropractic profession is relatively new within the respective population groups in terms of awareness, access and culture.

5.3 Comparison of Baseline Outcomes

Although baseline outcomes for right and left lumbar rotation, current NPRS and ODI scores (Table 4.2) were abnormally distributed among the total sample (N=50), objective and subjective baseline outcomes between the treatment groups A and B were not significantly different (Table 4.5 and 4.6). This shows that the randomization and inclusion/exclusion protocols were effective, resulting in homogeneity (Mouton, 1996). There was also no statistically significant difference in terms of sacroiliac sidedness between Groups A and B (*p*-value= 0.588).

5.4 Discussion of Treatment Effect

5.4.1 Intra-Group Analysis

5.4.1.1 Objective Outcomes

5.4.1.1.1 Inclinator ROM in the Hip Joint and Low back

Both groups increased significantly in terms hip internal and external rotation over time (Table 4.8 and 4.9). Group A showed a p -value of 0.019 in both internal and external rotation and Group B showed a p -value of 0.002 for internal rotation and 0.015 for external rotation.

The overall ROM of the hip joint and lumbar spine in flexion also increased significantly from treatments one to five in both groups. Table 4.7 reflects a highly significant change ($p < 0.001$) in flexion of the hip joint in Group A.

This supports the kinematic link between the low back and the hip joint, suggesting that low back manipulation alone does affect the ROM in the hip joint, and that hip manipulation has a beneficial effect on lumbar rotation. This phenomenon could be explained by the arthrogenic muscle inhibitory reflex described in Chapter 2.

Arthrogenic muscle inhibition refers to the presynaptic, protective, reflex inhibition of muscles surrounding a damaged, painful, distended or dysfunctional joint (Rice and McNair, 2010 and Hopkins and Ingersoll, 2000). This inhibition results in the failure of muscle groups within a common motor-neuron pool to recruit all motor units and therefore, abnormal muscle function (Ingersoll, Palmieri and Hopkins, 2003 Rice and McNair, 2010 and Suter *et al.*, 2000).

The hip joint and its' surrounding musculature share a common motor neuron pool with the low back (Sakamoto *et al.*, 2001). Suter *et al.*, (2000) describes that, through the excitation of joint receptors, low back/SIJ manipulation may alter afferent input to the motor neuron pool which supply the muscles of the hip. This process decreases arthrogenic inhibition and restores normal function to the joint (Suter *et al.*, 2000).

It should be noted that Group A showed a non-significant change in the lumbar ROM in terms of left and right rotation over time, with a p -value of 0.054 and 0.579, respectively, and Group B showed a significant change in left and right rotation of the lumbar spine with p -values of 0.050 and 0.001, respectively. This suggests that hip joint manipulation has a significant effect on lumbar spine ROM and further supports the kinematic link between the two and the role of the arthrogenic inhibitory reflex.

5.4.1.1.2 Force Dial Algometer

Both groups showed a statistically significant increase ($p < 0.05$) in pain tolerance at TP1 and TP2 over time (Table 4.13 and 4.14), reflecting that manipulation, as a treatment option for CNSLBP, has a positive effect on associated tenderness in surrounding musculature of the joint being manipulated (Bergman and Peterson, 2011).

The central theory for this positive effect implies the presence of a lesion (Gatterman, 1995) that affects the biomechanical function of a joint resulting in proximal and distal dysfunction and symptoms (Triano, 2000). This lesion is then reduced through manipulation which, in relation to this study, involves the restoration of balance to the joints and muscles composing the kinematic chain (Haldeman, 2005). This has a positive effect on the arthrogenic inhibitory reflex and breaks the pain cycle by stretching the surrounding muscle tissue and causing reflex relaxation (Van Tulder, Furnan and Gagnier, 2005).

5.4.1.2 Subjective Outcomes

Table 4.15 shows that both groups reflected a highly significant decrease, or improvement ($p < 0.001$), in terms of Oswestry Low Back Pain Disability Index (ODI) scores over time. This improvement relates to the participant's functional ability to perform normal everyday activities associated with LBP and motivates manipulation of the low back and/or hip joint when managing CNSLBP.

In terms of the Numerical Pain Rating Scale (NPRS), two values were taken. The first value reflected the participant's current perception of pain at the time of the consultation. This was recorded as NPRSc. The second value was taken as an average of various pain perceptions over the previous week. This was recorded as NPRSav. Table 4.16 reflects a highly significant change ($p < 0.001$) in both groups in terms of average and current NPRS scores over time. This shows that both groups perceived an improvement in terms of their pain.

The subjective results from the ODI and NPRS outcomes are similar to other studies which concur that low back manipulation is effective in the management of CNSLBP (Elleuch, 2009; Vernon, 2000; Bronfort, 2007; Descarreaux, 2004; DiFabio, 1992; Haldeman, 2005; Gatterman, 1990; Van Tulder, Furnan and Gagnier, 2005).

5.4.2 Inter-Group Analysis

5.4.2.1 Objective Outcomes

5.4.2.1.1 Inclinator

The results indicated that a combination of low back and hip manipulation does not result in a statistically significant differential treatment effect to low back manipulation alone in terms of increased hip and lumbar ROM.

5.4.2.1.2 Force Dial Algometry

A combination of low back and hip manipulation does not present a statistically significant differential treatment effect to low back manipulation alone in terms of pain tolerance in the Force Dial Algometry tests.

5.4.2.2 Subjective Outcomes

5.4.2.2.1 Oswestry Low Back Pain Disability Index

Table 4.28 reflected no evidence of a differential treatment effect between Groups A and B with a p -value of 0.418. Figure 4.33 showed that the profiles of both treatment groups appear to be relatively parallel over time, indicating that the outcome was not influenced by which treatment group the participant was in.

5.4.1.3.2 Numerical Pain Rating Scale

Table 4.26 (NPRSc) and Table 4.27(NPRSav) reflected no evidence of a differential treatment effect between Groups A and B with p -values of 0.966 and 0.702 respectively. Figures 4.31 and 4.32 showed that the profiles of both treatment groups appeared to be relatively parallel over time for both Nprsc and Nprsav respectively. This indicates that the treatment group does not influence this outcome.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

Comparison of baseline outcomes between the two treatment groups did not indicate significant differences and the groups were not different in terms of age, ethnicity and gender.

Both treatment groups showed statistically significant improvements in terms of the subjective and objective outcomes with regards to physical and perceived pain reduction and increased functionality.

Intra-Group testing showed that there was a significant difference over time with regards to hip internal rotation, hip external rotation, lumbar flexion, TP1/TP2 values and ODI values within both groups. Within Group A, the mean scores for hip flexion reflected a significant increase over time, and within Group B, the mean scores for lumbar left rotation and lumbar right rotation reflect a significant change over time.

This supports the proposed kinematic link between the low back and the hip as low back manipulation alone had a significant effect on hip flexion ROM and the group that included hip manipulation had a more significant effect on lumbar rotation ROM.

Inter-Group testing over time showed no significantly differential treatment effect for any of the outcomes, suggesting that both treatment protocols were equally effective. The research hypothesis suggested that a combination of hip manipulation and low back manipulation would be more beneficial than low back manipulation alone in the treatment of CNSLBP. This hypothesis, however, was not confirmed by the results of this research which suggested that neither treatment group benefited more than the other.

It is possible that the technique used in this study to manipulate the low back has a direct, positive mechanical effect on hip joint restriction. This would explain why Group B did not show better results with the combined/added hip joint manipulation. The arthrogenic muscle inhibitory reflex also affects the hip joint when manipulating the low back which could further explain why Group A and B showed similar improvements objectively and subjectively.

The study confirmed that manipulation is effective in the treatment of CNSLBP, supporting the current body of knowledge surrounding this field (Schaefer and Faye, 1990; Haldeman, 2005; Kirkaldy-Willis and Bernard, 1999; Elleuch, 2009; Vernon, 2000; Bronfort, 2007; Descarreaux, 2004; DiFabio, 1992; Van Tulder, Furnan and Gagnier, 2005). Due to the fact that both treatment groups received the low back manipulation intervention, it was predictable that both groups would respond similarly and favourably.

Unfortunately, there have been no previous studies related to the manipulation of the hip joint in the treatment of CNSLBP to compare with this study. Unpublished studies by Forbes (2009) and Russell (1996) also looked at treating LBP by focussing on joints distal to the low back and both studies concluded that each treatment group was as effective as the other, and that manipulation of the low back was effective in the management of low back pain.

6.2 RECOMMENDATIONS

In terms of the demographics of the study, the overall mean age of the participants in the sample did not reflect the prevalence of CNSLBP as presented by Louw (2007) who stated that the condition was most common between the ages 35-55 years. The study was conducted during normal working hours (Monday to Friday, 8am to 5pm) and therefore may have resulted in a younger sample group, as reflected by the high “drop-out” rate due to work-related commitments.

In order to prevent this age-influencing factor, the study should cater for the working-age population by allowing participants to schedule appointments outside of normal working hours.

Another recommendation that could prevent work-related ‘drop-outs’ would be to allocate a longer time period in which to complete the five consultations. It is recommended that a three week time period would suffice.

In future, and for similar studies, it would be beneficial to have a long term follow up appointment as the condition is chronic and often recurring. A follow-up consultation could provide data to better address the efficacy and long term effect of the treatment protocols. A larger sample size would further limit type-two errors.

It is also recommended that future studies add a third group to the study. This group would receive the hip adjustment alone and would provide data that directly relates the treatment of the hip joint to CNSLBP.

REFERENCES

- Airaksinen, O., Brox, J. and Cedraschi, C. 2006. European guidelines for management of chronic non-specific low back pain. *European Spine Journal*, 15 (2): 192-300.
- Andersson, G.B.J. 1992. Biomechanics of the Lumbar Spine. In Kirkaldy-Willis W.H. and Burton, C.V. *Managing Low Back Pain*. 3rd ed. New York: Churchill Livingstone.
- Andersson, G.B.J. 1999. Epidemiological features of chronic low back pain. *The Lancet*, 354: 581-585.
- Arokoski, M. H., Arokoski, J. P. A., Haara, M., Kankaanpää, M., Vesterinen, M., Niemitukia, L. H., Helminen, H. J. 2002. Hip muscle strength and muscle cross sectional area in men with and without hip osteoarthritis. *The Journal of Rheumatology*, 29 (9): 2185 –2195.
- Bailey, A. 2009. Risk factors for low back pain in women: still more questions to be answered. *Menopause*, 16(1): 3-4
- Balagué, F., Mannion, A., Pellise, F. and Cedraschi, C. 2012. Non-specific Low Back Pain. *Lancet*, 379: 482-491.
- Balagué, F., Troussier, B., Salminen, J.J. 1999. Non-specific low back pain in children and adolescents: risk factors. *European Spine Journal*, 8(6): 429-438.
- Béatrice, D. 2013. Priority Medicines for Europe and the World: A public health approach to innovation. Low Back Pain.
- Bensen, E., Young, A. E. and Shaw, W. S. 2015. Returning to work following low back pain: towards the model of individual psychosocial factors. *Journal of Occupational Rehabilitation*, 25(1): 25-37.
- Bergmann, T. and Peterson, D. 2011. *Chiropractic Technique*. 3rd ed. Philadelphia, US: Churchill Livingstone.
- Bernard, C., Laurene, C., Bouee, S., Adjemian, A., Chritien, J. and Niedhammer, I. 2011. Biomechanical and physiological work exposures and musculoskeletal symptoms among vineyard workers. *Journal of Occupational Health*. [In Press].

- Blauth, C., McDaniel, J., Perrin, C. and Perrin, P. B. 2011. *Age-Based Stereotypes: Silent Killer of Collaboration and Productivity*. Tampa: Achieve Global.
- Bloom, D. E. and Canning, D. 2000. Policy Forum: Public Health. The Health and Wealth of Nations. *Science*, 287(5456): 1207, 1209.
- Bogduk, N. 1997. *Clinical Anatomy of the Lumbar Spine and Sacrum*. 3rd ed. London, UK: Churchill Livingstone.
- Bolton, J. and Wilkinson, R. 1998. Responsiveness of pain scales: A comparison of the pain intensity measures in chiropractic patients. *Journal of Manipulative and Physiological Therapeutics*, 21 (1): 1-7.
- Borenstein, D.G., Wiesel, S.W. and Boden, S.D. 1995. Low Back Pain: medical diagnosis and comprehensive management. 2nd ed. Philadelphia, US: W.B. Saunders Company.
- Bork, B.E., Cook, T.M., Rosecrance, J.C., Engelhardt, K.A., Thomason, M.J., Wauford, I.J. and Worley, R.K. 1999. Work-Related Musculoskeletal Disorders amongst Physical Therapists. *Physical Therapy*, 76 (8): 827-835.
- Bouisset, S. 1991. Relationship between postural support and intentional movement: biomechanical approach. *Archives Internationales de Physiologie, de Biochimie et de Biophysique*, 99: A77–A92.
- Boyd, B. 2012. Measurement properties of a hand-held inclinometer during straight leg raise neurodynamic testing. *Physiotherapy*, 98: 174-179.
- Brantingham, J., De Luca, K., Globe, G. and Cassa, T. 2010. A single-group pre-test post-test design using full kinetic chain manipulative therapy with rehabilitation in the treatment of 18 patients with hip osteoarthritis. *Journal of Manipulative and Physiological Therapeutics*, 33 (6): 445-479.
- Brantingham, J., Bonnefin, D., Perle, S., Cassa, T., Globe, G., Pribicevic, M., Hicks, M. and Korporaal, C. 2012. Manipulative therapy for lower extremity conditions: update of a literature review. *Journal of Manipulative and Physiological Therapeutics*, 35 (2): 127-129.
- Bressler, H.B., Keyes, W.J., Rochon, P.A., Badley, E. 1999. The prevalence of low back pain in the elderly: A systematic review of the literature. *Spine*, 24(17): 1813-1819.

- Broadhurst, N.A. and Bond, M.J. 1998. Pain provocation tests for the assessment of sacroiliac joint dysfunction. *Journal of spinal Disorders*, 11 (4): 341-345.
- Bronfort G1, Haas M, Evans R, Kawchuk G, Dagenais S. 2007. Evidence-informed management of chronic low back pain with spinal manipulation and mobilization. *Spine Journal*, 8(1): 213-225.
- Brummitt, J., Matheson, J.W., Meira, E.P. 2013. Core stabilization exercise prescription: Part 1-current concepts in assessment and intervention. *Sports Health*, 5(6): 504-509.
- Burton, A.K., Tillotson, K.M., Main, C.J. and Hollis, S. 1995. Psychosocial predictors of outcome in acute and sub chronic low back trouble. *Spine*, 20(6): 722-728.
- Butler, D.S. and Moseley, G.L. 2003. *Explain pain*. NOI Group Publications, Adelaide, Australia.
- Byfield, D. 2005. *Chiropractic Manipulative Skills*. 2nd ed Philadelphia: Churchill Livingstone.
- Campbell, J. 2007. *The Relative Effect of Manipulation and Core rehabilitation on the treatment of Acute Mechanical Lower Back Pain in Athletes*. Master's Degree in Technology: Chiropractic. Durban University of Technology. Durban, South Africa.
- Cassidy, J. and Mierau, D. 1992. *Pathophysiology of the sacroiliac joint: Principles and Practice of Chiropractic*. East Norwalk: Appleton and Lange.
- Chaitow, L. and Leibenson, C. 2001. *Muscle Energy Techniques*. Edinburgh: Churchill Livingstone.
- Chistensen, M., Kollasch, M. and Ward, R. 2005. Job analysis of chiropractic 2005: a project report, survey analysis and summary of practice of chiropractic within the United States. Paper presented at. Greeley (Colo), 121-138.
- Cibulka, D.J. 1999. *The Relative Effectiveness and Cost Effectiveness of Piroxicam Compared to Manipulation in the Treatment of Acute Grades 1 and 2 Inversion Ankle sprains*. Master's Degree in Technology: Chiropractic. Durban University of Technology. Durban, South Africa.
- Cibulka, M. and Dellito, A. 1993. A comparison of two different methods to treat hip pain in runners. *Journal of Orthopaedic and Sports Physical Therapy*, 17: 172-176.

- Cibulka, M. T., Dellito, A., Koldehoff, R.M. 1988. Changes in innominate tilt after manipulation of the sacroiliac joint in patients with low back pain, an experimental study. *Physical Therapy*, 68: 1359-1363.
- Cibulka, M., Sinacore, D., Cromer, G. and Dellito, A. 1998. Unilateral hip rotation ROM asymmetry in patients with sacroiliac joint regional pain. *Spine*, 23: 1009–1015.
- Cohen, S. and Raja, S. 2007. Pathology, diagnosis and treatment of lumbar zygapophyseal joint pain. *Anesthesiology*, 106(3): 591-614.
- Cooperstein, R. 1991. The Derifield pelvic leg check: A kinesiological interpretation. *Chiro Tech*, 3: 60.
- Cooperstein, R. and Lew, M. 2009. The relationship between pelvic torsion and anatomical leg length inequality: A review of the literature. *S Chiro Med*, 8(3): 107-118.
- Cramer, G.D. and Darby, S.A. 1996. Clinical Pathoanatomy Related to Low Back Pain. *Topics in Clinical Chiropractic*, 3 (3): 1-8.
- Crombez, G., Vlaeyen, J.W., Heuts, P.H., Lysens, R. 1999. Pain-related fear is more disabling than pain itself: evidence on the role of pain related fear in chronic back pain disability. *Pain*, 80: 329–39.
- Crossman, A.R. and Neary, D. 1995. *Neuroanatomy: an illustrated colour text*. Philadelphia: Churchill Livingstone.
- Dananberg, J. and Guiliano, M. 1999. Chronic lower back pain and its response to custom made orthoses. *Journal of American podiatric Association*, 89 (3): 109-117.
- Dananberg, H.J. 1986. Functional Hallux Limitus and its Relationship to Gait Efficiency. *JAMPA*. 76: 648.
- Davidson, M. and Keating, J. 2002. A comparison of five low back disability questionnaires: reliability and responsiveness. *Physical Therapy*, 82 (1): 8-24.
- Davies, K., Silman, A., Macfarlane, G., Nicholl, B., Dickens, C., Morris, R., Roy, D. and Macbeth, J. 2009. The association between neighbourhood socio-economic status and the onset of chronic widespread pain: results from the EPIFUND study. *European Spine Journal*, 13(6): 635-640.

Delitto, A., George, S.Z., Van Dillen, L.R., Whitman, J.M., Sowa, G., Shekelle, P., Denninger, T.R. and Godges, J.J. 2012. Low back pain. *Journal of Orthopaedic Sports Physical Therapy*, 42(4):vA1-A57.

De Luca, K. M., Pollard, H., Brantingham J, Globe G, Cassa T. 2010. Chiropractic Management of the Kinetic Chain for the Treatment of Hip Osteoarthritis: An Australian Case Series. *Journal of Manipulative and Physiological Therapeutics*, 33 (6): 474-479.

De Schepper, E. I., Damen, J., van Meurs, J. B., Ginai, A. Z., Popham, M., Hofman, A., Koes, B. W. and Bierma-Zeinstra, S. M. 2010. The association between lumbar disc degeneration and low back pain: the influence of age, gender, and individual radiographic features. *Spine*, 35 (5): 531-536.

Descarreaux, M., Blouin, J.S., Drolet, M., Papadimitriou, S. and Teasdale, N. 2004. Efficacy of preventive spinal manipulation for chronic low-back pain and related disabilities: a preliminary study. *Journal of Manipulative Physiological Therapeutics*, 27(8): 509-514.

Deyo, R. A., Mirza, S. K. and Martin, B. I. 2006. Back pain prevalence and visit rates: estimates from U.S. national surveys, 2002. *Spine*, 31 (23): 2724-2727.

Diamond, S. and Borenstein, D. 2006 Chronic low back pain in the working age adult. *Best practice and research. Clinical Rheumatology*. 20 (40): 707-720.

Di Fabio, R. 1992. Efficacy of Manual Therapy. *Physical Therapy*, 72 (12): 853-864.

Docrat, A. 1999. *A Comparison of the Epidemiology of Low Back Pain in Indian and Coloured Communities in South Africa*. Master's Degree in Technology: Chiropractic. Durban University of Technology, Durban, South Africa.

Dorland, W. 2011. *Dorland's Illustrated Medical Dictionary*. 32nd ed. Philadelphia: WB Saunders Company.

Dreyfuss, P., Dreyer, S. J., Cole, A. and Mayo, K. 2004. Sacroiliac joint pain. *Journal of American Orthopaedic Surgery*, 12(4): 255-265.

Durban Metro. 1999. Population State [online]. Available at: <http://www.ceroi.net/reports/durban/drivers/Population/state.htm> [Accessed 14 April 2017].

Durban Metro: Population Census. 2011. [online]. Available at <https://census2011.adrianfrith.com/place/599054> [Accessed 14 April 2017]

Ebbehøj, N.E., Hansen, F.R., Harreby, M.S., Lassen, C.F. 2002. Low back pain in children and adolescents: Prevalence, risk factors and prevention. *Ugeskr Laeger*, 164(6): 755-758.

Elleuch, M.H. and Ghroubi, S. 2009. Vertebral manipulation in chronic low back pain: a prospective randomised study of 85 cases. *Journal International Musculoskeletal Medicine*, 31(2): 57-62.

Ellison, J., Rose, S. and Sahrmann, S. 1990. Patterns of rotation ROM: a comparison between healthy subjects and patients with low back pain. *Physical Therapy*, 70: 537–541.

Esterhuizen, T. M. 2015. E-mail communications. 21 April 2011 14:11PM.

Etnyre, B. R., Simmonds, M. J. and Radwan, H. 1999. Hip and knee displacements during sit-to-stand movements between low back pain patients and a control group. In: *Proceedings of 13th International Congress of World Confederation for Physical Therapy*. Yokohama, Japan.

Fairbank JC, Pynsent PB. 2000. The Oswestry Disability Index. *Spine*. 15; 25 (22): 2940-52; discussion 52.

Fillingim, R.B., King, C.D., Ribeiro-Dasilva, M.C., Rahim-Williams, B. and Riley, J.L. 2009. Gender and pain: a review of recent clinical and experimental findings. *Journal of Pain*, 10(5): 447-485.

Forbes, L. 2009. Lumbar spine manipulation, compared to combined lumbar spine and ankle manipulation for the treatment of chronic mechanical lower back pain. Master Degree in Technology: Chiropractic. Durban University of Technology.

Franke Jr, B.A. 2003. Formative Dynamics: The pelvic girdle. *The Journal of Manual and Manipulative Therapy*, 11 (1): 12-40.

Friberg, O. 1983. Clinical symptoms and biomechanics of lumbar spine and hip joint in leg length inequality. *Spine*, 8: 643-651.

Fujii, T., Matsudaira, K., Oka, H. 2013. Factors associated with fear-avoidance beliefs about low back pain. *Journal of Orthopaedic Science*, 18: 909–915.

Galukande, M., Muwazi, S. and Mugisa, B. 2005. Aetiology of low back pain in Mulago Hospital, Uganda. *African Health Sciences*, 5(2).

- Garland, E.L. 2012. The pain process in the human nervous system- a selective review of nociceptive and biobehavioural pathways. *Primary Care*, 39(3): 561-571.
- Gatterman, M.I. 1990. *Chiropractic Management of Spine Related Disorders*. Baltimore: Williams and Wilkins.
- Gatterman M. 1995. *Foundations of chiropractic subluxation*. St. Louis: Mosby.
- Gatterman, M. and Hansen, D. 1994. Development of chiropractic nomenclature through consensus. *Journal of Manipulative and Physiological Therapeutics*, 17 (5).
- Giles, L.G.F., Taylor, J.R. 1981. Low back pain associated with leg length inequality. *Spine*, 6: 510-621.
- Gill, K.P., Callaghan, M.J. 1998. The measurement of lumbar proprioception in individuals with and without low back pain, *Spine*. 23: 371–377.
- Globe, G., Morris, C., Whalen, W., Farabaugh, R. and Hawk, C. 2008. Chiropractic management of low back disorders: report from a consensus process. *Journal of Manipulative Therapy*, 31 (9): 651-658.
- Glover, W., McGregor, A., Sullivan, C. and Hague, J. 2005. Work-related musculoskeletal disorders affecting members of the Chartered Society of Physiotherapy. *Physiotherapy*. 91: 138-147.
- Good, C.J. 2016. Chiropractic Identity in the United States: Wisdom, Courage, and Strength. *Journal of Chiropractic Humanities*, 23 (1): 29–34.
- Haldeman, S. 2005. *Principles and practice of chiropractic*. 3rd ed. New York: McGraw-Hill Education.
- Ham, Y.W., Kim, D.M., Baek, J.Y., Lee, D.C., Sung, P.S. 2010. Kinematic analyses of trunk stability in one leg standing for individuals with recurrent low back pain. *Journal of Electromyographic Kinesiology*, 20: 1134–1140.
- Harrison, D. E., Harrison, D. D., Troyanovich, S. J. 1997. The Sacroiliac Joint: a Review of Anatomy and Biomechanics with Clinical Implications. *Journal of Manipulative and Physiological Therapeutics*, 20(9): 607 – 617.

- Haslett, C., Chilvers, E.R., Boon, N.A. and Colledge, N.R. 2002. *Davidson's Principles and Practice of Medicine*. 19th ed. London, UK: Churchill Livingstone.
- Hendler, N., Kozikowski, J. G., Morrison, C. and Sethuraman, G. 1995. Diagnosis and Management of Sacroiliac Joint Disease. *Journal of the Neuromusculoskeletal System*, 3 (4): 169 – 174.
- Hendrick, A. 2000. Training the Trunk for Improved Athletic Performance. *Strength and Conditioning Journal*, 22 (3): 50-61.
- Hendrick, P., Milosavljevic, S. and Hale, L. 2011. The relationship between physical activity and low back pain outcomes: systematic review of observational studies. *European Spine Journal*, 20 (3): 464-474.
- Herrero, P., Carrera, P., García, E., Gómez-Trullén, E.M. and Oliván-Blázquez, B. 2011. Reliability of goniometric measurements in children with cerebral palsy: A comparative analysis of universal goniometer and electronic inclinometer. A pilot study. *Biomedical Central Musculoskeletal Disorders*, 12: 155
- Hestbaek, L., Leboeuf-Yde, C., Manniche, C. 2003. Low back pain: what is the long-term course? A review of studies of general patient populations. *European Spine Journal*, 12(2): 149-165.
- Hodges, P.W. 2003. Neuromechanical control of the spine. *PhD thesis. Karolinska Institutet*, Stockholm, Sweden.
- Hodges, P.W. and Richardson, C.A. 1997. Contraction of the abdominal muscles associated with movement of the lower limb. *Physical Therapy*, 77:132.
- Hopkins, J.T. and Ingersoll, C.D. 2000. AML the limiting factor. *Journal of Sport Rehabilitation*, 9 (2): 135-159.
- Hodges, P.W. and Richardson, C.A. 1996. Inefficient muscular stabilization of the lumbar spine associated with low back pain. A motor control evaluation of the transversus abdominis. *Spine*, 21 (22): 2640.
- Hodges, P.W. and Moseley, G.L. 2003c. Pain and motor control of the lumbopelvic region; effect and possible mechanisms. *Journal of Electromyography and Kinesiology*. 13: 361.
- Holstege, G., Bandler, R. and Saper, C.B. 1996. *The emotional motor system*. Elsevier science, Amsterdam.

Hoy, D., Bain, C., Williams, G., March, L., Brooks, P., Blyth, F., Woolf, A., Vos, T. and Buchbinder, R. 2012. A systematic review of the global prevalence of low back pain. *Arthritis Rheumatology*, 64(6): 2028-2037.

Huson, A. 1997. Kinematic Models and the Human Pelvis. *Journal of Chiropractic Education*, 5 (4): 128-130.

Hussein, T., Simmonds, M. and Etnyre, B. 1999. Kinematics of gait in subjects with low back pain, with and without leg pain. Paper presented at the *Scientific Meeting and Exposition of the American Physical Therapy Association*. Washington, DC.

Ingersoll, C. D., Palmieri, R. M., and Hopkins, J. T. 2003. A joint dilemma. *Rehab management*, 16 (1), 38-42.

Inman, V. T., Ralston, H. J. and Todd, E. 1981. *Human Walking*. Baltimore: Williams and Wilkins.

Jenson, M., Karoly, P. and Braver, S. 1986. The measurement of clinical pain intensity: a comparison of six methods. *Pain*, 27 (1): 117-126.

Jegan, N.R.A., Brugger, M., Viniol, A., Strauch, K., Barth, J., Baum, E., Leonhardt, C. and Becker, A. 2017. Psychological risk and protective factors for disability in chronic low back pain – a longitudinal analysis in primary care. *Biomedical Central Musculoskeletal Disorders*, 18: 114.

Jo, H.J., Song, A.Y., Lee, K.J., Kim, Y.H., Sung, P.S. 2011. A kinematic analysis of relative stability of the lower extremities between subjects with and without chronic low back pain. *European Spine Journal*, 20: 1297.

Kapandji A.I. 2008. *The Physiology of the Joints: The Spinal Column, Pelvic Girdle and Head*. London, UK: Elsevier Health Sciences, Churchill Livingstone.

Katz, J.N. 2006. Lumbar disc disease and low back pain- socioeconomic factors and consequences. *Journal of Bone and Joint Surgery America*, 88(2): 21-24.

Kirkaldy-Willis, W. and Bernard, T. N. 1999. *Managing Lower Back Pain*. 4th ed. New York, US: Churchill Livingstone.

Kirkaldy-Willis, W. and Cassidy, J. 1985. Spinal Manipulation in the treatment of low back pain. *Canadian Family Physician*, 31: 535.

- Koes, B.W., Bouter, L.M. and van Mameren. H. 1992b. Randomised clinical trial of manipulative therapy and physiotherapy for persistent back and neck complaints: results of one year follow-up. *British Medical Journal*, 304: 601-605.
- Koes, B.W., Van Tulder, M., Lin, C.W., Macedo, L.G., McAuley, J., Maher, C. 2010. An updated overview of clinical guidelines for the management of non-specific low back pain in primary care. *European Spine Journal*, 19: 2075–94.
- Kopec, J., Esdaile, J., Abrahamowicz, M., Abenhaim, L., Wood-Dauphinee, S. and Lamping, D. 1995. The Quebec Back Pain Disability Scale. Measurement Properties. *Spine*, 20 (3): 341-352.
- Kovacs, F.M., Gestoso, M., Gil del real, M.T., Lopez, J., Mufraggi, N. and Mendez, J.I. 2003. Risk factors for non-specific low back pain in school children and their parents: a population based study. *Pain*, 103: 259-268.
- Kuslich, S.s Ulstran, C.C. and Michael, C.J. 1991. The tissue origin of low back pain and sciatica: A report of pain response to tissue stimulation during operations on the lumbar spine using local anaesthesia. *Orthopaedic Clinical North America*, 22: 181.
- Lamoth, C., Meijer, O., Wuisman, P., Van Dieën, J., Levin, M. and Beek, P. 2002. Pelvis-thorax coordination in the transverse plane during walking in persons with nonspecific low back pain. *Spine*, 27 (E): 92–99.
- Laslett, M. 2008. Evidence-based diagnosis and treatment of the painful sacroiliac joint. *Journal of Manipulative Therapy*, 16(3): 142-152.
- Lawrence, D. J., Meeker, W., Bronson, R., Bronfort, G., Cates, J. R., Hass, M., Harelne, M., Micozzi, M., Updyke, W., Mootz, R., Triano, J. J. and Hawk, C. 2008. Chiropractic management of low back pain and low back related leg complaints: A literature synthesis. *Journal of Manipulative and Pysiotherapeutic Therapy*, 31(9): 659-674.
- Lee, D.G. 2004. The Pelvic Girdle. 3rd ed. Edinburgh, Scotland: Churchill Livingstone.
- Leelavathy, K.R., Raju, R., Gokul Raj, S. 2011. Whole body vibration and back disorders among vehicle operators. *European Journal of Scientific Research*, (3): 328-380.

- Lephart, S.M., Pincivero, D.M., Giraldo, J.L., Fu, F.H. 1997. The role of proprioception in the management and rehabilitation of athletic injuries. *The American Journal of Sports Medicine*, 25 (1): 130-137.
- Leveille, S. G., Ling, S., Hochberg, M. C., Resnick, H. E., Bandeen-Roche, K. J., Won, A., & Guralnik, J. M. (2001). Widespread musculoskeletal pain and the progression of disability in older disabled women. *Annals of Internal Medicine*, 135(12), 1038-1046.
- Liebenson, C. 2007. Hip dysfunction and back pain. *Journal of Body Work and Movement Therapies*, 11: 111-115.
- Liebenson, C. 2007. *Rehabilitation of the Spine: A Practitioner's Manual*. 2nd ed. Baltimore: Lippincott/Williams and Wilkins.
- Linton, S.S., Hellsing, A.L. and Hellden, K. 1998. A population based-study of spinal pain among 35-45 year old individuals. Prevalence, sick leave and health care use. *Spine*, 23: 1457-1463.
- Livingston, T., Bernardi, D. and Carroll, M. 1998. *Algometer: User's Manual*. Salt Lake City: Jtech Medical Industries.
- Louw, Q., Morris, L. and Grimmer-Somers, K. 2007. The Prevalence of low back pain in Africa: a systematic review. *Biomedical Central Musculoskeletal disorders*, 8 (104): 1-14.
- Magee, D.J. 2006. *Orthopaedic Physical Assessment*. 4th ed. Philadelphia: W.B. Saunders Company.
- Maigne, J.Y., Aivalikis, A. and Pfefer, F. 1996. Results of sacroiliac joint double block and value of sacroiliac pain provocation tests in 54 patients with low back pain. *Spine*, 21: 1889-1892.
- Maitland, G., Hengeveld, E., Banks K., English, K. 2001. *Maitland's Vertebral Manipulation*. 6th ed. Canada: Elsevier.
- Manek, N.J. and MacGregor, A.J. 2005. Epidemiology of back disorders: prevalence, risk factors and prognosis. *Current Opinion in Rheumatology*, 17(2): 134-140.
- Maniadakis, N. and Gray, A. 2000. The economic burden of back pain in the UK. *Pain*, 84: 95-103.
- Manga, P., Angus, D. and Swan, W. 1993. Effective management of low back pain: It's time to accept the evidence. *Journal of the Canadian Chiropractic Association*, 37 (4): 221-229.

- Mannello, D.M. 1992. Leg length inequality. *Journal of Manipulative Physiological Therapy*, 15: 576.
- Matkovich, G. 2004. *The Immediate Effect of Sacroiliac Manipulation on Hip Strength in Patients Suffering from Chronic Sacroiliac Syndrome*. Master's Degree in Technology: Chiropractic. Durban Institute of Technology, Durban, South Africa.
- McGill, S., Grenier, S., Bluhm, M., Preuss, R., Brown, S. and Russell, C. 2003. Previous history of LBP with work loss is related to lingering deficits in biomechanical, physiological, personal, psychosocial and motor control characteristics. *Ergonomics*, 46: 731–746.
- McGregor, A. and Hukins, D. 2009. Lower limb involvement in spinal function and low back pain. *Journal of Back and Musculoskeletal Rehabilitation*, 22: 219-222.
- McIntosh, G. and Hall, H. 2011. Clinical Evidence: Low Back Pain (Acute). *British Medical Journal*, 10 (1102): 1-30.
- Mills, J.D., Traunton, J.E. and Mills, W.A. 2005. The Effect of a 10-week Training Regimen of Lumbo-pelvic Stability and Athletic Performance in Female Athletes: a Randomized-Controlled Trail. *Physical Therapy in Sport* [online]. 6 (2): 60-66. Available:
- Moore, K.L., Dalley, A.F. and Agur, A.R. 2013. *Clinically Orientated Anatomy*. 7th ed. Baltimore, US: Lippincott/Williams and Wilkins.
- Morris, C. 2007. Low Back Syndrome. *Clinical Chiropractic*, 10 (1016): 165-166.
- Morscher, E. 1977. Etiology and pathophysiology of leg length discrepancies. *Progress in Orthopaedic Surgery*. Vol. 1. Leg Length Discrepancy. The Injured Knee, pp. 9-19. Edited by D. S. Hungerford. New York, Springer, 1977.
- Moseley, G.L., Hodges, P.W. and Gandevia, S.C. 2002. Deep and superficial fibres of the lumbar multifidus muscle are differently active during voluntary arm movements. *Spine*, 27 (2): E29.
- Mouton, J.1996. *Understanding Social Research*. Pretoria: Van Schaik Publishers.
- Murray, C. J. and Lopez, A. D. 1997. Regional patterns of disability-free life expectancy and disability-adjusted life expectancy: global Burden of Disease Study. *Lancet*, 349 (9062): 1347-1352.

Nies, N., Sinnott, P.L. 1991. Variations in balance and body sway in middle-aged adults. Subjects with healthy backs compared with subjects with low-back dysfunction. *Spine*. 16: 325–330.

Ombregt, L., Bisschop, P., Ter Veer, H. J. 2013. *A System of Orthopaedic Medicine*. London: W.B. Saunders Company

Palmer, K.T., Walsh, K., Bendall, H., Cooper, C. and Coggon, D. 2000. Back pain in Britain: comparison of two prevalence surveys at an interval of 10 years. *British Medical Journal*, 320: 1577-1578.

Pengel, L.H.M., Herbert, R.D.H., Maher, C.G. and Refshauge, K. M. 2003. Acute low back pain: systematic review of its prognosis. *Biomedical Journal*, 327(7410): 323.

Picavet, H.S.J. and Schouten, J.S.A.G. 2002. Musculoskeletal pain in the Netherlands: provenances, consequences and risk groups, the DMC3-study. *Pain*, 102:167-178.

. *Pain*, 124(3): 305-11.

Pope, M.H., Anderson, G.B.J., Frymoyer, J.W. and Chaffin, D.B. 1991. *Occupational low back pain: Assessment, Treatment and Prevention*. Mosby Year Book.

Poul, J., West, J., Buchanan, N. and Grahame, R. 1993. Local action transcutaneous flurbiprofen in the treatment of soft tissue rheumatism. *British Journal of Rheumatology*, 32 (11): 1000-1003.

Quint, U., Wilke, H., Shirazi-Adl, A. 1998. Importance of the intersegmental trunk muscles for the stability of the lumbar spine. A biomechanical study in vitro. *Spine*, 23: 1937–1945.

Redwood, D. 1997. *Contemporary Chiropractic*. New York: Churchill Livingstone.

Reid, D. 1992. *Sports injury assessment and rehabilitation*. Philadelphia, US: Churchill Livingstone.

Reimann, F., Cox, J. J., Belfer, I., Diatchenko, L., Zaykin, D. V., McHale, D. P., Drenth, J. P., Dai, F., Wheeler, J., Sanders, F., Wood, L., Wu, T. X., Karppinen, J., Nikolajsen, L., Mannikko, M., Max, M. B., Kiselycznyk, C., Poddar, M., Te Morsche, R. H., Smith, S., Gibson, D., Kelempisioti, A., Maixner, W., Gribble, F. M. and Woods, C. G. 2010. Pain perception is altered by a nucleotide polymorphism in SCN9A. *Proc Natl Acad Sci US*, 107 (11): 5148-5153.

Rice, D.A. and McNair, P. 2010. Quadriceps orthopaedic muscle inhibition: neural mechanisms and treatment perspectives. *Seminar Arthritic Rheumatology*, 40(3): 250-266.

Richardson, C.A., Snijders, C.J., Hides, J.A., Damen, L., Pas, M.S. and Storm. J. 2002. The relationship between the transversely orientated abdominal muscles, sacroiliac joint mechanics and low back pain. *Spine*, 27 (4): 399.

Roberts, W., Gillette, R. and Kramis, R. 1989. Somatosensory input from lumbar paraspinal tissue: Anatomical terminators and neuronal responses to mechanical and sympathetic stimuli. *Social Neuroscience Abstract*, 15: 755.

Roncarti, A. and McMullen, W. 1988. Correlates of Low Back Pain in a General population Sample: a multidisciplinary perspective. *Journal of Manipulative and Physiological Therapeutics*, 11(3): 158-164.

Rowe, M.L. 1971. Low back disability in industry. Updated position. *Journal of Occupational Medicine*. 13: 476-478.

Russell, D.B. 1996. *Lumbar Spine Adjustments Alone, Versus Combined Lumbar, Thoracic and Cervical Spine Adjustments for the Treatment of Mechanical Low Back Pain*. Master's Degree in Technology: Chiropractic. Durban University of Technology, Durban, South Africa.

Sakamoto, N., Yamasitha, T., Takebayashi, T., Sekine, M. and Ishii, S. 2001. An electrophysiological study of mechanoreceptors in the sacroiliac joint and adjacent tissues. *Spine*, 26 (20): E468-E471.

Saur, P., Ensink, F., Frese, K., Seeger, D. and Hildebrandt, J. 1996. Lumbar ROM: reliability and validity of inclinometer technique in the clinical measurement of trunk flexibility. *Spine*, 21 (11): 1332-1338.

Schaefer, R.C. and Faye, L.J. 1990. *Motion Palpation and Chiropractic technique: Principles of dynamic Chiropractic*. 2nd ed. California, US: The motion palpation institute.

Schwarzer, A.C., Aprill, C.N. and Bogduk, N. 1995. The sacroiliac joint in chronic low back pain. *Spine*, 20: 31-37.

Shiri, R., Karppinen, J., Leino-Arjas, P., Solovieva, S. and Viikari-Juntura, E. 2010. The association between obesity and low back pain: a meta-analysis. *American Journal of Epidemiology*, 171 (2): 135-154.

- Simons, D.G., Travell, J.G. and Simons, L. S. 1999. *Myofascial Pain and Dysfunction: The Trigger Point Manual*. 2nd ed. U.S.A: Lippencott, Williams and Wilkins.
- Smart, K.M., Blake, C., Staines, A., Thacker, M and Doody, C. 2012. Mechanical-based classification of musculoskeletal pain: part 1 of 3- symptoms of central sensitisation in patients with low back pain and sciatica. *Manual therapy*, 17(4): 336-344.
- Snell, R.S. 2012. *Clinical Anatomy by Region*. 9th ed. Philadelphia: Lippincott Williams and Wilkins.
- Snijders, C., Hermans, P., Niesky, R., Spoor, C. and Stoeckart, R. 2004. The influence of slouching and lumbar support on the iliolumbar ligaments, intervertebral discs and sacroiliac joints. *Clinical Biomechanics*, 19: 323-329.
- Snijders, C.J., Vleeming, A. and Stoeckart, R. 1993. Transfer of lumbosacral load to iliac bones and legs. 1: Biomechanics of self-bracing of the sacroiliac joints and its significance for treatment and exercise. *Clinical Biomechanics*, 8: 285.
- Sparto, P., Paarnianpour, M., Reinsel, T. and Simon, S. 1997. The effect of fatigue on multijoint kinematics and load sharing during a repetitive lifting test. *Spine*, 22: 2647–2654.
- Stewart, W., Ricci, J. and Chee, E. 2003. Lost productive time/cost due to common pain conditions in the US work force. *Journal of the American Medical Association*, 290: 2443-2454.
- Subotnick, S.I. 1999. *Sports Medicine of the lower extremity*. 2nd ed. New York: Churchill Livingstone.
- Sung, P.S., Yoon. B., Lee, D.C. 2010. Lumbar spine stability for subjects with and without low back pain during one-leg standing test. *Spine*, 35: E753–E760
- Suter, E., McMorland, G., Herzog, W. and Bray, R. 2000. Conservative lower back treatment reduces inhibition in knee-extensor muscles: A randomised controlled trail. *Journal of Manipulative and Physiological Therapeutics*, 22 (3): 149-153.
- Swinkels, A. and Dolan, P. 1998. Regional assessment of joint position sense in the spine. *Spine*, 23 (5): 590-597.
- Thorson, D., Jurgenson-Ralbke, J., Hect, S., Campbell, R., Buttermann, G. and Kramer, C. 2008. Adult Low Back Pain. Clinical Practice Guidelines.
- Terrett, A.G.J. and Kleynhans, A.M. 1992. Cerebrovascular complications of ma-

nipulation. In: Haldeman S, editor. *Principles and practice of chiropractic*. Norwalk: Appleton and Lange.

Triano, J.J. and Schultz, A.B., 1997. Loads transmitted during lumbo-sacral spinal manipulative therapy. *Spine*, 22: 1955- 1964

Triano, J.J. 2000. The mechanics of spinal manipulation. In: Herzog, W (ed). *Clinical biomechanics of spinal manipulation*. New York: Churchill Livingstone.

Triano, J.J. 2009. Making lives better through practice and research. *Journal of the Canadian Chiropractic Association*, 53 (2): 87-94.

Tullberg, T., Blomberg, S., Branth, B. and Johnsson, R. 1998. Manipulation does not alter the position of the sacroiliac joint. A Roentgen Stereophotogrammetric Analysis. *Spine*, 10: 1124-1129.

Van Der Meulen, A. G. 1997. *An epidemiological investigation of low back pain in a formal black South African township*. Master's Degree in Technology: Durban University of Technology, Durban, South Africa.

Van Dillen L, M. M., Fleming D, Sahrman S. 2000. The effect of hip and knee position on hip extension ROM measures in individuals with and without low back pain. *Journal of Orthopaedic Sports Physical Therapy*, 30 (6): 307–316.

Van Kleef, M., Vanelderin, P., Cohen, S. P., Lakaster, A., Van Zondert, J. and Meklail, N. 2010. Pain originating from the lumbar facet joints. *Pain practitioner*, 10(5): 459-469.

Van Tulder, M.W., Furnan, A.D. and Gagnier, J.J. 2005. Complementary and Alternative Therapies for Low Back Pain. *Best Practice and Research Clinical Rheumatology*. 19 (4): 639-654.

Van Tulder, M. and Al, E. 2006. European guidelines for the management of acute nonspecific low back pain in primary care. *European Spine Journal*, 15 (2): 169.

Vernon, H. 2000. A Qualitative review of studies of manipulation-induced hypoalgesia. *Journal of Manipulative Physiological Therapeutics*, 23:134–138.

Vicenzino, B. and Al, E. 1998. An investigation of the inter-relationship between manipulative therapy-induced hypoalgesia and sympathoexcitation. *Journal of Manipulative Physiological Therapy*, 21: 488.

- Vieira, E.R., Kumar, S. and Narayan, Y. 2005. Smoking, No-exercise, Overweight and low back disorders in welders and nurses. *International Journal of Industrial Ergonomics*.
- Vlaeyen J.W., Linton S.J. 2000. Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. *Pain*, 85: 317–32.
- Vleeming, A., Mooney, V. and Stoeckart, R. 2012. *Movement, stability and Lumbopelvic Pain*. 2nd ed. New York: Churchill Livingstone.
- Vleeming, A., Pool-Goudzwaard, A.L., Stoeckart, R., van Wingerden, J. and Snijders, C.J. 1995. The Posterior Layer of the Thoracolumbar Fascia: Its function in load transfer from spine to legs. *Spine*, 20 (7): 753-758.
- Vleeming, A., Schuente, M.D., Masi, A.T., Daneels, L. and Willard, F. H. 2012. The sacroiliac joint: An overview of its anatomy, function and potential clinical implications. *Journal of Anatomy*, 221(6): 537-567.
- Vogt, L., Fiefferk, P. and Banzer, W. 2003. Neuromuscular control of walking with chronic low back pain. *Manual Therapeutics*, 8: 21-28.
- Waddell, G., Aylward, M. and Sawney, P. 2002. Low back pain, disability and social support. In: *Back Pain, Incapacity for Work and Social Security Benefits: An International Literature Review and Analysis*. The Royal society of Medicine Press, London.
- Walker, J. M. 1986. Age-Related Differences in the Human Sacroiliac Joint: A Histological Study; Implications for Therapy. *The Journal of Orthopaedic and Sports Physical Therapy*, 7 (6): 325 – 333.
- Walker, B.F. 2000. The prevalence of low back pain: a systematic review of the literature from 1966 to 1998. *Journal of Spinal Disorders*, 13(3): 205-217.
- Weber, K. A., II and He, X. 2010. Chiropractic students and research: assessing the research culture at a North American chiropractic college. *Journal of Chiropractic Education*, 24 (1): 35-45.
- White, A.A., Panjabi, M.M. 1990. *Clinical Biomechanics of the Spine*. 2nd ed. Philadelphia: J.B. Lippincott Company.

Wieser, S., Horisberger, B., Schmidhauser, S., Eisenring, C., Brügger, U., Ruckstuhl, A., Dietrich, J., Mannion, A. F., Elfering, A., Tamcan, Ö. and Müller, U. 2011. Cost of low back pain in Switzerland in 2005. *The European Journal of Health Economics*, 12 (5): 455-467.

Willson, J.D., Dougherty, C.P., Ireland, M.L. and Davis, I.M. 2005. Core stability and its relationship to lower extremity function and injury. *Journal of American Academy of Orthopaedic Surgery*, 13(5): 316-25.

Wong, D.A. and Transfeldt, E. 2006. *Macnab's Backache*. 4th ed. Baltimore: Lippincott Williams and Wilkins.

World Health Organisation, 2005. Guidelines on basic training and safety in chiropractic. Geneva, Switzerland, WHO, 20-24.

Yelverton, C., Hay, N. 2012. *The awareness of the chiropractic profession amongst the black population living in the East Rand in South Africa*. Master's Degree in Technology: Chiropractic. University of Johannesburg, Johannesburg, South Africa.

Yerys, S., Makofsky, H., Pennachio, J. and Cinkay, J. 2002. The effect of mobilization of the anterior hip capsule on gluteus maximus strength. *Journal of manual manipulative therapy*, 10: 218-224.

APPENDICES

APPENDIX A- Letter of Information and Consent



LETTER OF INFORMATION

Title of the Research Study:

The effect of low back manipulation compared to low back and hip manipulation for the treatment of chronic non-specific low back pain.

Principal Investigator/s/researcher:

Jesse Bruins Roberts (BTech Chiropractic)

Co-Investigator/s/supervisor/s:

Dr. Garrick Haswell (MTech Chiropractic, BCom)

Dear participant please read the following information regarding the above research topic:

Purpose of the Study:

This original study hypothesizes that restoring function to the hip joint in a patient suffering from low back pain will result in a more beneficial outcome for the patient, signifying a more holistic treatment protocol for low back pain.

Outline of the Procedures:

After signing the informed consent, you will be scheduled for your initial consultation at the DUT CDC. At the initial, the researcher will perform a case history, a physical exam, a lumbar regional exam and a hip regional exam. If you meet the required inclusion and exclusion criteria, you will also complete two brief subjective surveys, after which you will be allocated to a group. There will be a total of 40 participants divided randomly and equally into 2 groups. Group 1 will be treated with low back manipulation. Group 2 will be treated with combined low back and hip joint manipulation. Participants are expected to attend five treatment consultations over a 2 week period with regular measurement intervals. These consultations should take less than an hour each with the exception of the initial consultation that may take up to an hour and a half. Measurement outcomes include two subjective surveys, algometry which will be used to measure pain response to treatment and inclinometry which will be used to measure ROM.

Risks or Discomforts to the Participant:

Potential participants will be screened for contra-indications to manipulation and excluded from the study if necessary. The loads experienced in Lumbar spine and pelvic manipulations are safe (Trian and Shultz, 1997) and serious complications are extremely low (Terret and Kleyn, 1992). Those participants who have not received manipulation before will be informed with regards to the procedure and the potential side-effects.

Benefits:

Previous research studies have shown that Chiropractic manipulation of the low back is effective in the treatment of low back pain. Both groups will receive low back manipulation, and will therefore directly benefit in terms of treatment for low back pain.

You will help advance the knowledge surrounding a global burden, low back pain, and the treatment thereof. The researcher will, through completion of the study, be awarded their masters in chiropractic.

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

If the participant does not comply with the required treatment consultations within the required time, becomes ill, is found to fulfil an exclusion criteria or has an adverse reaction to treatment, they may be withdrawn from the study. You, as a participant, may withdraw from the study at any time for any reason what so ever. This withdrawal will not affect your relationship with the researcher, the supervisor, DUT or any other affiliations associated with this research

Remuneration and costs of the study:

You will not be charged for any treatment, services or consumables rendered by the researcher and no financial gain will be awarded to the participant or the researcher.

Confidentiality:

All information and data collected will be strictly confidential, and your name will not appear in any research publication or replication thereof. All the data collected will be stored for 5 years, and thereafter it will be destroyed.

Research-related Injury:

Should there be a research-related injury or adverse reaction the participant shall not receive compensation.

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

Please contact the researcher (Jesse Bruins Roberts: 082 465 2060), my supervisor (Dr. Garrick Haswell-garrick@tranco.co.za) or the Institutional Research Ethics Administrator on 031 373-2900. Complaints can be reported to the Director: Research and Postgraduate Support, Prof S Moyo on 031 373 2577 or moyos@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 gender, 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 computerised 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**

APPENDIX B- Case History



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: _____
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CONDITIONAL:

Reason for Conditional:

Signature: _____

Date: _____

Conditions met in Visit No: _____	Signed into PTT: _____	Date: _____
-----------------------------------	------------------------	-------------

Case Summary signed off: _____	Date: _____
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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 C- Physical Exam



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 D- Lumbar Regional Exam



CHIROPRACTIC PROGRAMME

REGIONAL EXAMINATION LUMBAR SPINE AND PELVIS

Patient: _____

File#: _____ Date: _____

Student: _____

Clinician: _____

STANDING:

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

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

GAIT:

Normal walking
Toe walking
Heel Walking
Half squat

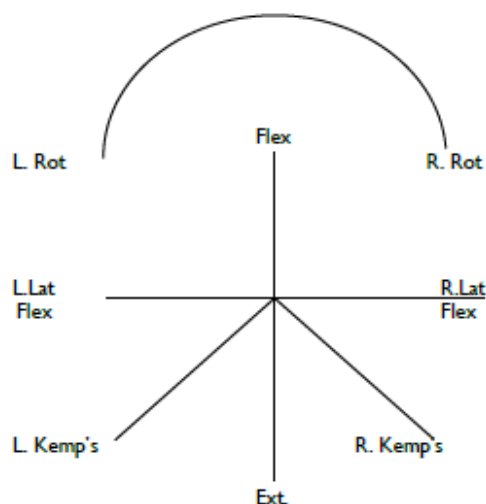
ROM:

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? (SI)
- Aggravates? (disc, muscle strain)

SUPINE:

Observe abdomen (hair, skin, nails)

Palpate abdomen/groin

Pulses - abdominal
- lower extremity

Abdominal reflexes

SLR		Degree	LBP?	Location	Leg pain	Buttock	Thigh	Calf	Heel	Foot	Braggard
	L										
	R										
						L			R		
Bowstring											
Sciatic notch											
Circumference (thigh and calf)											
Leg length: actual -											
apparent -											
Patrick FABERE: pos/neg – location of pain?											
Gaenslen's Test											
Gluteus max stretch											
Piriformis test (hypertonicity?)											
Thomas test: hip \ psoas \ rectus femoris ?											
Psoas Test											

SITTING:

Spinous Percussion
Lhermitte

Valsalva

APPENDIX E- Hip Regional Exam



CHIROPRACTIC PROGRAMME

HIP REGIONAL EXAMINATION

Patient: _____ File no: _____ Date: _____

Student: _____ Signature: _____

Clinician: _____ Signature: _____

Hip with complaint: Right ☐ Left: ☐

OBSERVATION

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

PALPATION

- **Anterior aspect**

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

- **Posterior aspect**

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

ACTIVE MOVEMENTS (note rom and pain)			Right	Left
1.	Flexion (110-120°)			
2.	Extension (10-15°)			
3.	Adduction (30°)			
4.	Abduction (30-90°)			
5.	Medial rotation (30-40°)			
6.	Lateral rotation (40-60°)			
PASSIVE MOVEMENTS (note end-feel, rom and pain)			Right	Left
1.	Flexion (tissue stretch or approximation)			
2.	Extension (tissue stretch)			
3.	Adduction (tissue stretch or approximation)			
4.	Abduction (tissue stretch)			
5.	Medial rotation (tissue stretch)			
6.	Lateral rotation (tissue stretch)			
RESISTED ISOMETRIC MOVEMENTS (note strength and pain)			Right	Left
1.	Hip Flexion			
2.	Hip Extension			
3.	Adduction			
4.	Abduction			
5.	Medial rotation			
6.	Lateral rotation			
7.	Knee flexion			
8.	Knee extension			
REFLEXES			Right	Left
1.	Patella			
2.	Achilles			
DERMATOMES (indicate deficits by level and location)				
1.	Level			
2.	Location			
JOINT PLAY MOVEMENTS			Right	Left
1.	Caudal glide (long axis traction superior – inferior)			
2.	Compression @ 90° (inferior – superior)			
3.	Medial ➤ lateral @ 180° / @ 90°			
4.	Lateral ➤ medial @ 180° / @ 90°			
5.	Internal rotation			
6.	External rotation			
7.	Anterior ➤ posterior			
8.	Posterior ➤ anterior			
9.	Quadrant (scouring) test			
SPECIAL TESTS			Right	Left
1.	Patrick/FABER Test			
2.	Trendelenberg's Test			
3.	Craig's Test			
4.	Leg Length	Actual Apparent		
5.	Sign of the Buttock			
6.	Thomas Test (hip flexion contracture)			
7.	Rectus Femoris Contracture Test			
8.	Iliopsoas contracture Test			
9.	Ely's Test (rectus femoris hypertonicity)			
10.	Ober's Test (ITB contracture)			
11.	Noble Compression Test (ITB Friction Syndrome)			
12.	Piriformis Test			
13.	Hamstrings	Hamstring Contracture Test Tripod Test		



CHIROPRACTIC PROGRAMME

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

APPENDIX G- Numerical Pain Rating Scale

Pain Numeric Rating Scale

1. On a scale of 0 to 10, with 0 being no pain at all and 10 being the worst pain imaginable, how would you rate your pain RIGHT NOW.

0	1	2	3	4	5	6	7	8	9	10
No Pain									Worst Pain Imaginable	

2. On the same scale, how would you rate your USUAL level of pain during the last week.

0	1	2	3	4	5	6	7	8	9	10
No Pain									Worst Pain Imaginable	

3. On the same scale, how would you rate your BEST level of pain during the last week.

0	1	2	3	4	5	6	7	8	9	10
No Pain									Worst Pain Imaginable	

4. On the same scale, how would you rate your WORST level of pain during the last week.

0	1	2	3	4	5	6	7	8	9	10
No Pain									Worst Pain Imaginable	

APPENDIX H- Oswestry LBP Disability Questionnaire

(Fairbank and Pynsent, 2000)

For each section the total possible score is 5; if the first statement is marked the section score = 0; if the last statement is marked, it = 5. If all 10 sections are completed the score is calculated as follows:

Example: 16 (total scored)

50 (total possible score) x 100 = 32%

If one section is missed or not applicable the score is calculated:

16 (total scored)

45 (total possible score) x 100 = 35.5%

Minimum detectable change (90% confidence): 10% points (change of less than this may be attributable to error in the measurement)

Oswestry Low Back Pain Disability Questionnaire

Instructions

This questionnaire has been designed to give us information as to how your back or leg pain is affecting your ability to manage in everyday life. Please answer by checking ONE box in each section for the statement which best applies to you. We realise you may consider that two or more statements in any one section apply but please just shade out the spot that indicates the statement which most clearly describes your problem.

Section 1 – Pain intensity

- ☐ I have no pain at the moment
- ☐ The pain is very mild at the moment
- ☐ The pain is moderate at the moment
- ☐ The pain is fairly severe at the moment
- ☐ The pain is very severe at the moment
- ☐ The pain is the worst imaginable at the moment

Section 2 – Personal care (washing, dressing etc)

- ☐ I can look after myself normally without causing extra pain
- ☐ I can look after myself normally but it causes extra pain
- ☐ It is painful to look after myself and I am slow and careful
- ☐ I need some help but manage most of my personal care
- ☐ I need help every day in most aspects of self-care
- ☐ I do not get dressed, I wash with difficulty and stay in bed

Section 3 – Lifting

- ☐ I can lift heavy weights without extra pain
- ☐ I can lift heavy weights but it gives extra pain
- ☐ Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently placed eg. on a table
- ☐ Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned
- ☐ I can lift very light weights
- ☐ I cannot lift or carry anything at all

Section 4 – Walking*

- ☐ Pain does not prevent me walking any distance
- ☐ Pain prevents me from walking more than 1 mile
- ☐ Pain prevents me from walking more than 1/2 mile
- ☐ Pain prevents me from walking more than 100 yards
- ☐ I can only walk using a stick or crutches
- ☐ I am in bed most of the time

Section 5 – Sitting

- ☐ I can sit in any chair as long as I like
- ☐ I can only sit in my favourite chair as long as I like
- ☐ Pain prevents me sitting more than one hour
- ☐ Pain prevents me from sitting more than 30 minutes
- ☐ Pain prevents me from sitting more than 10 minutes
- ☐ Pain prevents me from sitting at all

Section 6 – Standing

- ☐ I can stand as long as I want without extra pain
- ☐ I can stand as long as I want but it gives me extra pain
- ☐ Pain prevents me from standing for more than 1 hour
- ☐ Pain prevents me from standing for more than 30 minutes
- ☐ Pain prevents me from standing for more than 10 minutes
- ☐ Pain prevents me from standing at all

Section 7 – Sleeping

- ☐ My sleep is never disturbed by pain
- ☐ My sleep is occasionally disturbed by pain
- ☐ Because of pain I have less than 8 hours sleep
- ☐ Because of pain I have less than 4 hours sleep
- ☐ Because of pain I have less than 2 hours sleep
- ☐ Pain prevents me from sleeping at all

Section 8 – Sex life (if applicable)

- ☐ My sex life is normal and causes no extra pain
- ☐ My sex life is normal but causes some extra pain
- ☐ My sex life is nearly normal but is very painful
- ☐ My sex life is severely restricted by pain
- ☐ My sex life is nearly absent because of pain
- ☐ Pain prevents any sex life at all

Section 9 – Social life

- ☐ My social life is normal and gives me no extra pain
- ☐ My social life is normal but increases the degree of pain
- ☐ Pain has no significant effect on my social life apart from limiting my more energetic interests eg, sport
- ☐ Pain has restricted my social life and I do not go out as often
- ☐ Pain has restricted my social life to my home
- ☐ I have no social life because of pain

Section 10 – Travelling

- ☐ I can travel anywhere without pain
- ☐ I can travel anywhere but it gives me extra pain
- ☐ Pain is bad but I manage journeys over two hours
- ☐ Pain restricts me to journeys of less than one hour
- ☐ Pain restricts me to short necessary journeys under 30 minutes
- ☐ Pain prevents me from travelling except to receive treatment

Interpretation of scores

0% to 20%: minimal disability:	The patient can cope with most living activities. Usually no treatment is indicated apart from advice on lifting sitting and exercise.
21%-40%: moderate disability:	The patient experiences more pain and difficulty with sitting, lifting and standing. Travel and social life are more difficult and they may be disabled from work. Personal care, sexual activity and sleeping are not grossly affected and the patient can usually be managed by conservative means.
41%-60%: severe disability:	Pain remains the main problem in this group but activities of daily living are affected. These patients require a detailed investigation.
61%-80%: crippled:	Back pain impinges on all aspects of the patient's life. Positive intervention is required.
81%-100%:	These patients are either bed-bound or exaggerating their symptoms.

APPENDIX I- Algometry Readings

ALGOMETER READINGS:

Patient Name: _____

File number: _____

		Trigger point 1				Trigger point 2			
Visit	Date	1	2	3	Mean	1	2	3	Mean
Before 1 st									
Before 3 rd									
@ final follow up									

APPENDIX J- Inclinomater Readings- Hip and Low Back

LUMBAR	Flexion	Left Rotation	Right Rotation
1 st			
3 rd			
5th			

TREATMENT!!

Are you between the ages of 18 and 45?

**Do YOU suffer from LOWER
BACK PAIN??**



If the answer is YES and you're interested in
participating in research at the DUT Chiropractic Day
Clinic then contact:

JESSE BRUINS ROBERTS: 0824652060 or the
DUT Chiropractic Clinic: 0313732205

APPENDIX L- Telephonic Interview

Telephonic Interview

A new sim-card and spare cell phone will be used solely for research participant recruitment purposes. Potential participants responding to the flyers and posters will undergo a brief telephonic interview/ screening in order to determine if they are viable for the study. Those who are viable for the study will be booked for initial consultation personally by the researcher and those who are not viable for the study will be referred to the DUT CDC reception to book a consultation.

The interview will proceed as follows:

An introduction:

- Jesse Bruins Roberts
- Chiropractic student at DUT
- Invites you to take part in research
- Do I have your consent to give you some information about the study and ask you a few questions in order to ascertain whether or not you are a viable candidate for the study?
- All information is private and confidential and you may withdraw from the study at any time, at which point all your personal information will be destroyed.
- No financial gains will be awarded to the researcher or the participant and you will not be charged for any treatment, services or consumables rendered by the researcher.
- The purpose of the study is to test a specific method of treatment for low back pain.
- The telephonic screening will follow (*next page*)

The following screening criteria will be assessed:

	Question	Required Answer
1	This should take less than 6 minutes of your time, all information is strictly confidential and protected.	
2	Are you willing to proceed with a few medical questions to ensure that you have a high likelihood of meeting the inclusion criteria for the study?	Yes
3	"How old are you?"	18 – 45 years of age
4	Have you had low back pain for more than 6 Weeks?	Yes
5	Have you experienced any associated numbness, pins+ needles or sharp shooting pain in the lower limbs?	No

6	<p>Do you suffer from any of the following:</p> <ul style="list-style-type: none"> • Abdominal Aneurysm • Tumour and space occupying lesion • Fever • Infectious disease • Disc herniation • Spinal surgery/fusions • Fracture • Severe Instability • Spondyloarthropathy • Bleeding Disorders • Osteopenia • Diabetic neuropathy • Metal implants or prosthesis • Malingering, Hysteria, Hypochondriac • CNS disorders, Alzheimer's disease 	No
7	Have you had hip or spinal surgeries in the past	No
8	Have you received treatment within the last 48 hours? (if the participant answers "yes," they must wait 3 days before initial consultation)	No
9	Are you able to attend 5 consultations within a two week period?	Yes
OR 10	Thank you for your telephonic participation, but you do not seem to meet my inclusion criteria and it is likely that you will not be eligible for my study.	

APPENDIX M- Permissions to use the Chiropractic Day Clinic for Research Purposes

MEMORANDUM

To : Prof Puckree
Chair : RHDC

Prof Adam
Chair : IREC

From : Dr Charmaine Korporaal
Clinic Director : FoHS Clinic

Date : 14.09.2015

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

Permission is hereby granted to :

Mr Jesse Bruins Roberts (Student Number: 21020467)

Research title : "The effect of low back manipulation compared to combined low back and hip manipulation for the treatment of chronic nonspecific low back pain".

Mr Bruins Roberts, is requested to submit a copy of his RHDC / IREC approved proposal along with proof of his MTech: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 him seeing patients.

Thank you for your time.

Kind regards



Dr Charmaine Korporaal

Clinic Director : Chiropractic Day Clinic : Chiropractic and Somatology

Cc: Mrs Pat van den Berg : Chiropractic Day Clinic
Dr L O'Connor : Research co-ordinator
Dr G Haswell : Research supervisor



*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
E-mail: moyos@dut.ac.za*

15th August 2016

Mr Jesse Bruins Roberts
c/o Department of Chiropractic
Faculty of Health Sciences
Durban University of Technology

Dear Mr Roberts

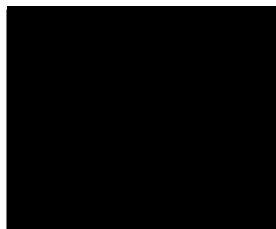
PERMISSION TO CONDUCT RESEARCH AT THE DUT

Your email correspondence in respect of the above refers.

I am pleased to inform you that the Institutional Research Committee (IRC) has granted full permission for you to conduct your research "The effect of low back manipulation compared to combined low back and hip manipulation for the treatment of chronic non-specific low back pain" at the Durban University of Technology.

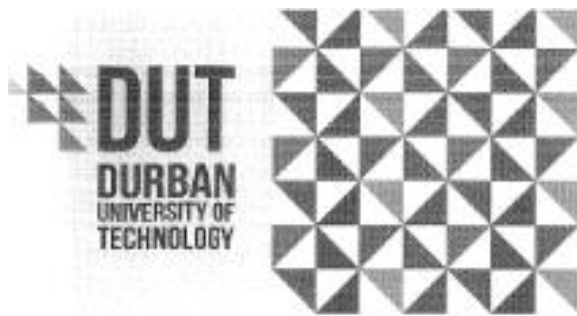
We would be grateful if a summary of your key research findings can be submitted to the IRC on completion of your studies.

Kindest regards.
Yours sincerely



PROF. S. MOYO
DIRECTOR: RESEARCH AND POSTGRADUATE SUPPORT

APPENDIX N- Ethical Clearance



Institutional Research Ethics Committee
Faculty of Health Sciences
Room HS 45, Mainfield School Site
Gate 8, Ntsoni Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2900

Fax: 031 373 3407

Email: irec@dut.ac.za

http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

16 August 2016

IREC Reference Number: **REC 60/16**

Mr J Bruins Roberts
4 Heath Row Road
Essenwood
Durban
4001

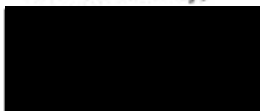
Dear Mr Bruins Roberts

The effect of low back manipulation compared to combined low back and hip manipulation for the treatment of chronic non-specific low back pain

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

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

Yours Sincerely,



Professor J K Adam
Chairperson: IREC



Appendix O- RHDC Approval Email

Proposal Review - Mr J Bruins Roberts (Chiropractic)



Sugendran Reddy <sugendranr@dut.ac.za>

Tue 2016-04-26, 11:00 AM

You; garrick@tranco.co.za; Aadil Docrat (aadild@dut.ac.za); Laura Wilson (lauraw@dut.ac.za); Khulekani Shange (KhulekaniS@dut.ac.za) 4

This message was sent with high importance.

Dear Mr Bruins Roberts

I am pleased to inform you that **RHDC** has granted your PG2a full approval. I will now forward your documentation to IREC for processing.

Regards,

Mr Sugan Reddy
Faculty Research Officer
Faculty of Health Sciences
Durban University of Technology

Telephone: (031) 373 2055

APPENDIX P- Data Sheet

Patient Name	Group	Ap/Date	Age	Sex	Race	SI	Hip	Flx	Int	Ext	L/S	Flx	Lrot	Rrot	TP1	TP2	NPRSc	NPRSav	ODI
		<u>1</u>																	
		3																	
		5																	
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