The effect of four different manipulative techniques on Iliotibial Band Friction Syndrome (ITBFS) in terms of primary and secondary outcome measures.

By

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Dissertation submitted in partial compliance with the requirements for the Master's Degree in Technology: Chiropractic Durban University of Technology

I, Jacques Andre Botes, do declare that this dissertation is representative of my own work in both conception and execution.

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DEDICATION

I would like to dedicate my absolute and overwhelming gratitude and love to my beautiful wife Irena Botes who has been a tremendous support structure on our journey and throughout this course. I am eternally grateful for all her love and continued devotion and selflessness to support and stand by my side through all these years.

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ABSTRACT

Background: Iliotibial band friction syndrome is a common dysfunction seen in athletes. Athletes develop biomechanical changes yet still continue with their sport. However, this syndrome limits their ability to participate at peak performance. This study determined which participants benefitted in terms of biomechanical and clinical outcomes in one of four groups: ankle joint, superior tibio-fibular joint, sacroiliac joint or a combination manipulation group (which contained any two of the three joint restrictions).

Methods: This Durban University of Technology Institutional Research and Ethics Committee approved prospective clinical trial, utilised stratified sampling, with 48 participants across four groups: ankle (14); superior tibio-fibular (11), sacroiliac (12) and combination (11). The participants underwent six treatments in three weeks. Data collection occurred before consultations one, three, five and seven. The data included primary measures of the knee score questionnaire (KSQ), the algometer, the visual analogue scale (VAS) and the secondary measures of the Feiss line, the heel leg alignment, bilateral leg length, Q angle and tibio-femoral angle. All data was computed utilising the ANOVA testing, with a *p*-value <0.05 being significant and a 95% confidence interval. Pearson's correlations were completed for intragroup associations between primary and secondary outcome measures.

Results: The intragroup analysis revealed that all groups had significant changes in the KSQ and VAS, with the exception of the sacroiliac joint manipulation group (KSQ outcome not significant). Intergroup analysis revealed no differences between the groups with the exception of the combination group, which showed a significant increase in the tibio-femoral angle. Most commonly, the Pearson's correlation revealed that changes in leg length were related to differences in primary outcome measures, irrespective of the group being tested.

Conclusion: The outcomes of this study indicated that manipulation of the distal kinematic chain improved alignment and clinical outcomes to a greater degree than manipulating proximal restrictions. It is suggested with caution (due to limited sample size) that patients should first have their distal kinematic chain manipulated before more proximal joints are manipulated to achieve better outcomes.

Key indexing terms: *Iliotibial band syndrome, manipulation, knee joint, hip joint, ankle joint, clinical trial, athletes, sports injuries.*

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
CDC	Chiropractic day clinic
cm	Centimetre
CPRs	Clinical prediction rules
DJD	Degenerative joint disease
DUT	Durban University of Technology
e.g.	Exempli Gratia – which means "*for example"*
IAR	Instantaneous axis of rotation
i.e.	Id Est - which means "*that is"*, "*namely"*, or "*in other words"*
IREC	Institutional Research and Ethics Committee
ITB	Iliotibial band
ITBFS	Iliotibial band friction syndrome
km	Kilometre
KSQ	Knee scoring questionnaire
LFE	Lateral femoral epicondyle
MCID	Minimally clinical important distance
MFTP	Myofascial trigger points
mm	Millimetre
N	Full sample size
n	Sample size per group
OA	Osteoarthritis
p	*p*-Value: Means information is of statistical value or that which indicates the data is statistically significant (Hinton, 2001; Campbell and Machin, 1999; Wright, 1997; Bland, 1996; Swinscow, 1996)
PFPS	Patella-femoral pain syndrome
Q angle	Quadriceps angle
r	Pearson's correlation coefficient
ROM	Range of motion
SD	Standard deviation
SMT	Spinal manipulative therapy
VAS	Visual analogue scale
>	Strict inequality meaning 'greater than"
<	Strict inequality meaning 'less than"

List of Definitions

Chiropractic Adjustment

It is a specific form of articular manipulation that consist of a short lever, high-velocity, low amplitude thrust, applied to a specific location to restore normal range of motion, in an attempt to improved functional mobility following its application (Bergmann and Peterson, 2002).

Clinical Prediction Rules (CPRs)

Clinical prediction rules are mathematical tools used in clinical research studies to determine the most appropriate combination of medical signs, symptoms, and other clinical effects have in predicting the diagnosis, prognosis or probability of a specific disease or outcome (Herbert and Fritz, 2012).

Degenerative Joint Disease (DJD)

Degenerative joint disease (e.g. osteoarthritis) is characterised by a chronic inflammatory reaction in a joint, which consequently causes damage to the structural integrity of the joint resulting in subsequent loss of the cartilage tissue and spur formation at joint margins (Kumar *et al.*, 2007).

Gate Control Theory

The gate control theory as suggested by Melzack and Wall (1965) proposed that painful stimulation (conveyed by thinner (small) nerve fibers) can be override by non-painful stimulation (conveyed in thicker (larger nerve fiber). This is because less pain is being felt when a greater number of larger nerve fibers (touch, pressure, vibration) are activated which prevents pain sensation from traveling to the central nervous system.

Gerdy's Tubercle

It is the proximal anterolateral aspect of the lateral femoral epicondyle of the tibia where the Iliotibial band and TFL inserts.

Incidence

It is the rate at which a particular event occurs, e.g. the number of new cases occurring within a period of time (e.g., per month, per year) (Dorland's Illustrated Medical Dictionary, 2003).

Joint dysfunction

Joint dysfunction is described as a disruption in functional range of motion without structural alteration resulting in an aberrant (increased, decreased or abnormal) joint motion (Bergmann and Peterson, 2002).

Joint receptors

Joint receptors are specialized cells that react to various stimuli from the extrinsic or intrinsic environment (Hopkins and Ingersoll, 2000).

Kinetic Chain

The kinetic chain can be described as the sequential arrangement of several joints (e.g.: hip, knee and ankle) that functions as a complex unit (Sahrmann, 2010; Bergmann and Peterson, 2002).

Manual and Manipulative Therapy

It is the use of physical treatment therapeutics through manual application, which may include procedures such as mobilization, manipulation, and massage to facilitate healing and restore good health (Gatterman, 2005).

Manipulation

Described as a specific form of articular manipulation characterized by direct (short lever), specific, high-velocity, low amplitude thrust, usually associated with restored range of motion, pain-free mobility and improved function following its application (Bergmann and Peterson, 2002). This definition is also referred to in the literature as a chiropractic adjustment (see definition above).

Mechanoreceptor

It is a specialized sensory cell that responds to mechanical stimulation such as sound, touch, vibration and motion (Redwood, 1997).

Nociceptor

It is a specialized nerve cell that responds to painful stimulation caused by injury to tissues due to physical, mechanical or chemical damage (Redwood, 1997).

Myofascial Trigger Points (MFTPs)

Myofascial trigger points are defined as a hyper-irritable spots located within a taut band of skeletal muscle. It can be categorized as active or latent and can be painful when compressed, consequently giving rise to a characteristic referred pain within the referred pain zone (Chaitow and Delany, 2002; Travell and Simons, 1983).

Placebo

It is a dummy clinical treatment provided to a control group within a controlled clinical trial used purely for the psychophysiological effects of the treatment, so that the specific and nonspecific effects of the experimental treatment can be distinguished (Dorland's Illustrated Medical Dictionary, 2003)

Prevalence

It is the number of cases present within a population at a specific time. This may be at a particular point in time or over a period of time (Dorland's Illustrated Medical Dictionary, 2003).

Primary restriction

A primary restriction is the principle cause of biomechanical dysfunction in a kinematic chain (Bergman and Peterson, 2011).

Secondary restriction

It is a biomechanical dysfunction within a kinematic chain that occurs as a result of another biomechanical lesion (primary restriction) as a result of compensation (Bergman and Peterson, 2011).

Chapter One
Introduction

1.1 The problem and its setting

James Renne (1975) was the first to describe iliotibial band friction syndrome (ITBFS). This syndrome is now a well-documented and recognized overuse injury resulting from friction between the iliotibial band (ITB) and the lateral femoral epicondyle (LFE) (Holmes *et al*., 1993; Grady *et al*., 1986; Lindenburg *et al*., 1984; Noble *et al*., 1982; Williams, 1980). The ITB is a fascio-tendinous band that extends inferiorly as part of gluteus maximus and tensor fascia latae (TFL) along the lateral thigh, passing over the tibio-femoral joint line to insert on the anterolateral aspect of the tibia (Gerdy's tubercle) (Magee, 2008; Moore and Dalley, 2006). ITBFS is a debilitating injury that can greatly affect an athlete's ability to perform, often causing the athlete to cease training in order to recover (Wood, 1997).

The most common symptoms of ITBFS include a sharp or burning type pain in the lateral aspect of the knee (at the LFE or slightly inferior to it) (Fredericson *et al*., 2002). ITBFS afflicted patients may report no pain at the start of an activity, however with subsequent increased activity symptoms become more pronounced (Ellis *et al*., 2007; Reid, 1992; Anderson, 1991). This pain can be more noticeable with downhill running and may persist after running (Ellis *et al*., 2007; Norris, 1998; Nicholas and Hershman, 1995; Noble *et al*., 1982; Noble, 1980).

As the condition progresses, the athlete may complain of a subsequent reduction in the time interval between the start of activity and the onset of ITBFS symptoms (Ellenbecker *et al*., 2009; Ellis *et al*., 2007; Reid, 1992; Anderson, 1991). In addition the individual may begin to experience pain during routine daily activities such as ascending or descending stairs, standing or sitting for prolong periods, as well as during general walking (Fredericson *et al*., 2002; Reid, 1992). Furthermore, the increased discomfort and pain experienced by the athlete may subsequently lead to a decrease in activity or complete withdrawal from activity (Fredericson *et al*., 2002; Reid, 1992). As such, ITBFS is one of the most prevalent overuse sports injuries known to athletes (Holmes *et al*., 1993; Noble, 1985; Noble *et al*., 1982; Noble, 1979; Orava, 1978), and is the second most common cause of knee pain (Taunton *et al*., 2002).

According to Lavine (2010), ITBFS occurs after repetitive motion of the knee, typically in a runner and cyclist. Its incidence extends between the ranges of 1.6% – 22% in runners (Lavine, 2010; Taunton *et al.*, 2002; Fredericson *et al.,* 2000; Messier *et al.*, 1995; Orava, 1978) to 15% - 24% in cyclists (Farrell *et al.*, 2003; Holmes *et al.* 1993).

According to Noehren *et al.* (2007), Fredericson *et al.* (2000), Orchard *et al.* (1996) and Messier, *et al.* (1995), there are a number of proximal, local and distal anatomical and biomechanical factors that are thought to play a role in the development of ITBFS. These factors may include ankle joint (Meadows, 2002; Schepsis et al., 2002; Anderson, 1991; McNicol, 1981; Smart *et al.*, 1980), sacroiliac joint (Hillermann *et al.*, 2006; Cohen, 2005; Brolinson *et al.*, 2003; Cookson, 2003), and local superior tibio-fibular joint dysfunctions (Barwick *et al.*, 2012; Birnbaum *et al.*, 2004; Fredericson *et al.*, 2000; Kirk *et al.*, 2000; Noble *et al.*, 1982; Renne, 1975). Similarly, previous literature has only anecdotally suggested that lower extremity dysfunction or asymmetry, such as forefoot supination with compensatory pronation, weak hip abductors and increased knee internal rotation, genu varum, cavus foot and leg length discrepancies, are some of the anatomical factors believed to contribute to ITBFS (Ellen *et al.*, 1999; Reid, 1992; Lindenburg *et al.*, 1984). However these have only been investigated to a limited extent and there is a paucity of literature on the clinical effect of superior tibio-fibular joint manipulation, sacroiliac joint manipulation and ankle joint manipulation either as a singular treatment or in combination in the treatment of ITBFS (Barwick *et al.*, 2012).

Brantingham *et al.* believed that an investigation into the effects of specific manipulative procedures would assist in providing an understanding of the effect of kinematic chain manipulative therapy (manipulation of sequential articular joint surfaces of the lower extremity, i.e.: sacroiliac joint, superior tibio-fibular joint, ankle joint, or in combination) in the treatment of ITBFS (Brantingham *et al.*, (2012(a); Brantingham *et al.*, (2012(b); Brantingham *et al.*, (2009(b)). Considering the iliotibial band's (ITB) origin and insertion, it is clear that the sacroiliac joints, hip joints and knee joints play an important role in contributing to ITB dysfunction or being affected by it (Fredericson *et al.*, 2000; Reid, 1992). This is of particular relevance as both sacroiliac joint and superior tibio-fibular joint dysfunctions are biomechanically related to the ITB (Barwick *et al.*, 2012; Noehren *et al.*, 2006; Niemuth *et al.*, 2005; Meadows, 2002; Fredericson *et al.*, 2000; Kavanagh, 1999; Lewit, 1999; Orchard *et al.*, 1996; Messier *et al.*, 1995; Baker, 1995). Additionally, fibula movement and function are prevented by the normal posterior translation of the talus in relation to the mortise during dorsiflexion, by decreased ankle joint dorsiflexion (Hubbard *et al.*, 2006; Berkowitz and Kim, 2004; Lun *et al.*, 2003; Eren *et al.*, 2003; Denegar *et al.*, 2002; Meadows, 2002; Dananberg *et al*., 2000; Scranton *et al*., 2000), which has been shown to contribute to aberrant knee joint function (tibio-fibular joint and tibio-femoral joint), which may result in ITB dysfunction and predispose to ITBFS (Barwick *et al*., 2012; Hubbard *et al*., 2006; Berkowitz and Kim, 2004; Lun *et al*., 2003; Eren *et al*., 2003; Denegar *et al*., 2002; Scranton *et al*., 2000). These reciprocal effects further support the theory that kinematic chain dysfunctions can contribute to the development of ITBFS (Barwick *et al*., 2012; Hubbard *et al*., 2006; Noehren *et al*., 2006; Niemuth *et al*., 2005; Berkowitz and Kim, 2004; Lun *et al*., 2003; Eren *et al*., 2003; Denegar *et al*., 2002; Fredrickson *et al*., 2000; Scranton *et al*., 2000; Orchard, *et al*., 1996; Messier *et al*., 1995; Baker, 1995).Thus, addressing dysfunctions in these joints should affect ITBFS through changes in the kinematic chain.

Furthermore, the literature reveals the necessity of a multimodal approach in the treatment of ITBFS, in order to achieve a beneficial effect and clinical outcome for the condition (Fredericson *et al*., 2000; Reid, 1992). To support this, there is a need for further research in the form of randomized controlled clinical trials with regards to Chiropractic specific procedures in the treatment of ITBFS (Brantingham *et al*., 2012; Ellis et al., 2007). Therefore, this research aimed to add to the literature by evaluating the effect of the individual treatments of the ankle joint (talocrural joint), superior tibio-fibular joint and sacroiliac joint by manipulation. Additionally, the study also combined these treatments to evaluate the effect of the combined therapy on the kinematic chain in the treatment.

1.2 Aims and objectives of the study

The aim of the study was to determine the differences between superior tibio-fibular joint manipulation alone versus sacroiliac joint manipulation alone, versus subtalar joint manipulation alone, as well as a combination of the three interventions in the treatment of ITBFS.

The *objectives* were to measure the differences between the four interventions, if any, in terms of primary outcome measures, clinical outcome measures (visual analogue scale, knee score questionnaire and algometer) and secondary outcome measures biomechanical measures (Leg length, Q angle, tibio-femoral angle, Feiss line and leg heel alignment), with regards to the following:

- Objective one was to determine the effect of ankle joint manipulation in the treatment of ITBFS.

- Objective two was to determine the effect of superior tibio-fibular joint manipulation in the treatment of ITBFS.
- Objective three was to determine the effect of sacroiliac joint manipulation in the treatment of ITBFS.
- Objective four was to determine the effect of a combination of these three treatments in the treatment of ITBFS.
- Objective five was to compare a trend amongst the four different groups in terms of the findings and to determine the relative effect of lower extremity manipulation in the treatment of ITBFS.

1.3 Null Hypothesis

A combination treatment would be no different when compared to the primary and secondary outcome measures when compared to:

One: Manipulation of the superior tibio-fibular joint in the treatment of ITBFS

Two: Manipulation of the ankle joint in the treatment of ITBFS

Three: Manipulation of the sacroiliac joint in the treatment of ITBFS.

1.4 Limitations

In terms of the outcomes of this study, it was anticipated that all patients were open and honest about their clinical condition at the times when measurements were taken. Patients that intended to please the doctor ("observer effect") (Mouton, 1996) or those that perceived placebo or alternative treatment options differentially (Mouton, 1996) may, however, have not accurately reported their pain rating (as an example), therefore inadvertently affecting the study's outcome. In order to limit the effect of this, the patients were instructed to report the pain as they perceived it at the time that measurements were taken. However, the researcher was limited in countering this effect, if it were present (Mouton, 1996).

1.5 Conclusion

Chapter One presented an introduction to the problem and its setting with the aims and objectives for the study. Chapter Two provides an overview of the reviewed literature on Iliotibial Band Friction Syndrome (ITBFS) in terms of the anatomical and biomechanical structures involved, with the aim of providing a clearer understanding of the condition in terms of its anatomy, aetiology, epidemiology, pathology, and interventions utilised in the treatment and management of ITBFS. In Chapter Three, the methodology for this study is discussed and includes a detailed description of the study design and protocols followed with respect to advertising, sampling, clinical procedures, interventions, measurement tools, and statistical analysis. This is followed by Chapter Four which presents the results of the statistical data that was collected during the course of the study with an accompanying discussion of the results. Finally, Chapter Five provides a conclusion of the study with recommendations on how future studies could be improved.

Chapter Two
Literature Review

2.1 Introduction

Chapter Two provides an overview of the reviewed literature on Iliotibial Band Friction Syndrome (ITBFS) in terms of the anatomical and biomechanical function involved with the aim of providing a clearer understanding of the condition in terms of its anatomy, aetiology, epidemiology, pathology, and interventions utilised in the treatment and management of ITBFS.

This research study aimed to add to the literature by determining the effect of four different manipulative techniques on Iliotibial Band Friction Syndrome (ITBFS) in terms of primary and secondary outcome measures.

2.2 Definition

Iliotibial Band Friction Syndrome (ITBFS) is a prevalent overuse injury amongst athletes, which causes pain along the lateral aspect of the knee (Strauss *et al.*, 2011; Ellis *et al.*, 2007; Fredericson and Wolf*,* 2005*;* Khaund and Flynn, 2005; Taunton *et al.*, 2002; Fredericson *et al.*, 2000; Hyde and Gengenbach, 1997; Barber and Sutker, 1992). The pain is thought to be a result from friction caused by repetitive motion between the iliotibial band (ITB) (previously known as Maissiat's band) and the lateral femoral epicondyle (LFE) of the femur during flexion and extension movements with associated secondary inflammation (Lavine, 2010; Fredericson *et al.*, 2000; Krivickas, 1997; Orchard *et al.*, 1996; Messier *et al.*, 1995; Holmes *et al.*, 1993; Barber and Sutker, 1992; Grady *et al.*, 1986; Lindenburg *et al.*, 1984; Noble *et al.*, 1982; Williams, 1980).

This friction, according to Kirk *et al.* *(*2000), Noble *et al.* (1982) and Orava (1978), causes pain around the LFE, or slightly inferior to it, with subsequent referral upward along the lateral aspect of the thigh or downward to the upper calf region.

In addition to the above well accepted definition of ITBFS, a more recent anatomical study conducted by Fairclough *et al.* (2006), suggests that ITBFS may be more of a compression syndrome rather than that of a true frictional syndrome. Fairclough *et al.* (2006) made reference to the possible existence of a highly innervated “fat pad” situated between the ITB and the distal femur, and it is thought that compression of this “fat pad” contributes to the perceived pain felt by individuals with ITBFS.

In order to promote an understanding of these theories, the following section deals with the anatomy of the ITB.

2.3 Anatomy

2.3.1 Iliotibial band (ITB) / Maissiat's band

Anatomically, the iliotibial band (ITB) (Figure 2.1) is described as a long fascio-tendinous extension of the tensor fascia lata (TFL) and gluteus maximus musculature in the anterolateral and posterior thigh respectively. Proximally, the TFL joins the larger superior and superficial inferior fibres of the gluteus maximus muscle, inserting into the ITB tract to share a common distal attachment to the anterolateral tibia (Standring, 2009; Moore and Dalley, 2006; White *et al*., 2004; Gruen *et al*., 2002; Anderson *et al*., 2001). Proximally, the ITB also indirectly shares the attachment of the TFL (anterolaterally) and gluteus maximus musculature (posterolateral) to the iliac crest, sacrum, coccyx and the pelvic supporting ligaments (e.g. sacrotuberous, sacrospinous and posterior sacroiliac ligaments), as it is confluent with the fascial sheath that envelope these muscles (Standring, 2009; Moore and Dalley, 2006; White *et al*., 2004; Gruen *et al*., 2002; Anderson *et al*., 2001). This is supported by Pribut (2012), Birnbaum *et al*. *(*2004), Muhle *et al*. *(*1999), Simons *et al*. *(*1999), Reid (1992) and Orava (1978), who suggested that the ITB joins the fascia of gluteus maximus, gluteus medius and the TFL as it passes over the greater trochanter of the femur. This suggests that it is therefore possible that the ITB can be influenced through these indirect attachments, by sacroiliac joint dysfunction (Bergmann and Peterson, 2011; Morris, 2006; Haldemann, 2005; Reid, 1992; Bernard and Kirkaldy-Willis, 1987) and superior tibio-fibular dysfunction (Barwick *et al*., 2012; Fujii *et al*., 2010; Hannon, 2006), thereby affecting the ITB function.

Along its length, the ITB (Figure 2.1) runs vertically with the lateral intermuscular septum, attaching superficially to the fascia that encases the lateral aspect of the quadriceps femoris muscle (vastus lateralis muscle) and the hamstring muscle group (biceps femoris muscle) (Pribut, 2012; Standring, 2009; Moore and Dalley*.,* 2006; Birnbaum *et al*., 2004; White *et al*., 2004; Gruen *et al*., 2002; Anderson *et al*., 2001; Muhle *et al*., 1999; Simons *et al*., 1999;

Orava, 1978). Therefore, due to this integrated relationship between the musculature, it has previously been theorised that dysfunction of these muscles may impact negatively on the function of the ITB resulting in patella-femoral pain syndrome (PFPS) or ITBFS (Paoloni *et al.,* 2011; Pattyn *et al.,* 2011; White *et al.,* 2009; Dippenaar *et al*., 2008; Pribut, 2008; Lin *et al*., 2004; Powers *et al*., 1996).

Similarly, the inferior end of the ITB (Figure 2.1) is confluent with the lateral patellar retinaculum anteriorly, the lateral collateral ligament posteriorly and the lateral portion of the capsule of the tibio-femoral joint superficially (Pribut, 2012; Standring, 2009; Moore and Dalley*,* 2006; Birnbaum *et al*., 2004; Daniel *et al*., 1990), before attaching to the tibia (Gerdy's tubercle) (Standring, 2009; Moore and Dalley, 2006; Krivickas, 1997; Orchard *et al*., 1996). According to Pribut (2012), Birnbaum *et al*. (2004), Moore and Dalley (2006), Muhle *et al*. (1999), Simons *et al*. (1999) and Orava (1978), the ITB divides into two main parts after crossing the LFE; an iliopatella band that becomes confluent with the lateral aspect of the patella, and an extended continuation of the ITB that becomes confluent with the biceps femoris muscle and fascia before attaching to the tibia (Gerdy's tubercle). Therefore, dysfunction of any of these ligamentous structures (e.g. hyperpressure syndrome (Ficat and Hungerford, 1977)), with resultant tibio-femoral joint as well as superior tibio-fibular joint dysfunction (Barwick *et al*., 2012; Paoloni *et al.,* 2011; Pattyn *et al.,* 2011; Fujii *et al*., 2010; Hannon, 2006; Reid, 1992) may result in ITBFS.

Furthermore, the ITB crosses both the hip and knee joints, supporting the weight-bearing lower limb, especially in the stance phase of the gait cycle (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). It achieves this in part due to its attachment to the femur via the lateral intermuscular septum, thereby preventing adduction of the lower limb (Standring, 2009; Magee, 2008; Moore and Dalley, 2006); through increasing the tension in the tensor fascia lata muscle, which is generated by its synergistic (e.g. gluteus maximus muscle) and confluent (e.g. biceps femoris muscle) muscles contracting (Standring, 2009; Moore and Dalley, 2006; Reid, 1992). Therefore, it has been suggested that subsequent dysfunction in the muscular components controlling lower limb movement in the gait cycle may therefore lead to aberrant kinematic chain function, predisposing to increased tension in the ITB, leading to ITBFS (Paoloni *et al.,* 2011; Pattyn *et al.,* 2011; Dippenaar *et al*., 2008; Birnbaum *et al*., 2004; Gunter and Schwellness, 2004; Taunton *et al*., 2002; Fredericson *et al*., 2000; Kirk *et al*., 2000; Orchard *et al*., 1996; Powers *et al*., 1996; Kendall *et al*., 1993; Barber and Sutker, 1992, Reid, 1992; Anderson, 1991).

In order to understand the role and function of the muscles that contribute to the ITB, its function and dysfunction, it is important to understand their origin, insertion, synergists, and antagonists. These will therefore be covered in the following section.

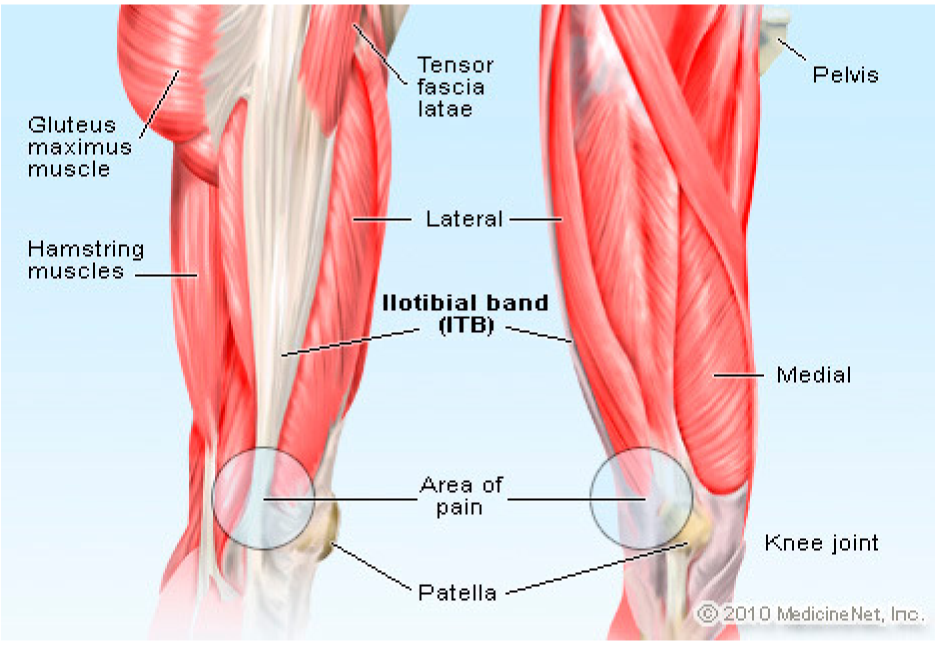

Figure 2.1: Anatomical Representation of ITB

Picture obtained from MedicineNet, Inc. (Approved 26 June 2015)

(http://www.medicinenet.com/image-collection/iliotibial_band_itb_picture/picture.htm, 2015)

2.3.2 Tensor fascia latae (TFL) muscle

According to Moore and Dalley (2006), the TFL muscle (Figure 2.1) is approximately 15 cm long and is enclosed between two layers of fascia lata. It attaches to and originates from the anterolateral aspect of the iliac crest, after which it passes inferiorly along the lateral aspect of the femur to join the fibres of gluteus maximus to insert into the ITB tract, to finally attach onto the lateral condyle of the tibia (Standring, 2009; Moore and Dalley, 2006; Birnbaum *et al.*, 2004; White *et al.*, 2004; Gruen *et al.*, 2002; Anderson *et al.*, 2001). This description is supported by Travell and Simons (1983), who suggest that the TFL muscle consists of two parts: anteromedial fibres that are confluent with the lateral patella retinaculum and deep lateral fascia of the leg, and posterolateral fibres that insert below the tibio-femoral joint onto the anterolateral tibia.

The TFL muscle's main function is to assist with hip flexion and abduction, medial rotation of the thigh, and pelvic stabilization (Standring, 2009; Moore and Dalley, 2006; Norkin and Levangie, 1992). Due to its integrated relationship with the ITB tract and distal attachment, the TFL muscle assists with supporting the femur on the tibia, thereby contributing to the stabilization of the knee during the gait cycle. In addition, the TFL muscle acts as a weak antagonist to the gluteus maximus muscle, which is the main hip extensor (Moore and Dalley, 2006; Travell and Simons, 1983).

2.3.3 Gluteus maximus muscle

According to Moore and Dalley (2006), the gluteus maximus muscle forms part of the gluteal muscle group which shares a common compartment that is divided into superficial and deep layers. The gluteus maximus muscle forms part of the superficial layer which it shares with the other gluteal muscles (gluteus medius and gluteus minimus) and TFL muscle (Standring, 2009; Magee, 2008; Moore and Dalley, 2006; Birnbaum *et al.*, 2004; White *et al.*, 2004; Gruen *et al.*, 2002; Anderson *et al.*, 2001). The gluteus maximus muscle attaches proximally to the posterolateral surface of the ilium, sacrum and coccyx, as well as the sacrotuberous ligament, the facia of gluteus medius, and the thoracolumbar fascia / aponeurosis of erector spinae muscles (Magee, 2008; Morris, 2006; Moore and Dalley, 2006; Birnbaum *et al.*, 2004; White *et al.*, 2004; Gruen *et al.*, 2002; Anderson *et al.*, 2001). The insertion of the gluteus maximus muscle is two-fold with some deep and distal fibres attaching to the gluteal tuberosity of the femur, and the remaining larger part of the superior and inferior superficial fibres inserting into the ITB (Standring, 2009; Magee, 2008; Moore and Dalley, 2006; Travell and Simons, 1983).

The main function of the gluteus maximus includes hip extension (especially from a flexed position), and external rotation of the thigh. In addition, it contributes to trunk extension on fixed lower limb(s), thus because of its direct relationship to the pelvic girdle and thoracolumbar fascia the gluteus maximus muscle also acts as a lumbar and pelvic stabilizer (Standring, 2009; Magee, 2008; Moore and Dalley, 2006; Vleeming *et al.*, 2001). This is important for load transfer (especially during trunk rotation) from the ipsilateral latissimus dorsi muscle to the contralateral gluteus maximus muscle (Vleeming *et al.*, 1995). Therefore, dysfunction of the gluteus maximus muscle (due to muscle weakness / tightness, MFTP or sacroiliac joint dysfunction) may impact negatively on the ITB's functional ability to act as a hip and knee stabilizer during the gait cycle (Cael, 2011; Hansen et al., 2007; Cookson, 2003; Fredericson *et al.*, 2000 Kendall et al., 1993), and consequently predispose an athlete to ITBFS.

2.3.4 Vastus lateralis muscle

According to Moore and Dalley (2006), the vastus lateralis muscle forms part of the vasti muscle group, which forms part of quadriceps femoris muscle bulk. The vastus lateralis muscle originates from the greater trochanter and lateral lip of the linea aspera of the femur and runs inferiorly along the anterolateral aspect of the thigh where it inserts distally onto the patella and tibia via the quadriceps aponeuroses and patellar ligament respectively (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). However, a small number of fibres also attach to the patella retinaculum (Standring, 2009; Reid, 1992, Travell and Simons, 1983). In addition, the fascial sheath surrounding the vastus lateralis muscle also attaches to the lateral intermuscular septum, thus creating an almost continuous relationship between the vastus lateralis muscle (from near its origin to its insertion) with the intermuscular septum and the ITB (Pribut, 2012; Standring, 2009; Birnbaum *et al*., 2004; Moore and Dalley*.,* 2006; Muhle *et al*., 1999; Simons *et al*., 1999; Orava, 1978).

The main function of the vastus lateralis muscle is to extend the knee and it acts in opposition to vastus medialis muscle in pulling the patella laterally. In this latter function it assists in conjunction with vastus medialis muscle to maintain patella tracking (Paoloni *et al.,* 2011; Pattyn *et al.,* 2011; Standring 2009; Moore and Dalley, 2006). This balance between the vastus lateralis and vastus medialis muscles is important in maintaining not only patella-femoral function (Paoloni *et al.,* 2011; Pattyn *et al.,* 2011; Standring, 2009; Moore and Dalley, 2006), but it also impacts on the ability of the ITB to perform its role in stabilising the lower limb during the gait cycle (Cael, 2011; Standring, 2009; Dippenaar *et al*., 2008; Moore and Dalley, 2006; Fredericson, *et al*., 2000; Reid, 1992; Terry *et al*., 1986).

2.3.5 Biceps femoris muscle

The biceps femoris muscle lies within the posterior compartment of the thigh and consists of two heads (long and short), which pass from the pelvis to the fibula and tibia (Standring, 2009; Moore and Dalley, 2006). Each head has its own origin on the pelvis; the long head originates on the ischial tuberosity and the short head originates from the linea aspera and lateral supracondylar line of the femur (Standring, 2009; Moore and Dalley, 2006). Both the biceps femoris muscle heads pass inferolaterally with their distal insertions via a common tendon onto the fibula head (Pribut, 2012; Standring, 2009; Birnbaum *et al*., 2004; Moore and Dalley*.,* 2006; Muhle *et al*., 1999; Simons *et al*., 1999; Orava, 1978). Travell and Simons (1983) also suggest that the long head may have an attachment to the lateral aspect of the tibia via a small tendinous slip. This latter attachment, along with the fascial sheath that envelopes the biceps femoris muscle are the two points at which this muscle interacts with the ITB (Pribut, 2012; Cael, 2011; Birnbaum *et al.*, 2004; Moore and Dalley*.,* 2006; Muhle *et al.*, 1999; Simons *et al.*, 1999; Orava, 1978).

The biceps femoris muscle's main functions include flexing of the tibio-femoral joint, external rotation of the thigh when the knee is flexed, and assisting with hip extension when starting to walk. In addition, the biceps femoris muscle, in conjunction with the ITB, shifts into a more lateral position in relation to the tibia when the knee is flexed to 90°. Therefore, contraction of the TFL and biceps femoris muscle produces 40° of lateral (external) rotation of the tibia at the tibio-femoral joint, when the femur is fixed (Standring, 2009; Moore and Dalley, 2006). Furthermore, the hamstring muscles' play an important role in that it aids in stair climbing and facilitates deceleration of the body during the gait cycle (walking or running) (Noakes, 2003; Noakes, 1992; Travell and Simons 1983). In addition, previous literature found that both a functional and anatomical link between the biceps femoris muscle and sacrotuberous ligament exist, and that through this connection it facilitates an important intrinsic role in providing sacroiliac stability (Adams and Dolan, 1997; van Wingerden *et al.*, 1993; Vleeming *et al.*, 1989(a); Vleeming *et al.*, 1989(b)). Therefore, dysfunction in the biceps femoris muscle may impact negatively on the ITB because of this indirect functional relationship, and subsequently predispose an athlete to ITBFS.

Furthermore it must be noted at this point that the four muscles made reference to, each have a direct connection to the ITB. However, omission of their respective agonist muscle groups', antagonist muscles and synergist muscles was not an oversight, as previous literature has indicated the effects of muscle imbalances on functional activity and resultant kinematic chain dysfunction and vice versa. Therefore, any dysfunction in theses muscles or negative effects as a consequence of joint dysfunction on these muscles may have an effect on the ITB, and subsequently predispose an athlete to the development of ITBFS (Barwick *et al.*, 2012; Bergmann and Peterson, 2011; Cael, 2011; Paoloni *et al.,* 2011; Pattyn *et al.,* 2011; Fujii et al., 2010; Dippenaar *et al.*, 2008; Pribut, 2008; White *et al.,* 2008; Hansen et al., 2007; Hannon, 2006; Hubbard *et al.*, 2006; Morris, 2006; Haldemann, 2005; Willems *et al.*, 2005; Birnbaum *et al.*, 2004; Gunter and Schwellnus, 2004; Lin *et al.*, 2004; Lun *et al.*, 2004; White *et al.*, 2004; Cookson, 2003; Denegar *et al.*, 2002; Gruen *et al.*, 2002; Taunton *et al.*, 2002; Fredericson *et al.*, 2000; Anderson *et al.*, 2001; Orchard *et al.*, 1996; Powers *et al.*, 1996; Messier *et al.*, 1995; Kendall *et al.*, 1993; Barber and Sutker, 1992; Reid, 1992; Anderson, 1991; Bernard and Kirkaldy-Willis, 1987; Terry *et al.*, 1986; McNicol, 1981; Noble, 1980; Renne, 1975).

In order to understand this functional relationship between the above muscles and their associated joints, along with their impact on the ITB, it is necessary to understand the biomechanics of these structures. Therefore, the next section looks at the anatomy and biomechanics of the joints related to the ITB.

2.4 Joints related to the ITB

According to Moore and Dalley (2006), the skeleton of the lower limb can be divided into two functional components:

- Pelvic girdle and
- Bones of the free lower limb/ kinematic chain.

The pelvic girdle forms a bony ring and consists of the sacrum, which connects the axial skeleton to the pelvic girdle posteriorly, and the two hip bones (formed by fusion of the ilium, ischium, and pubic crest), which are joined anteriorly at the symphysis pubis (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). The pelvic girdle's primary function includes bearing the weight of the upper body, as well as transferring weight from the axial skeleton (vertebral column) through the sacroiliac joints to the pelvic girdle and subsequently through the hip joints to the femurs, and providing attachments for muscles of the lower limb and the axial skeleton (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). The femoral bones are arranged at an oblique angle within the thighs resulting in the knees lying directly underneath the trunk, which restores the centre of gravity of the body (Norkin and Levangie, 2011; Magee, 2008). In females, the femoral bones are directed more obliquely due to a wider pelvis (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). The distal end of each femur articulates with the corresponding patella and tibia of the same leg forming the knee or tibio-femoral joint and the patella-femoral joint (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). The fibula serves as an attachment point for muscles at its proximal end and contributes to the formation of the ankle mortise at its distal end with limited involvement in weight-bearing (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). Weight is transferred through the femurs onto the tibia and from the tibia to the talus at the ankle joint, which forms the keystone of the foot (Standring, 2009; Magee, 2008; Moore and Dalley, 2006).

2.4.1 Sacroiliac joint

Part of the pelvic girdle, the two sacroiliac joints are formed between the sacrum and the two pelvic bones (os coxa) ((Standring, 2009; Magee, 2008; Moore and Dalley, 2006).

According to Moore and Dalley (2006), Brolinson *et al*. (2003) and Harrison *et al*. (1997) the sacroiliac joints are strong, weight-bearing diarthrodial joints that are orientated at oblique angles to the sagittal plane, and consist of two articular surfaces: an anterior synovial joint and a posterior syndesmosis (or fibrous) joint. In addition, the joints are irregularly shaped, but their surfaces are congruent with interlocking elevations and depressions (Magee, 2008; Moore and Dalley, 2006; Bernard, 1997; Snijders *et al*., 1997; Willard, 1997; Mitchell, 1995; Willard, 1995; Williams, 1995; Vleeming *et al*., 1990(a); Vleeming *et al*., 1990(b); Bowen and Cassidy, 1981). Harrison *et al*. (1997) suggested that the articular surfaces of the sacrum and ilium are not arranged uniformly, but have more of an overall "propeller" shape with the superior portion being wider anteriorly than posteriorly, and the inferior surface being wider posteriorly than anteriorly (Bernard, 1997; Snijders *et al*., 1997; Willard, 1997; Willard, 1995; Vleeming *et al*., 1990(a); Vleeming *et al*., 1990(b)). This irregularity in the joints' shape provides increased stability in resisting flexion of the sacrum between the ilia when the joints are compressed, but still allows for nutation and counter-nutation to occur during normal movement (Standring, 2009; Moore and Dalley, 2006; Lee, 2004; Vleeming *et al*., 2001; Bernard, 1997; Harrison *et al*., 1997; Snijders *et al*., 1997; Willard, 1997; Mitchell, 1995; Willard, 1995; Williams, 1995; Vleeming *et al*., 1990(a); Vleeming *et al*., 1990(b); Bowen and Cassidy, 1981).

Furthermore, literature suggests that the sacroiliac joints are supported and anchored by several massive ligaments, described by Willard (1995) and Willard (1997) as a continuous ligamentous stocking, resulting in a two part relationship whereby the bony and soft tissue arrangement function as an integrated, complex link between the spine and lower extremities (Vleeming *et al*., 2001; Heidemann *et al*., 1999; Ingber, 1998; Harrison *et al*., 1997; Levin, 1997; Maniotis *et al*., 1997). This is supported by Moore and Dalley (2006) who found that the sacrum is suspended between the iliac bones, by the firm attachments of the anterior, posterior, and interosseous sacroiliac ligaments (Vleeming *et al*., 2001; Heidemann *et al*., 1999; Ingber, 1997; Maniotis *et al*., 1997). The interosseous ligaments are the thickest and strongest of these ligaments, forming the primary structure for transferring weight (Magee, 2008; Moore and Dalley, 2006; Vleeming *et al*., 2001; Willard, 1997; Willard, 1995). These fibres in conjunction with the posterior sacroiliac ligament spans obliquely upward and outward from the sacrum to the ilia, thereby pulling it medially and locking the sacroiliac joints firmly in place when axial weight is applied onto the sacrum (Standring, 2009; Magee, 2008; Moore and Dalley, 2006; Lee, 2004; Vleeming *et al*., 2001; Heidemann *et al*., 1999; Ingber, 1997; Maniotis *et al*., 1997).

Sacroiliac joints vary considerably amongst individuals and within the individual (Bernard, 1997; Harrison *et al*., 1997; Snijders *et al*., 1997; Vleeming *et al*., 1997; Willard, 1997; Mitchell, 1995; Willard, 1995; Williams, 1995; Gatterman, 1990; Bowen and Cassidy, 1981). These variations can be attributed to the sacroiliac joints' mechanical behaviour that is influenced by the structural configuration of the sacrum and ilia, the size and shape of sacroiliac surfaces, the large ligaments that surround the area and the fascial and muscular structures that act on the area (Snijders *et al*., 1997; Vleeming *et al*., 1997; Willard, 1997; Mitchell, 1995; Willard, 1995; Dijkstra *et al*., 1989). This interdigitating relationship between the irregular interlocking surfaces and associated sacroiliac ligaments allows for limited mobility at the sacroiliac joints, permitting only slight gliding and rotary translation (Standring 2009; Moore and Dalley, 2006; Harrison *et al*., 1997; Snijders *et al*., 1997; Vleeming *et al*., 1997; Willard, 1997; Mitchell, 1995; Gatterman, 1990).

The sacroiliac joint is considered both a synovial and diarthrodial joint, as part of the sacral articular surfaces are covered by hyaline cartilage and the iliac surfaces are covered by fibrocartilage (Standring 2009; Moore and Dalley, 2006; Lee, 2004; Vleeming *et al*., 2001; Bernard, 1997; Harrison *et al*., 1997; Snijders *et al*., 1997; Willard, 1997; Mitchell, 1995; Willard, 1995; Williams, 1995; Gatterman, 1990; Bowen and Cassidy, 1981). Some studies have suggested that the ilia articular surfaces may, in part, also be of hyaline cartilage (Bernard, 1997; Harrison *et al*., 1997; Williams, 1995). In addition, previous literature suggested that the hyaline cartilage on the sacral articular surfaces is three times thicker than that of the fibrocartilage that surrounds the articular surfaces of the ilia (Bernard, 1997; Harrison *et al*., 1997; Snijders *et al*., 1997; Willard, 1997; Mitchell, 1995; Williams, 1995; Bowen and Cassidy, 1981. This is supported by Lee (2004) who reports a ratio of 1:3 between iliac and sacral surfaces.

Based on the above structure, the sacroiliac joints' main function is to provide increased stability to the pelvic ring by limiting movement between the sacrum and ilia, whilst allowing for limited motion that supports and affects the spinal column that arises from it (Norkin and Levangie, 2011; Standring, 2009; Magee, 2008; Moore and Dalley, 2006; Vleeming *et al*., 2001). This collectively allows for the transmission of forces between the axial skeleton and lower extremities and vice versa (Norkin and Levangie, 2011; Standring, 2009; Magee, 2008; Moore and Dalley, 2006; Vleeming *et al*., 2001). The structure also dampens and distributes ground reaction forces during walking or running (Standring, 2009; Moore and Dalley, 2006; Vleeming *et al*., 2001; Harrison *et al*., 1997). As a result of the close association between the gluteus maximus, gluteus medius and piriformis muscles with the sacroiliac joint, there is an increased likelihood of joint and muscular dysfunction due to changes in passive (form closure), active (force closure) and control (motor subsystem) systems that control the sacroiliac joint (Panjabi, 2003; Adams and Dolan, 1997; Vleeming *et al*., 1995; Snijders *et al*., 1993; van Wingerden *et al*., 1993; Vleeming *et al*., 1989(a); Vleeming *et al*., 1989(b)). The passive subsystem is involved in the optimal functioning of the osteo-articular structures (joints and ligaments) (Brolinson *et al*., 2003; Mens *et al*., 2001) whereas the active subsystem stems from the local muscles (Akuthota and Nadler, 2004; Brolinson *et al*., 2003). Lastly, the control subsystem refers to the central and peripheral neural connections that co-ordinate the interactions of the passive and active systems (Stevens *et al.,* 2006; Brolinson *et al*., 2003; Mens *et al*., 2001; Jull and Richardson, 2000). It is therefore evident that at the bare minimum, the gluteus maximus and hamstring muscles forms a component part of sacroiliac joint dysfunction (Hillermann *et al*., 2006; Morris, 2006; Cohen, 2005; Cookson, 2003; Adams and Dolan, 1997; Vleeming *et al*., 1995; Snijders *et al*., 1993; van Wingerden *et al*., 1993; Kirkaldy-Willis, 1992; Vleeming *et al*., 1989(a); Vleeming *et al*., 1989(b)). As a result, its effect on the anatomical and physiological relationship with the ITB would be compromised, predisposing to dysfunction of the ITB and thus ITBFS (Barwick *et al*., 2012; Cael, 2011; Paoloni *et al.,* 2011; Pattyn *et al.,* 2011; Fujii *et al*., 2010; Dippenaar *et al*., 2008; Pribut, 2008; White *et al.,* 2008; Hannon, 2006; Hubbard *et al*., 2006; Willems *et al*., 2005; Birnbaum *et al*., 2004; Gunter and Schwellnus, 2004; Lin *et al*., 2004; Lun *et al*., 2004; White *et al*., 2004; Denegar *et al*., 2002; Gruen *et al*., 2002; Taunton *et al*., 2002; Fredericson *et al*., 2000).

2.4.2 Hip joint

The hip joint consists of the acetabulum and head of femur (Standring, 2009; Moore and Dalley, 2006). This forms the direct connection between the pelvic girdle and lower limb (Norkin and Levangie, 2011). The hip joint is a strong, multi-axial ball and socket type synovial joint (Standring 2009; Magee, 2008; Moore and Dalley, 2006). The acetabulum is formed by the three separate bones (ilium, ischium and pubis) which constitute the pelvic bone (os coxa), and appears as a large cup shaped spherical cavity situated on the anterolateral aspect of the pelvic bone and represents the socket in which the head of the femur (representing the ball) articulates (Magee, 2008; Moore and Dalley, 2006). The joint is reinforced by the surrounding musculature (e.g. gluteus maximus, gluteus medius, piriformis, and TFL muscles) and ligaments (e.g. iliofemoral, pubofemoral, and ischiofemoral) which allow for greater stability over a wider range of motion (ROM) (Standring 2009; Magee, 2008; Moore and Dalley, 2006).

Although the hip joint may have an anatomically close relationship to the ITB (Moore and Dalley, 2006), its functional impact is at best indirect through the surrounding musculature (i.e. piriformis and gluteus medius muscles) which, according to Norkin and Levangie (2011), could indirectly play a role in influencing the proper functioning of the ITB. These muscles span from the sacrum and iliac crest respectively to attach to the greater trochanter of the femur (Standring, 2009). This is also the region of fascial confluence of the fascia related to the gluteus maximus muscle and the TFL muscle into the fascial structure of the ITB (Pribut, 2012; Birnbaum *et al*., 2004; Moore and Dalley*.,* 2006; Muhle *et al*., 1999; Simons *et al*., 1999; Orava, 1978). It has therefore been theorized that the piriformis and gluteus medius musculotendious insertions form a joint relationship in the confluence of the lateral fascial sheath forming the ITB (Sahrmann, 2002). Furthermore, the piriformis muscle could indirectly influence the ITB as it spans between the sacrum and the femur, thereby facilitating external rotation as an aid to the gluteus maximus muscle (Norkin and Levangie, 2011). Therefore, subsequent sacroiliac joint dysfunction may compromise the piriformis muscle effecting changes in pelvic mechanics, which are thought to have an impact on the function of the ITB and its role in stabilizing the lower extremity leading to ITBFS (Morris, 2006; Travell and Simons, 1983).

2.4.3 Knee joint

The knee joint complex consists of three interdependent articulations, the tibio-femoral or knee joint (lateral and medial femoral condyles of the femur and that of the tibia), the tibio-fibular (between the tibia and fibular) and the patello-femoral joint (patella and the femur). The latter is an extension of the tibio-femoral joint (Standring, 2009; Magee 2008; Moore and Dalley, 2006).

The tibio-femoral joint is a large superficial joint that functions as a synovial type, modified hinge joint allowing flexion and extension with subsequent gliding, rolling, and rotation about the vertical axis (Standring, 2009; Magee 2008; Moore and Dalley, 2006). Thus, the knee joint is designed for straight line locomotion (forward movement in sagittal plane), particularly given its awkward location between two long bones and incongruent articular surfaces. This allows for large amounts of movement between the femur and tibia, which contributes to the joints' particularly weak mechanical nature and the subsequent increased instability that makes it more susceptible to traumatic (e.g. direct blow) injury (Standring, 2009; Magee

2008; Moore and Dalley, 2006). The instability is partly limited by two menisci (lateral and medial) that fill the space between the tibia and femur for added articular congruency (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). Furthermore, the lateral femoral condyle is placed slightly more anteriorly than the medial femoral condyle, thus preventing lateral dislocation of the patella (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). In addition, the tibio-femoral joint is further supported by the strong musculature and ligaments that surround and reinforce the joint, providing added stability and guided movement respectively (Standring, 2009; Magee 2008; Moore and Dalley, 2006). These latter two functions are particularly important for the patello-femoral joint (Magee, 2008). To this end, Earl and Hoch (2011), Heng and Haw (1996), and Hungerford and Barry (1979) made reference to the biomechanical importance of the patella and how it contributes towards the effective functioning of the quadriceps femoris musculature in maintaining straight line locomotion at the tibio-femoral joint during knee extension and flexion.

Therefore, an imbalance in the antagonistic relationship between the medial and lateral quadriceps musculature can result in abnormal functional movement at the patella-femoral joint (e.g. abnormal patella tracking) indirectly affecting the ITB (Paoloni *et al.,* 2011; Pattyn *et al.,* 2011; Magee, 2008; Lin *et al*., 2004; Sahrmann, 2002; Chaitow and Delany, 2002; Simons *et al*., 1999). Previous studies support this theory, but go on to suggest that quadriceps femoris muscle inhibition is due to the contracture and pain associated with ITBFS (Dippenaar *et al*., 2008; Suter *et al*., 2000). However, Birnbaum *et al*. (2004), Gunter and Schwellnus (2004) and Lin *et al*. (2004) suggested that mal-alignment of the lower limb (e.g. tibial torsion) may contribute to an increased quadriceps angle (Q angle) causing lateral patella tracking, which is thought to impact on the proper functioning of the ITB (Noehren *et al*., 2007; Gunter and Schwellnus, 2004; Norris, 2004 Taunton *et al*., 2002; Fredericson *et al*., 2000; Kirk *et al*., 2000; Messier *et al*., 1995). Therefore, it could also be theorized that the key aspects of the patella-femoral joint, with regards to the ITB, are the:

- surrounding and closely related musculature (e.g. vastus lateralis, biceps femoris, TFL muscles),
- lateral ligaments and capsule of the tibio-femoral joint, and the
- capsule of the tibio-fibular joint and the supporting ligamentous structures (retinaculum).

These key aspects are all attached to the distal end of the ITB as it passes over these structures to its final destination onto the lateral aspect of the tibia (Gerdy's tubercle) (Standring 2009; Magee, 2008; Moore and Dalley, 2006). Thus, it is likely that disruption of these structures may predispose to the development of ITBFS (Norkin and Levangie, 2011; Dippenaar *et al*., 2008; Norris, 2004; Lin *et al*., 2004; Suter *et al*., 2000; Simons *et al*., 1999).

2.4.4 Tibio-fibular joints

The lower limb (or leg) consists of two bones, the tibia and fibula, which connect to form two joints: the superior tibio-fibular joint and the inferior tibio-fibular joint (Standring, 2009; Magee, 2008; Moore and Dalley, 2006).

2.4.4.1 Superior tibio-fibular joint:

This joint is a plane synovial joint formed between two articulations of the fibular head and the posterolateral surface of the lateral tibial condyle (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). The joint is surrounded by a dense joint capsule (attached to the articular surfaces of the tibia and fibula), which is reinforced by anterior and posterior tibio-fibular ligaments which pass superomedially from the fibular head to the lateral tibial condyle (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). The popliteal tendon also crosses the joint posteriorly, providing reinforcement of the joint (Moore and Dalley, 2006). The superior tibio-fibular joint is restricted in motion, allowing only slight upward movement of the fibula to occur when the foot is dorsiflexed at the talocrural joint, due to the talus wedging between the malleoli (Standring 2009; Magee, 2008; Moore and Dalley, 2006).

2.4.4.2 Inferior tibio-fibular joint (Syndesmosis) and Ankle joint:

This joint is formed between the distal ends of the tibia and fibula bones that are united by the strong syndesmosis / interosseous membrane uniting the shafts of these bones. The anterior and posterior tibio-fibular ligaments, and the interosseous membrane that joins these bones provide for a compound fibrous joint (Standring 2009; Magee, 2008; Moore and Dalley, 2006) and a synovial talocrural joint with the talus at their distal most end (Moore and Dalley, 2006).

These articulations and the strong ligamentous support resist the downward pull placed on the fibula by the musculature attached to it (Magee, 2008; Moore and Dalley, 2006). In addition, the rigid association between the superior tibio-fibular joint and its inferior counterpart means that both cannot move without concomitant movement at the other joint (Norkin and Levangie, 2011). The proximal and distal tibio-fibular joints are thus dynamic entities that facilitate movement during normal functional activities (Standring 2009; Magee, 2008; Moore and Dalley, 2006; Meadows, 2002; Levangie and Norkin, 2001; Leardini *et al.*, 2000; Soavi *et al.*, 2000; Kapandji, 1970). Thus a lack of normal functional activities within these joints may negatively impact on the ITB resulting in ITBFS, which may be restored by manipulation of the respective joints.

2.4.5 Ankle joint

The inferior tibio-fibular joint together with the trochlea of the talus forms the talocrural joint (more commonly known as the mortise or ankle joint), which is a synovial hinge-type joint (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). The tibia's inferior surface forms the roof of the malleolus mortise which transfers the body's weight onto the talus, and its medial malleolus (medial wall / medial crus) articulates with the medial surface of the talus (Standring, 2009; Magee, 2008; Moore and Dalley, 2006). The fibula forms the lateral malleolus (lateral wall / lateral crus) which articulates with the lateral surface of the talus (Standring 2009; Magee, 2008; Moore and Dalley, 2006).

The posterior wall is formed by the strong, deep transverse ligament that spans between the distal ends of the medial and lateral malleoli and the talus (Magee, 2008; Moore and Dalley, 2006). The malleoli "grip" the talus tightly during ankle movement, especially when the foot is dorsiflexed (Levangie and Norkin, 2001; Hintermann, 1999) as this is when the larger anterior part of the talus becomes wedged between the malleoli (closed packed position) (Subotnick, 1999; Reid, 1992). Therefore, the deep transverse ligament allows slight movement to permit wedging of the wider anterior part of the trochlea of the talus into the crura during dorsiflexion of the ankle joint (Subotnick, 1999). The anterior wall does not exist as it forms an integral opening for movement (Magee, 2008; Moore and Dalley, 2006). Levangie and Norkin (2001) and Hintermann (1999) indicated that the laxity of the anterior joint capsule allows for a greater degree of plantarflexion compared to dorsiflexion. During plantarflexion, the talocrural joint is relatively unstable due to the narrower posterior part of the talus sitting loosely in the "wider" talocrural joint, which predisposes it to injury (open packed position) (Subotnick, 1999; Reid, 1992). To provide stability in this position, the talocrural joint is supported by the joint capsule and reinforced by the lateral and medial (deltoid) ligaments (Magee, 2008; Moore and Dalley, 2006). Thus, the integrity of bony and ligamentous structures of this joint play an important role in the normal functioning of the talocrural motion and therefore providing stability (Standring 2009; Magee, 2008; Moore and Dalley 2006).

With respect to injury induced hypermobility, this causes an increase in the accessory movement at a joint (Panjabi, 1992; Siegler *et al.*, 1990). Therefore, increased accessory movement produces abnormal patterns of movement around the instantaneous axis of rotation (IAR) (Bogduk, 1997; White and Panjabi, 1990). Concomitantly, the occurrence of hypomobility at any joint causes an abnormal restrictive barrier to accessory movement, which causes changes in the normal pattern of movement of the IAR of the joint (Bogduk, 1997; White and Panjabi, 1990; Sammarco *et al.*, 1973). Wolfe *et al.* (2001), Baumhauer *et al.* (1995), Kannus and Renström (1991) and Milgrom *et al.* (1991) suggested that, the most common mechanism of ankle injury involves excessive inversion of the ankle complex. Therefore, it is likely that those structures limiting this movement (e.g. lateral joint capsule) may become dysfunctional (Denegar and Miller, 2002). As a result, it has been suggested that after injury to the ankle, hypomobility occurs at the ipsilateral subtalar joint (Meadows, 2002; Greenman, 1996), talocrural joint (Denegar *et al.*, 2002; Green *et al.*, 2001), distal tibio-fibular joint (Kavanagh, 1999; O'Brien and Vicenzino, 1998; Hetherington, 1996), and / or proximal tibio-fibular joint (Meadows, 2002; Greenman, 1996). This occurs in order to compensate for the lack of ligamentous integrity / injury (Grindstaff *et al.*, 2011). If the hypomobility of the ankle joint complex is not addressed, it further predisposes it to continued dysfunction (Meadows, 2002; Kavanagh, 1999; Lewit, 1999), including altered fibula motion (with anterior and inferior displacement at the proximal or distal tibio-fibular joint) (Meadows, 2002; Dananberg *et al.*, 2000; Johnson, 1989); decreased dorsiflexion ROM (Drewes *et al.*, 2009), and restricted joint mobility (Denegar *et al.* 2002). These common impairments are known to alter joint mechanics during functional activities, such as walking or running (Drewes *et al.*, 2009; Monaghan *et al.*, 2006).

More proximally, the degree of superior tibio-fibular dysfunction can be directly related to the degree to which the talar complex of the ankle is able to facilitate dorsiflexion (Barwick *et al.*, 2012; Grindstaff *et al.*, 2011; Noehren *et al.*, 2006; Niemuth *et al.*, 2005; Denegar and Miller, 2002; Fredericson *et al.*, 2000; Orchard *et al.*, 1996; Messier *et al.*, 1995; Ogden, 1974). This shows that a lack of dorsiflexion increases the likelihood of proximal tibio-fibular dysfunction (Grindstaff *et al.*, 2011), thus indicating that the lower limb kinematic chain biomechanics (see Section 2.4.4) may have a predisposition towards ITB dysfunction when fixated joints are present. This is not dissimilar to talocrural joint restrictions (see Section 2.4.5) and sacroiliac joint restrictions (see Section 2.4.1). Therefore, in theory, the role of these joints should be considered in the treatment of ITBFS. Thus, this research aimed to add to the literature by evaluating the effect of superior tibio-fibular manipulation; talar manipulation and sacroiliac joint manipulation singularly and in combination for ITBFS; so to identify a possible missing link in the treatment and management of ITBFS (Brantingham *et al.*, 2012(b); Grindstaff *et al.*, 2011; Brantingham *et al.*, 2009(b)).

Although it has been suggested in pragmatic studies that manipulation may be of benefit to ITBFS patients, research for its use in clinical practice is limited (Brantingham *et al.*, 2012(b); Brantingham *et al.*, 2009(b)). In order to understand how an intervention such as manipulation may affect ITBFS, it is important to first consider the syndrome, its impact and how manipulation is placed in terms of possible treatment options. These topics will be addressed sequentially through the remaining sections of this chapter.

2.5 Pathology

2.5.1 Iliotibial band friction syndrome (ITBFS)

James Renne (1975) was the first to describe ITBFS, which is now a well-documented and recognized overuse injury resulting from friction between the iliotibial band and the lateral femoral epicondyle (LFE) (Gerdy's tubercle) of the knee. Renne (1975) pointed out that this friction of the ITB against the LFE is said to occur at around 30˚ of knee flexion and is referred to as the zone of impingement (Farrell *et al.*, 2003; Orchard *et al.*, 1996). It is thought that the condition occurs more as a result of repetition through the impingement zone rather than force and time spent in the impingement zone (Farrell *et al.*, 2003). The thickest portion of the ITB, which is adjacent to the LFE, moves anterior to the axis of motion in the last 30˚ of knee extension and moves posterior to the axis of the motion (and the epicondylar prominence) during knee flexion movements of more than 30˚ (Reid, 1992). The band remains tense in both these positions (Reid, 1992) and with this constant movement friction results in irritation and inflammation of the tissues between the ITB and the LFE (Messier *et al.*, 1995; Noble, 1980; Orava, 1978; Renne, 1975). The particular areas that become irritated and inflamed include the lateral synovial recess (Fredericson *et al.*, 2002; Nishimura *et al.*, 1997; Nemeth and Sanders, 1996; Orava, 1978 Renne, 1975); the posterior fibres of the ITB (Fredericson *et al.*, 2002) and the periosteum of the LFE (Kirk *et al.*, 2000; Nishimura *et al.*, 1997; Noble *et al.*, 1982). It has been suggested that through repetitive irritation, the tissues simply do not have adequate time to heal and the resultant syndrome develops (Kirk *et al.*, 2000).

By contrast, a second theory proposes that the compression of the fat pad, which separates the ITB from the LFE during flexion and extension, results in associated inflammation and pain (Fairclough *et al.*, 2006; Fredericson *et al.*, 2000; Orchard *et al.*, 1996; Holmes *et al.*, 1993; Barber and Sutker, 1992; Schwellnus *et al.*, 1992; Anderson, 1991; Grady *et al.*, 1986; Lindenburg *et al.*, 1984; Noble *et al.*, 1982; Williams, 1980).

Irrespective of the causative mechanism, literature indicates that ITBFS is an acute inflammatory reaction at or near the LFE. A study conducted by Ekman *et al.* (1994) which examined magnetic resonance imaging (MRI) of the ITB, found that patients who presented with ITBFS had thickened iliotibial bands towards the distal insertion in the region of the LFE. This correlates with Mansour *et al.* (2014) who found similar results. This could be suggestive of chronic inflammation of a potential bursa that exists between the fascial band and the LFE (Ekman *et al.*, 1994). Thus, according to Lavine (2010), ITBFS involves pain in the region of the LFE or slightly inferior to it, that occurs after repetitive motion of the knee.

Thus, irrespective of the mechanism of injury or the chronicity of the inflammatory process, ITBFS is a debilitating overuse injury that can greatly affect an athlete's ability to perform (Strauss *et al.*, 2011; Ellis *et al.*, 2007; Fredericson and Wolf, 2005; Khaund and Flynn, 2005; Taunton *et al.*, 2002; Wood, 1997).

2.5.2 Epidemiology

Recreational activities amongst people are continuously increasing with increased participation in outdoor activities, including running (Paluska, 2005). Running accounts for a large number of associated sports injuries (Lun *et al.*, 2004). In support of this, the literature has found the incidence rate for injury to be between 24% - 82% in runners alone. In addition reports indicated that numerous runners struggle with lateral knee pain (Lun *et al.*, 2004; Taunton *et al.*, 2002; Kirk *et al.*, 2000; Wen *et al.*, 1998; Anderson, 1991; Newell and Bramwell, 1984). As a result, ITBFS is one of the most prevalent overuse injuries known to athletes (Holmes *et al.*, 1993; Noble, 1985; Noble et al., 1982; Noble, 1979; Orava, 1978), and is the second most common cause of lateral knee pain (Taunton *et al.*, 2002). Sutker *et al.* (1985) evaluated 48 participants for ITBFS and found that 73% (35 participants) presented with unilateral ITBFS.

The incidence of ITBFS extends between the ranges of 1.6% to 52% in runners (Lavine, 2010; Taunton *et al.*, 2002; Fredericson *et al.*, 2000; Messier *et al.*, 1995; Linenger, 1992; McNicol *et al.*, 1981; Orava, 1978), and 15% to 24% in cyclists (Farrell *et al.*, 2003; Holmes *et al.*, 1993). In addition, it must be noted that ITBFS is not only limited to runners and cyclists, but the development of ITBFS can be observed in athletes participating in a variety of sports, including but not limited to volleyball, tennis, soccer, skiing, weight lifting and aerobics (Messier *et al.*, 1995). However, with the increased popularity of running, the incidence of ITBFS can be as high as 50% (Taunton *et al.*, 2002; Fredericson *et al.*, 2000; Kirk *et al.*, 2000; Messier *et al.*, 1995).

2.6 Aetiological factors

Injuries are a common reason for withdrawal from sporting and recreational activities amongst athletes (Lun *et al.*, 2004). With ITBFS having such a high incidence and prevalence rate, it stands to reason that there are a wide number of possible causative agents that are responsible for its development (Lavine, 2010; Taunton *et al.*, 2002; Fredericson *et al.*, 2000; Messier *et al.*, 1995; Linenger, 1992; Noble, 1985; McNicol *et al.*, 1981; Orava, 1978). These are categorised into extrinsic factors (external or risk factors that are usually environmental in nature (Lun *et al.*, 2004; Messier et al., 1995; McKenzie *et al.*, 1985; Sperryn and Restan, 1983; Clement *et al.*, 1981; McNicol *et al.*, 1981; James *et al.*, 1978)) and intrinsic factors (factors personal to the athlete (Gosling *et al.*, 2008; Kendall et al., 1993; Reid, 1992)).

Thus, intrinsic factors may include the following: age (Burns *et al.*, 2003), gender (Egermann *et al.*, 2003), body form or anthropometric characteristics (Vleck and Garbutt, 1998), running experience (Villavicencio *et al.*, 2006), previous injury or lack thereof (Korkia *et al.*, 1994), and biomechanics of running (Manninen and Kallinen, 1996; Gosling *et al.*, 2008). Whereas, examples of extrinsic risk factors include: training hours per week (O'Toole *et al.*, 1989), training / running distance per week (Massimino *et al.*, 1988), training / running sessions per week (Vleck and Garbutt, 1998), training / running intensity (Manninen and Kallinen, 1996), presence or absence of a trainer (Collins *et al.*, 1989), provision and access to medical care (Egermann *et al.*, 2003), the type of running surface (Korkia *et al.*, 1994) and cross training / participation in other sporting activities (Gosling *et al.*, 2008; Collins *et a*l., 1989).

Each of these factors will now be discussed in more detail, indicating how these factors may contribute to ITBFS.

2.6.1 Extrinsic

2.6.1.1 Camber / Track

Lindenburg *et al.* (1984) suggested that the camber (slope) of the road plays a contributing role in the development of ITBFS. Similarly, Sutker *et al.* (1985) suggested that running on a cambered terrain would predominantly have an effect on one leg. Numerous researchers reasoned that the sloping effect of the road could create a functional/ biomechanical long leg – short leg syndrome (Fujii *et al.*, 2010; Landrum *et al.*, 2008; Vicenzino *et al.*, 2006; Whitman *et al.*, 2005; Decker *et al.*, 2003; Pinshaw *et al.*, 1984). This continuous perpetuating factor is known to affect muscle functioning over prolonged periods of repetitive training (e.g. running the track in the same direction; running the same course in the same direction) (Decker *et al.*, 2003). This causes muscle imbalances that lead to the development of ITBFS (Landrum *et al.*, 2008; Vicenzino *et al.*, 2006, Whitman *et al.*, 2005; Fujii *et al.*, 2010).

2.6.1.2 Shoes

Shoes represent an important training tool in the world of a runner (Noakes, 2003). Shoes provide protection and act as a shock absorber and stabilizer during running (Subotnick, 1999). The wrong shoe type may affect foot biomechanics or influence ground reactive forces that enter through the shoe's sole affecting the foot's natural ability to absorb and properly disperse the shock through the foot up the leg / kinematic chain (Larson, *et al.*, 2011; Huston *et al.*, 2001; Zhang *et al.*, 2000; McNitt-Gray *et al.*, 1993). This has been shown to predispose an athlete to ITBFS (Larson, *et al.*, 2011). A previous study conducted by Messier *et al.* (1995), indicated that a direct correlation exists between the numbers of athletes injured and the use of a particular shoe (Messier, *et al.*, 1995).

Similarly, the use of worn running shoes, which have lost their shock absorbing ability, have been found to place an athlete at a significant risk for the development of ITBFS and recurrent episodes of ITBFS (Messier *et al.*, 1995; Clement *et al.*, 1983). This was supported by the outcome of Messier's *et al.* (1995) study in which it was found that uninjured runners were able to exceed their shoe life expectancy by approximately 170 miles (272 km). This implies that the runners with optimal biomechanics are better able to fully utilise their shoes' shock absorption capacity, which was not seen in runners that had a previous injury. The latter seems to hold true in that the runners with previous injuries wore their shoes out faster and were predisposed to injury sooner than their uninjured counterparts (Messier *et al.*, 1995).

Thus, it would seem that the manner in which the foot strikes the ground is crucial in the dispersion of the ground reactive forces through the body, which could ultimately place excessive strain on the:

- pelvic stabilisers,
- kinematic chain (ankle, knee, hip) and
- kinetic (ankle joint, knee joint, hip joint) structures,

thereby having an indirect effect on the ITB, predisposing the athlete to ITBFS (Decker, *et al.*, 2003).

2.6.1.3 Training

A number of training factors have been associated with the development of ITBFS (Fredericson *et al.*, 2000; Kirk *et al.*, 2000; Messier *et al.*, 1995; Sutker *et al.*, 1985; Noble *et al.*, 1982; Orava, 1978). According to Messier *et al.* (1995), who conducted a study on the aetiology of ITBFS, there are five important factors that play a significant role in predisposing an athlete to ITBFS. These include: weekly mileage, training pace, number of months utilising a single training protocol, the percentage time spent on a composition track, and the percentage of time spent training. According to Fredericson *et al.* (2000), excessive mileage is the biggest influential contributor / predictor for the development of ITBFS; however, it is unlikely that mileage alone will result in ITBFS (Fredericson *et al.*, 2000; Kirk *et al.*, 2000; Sutker *et al.*, 1985; Noble *et al.*, 1982; Orava, 1978). Messier *et al.* (1995) suggested that mileage interacts with several other variables (i.e. anthropometric, biomechanical, and training factors) that may combine with excessive mileage in contributing to ITBFS. These authors also suggested that if an athlete with prerequisite factors remains within the threshold zone (ability of athlete to adapt to the environment), the athlete is likely to remain injury free. However, exceeding the threshold will result in an overuse injury (Gosling *et al.*, 2008; Messier *et al*,. 1995).

In addition, Messier *et al.* (1995) cited a previous study (Collins *et al.*, 1989) that suggested that incorporating cross-training as part of an athlete's training programme is a good method of avoiding overuse injuries (Gosling *et al.*, 2008 Clement *et al.*, 1984; James *et al.*, 1978). However, contrary to the statement above, Marti *et al.* (1988)

suggested that participation in multidisciplinary sport activities does not reduce an athlete's risk of sustaining a sport injury (Messier *et al*., 1995). This controversy may be related to the degree of impact within the sporting activities that are cross trained, the intensity of one or both sports activities and the healing / rest time between participation in these sports activities or a combination of these factors (Gosling *et al*., 2008; Manninen and Kallinen, 1996).

Messier *et al*. (1995) also noticed that ITBFS is more prevalent amongst novice runners with less experience. They found that these athletes deviate more frequently from their training protocol and are more likely to exceed the mileage threshold. In addition, it was found that athletes who spent more time on the track were more at risk of developing ITBFS and although there was no conclusive evidence exists, it has been suggested that interval training as part of the training protocol (used to develop speed and stamina) may also play a role in the development of ITBFS (Manninen and Kallinen, 1996).

Another contributing training factor that has been associated with ITBFS is downhill running (Fredericson and Wolf, 2005). It was suggested by Messier *et al*. (1995), Barber and Sutker (1992) and Linderburg *et al*. (1984) that a consequence of downhill running is increased knee flexion at heel strike, thereby amplifying friction over the LFE by the ITB, predisposing runners to ITBFS. This is in agreement with Renne (1975), who suggested that friction between the ITB and LFE occurs around 30° of knee flexion; an area referred to as the zone of impingement (Farrell *et al*., 2003; Orchard *et al*., 1996). Farrel *et al*. (2003) suggested that ITBFS is a consequence of excessive repetition through the impingement zone rather than force and time spent in the impingement zone. In addition, Reid (1992) asserted that in the impingement zone, the ITB remained tense, resulting in excessive friction which may cause irritation and inflammation of the tissues between the ITB and the LFE, resulting in ITBFS (Renne, 1975; Orava, 1978).

2.6.1.4 Trauma

ITBFS is a common debilitating overuse injury affecting athletes (Fredericson *et al*., 2000; Orchard *et al*., 1996; Holmes *et al*., 1993; Noble, 1985; Noble et al., 1982; Noble, 1980; Noble, 1979; Orava, 1978). ITBFS has always been classified as a friction syndrome associated with overuse injury of the ITB that result in lateral knee pain (Farrell *et al*., 2003; Orchard *et al*., 1996; Renne, 1975). However, Terry *et al*. (1993) suggested that a relationship may exist between ITB disruption and anterior cruciate ligament (ACL) tears. This is supported by Mansour *et al*. (2014) who studied 200 MRI scans of the ITB in acute knee injury. They found that ITB injury (defined as either sprained (grades 1 and 2) or torn (grade 3)), rarely occurs in isolation and that a correlation seems to exist between ITB injury and acute tibio-femoral injury. Their study included several acute knee injury cases representing anterior cruciate ligament (ACL) tears (97); patellar dislocation (31); medial collateral ligament (MCL) tears (25); meniscal tears (10); ACL and posterior cruciate ligament (PCL) tears (9); PCL tears (7); bone bruising only (7); ACL tears and patellar dislocation (1). They concluded that ITB injury is a fairly regular occurrence in knee trauma and suggested that it is an important gauge of substantial internal injury. However, their study was purely based on radiological features with no physical examination of the ITB in the injured knees. It is therefore, uncertain whether the association of ITBFS as represented by swelling and other radiological features was as a result of an external force (i.e. acute trauma induced by a hockey stick or tackle) or the presence of ITBFS (chronic injury) as a stand-alone syndrome or ITBFS associated with the ligament disruptions (acute injury).

It does, however, stand to reason that trauma to the lateral aspect of the thigh may place additional stress on the ITB through the production of bruising, swelling, reactive muscle spasm or a combination of these. This may predispose ITB to tighten (not unlike that which is seen in the development of trauma induced trochanteric bursitis) (Reid, 1992), resulting in an ITBFS.

The four extrinsic factors – camber, shoes, training and trauma – each impact on the lower extremity either through changes in muscle balance, joint function or both, thus changing the biomechanics of the lower extremity. These changes result in adaptive joint mobility changes which predisposes the lower kinematic chain to injury (e.g. ITBFS). In addition to appropriate management of extrinsic factors to reduce injury; it is important to understand the role that manipulation play in restoring normal function and reducing the clinical signs and symptoms once injuries present (Brantingham *et al*., 2012(b)). In addition, the use of manipulation to address regions of hypomobility may also assist in preventing further injury (Brantingham *et al*., 2012(b)). Thus, this study investigated the effects of manipulation on the sacroiliac joint, superior tibio-fibular joint, the talocrural joint and a combination of these joints on the clinical presentation of ITBFS.

2.6.2 Intrinsic

2.6.2.1 Gender

It has long been hypothesised that gender plays a role in the predisposition of sport injuries in athletes (Decker *et al.*, 2003). This is supported by previous literature that suggests that females execute high functional manoeuvres (e.g. jumping from an elevated position) differently, thereby predisposing them to greater knee joint stress (Wiesenfeld-Hallin, 2005; Wise et al., 2002; Woitys *et al.*, 2002; Colby *et al.*, 2000; Cowling and Steele, 2001; Huston *et al.*, 2001; Kirkendall and Garrett, 2000), and subsequently increasing the risk for ligamentous injury (Decker *et al.*, 2003). This is supported by previous studies that indicate that females' knees have a greater degree of extension during heel strike, resulting in greater total energy absorption, which contributes to a greater force being placed through the anterior cruciate ligaments (Decker *et al.*, 2003). This is further reinforced by the fact that females have inadequate neuromuscular functioning of their hamstring musculature, which often predisposes them to compensatory injuries more than males (e.g. ITBFS) (Colby *et al.*, 2000; Cowling and Steele, 2001; Huston *et al.*, 2001; Malinzak *et al.*, 2001; McLean *et al.*, 1999; Rozzi *et al.*, 1999).

From the above it can be argued that gender does have a role to play in the predisposition towards ITBFS. This is also supported by previous literature that states that being slightly taller, heavier and stronger are positive attributes towards protecting an athlete from running injuries. Thus pertaining to the attributes more commonly associated with males rather than females (Messier, *et al.*, 1995; Powell, *et al.*, 1986), there may be different factors that influence the development of ITBFS. It is possible that the anatomic, kinematic and biomechanical differences between the male and the female pelvis, its articulations and the resultant relationship with the lower extremity also have an effect on predisposing males and females to different types of injuries (Hyde and Gengenbach, 2007; Subotnick, 1999; Reid, 1992). As an example, females are more likely to have a wider pelvis with a tendency to a genu valgum position of the knees and therefore they have been anecdotally noted to have a higher incidence of trochanteric bursitis (Reid, 1992). Similarly, the ligamentous laxity of pregnancy may predispose females to more "bandiness" as compared to male counterparts, which means there is less likelihood for ligamentous tears, but increased likelihood for earlier degeneration (Myer *et al.*, 2010; Ivković *et al.*, 2007; Kannus, 1997; Felson, 1990).

2.6.2.2 Age

Radiographic findings of knee OA increases from 27.4% in people 60 years of age and older compared to 43.7% in people 80 years or older (Cooper *et al.*, 2000; Felson, 1990). ITBFS affects individuals between the ages of 20 and 40 years of age (Lindenburg *et al.*, 1984; Noble *et al.*, 1982). ITBFS may be a precursor to earlier knee degeneration in those patients that present with ITBFS, more than those patients that do not.

This age range in the literature agrees with Lindenburg *et al.* (1984), indicating that ITBFS does not seem to be prevalent in younger populations (less than 18 years of age) and in older populations (older than 45 years of age). This concurs with the study by Shivananda *et al.* (2014), who indicated an age range of 19 to 21 years with an average age of 20 years in their study. It is, however, possible that these differences are directly as a result of the differences in the inclusion criteria for the more recent clinical trial (Shivananda *et al.*, 2014) as opposed to the others, which are epidemiological studies (Lindenburg *et al.*, 1985; Noble *et al.*, 1982). Therefore, age ranges for any conditions, including ITBFS need to be interpreted within the context of the study type and purpose.

2.6.2.3 Diet / Nutrition / Hydration

Inadequate nutrition or hydration is likely to cause injury to ligamentous and soft tissue structures like that of the ITB (Ivković *et al.*, 2007; Paluska, 2005; Christmas *et al.*, 2002). These are thought to be as a result of decreased ability of the collagen to heal itself without adequate hydration resources (increasing the functionality of the collagen water domains) (Bella *et al.*, 1995) and nutrition (vital in the process of providing energy in the form of ATP) (Leach 2004; Bella *et al.*, 1995). Therefore, lack of hydration leads to increased “stickiness” of the collagen and non-collagenous proteins through changes in the water binding domain structures (Leach 2004; Bella *et al.*, 1995). This “stickiness” provides for decreased flexibility, increased tautness and thus increased likelihood for friction or tearing (Ivković *et al.*, 2007; Leach, 2004; Christmas *et al.*, 2002). Thus, if these factors are not addressed, ITBFS injuries may reoccur when athletes resume their previous training protocols without addressing nutrition / hydration.

2.6.2.4 Systemic disease

ITBFS has several differential diagnoses that need to be considered as probable causes of the pain before the diagnosis of ITBFS is reached. These differential diagnoses include, but are not limited to, biceps femoris tendinopathy, degenerative joint disease (gout, crystalline deposition disorders, rheumatoid arthritis (Boon *et al.*, 2006)), lateral collateral ligament sprain, lateral meniscal tears, myofascial pain, patello-femoral stress syndrome, popliteal tendinopathy, referred pain from lumbar spine stress fractures and / or superior tibiofibular joint sprain (Foster *et al.*, 2007; Khaund and Flynn, 2005), common peroneal nerve injury (Foster *et al.*, 2007; Reid, 1992) and referred pain from the lumbar spine (Morris, 2006; Brolinson *et al.*, 2003, Chaitow and Delany, 2002). Each of these conditions, if present is also likely to contribute to the development of ITBFS, as each of these conditions may result in altered lower extremity biomechanics, changes in 'tensegrity' (tensional integrity) (Earls and Myers, 2010, Chen and Ingber, 1999) and therefore increased likelihood of changes in the form or function of the ITB (Dodd *et al.*, 2006). This may either be as a result of immobility or change in function (Dodd *et al.*, 2006) or tautness (Dwyer *et al.*, 2015) or inflammation (Fredericson and Yoon, 2006), for which the body is required to compensate (Sharp, 2012; Langevin, 2008; Reid, 1992).

2.6.2.5 Previous surgery

Following knee surgery, an individual is at risk of scar tissue formation (arthrofibrosis). This can subsequently alter biomechanical functioning of the ipsilateral leg, influencing the surrounding musculature (e.g. vastus lateralis, biceps femoris, TFL, vastus medialis muscles), consequently predisposing an athlete to ITBFS.

2.6.2.5.1 Scar tissue (Arthrofibrosis)

Arthrofibrosis of the knee is a debilitating consequence following knee surgery (Shelbourne *et al.*, 1996), which over time can affect knee ROM by causing limitation in knee extension and/or flexion (Paulos *et al.*, 1987). In addition, Paulos *et al.* (1987) suggested that arthrofibrosis may impact on knee function by disrupting normal knee kinematics and predisposing an individual to progressive degenerative changes in the tibio-femoral joint. This is supported by Sachs *et al.* (1989), who found that arthrofibrosis is associated with subsequent patello-femoral pain syndrome, muscle weakness, and overall knee dysfunction. It could, therefore, be theorised that the formation of scar tissue following surgery or injury could influence normal knee biomechanics and as such (where there is resultant limitations in ROM) impact on the supporting muscles (e.g. vastus lateralis, biceps femoris, TFL, vastus medialis muscles) and ligaments, thus predisposing an individual to the development of ITBFS (Paulos *et al.*, 1987). It may also be theorised that because of constant inflammation due to chronic ITBFS, or the athlete's reluctance to cease from activity, he or she may cause greater trauma to surrounding structures (Paulos *et al.*, 1987; Hughston, 1985). This may result in a consequent arthrofibrosis impacting on the tibio-femoral or patello-femoral joints, affecting arthrokinematics (Sachs *et al.*, 1990). However, knee stability is not usually affected by arthrofibrosis, but the subsequent resultant symptoms and subjective feeling of knee dysfunction frequently prompts individuals to seek treatment (Hillermann *et al.*, 2006). The associated stiffness and pull on the lateral aspect that can affect arthrokinematics of the knee often results in a perpetuating injury cycle of ITBFS (Reid, 1992). In these cases, an athlete may opt for surgery to gain relief (Reid, 1992). This is supported by previous literature that indicated that failure to regain full knee extension following ligamentous surgery is a contributing factor for the development of anterior knee pain, patellofemoral crepitus on extension, stiffness, impaired strength, antalgic gait patterns, decreased knee function and difficulty returning to desired level of activity and slower recovery progress (Sachs *et al.*, 1990; Paulos *et al.*, 1987; Hughston, 1985).

A change in arthrokinematics may also impact on the sacroiliac and ankle joints respectively (Noehren *et al.*, 2007; Birnbaum *et al.*, 2004; Kasunich, 2003; Kirk *et al.*, 2000; Norkin and Levangie, 1992). Numerous researchers also argue that with subsequent loss of knee extension, there is the likelihood of developing a short leg syndrome (Fujii *et al.*, 2010; Landrum *et al.*, 2008; Vicenzino *et al.*, 2006; Whitman *et al.*, 2005; Decker *et al.*, 2003; Pinshaw *et al.*, 1984). According to these researchers, this syndrome may lead to altered gait patterns, which impacts the sacroiliac and ankle joints. The altered biomechanics may put more strain on the ipsilateral musculature, thus impacting the ITB which may subsequently result in ITBFS (Fujii *et al.*, 2010; Landrum *et al.*, 2008).

2.6.2.5.2 Osteoarthritis (OA)

Osteoarthritis (OA) of the knee is a common complication following injury to the knee (e.g. ITBFS) or knee surgery for meniscal or cruciate ligament tears (Amin *et al.*, 2008; Berthiaume *et al.*, 2005). In addition, it was suggested that altered knee joint mechanics and static alignment can be linked to the development of knee osteoarthritis (Andriacchi *et al.*, 2004; Childs *et al.*, 2004; Messier *et al.*, 1992). This is supported by more recent studies that suggested that a correlation exists between meniscal and cruciate ligament repairs and subsequent knee joint instability and resultant osteoarthritic development (Amin *et al.*, 2008; Berthiaume *et al.*, 2005). This supports the work of Terry *et al.* (1993), who indicated that a relationship may exist between ITB disruption and ACL tears. Mansour *et al.* (2014), looked at 200 MRI scans of the ITB in acute knee injury and found that i) ITB injury rarely occurs in isolation; ii) a correlation seems to exist between ITB injury and acute knee injury. Other research suggests that trauma / injury to the knee compromises the integrity of the tibio-femoral joint, therefore causing altered or dysfunctional arthrokinematics and/or mal-alignment, resulting in an inherent instability, which could then ultimately predispose an athlete to early onset osteoarthritis and / or ITBFS (Andriacchi *et al.*, 2004; Childs *et al.*, 2004; *Sharma et al.*, 2001; Sharma *et al.*, 2000; Messier *et al.*, 1992).

Alternatively, an athlete afflicted with ITBFS may develop altered biomechanics (Fredericson and Wolf, 2005), which impacts the arthrokinematics of the ipsilateral leg (Decker *et al.*, 2003), thereby predisposing the athlete to tibio-femoral instability and subsequently osteoarthritis (Amin *et al.*, 2008; Berthiaume *et al.*, 2005; Andriacchi *et al.*, 2004; Childs *et al.*, 2004; Messier *et al.*, 1992). However, the relationship between dysfunctional arthrokinematics of the knee joint and athletes' self-reported instability in respect of knee osteoarthritis remains unclear (Farrokhi *et al.*, 2012).

2.6.2.5.3 Arthroscopy

There has been a steady rise in arthroscopic knee surgery over the past decades (Reigstad and Grimsgaard, 2006). Arthroscopy is a surgical procedure that is commonly used (between 18,000 and 19,000 procedures annually in the United States of America) to investigate the integrity of structures inside the tibio-femoral joint and to assess for any abnormal pathology (Blahd and Koval, 2013; Reigstad and Grimsgaard, 2006; Noble, 1992). Several serious complications are associated with arthroscopy and there is a strong correlation between operation time and (1) intraoperative surgical complications, and (2) postoperative complications (Reigstad and Grimsgaard, 2006; Allum, 2002; Babcock *et al.*, 2002; Kim *et al.*, 2002; Rozencwaig *et al.*, 1996; Arthroscopic Association of North America, 1986). Some of these complications may include post-surgical stiffness, joint pain and swelling, with the consequence of joint injury and internal bleeding (Blahd and Koval, 2013; Reigstad and Grimsgaard, 2006). This may result in an arthrofibrosis due to the fibrosis post injury within the joint structures (Robergs and Roberts, 1997), with subsequent impact on the knee joint complex which affects arthrokinematics (Norkin and Levangie, 1992). This correlates and ties in with the discussion presented in Section 2.6.2.5.1 'Scar Tissue'.

2.6.2.5.4 Meniscal injury

Through the "unhappy triad", it is likely that meniscal injury, anterior cruciate ligament injury, and medial collateral ligament injury occur together (Magee, 2008), and may be associated with ITB dysfunction (Mansour *et al.*, 2014). Meniscal injury usually occurs when the knee is flexed with associated rotary movement on a fixed lower limb, resulting in a meniscal tear (Ellen *et al.*, 1999). Meniscal tears can influence biomechanical functioning (usually associated with a bucket-handle tear, where a flap of a meniscus gets trapped between the femur and tibia (Ellen *et al.*, 1999; Fithian *et al.*, 1990; Kurosawa *et al.*, 1979)). This may lead to a change in load distribution, causing greater damage to the meniscus and eventually the articular surfaces, resulting in pain and arthrogenic muscle inhibition (Hillermann *et al.*, 2006; Suter *et al.*, 2000; Ellen *et al.*, 1999; Fithian *et al.*, 1990; Kurosawa *et al.*, 1979). In severe cases, surgery may be required to either remove or repair the meniscus (Ellen *et al.*, 1999). This may result in consequent arthrofibrosis (Robergs and Roberts, 1997), and subsequently impact on the knee joint complex which would have an effect on arthrokinematics. This correlates and ties in with the previous discussion presented in Section 2.6.2.5.1 'Scar Tissue'.

2.6.2.6 Leg length

Leg length discrepancy has been suggested by several authors as an important contributing factor in the development of ITBFS (McCaw, 1992; Pinshaw, *et al.*, 1984; Noble et al., 1982; Clement, *et al.*, 1981). According to Kibler *et al.* (1991), a functional leg length is the result of compensatory muscular imbalance surrounding the pelvis and / or ankle, where a structural leg length is the result of a physical discrepancy in one or more lower extremity bones. According to Knutson (2005) the literature reviewed indicated that there is some degree of structural leg length discrepancy (with a mean of 0.5 cm) in 90 percent of the general population. As a consequence, practitioners may hastily assess leg length and recommend a heel lift to compensate for the short stature of the limb (Powell *et al.*, 1986). However, although emphasis is placed on leg length discrepancy, as a key factor in overuse injuries, it is at best an anecdotal association (Messier *et al.*, 1995; McCaw 1992). Powell *et al.* (1986) cautioned that, this association has been derived by utilising limited samples of runners which do not adequately represent the entire population (Messier *et al.*, 1995).

According to Brand and Yack (1996), leg length discrepancy of 2.3 cm caused no variation in gait or hip forces, and consequent movements. In addition, Goel *et al.* (1997) found that leg length discrepancy of 1.25 cm had no significant effect on joint movement and further suggested that the body can easily compensate for any minor inequality present of up to 2 cm. This is supported by Perttunen *et al.* (2004), who found that a mean discrepancy of at least 2.5 cm was necessary to affect change in normal gait. Knutson (2005) concluded that leg length discrepancies of less than 2 cm have no significant clinical effect and therefore do not require heel lifts. The difference in runners compared to non-runners may lie in the fact that Renström and Peterson (2003) showed that the ground reaction force at mid-stance in the gait cycle is equal to a vertical force of 1.5 to 5 times the body weight during running. According to Noakes and Granger (2003), when this force is applied repetitively over long distances or for extended periods of time, the body is continuously supporting a heavy load for what could be many hours. Thus, the increased and amplified forces with which runners carry may provide a clue as to the possible link between leg length and the development of ITBFS. This latter assertion concurs with Section 2.6.1.1 ‘Camber / Track’ and Section 2.6.1.3 ‘Training’.

In reference to the above discussion on the intrinsic factors, it is evident that they have a significant effect on changing the biomechanics of the lower extremity kinematic chain. As a result of this, it was considered important that the study population fell within a limited age range (20 to 40 years); that the gender was stratified between the treatment groups; and that several of the intrinsic factors were considered as exclusion criteria (e.g. surgery, arthroscopy, systemic disease affecting joint mechanics, degeneration, meniscal injury and leg length) as their modification of the participant's biomechanics would have impacted negatively on the ability of the study to measure the effects of manipulative therapy.

2.6.3 Biomechanical factors that contribute to ITBFS

There are several lower extremity biomechanical dynamics to consider in ITBFS (Lavine, 2010; Noehren *et al*., 2007; Hubbard *et al*., 2006; Lun *et al*., 2004; Denegar *et al*., 2002; Orchard et al., 1996; Messier *et al*., 1995; Reid, 1992; Anderson, 1991; McNicol *et al*., 1981; Noble *et al*., 1982). There is a paucity of literature supporting the specific lower extremity biomechanical dynamics in ITBFS (Noehren *et al*., 2007; Fredericson *et al*., 2000; Orchard *et al*., 1996; Messier *et al*., 1995). This correlates with Ellen et al. (1999), Reid (1992), and Lindenburg *et al*. (1984), who found limited data in support of lower extremity biomechanical dynamic deficits (i.e. forefoot supination with compensatory pronation, weak hip abductors, increased knee internal rotation, genu varum, cavus foot, leg length discrepancies, sacroiliac joint and fibular head dysfunctions) that have been reported to contribute to ITBFS. Lun *et al*. (2004) investigated static alignment measurements as potential intrinsic risk factors for running injuries. Their study included factors commonly associated with ITBFS including: leg length discrepancy (greater than 1 cm), femoral neck anteversion, knee genu varum, valgum and recurvatum, excessive Q angle, patella alta, tibial torsion, increased ankle dorsiflexion, and excessive subtalar and forefoot varus, and concluded that lower limb static alignment measurements are not a predictor of injury in runners.

Thus, to establish a relationship between ITBFS and the lower extremity, consideration must be given to the normal functional biomechanics of the lower extremity kinematic chain (Reid, 1992).

2.6.3.1 Weak hip abductors

According to Messier *et al*. (1995), muscular weakness plays an important role as a contributing factor in running injuries. Deficits in abductors may result in decreased pelvic stability where the increased pull of the adductors could cause excessive internal rotation of the femur (Sahrmann, 2002; Chaitow and DeLany, 2002; Simons *et al*., 1999). Internal rotation also increases the pull on the lateral knee structures, which affect the ITB as it passes over the LFE (Noehren *et al.*, 2007; Fredericson *et al.*, 2000; MacMahon *et al.*, 2000). This is supported by Fredericson *et al.* (2000), who found that as a consequence of increased adduction, weak hip abductors result in femoral internal rotation that subsequently adds a valgus stress to the knee during running. This could potentially place increased strain on the TFL and ITB that function as hip stabilizers (Chaitow and DeLany, 2002; Sahrmann, 2002; Simons *et al.*, 1999). This conflicts with Grau *et al.* (2011), who could not find a correlation / relationship between weak hip abductors and ITBFS. The small sample size of their study may, however, have had a negative impact on the outcomes of their study. There is thus insufficient literature to conclude whether weak hip abductors contribute to the development of ITBFS or whether subsequent myofascial trigger points (MFTPs) cause or result from the abnormal biomechanical relationships (Sahrmann, 2002; Chaitow and DeLany, 2002; Simons *et al.*, 1999).

The literature remains conflicted regarding the relationship between pelvic stabilizers and ITBFS. However, there are several authors who support the notion of functional abductor deficit (consequence of pain / MFTP) as a contributing factor in the development of ITBFS (Grau *et al.*, 2011; Dippenaar *et al.*, 2008; Daly, 2005; Weyer-Henderson, 2005; Chaitow and DeLany, 2002).

2.6.3.2 Tight iliotibial band

Earlier work by Anderson (1991) suggested that pelvic musculature deficits resulted in a pelvic imbalance, affecting the centre of gravity at pelvic level, thus increasing the tension within the ITB and contributing to ITBFS (Tucker, 2007). This notion was supported by Fredericson *et al.* (2000), who found that athletes afflicted with ITBFS presented with greater ITB tightness. This concurs with more recent studies where it was suggested that hypertonicity in the musculature of TFL, gluteus maximus, gluteus medius, vastus lateralis, and biceps femoris muscles result in tightening of the ITB, causing it to shorten and as such, predisposing the athlete to ITFBS (Sharp, 2012; Cael, 2011; Broadhurst, 2004).

However, a second contradictory theory suggested by Hamill *et al.* (2008) is that ITB appears looser in athletes afflicted with ITBFS. This, they state, is a consequence of external rotation loading during running, causing elongation that has resulted in subsequent increased ITB strain (Hamill *et al.*, 2008). Thus, the current literature seems at best contradictory on the role of ITB tautness in the development of ITBFS.

2.6.3.3 Angle of knee flexion

According to the literature, the most likely point of ITBFS impingement is around 30° of knee flexion through the impingement zone (Farrell *et al.*, 2003; Orchard *et al.*, 1996; Renne, 1975). It is indicated as the location of greatest risk for friction or compression of underlying structures (Farrell *et al.*, 2003; Orchard *et al.*, 1996; Renne, 1975). Orchard *et al.* (1996) and Noble (1980) suggested that knee flexion during running varies and could be a discriminatory factor in the development of ITBFS. A consequence of downhill running is increased knee flexion at heel strike, thereby amplifying friction over the LFE, which predisposes runners to ITBFS (Fredericson and Wolf, 2005; Messier *et al.*, 1995; Barber and Sutker., 1992; Linderburg *et al.*, 1984). This is supported by Miller *et al.* (2007), who found that the degree of knee flexion increases at heel strike in runners afflicted with ITBFS consequently as a result of muscle fatigue after an exhaustive run, thus influencing biomechanics of the kinematic chain, increasing the risk for developing ITBFS. In addition, Lavine (2010) supports the notion of greater knee flexion at heel strike, increasing friction of the ITB over the LFE. Orchard *et al.* (1996) however, found no difference in the degree of knee flexion at heel strike in runners, with or without ITBFS.

2.6.3.4 Rearfoot eversion

There appears to be a significant correlation between rearfoot motion and consequent overuse injuries in athletes (Messier and Pittala, 1988; Warren and Jones, 1987; Renstrom and Johnson 1985; Clement *et al.*, 1981). Messier and Pittala (1988) found that athletes afflicted with ITBFS presented with a trend toward greater pronation, but it was not statistically significant. In addition, Messier *et al.* (1995) found little difference in rearfoot motion, but contrary to the previously stated literature, they found that athletes afflicted with ITBFS presented with less pronation. They suggested that a less inverted heel allows for a more neutral biomechanical angle, providing a more stable base at heel strike and consequently an overall decreased pronation. However, other literature has found that athletes who over pronate are at greater risk of sustaining a lower extremity injury and a diagnosis of ITBFS (Busseuil *et al.*, 1998).

2.6.3.5 Other biomechanical factors

According to Noehren *et al.* (2007), Birnbaum *at al.* (2004), Devan (2004), Busseuil *et al.* (1998), Messier *et al.* (1995), Anderson (1991) and McNicol *et al.* (1981), there are other biomechanical factors that may contribute to the development of ITBFS. These include: landing force at heel strike, knee internal rotation, hamstring muscular deficit (ipsilateral side) and genu recurvatum.

2.7 Patient Evaluation

2.7.1 History

ITBFS usually presents as a sharp often burning pain on the lateral aspect of the knee (Lavine, 2010; Ellenbecker *et al.*, 2009; Ellis *et al.*, 2007; Fredericson *et al.*, 2002; Magee, 2002; Reid, 1992; Noble *et al.*, 1982; Orava, 1978; Renne 1975). However, the perception of the type of pain may vary amongst athletes (Fredericson and Wolf, 2005). The pain is progressive in intensity, frequency and duration, which is experienced after or during running (flat surface, downhill or uphill) (Norris, 1998; Nicholas and Hershman, 1995; Noble *et al.*, 1982). Initially, the athlete will continue training as per normal, experiencing a slight niggle at the knee, which subsides after or shortly after the initial run (Fredericson and Wolf, 2005; Messier *et al.*, 1995). But, with subsequent training sessions, the slight niggle turns into discomfort and the athlete may complain of increased lateral or anterolateral knee pain (Lavine, 2010; Norris, 2004; Messier *et al.*, 1995; Reid, 1992), with subsequently shorter periods between onset of symptoms, which may persist the day after the run (Lavine, 2010; Ellenbecker *et al.*, 2009; Ellis *et al.*, 2007; Fredericson and Wolf, 2005). Furthermore, the athlete while running, may experience referred pain inferiorly on to the lateral calf muscle just below the knee or more commonly, superiorly along the lateral aspect of the thigh to the region of the greater trochanter of the femur. In addition, secondary inflammation proximal to the joint line, on the lateral aspect of the knee may be noticed (Lavine, 2010; Ellenbecker *et al.*, 2009; Ellis *et al.*, 2007; Fredericson and Wolf, 2005; Messier *et al.*, 1995). Another noticeable symptom is increased severity of pain running up / downhill and subsequent secondary inflammation at the lateral aspect of the knee (Ellis *et al.*, 2007; Khuand and Flynn, 2005; Reid, 1992; Anderson, 1991; McNicol *et al.*, 1981). The effect of ITBFS may influence daily activities with pain on ascending and descending stairs, sitting / standing for prolonged periods of time, a steady decrease in running mileage and less commonly - walking (Ellis *et al.*, 2007; Fredericson *et al.*, 2002; Reid, 1992; Renne, 1975).

2.7.2 Physical examination

Physical examination for ITBFS is based on a diagnosis by exclusion. On observation, the knee appears normal but, inflammation on the lateral aspect of the knee, proximal to the joint line may be noticed (Lavine, 2010; Fredericson *et al.*, 2000; Orchard *et al.*, 1996; Holmes *et al.*, 1993; Grady *et al.*, 1986; Lindenburg *et al.*,, 1984; Noble *et al.*, 1982; Williams, 1980). Palpation along the length of the ITB commonly elicits pain and tenderness, with little or no tenderness of surrounding lateral structures of the knee joint complex (Fredericson *et al.*, 2000; Simons *et al.*, 1999). In addition, it has been found that severe cases of ITBFS may be associated with crepitus, snapping and / or pitting oedema proximal to the joint line in the region of the LFE (Fredericson and Wolf, 2005).

Orthopaedic tests also commonly include Noble's and Ober's Tests (Magee, 2008; Reider, 1999; Reid, 1992). In association with ITB tenderness, Noble's compression test can be used to confirm the presence of ITBFS (Magee, 2008; Reider, 1999). The test is conducted by applying pressure over the ITB at the LFE with the knee flexed at 90°. The knee is then passively extended by the clinician / practitioner and if pain is elicited before / at the last 30° a positive test for ITBFS is diagnosed. Ober's Test assesses tightness at the ITB, where the patient is in a side lying position with lower leg flexed at the hip and knee for stability (involved side furthest from the bed). The practitioner then passively abducts and extends the athlete's upper leg with the knee straight and then slowly lowers the limb (once anterior to the patient and once posterior to the patient). If a contracture is present, the leg remains abducted and does not "fall" to the table (Magee, 2008; Reider, 1999).

In addition, muscle strength and flexibility should be assessed for deficits (Chaitow and DeLany, 2002; Simons *et al.*, 1999). It is suggested that a correlation exists between gastrocnemius and soleus muscle tightness and closed chain biomechanical pronation of the feet, and coupled with reduced dorsiflexion, results in increased ankle pronation and knee flexion (Willems *et al.*, 2005; Lun *et al.*, 2004; Denegar, *et al.*, 2002; Norkin and Levangie, 1992). Additionally, abductors should also be assessed for weakness or presenting deficits (Fredericson and Wolf, 2005). Examination of surrounding lateral musculature (e.g. gluteus minimus, piriformis, vastus lateralis and distal biceps femoris muscles) may reveal active myofascial trigger points (Chaitow and DeLany, 2002; Fredericson *et al.*, 2000; Simons *et al.*, 1999). Myofascial restrictions in surrounding lateral musculature and ITB can attribute to increased pain and discomfort associated with ITBFS (Sharp, 2012; Fredericson and Wolf, 2005). Myofascial restrictions include trigger points, muscle contractures and fascial adhesions (Sharp, 2012). It is suggested that myofascial restrictions result in increased tension on the ITB and concomitantly have an adverse effect on the ITB. In addition, if not addressed, myofascial restrictions may persist after ITBFS has subsided, which may cause perceived ITBFS lateral knee pain (Dippenaar *et al.*, 2008; Chaitow and DeLany, 2002; Fredericson *et al.*, 2000; Simons *et al.*, 1999).

Fredericson and Wolf (2005) concluded that other reasons for pronation (i.e. pes planus, forefoot varus, metatarsus adductus, or femoral and tibial torsion) should also be assessed.

The need for radiographic and MRI scans are rarely indicated, other than when suspicion of a more complex diagnoses or consideration for surgery needs to be ruled out (Boon *et al.*, 2006). Radiographic imaging may reveal an enlarged LFE that has breached into the impingement zone. The consequence of this enlargement affect the lateral knee structures including the ITB, causing a predisposition to chronic impingement or fat pad syndrome of the ITB. MRI studies may reveal a thickened ITB over the LFE with subsequent inflammation deep to the structures in the same region (Mansour *et al.*, 2014; Fredericson and Wolf, 2005; Ekman *et al.*, 1994).

2.7.3 Differential diagnoses

2.7.3.1 Primary myofascial trigger points (MFTP)

Myofascial trigger points (MFTP) have been shown to negatively affect muscle functioning and greatly impact on the performance ability of that muscle (Ge *et al.,* 2011; Laferriere *et al.,* 2008; Chaitow and DeLany, 2002; Fredericson *et al.*, 2000; Mense and Simons, 2001; Simons *et al.*, 1999; Travell and Simons, 1983). Previous literature has found that MFTP in the surrounding lateral thigh musculature (e.g. vastus lateralis muscle and biceps femoris muscle) can mimic ITBFS lateral knee pain (Chaitow and DeLany, 2002; Fredericson *et al.*, 2000; Simons *et al.*, 1999; Travell and Simons, 1983). However, these MFTP can be differentiated from ITBFS by their characteristic pain referral pattern (Chaitow and DeLany, 2002; Travell and Simons, 1983). Therefore, on examination of the athlete with ITBFS, MFTP should be excluded and if present, treated concurrently with the ITBFS, as MFTP of the vastus lateralis muscle, biceps femoris muscle and ITB can produce significant lateral knee pain, which may persist long after the ITBFS has resolved (Chaitow and DeLany, 2002; Fredericson *et al.*, 2000; Mense and Simons, 2001; Simons *et al.*, 1999; Travell and Simons, 1983).

2.7.3.2 Patello-femoral pain syndrome (PFPS)

It is believed that a tight ITB contributes to patello-femoral pain syndrome (Reid, 1992; Malek and Mangine, 1981). This notion is based on the idea that a tight ITB pulls the patella laterally during knee flexion, thereby affecting patella tracking alignment and subsequently contributing to PFPS (Hilyard, 1990; Gerrard, 1989; McConnell, 1986). In support of Smillie (1978), Noble (1979) found that a tight ITB may snap over the LFE (snapping ITB) as a consequence of abnormal attachment distally. However, this notion stands in contradiction to previous studies done by Noble (1979) and Kaplan (1958) who found no evidence suggesting that a tight ITB pulls the patella laterally. Patello-femoral pain often presents with a positive Clarke's test (Magee, 2008; Reider, 1999), positive Grind test if there is involvement of the inferior surface of the patella, aberrant patella motion (instability) (Magee, 2008; Reider, 1999) as well as pain that is retro-or peri-patellar (Dippenaar *et al*., 2008) as opposed to the lateral knee pain in ITBFS.

2.7.3.3 Early degenerative joint disease (DJD)

Degenerative joint disease (e.g. osteoarthritis) is caused by chronic inflammation in a joint. The inflammation consequently causes damage to the structural integrity of the joint resulting in subsequent loss of the cartilage tissue (Muraki *et al*., 2009; Felson *et al*., 2000; Felson *et al*., 1997; Felson *et al*., 1993). Individuals afflicted with DJD most commonly experiences pain along the joint line of the affected joint after repetitive use (e.g.: running) with subsequent stiffness the following day. In addition the pain gets progressively worse throughout the day and there may be associated swelling with a subsequent redness and warmth around the joint (Muraki *et al*., 2009; Boon *et al*., 2006; Yochum and Rowe, 2005; Felson *et al*., 2000; Felson *et al*., 1997; Felson *et al*., 1993). Therefore these signs along with a positive McMurry's test may indicate degenerative joint disease, although McMurry's is usually indicated for meniscal injury (Reider, 1999), as opposed to ITBFS. The most conclusive test would be a knee radiograph confirming a lack of internal joint integrity (Yochum and Rowe, 2005), which would definitely provide a diagnosis of degenerative joint disease over ITBFS.

2.7.3.4 Meniscal pathology

Menisci (medial and lateral) are cartilaginous structures that sit between the tibio-femoral joint where they acts as shock absorbers to ground reactive forces (Magee, 2008). The lateral meniscus is the stronger of the two and not commonly injured (Magee 2008; Moore and Dalley 2006). In addition lateral meniscal injury does not occur in isolation and is usually associated with a concomitant anterior cruciate ligament tear that results from a sudden twist or constant accelerated stop-start actions (Mansour 2014; Armfield *et al*., 2004; Ellen *et al*., 1999). It is suggested by previous literature that meniscal injury may remain asymptomatic and complication free, however in more severe cases the athlete may complain of knee pain with associated swelling, indicate that they have heard a popping sound, and consequently a feeling of joint instability (Ellen *et al*., 1999). Subsequently the pain may settle over a few days or weeks, but return to normal activity may be disturbed by pain, swelling on activity, and joint instability. On orthopaedic examination of the knee for a meniscal injury the use of McMurry's, Appley's and Duck-waddle tests are indicated to specifically isolate meniscal lesions (Magee, 2008; Reider, 1999;).

2.7.3.5 Superior tibio-fibular joint sprain

The superior tibio-fibular joint is often overlooked or forgotten during a routine examination; however it can be an important source of lateral knee pain (Beazell *et al*., 2009; Bozkurt *et al*., 2003). According to Bozkurt *et al*. (2003) the superior tibio-fibular joint plays an important role in dissipating torsion stresses and associated lateral tibial bending in addition to transferring axial loads during weight-bearing. In addition, Bozkurt *et al*. (2003) found that the tibio-fibular joint communicates with the tibio-femoral joint and therefore can be affected by increased loads, increasing the risk of injury during direct trauma. However, indirect trauma (e.g.: varus strain, hyper flexion or hyperextension) can also significantly impact on the tibio-fibular joint, with subsequent resultant localised lateral knee pain (Beazell *et al*., 2009; Bozkurt *et al*., 2003). Tibio-fibular joint pain associated with dysfunction / injury can be assessed on physical examination through motion palpation, orthopaedic muscle and ROM testing, and by performing subsequent functional movement examinations (e.g.: squat test, single leg stance and stepdown test) (Beazell *et al*., 2009).

2.7.3.6 Popliteal tendinitis

The popliteus muscle is a thin triangular muscle that forms the floor of the inferior part of the popliteal fossa (Moore and Dalley 2006). It is responsible for flexing and rotation of the knee joint. In addition it is plays an important role in unlocking the lock knee by rotating the tibia medially on the femur and the femur laterally on fixed tibia (Standring, 2009; Magee; 2008; Moore and Dalley, 2006). During strenuous activity requiring repetitive flexion and extension motion (e.g.: running) the popliteus muscle may be subjected to an acute injury through overuse. Consequently the athlete may complain of posteriorly located knee pain on crouching, walking or running downhill or descending stairs (Travell and Simons, 1983), in addition to tenderness on palpation at the back of the knee. Subsequently the pain can be reproduced on resisted isometric testing whereby the patient sits at the edge of the table with the involved femur fixed and the knee flexed at 90°. A positive finding is indicated by pain on resisted movement as the practitioner passively externally rotates the tibia on the femur (Travell and Simons, 1983).

2.7.3.7 Biceps femoris tendinitis

The biceps femoris muscle consists of two heads that insert onto the fibula head (Magee 2008; Moore and Dalley 2006). The biceps femoris tendon is usually injured in sporting activities that results in repetitive overuse. Injury of the biceps femoris tendon is associated with tenderness on palpation and secondary swelling with subsequent posterolateral knee pain and hamstring muscle stiffness. Pain can be reproduced with a straight leg raise test (Reider, 1999). In addition the pain also is reproduced through resisted isometric testing of the hamstring muscles (Reider, 1999). Positive tests are indicated in both instances with the reproduction of pain at the back of the knee and along the length of the muscle bulk (Magee, 2008).

2.7.3.8 Common peroneal nerve injury

Patient may complain of lateral knee pain, however on examination a foot drop may be noticed, which would differentiate this diagnosis from that of ITBFS (Foster *et al.*, 2007; Boon *et al.*, 2006; Bozkurt *et al.*, 2003).

2.7.3.9 Referred pain from lumbar spine

With nerve root entrapment at the levels of L4/L5 the patient may experience radicular pain that radiates down the posterolateral aspect of the thigh to the lateral aspect of the knee (Bogduk, 2009; Bogduk, 1997; Kirkaldy-Willis and Burton, 1992). However, the pain is usually sharp in nature and does not subside with rest (Bogduk, 2009; Bogduk, 1997; Kirkaldy-Willis and Burton, 1992). Orthopaedic tests such as Kemp's, Tripod, Slump seven, and Straight leg raise can be used to assess for radicular pain (Magee 2008; Reider, 1999; Kirkaldy-Willis and Burton, 1992), with positive tests eliciting aggravation of the sharp pain from the low back to the knee, that often results in the patient attempting to relieve the pull on the nerve by moving out of the designated test positions (Magee 2008).

Because ITBFS is a diagnosis of exclusion it requires the examiner to exclude other potential causes that may mimic lateral knee pain (ITBFS). It was therefore crucial for this study to rule out these stated differential diagnoses as discussed in this section in order to prevent them from affecting the outcome of this study which required all participants to have a diagnosis of ITBFS.

2.8 Current treatments

According to Reid (1992) and Fredericson and Wolf (2005), the accepted treatment of ITBFS begins with treatment of the acute inflammatory phase, and then progressively working through a corrective treatment phase until one can return to regular activity.

ITBFS is an overuse injury that has multiple contributing factors and therefore requires a multi-faceted treatment approach (Fredericson and Wolf, 2005; Gunter and Schwellnus, 2004; Taunton *et al*., 2002; Messier *et al*., 1995; Reid, 1992; McNicol *et al*., 1981; Noble, 1980). Treatments commonly used include R.I.C.E (rest, ice, compression, and elevation), non-steroidal anti-inflammatory medication, stretching, foam roller (stretching combined with ischaemic compression), and dry needling (Fredericson and Wolf, 2005; Fredericson *et al*., 2002; Messier *et al*., 1995; Reid, 1992; Noble *et al*., 1982). Other treatment measures include correction of training equipment, training style, and training surface, correction of abnormal biomechanics through the use of orthotics and manipulation, and surgery in severe chronic cases (Fredericson and Wolf, 2005; Gunter and Schwellnus, 2004; Levin, 2003; Souza, 2001; Fredericson *et al*., 2000; Baer, 1999; Messier *et al*., 1995; Reid, 1992; Noble *et al*., 1982).

2.8.1 Surgery

Conservative therapy in the treatment of ITBFS has been a very successful approach. However, it may be necessary to consider surgical intervention (Levin, 2003; Kirk *et al.*, 2000; Anderson, 1991; Firer, 1989). Surgical intervention as an effective treatment option is supported by previous studies, which indicate that excision of a bursa, cyst, or portion of the lateral synovial recess resulted in relief from ITBFS (Hariri *et al.*, 2009; Costa *et al.*, 2004; Drogset *et al.*, 1999; Nemeth *et al.*, 1996).

2.8.2 Oral anti-inflammatory medication and corticosteroid injections

Non-steroidal anti-inflammatory medication (NSAID's) are commonly used by athletes to decrease the pain and associated secondary inflammation (that may / may not be present) in ITBFS (Almekinders, 1990). However, there exists paucity in the literature / scepticism surrounding the use and benefits of NSAID's in a tendinitis and / or tendinosis (Astrom and Westlin, 1992, Schwellnus *et al.*, 1991; Almekinders, 1990; Kulick *et al.*, 1986). In addition, it has been found that the use of NSAID's can have a negative impact on the healing process of connective tissue by causing a delay in healing or resulting in poorer healing (Almekinders *et al.*, 1995). Furthermore, it was suggested that the analgesic effect of NSAID's (Almekinders, 1990), may negatively influence the perception of the severity of an injury. This may cause an athlete to ignore the presenting signs and symptoms, resulting in further injury and damage, and a subsequent delay in healing (Rolf *et al.*, 1997). However, contrary to the statement above, Weiler (1992), Schwellnus *et al.*, 1991, Noble (1980), Vogel (1977) and Renne (1975) suggested that the use of NSAID's may have a positive effect in promoting tendon healing. In addition, Schwellnus *et al.* (1991) found that the use of NSAID's in conjunction with manual therapy provided faster recovery and greater outcomes for the patient with tendon conditions. This concurs with Strauss *et al.* (2011), Ellis *et al.* (2007) and Baker (1995), who reported similar findings.

The use of corticosteroid injections in ITBFS is not uncommon. However, it was suggested by Kapetanos (1982), Anastassiades and Dziewiatkowski (1970) and Berlinder and Nabros (1967), that the rationale for using corticosteroids in tendon injuries be reassessed, as it inhibits collagen synthesis. This was supported by Fedale and Wiggins (1994), Wiggins *et al.* (1994) and Nirschl (1992), who reported similar findings and indicated that, the use of corticosteroid injection in the treatment of tendon injuries contributes to a delay in healing, tendon and ligament atrophy, fragmentation of collagen bundles, reduced biomechanical properties and cell death. However, Gunter and Schwellnus (2004) found that corticosteroid injection into the ITB had a significant effect on ITBFS pain reduction and should be considered as an adjunctive treatment option.

2.8.3 Cryotherapy

Cryotherapy is frequently recommended in the treatment of ITBFS, as it reduces the inflammatory reaction present as well as directly reducing pain (Khaund and Flynn, 2005; Noble *et al*., 1982; Orava, 1978). According to Baker (1995), McMaster (1982), Noble (1980) and Orava (1978), the use of ice is recommended in the treatment of ITBFS due to its effect on the inflammatory process and the pain associated with it as well as its effect on pain secondary to myofascial trigger points.

2.8.4 Myofascial release and trigger point therapy

In Section 2.7.3.1 'Primary MFTP', it has been shown by the literature that MFTP of the lateral thigh musculature and ITB can produce significant lateral knee pain, which may persist long after the ITBFS has resolved (Chaitow and DeLany, 2002; Fredericson *et al*., 2000; Mense and Simons, 2001; Simons *et al*., 1999; Travell and Simons, 1983). Therefore, on examination of the athlete with ITBFS, subsequent MFTP (either as a causative factor or as a result of the existing ITBFS) within the muscles should be addressed and treated concurrently to the ITBFS (Chaitow and DeLany, 2002; Fredericson *et al*., 2000; Mense and Simons, 2001; Simons *et al*., 1999; Travell and Simons, 1983). The use of MFTP therapy, either in the form of direct compression (ischaemic compression or deep tissue massage) (Chaitow and DeLany, 2002; Simons *et al*., 1999) or stretching (Chaitow and DeLany, 2002; Simons *et al*., 1999) of the muscles, aids in reducing pain (Hong *et al.,* 2006) and contracture (Chaitow and DeLany, 2002; Simons *et al*., 1999) within the associated musculature, as well as reducing the tension present in the ITB (Chaitow and DeLany, 2002; Simons *et al*., 1999). This is supported by Fredericson (2009), Hammer (2009) and Pedowitz (2005), who agrees that the treatment of myofascial restrictions not only of the ITB, but also that found in surrounding musculature, is an effective form of treatment for ITBFS (Fredericson, 2009; Hammer, 2009; Pedowitz, 2005).

2.8.5 Cross friction therapy

Cross friction therapy as an adjunct treatment was found not to have any significant effect in the treatment of ITBFS (Schwellnus *et al.*, 1992). However, contrary to the statement above, James (1995) found that cross friction therapy can assist breakdown of scar tissue contracture and aid in better healing. Furthermore, Ellis *et al.* (2007) reviewed previous literature and have found that deep transverse friction massage added no benefit in the treatment of ITBFS.

2.8.6 Stretching

It has been suggested in the literature that stretching only affects the proximal section of the ITB and has no influence on its distal part (McConnell, 1986). This view was supported by Chaitow (1997), Chadwick (1987), Kisner and Colby (1987). However, the validity and effect of stretching as an adjunct treatment for ITBFS has been supported by various other authors (Falvey, 2010; Chaitow and Delany, 2002; Fredericson *et al.*, 2002; Hall, 1997; Baker, 1995; Firer, 1989; Travell and Simons, 1983). According to Noerhen *et al.* (2007), Chaitow and Delany (2002) and Travell and Simons (1983), stretching of the surrounding musculature (i.e. gluteus maximus, gluteus medius and TFL muscles) could effectively restore the muscles to their original length, thereby influencing muscle balance and reducing tension on the ITB, providing relief from ITBFS. In addition, Noehren *et al.* (2007) suggested that there exists a lack of support for the association between stretching of the ITB and the long-term effect. This is supported by Lavine (2010), who suggests that there still exists a need for future investigation assessing the correlation between stretching and distension of the iliotibial band, and the consequences on the short-term and long-term changes in the tissue's mechanical response, the effects on running mechanics, and improvement of ITBFS. Cael (2011) suggests stretching surrounding musculature to maintaining ITB flexibility as well as addressing lower limb biomechanical abnormalities positively affects alignment, reducing the repetitive stress placed on the ITB.

In addition, it has been shown that stretching is an effective treatment option and can effect change at the ITB, and consequently reduce pain and discomfort associated with ITBFS (Falvey, 2010; Fredericson *et al.*, 2002; Hall, 1997; Baker, 1995; Firer, 1989). However, according to Lavine (2010), a paucity of literature surrounding the rationale for stretching the ITB still exists.

2.8.7 Muscle strengthening

Lavine (2010) found that a paucity of literature exists regarding the effectiveness of strengthening exercises in the treatment of ITBFS, however Fredericson and Wolf (2005) indicated that previous literature recommend strengthening of the adductor muscles. A previous study conducted by Fredericson *et al*. (2000) found a significant improvement in athletes afflicted with ITBFS following a six week strengthening programme for their adductor muscles. However, it could not be determined whether ITBFS was the consequence of weak adductor muscles or whether weak adductor muscles played a contributing role in the development of ITBFS. These findings were supported by a study conducted by Beers *et al*. (2008), who found that by strengthening the adductor muscles in athletes with ITBFS, this resulted in a statistically significant improvement of the ITBFS symptoms.

This correlates with previous literature on weak adductors which indicates that deficits in abductor muscle strength may result in decreased pelvic stability, increasing the pull of the adductors and causing excessive internal rotation of the femur (Sahrmann, 2002; Chaitow and DeLany, 2000; Simons *et al*., 1999). Internal rotation of the femur also increases the pull on the lateral knee structures, consequently affecting the ITB as it passes over the LFE (Noehren *et al*., 2007; Fredericson *et al*., 2000; MacMahon *et al*., 2000). In addition, Noehren *et al*. (2007) advocated strengthening of the pelvic musculature as being beneficial in the management of ITBFS (Sahrmann, 2002), as well as neuromuscular control of the hip joint. Although further investigation is advocated by Pettitt and Dolski (2000), who found positive results for the use of training based neuromuscular facilitation exercises.

2.8.8 Dry needling

Dry needling is thought to interrupt the abnormal neural circuits responsible for perpetuating the pain-spasm-pain-cycle by mechanically disrupting the dysfunctional nerve endings or contractile elements of the muscle, which sustain trigger point (TP) activity (Melzack, 1981). The effect of dry needling results in the alleviation of the patient’s symptoms (Chaitow and Delany, 2002; Travell and Simons, 1983) and is effective in the treatment of ITBFS (Vernon and Schneider, 2009; Hall, 1997; Baldry, 1989).

2.8.9 Electro modalities

Electrical modalities have been advocated in the treatment of ITBFS. Reid (1992) found the use of ultrasound and transcutaneous electrical stimulation (TENS) to be effective in the treatment of ITBFS. He found that the effect of ultrasound improves oxygen delivery, microcirculation, and plasticity of collagen, and decreases pain and spasm. In addition, ultrasound helps in decreasing inflammation, speeds up haematoma resorption, promotes healing and performs phonophoresis (Kitchen and Bazin, 1998). Biscoff *et al.* (1995) indicated in their study that when comparing phonophoresis and immobilization in the treatment of ITBFS, that phonophoresis had a significant effect on decreasing pain and aided in faster recovery of ITBFS. It was further suggested by Reid (1992) that TENS minimizes atrophy due to immobilization and therefore can maintain muscle tone, reinforce voluntary contraction, increase ROM, breakdown adhesions and overcome reflex inhibition, all of which can assist in the relief of ITB pain and spasm.

2.8.10 Rest

Rest is a common form of treatment and is often recommended to patients suffering with ITBFS. This is supported by literature suggesting that rest plays a significant role in recovery from ITBFS (Fredericson and Wolf, 2005; Sutker *et al.*, 1985; Noble *et al*, 1982; Noble, 1980). In addition, it is advisable to decrease activity levels or refrain from any activity that could potentially aggravate the condition for periods of between four to six weeks (Fredericson and Wolf, 2005; Dubin, 2005; Clement *et al.*, 1984; Noble *et al.*, 1982; James *et al.*, 1978). It is suggested that rest results in decreased inflammation and subsequently less pain (Noble *et al.*, 1982). Continuation of activity may contribute to further injury of the lateral structures and consequently result in greater damage to the knee (Fredericson and Wolf, 2005; Dubin, 2005).

2.8.11 Orthotics

Orthotics are routinely used for the correction of biomechanical and leg length discrepancies associated with structural/functional abnormalities of the lower kinematic chain, and consequentially also for the musculature's compensatory effects (Fredericson and Yoon, 2006). This can be seen in abnormalities associated with severe genu varum, high arched feet, over pronation or supination of the feet, and severe leg length discrepancies which are predisposing factors for ITBFS (Noakes, 1992; Reid, 1992; Sutker 1985; Lindenburg *et al.*, 1984). The application of orthotics or wedges can affect change in the biomechanical functioning of the feet allowing for greater shock absorption and consequently reducing the ground reactive force dissipation on the supporting musculature and pelvic stabilizers, thereby effectively decreasing ITB strain (Noakes, 1992; Reid, 1992; Sutker 1985; Lindenburg *et al.*, 1984). In addition to this, Walsh (1994) states that orthotics can effect change by reducing compensatory biomechanical medial / lateral tibial rotation, thereby consequently decreasing excessive ground reactive force dissipation on the musculature supporting the knee joint. This concept is supported by Landrum *et al*. (2008), Vicenzino *et al*. (2006), Whitman *et al*. (2005), Collins *et al*. (2004), Green *et al*. (2001), Pellow and Brantingham (2001), O'Brien and Vicenzino (1998) and Mulligan (1995). These authors additionally indicated that effecting change in tibial rotation by use of an orthotic also results in approximation of the femur to the tibia, thereby further releasing pressure on the lateral thigh musculature at the knee; providing relief from the tightness of the ITB which is associated with the ITBFS.

2.8.12 Training modifications

Training modifications form an integral part in recovery from ITBFS (Fredericson and Wolf, 2005; Dubin, 2005; *Sutker et al., 1985*; Clement *et al.*, 1984; Noble *et al.*, 1982; James *et al.*, 1978). There are several factors to consider including, terrain or training surface (tar, grass, gravel) (Messier *et al.*, 1995; Sutker *et al.*, 1985; Lindenburg *et al.*, 1984); training intensity, frequency, intensity and duration (Norkin and Levangie, 1992; Reid, 1992); changing running shoes (Messier *et al.*, 1995; Barber and Sutker, 1992); arch support (Barber and Sutker, 1992; Anderson, 1991); stretching (Morelli and Smith, 2001; Heidt *et al.*, 2000; Mirzabeigi *et al.*, 1999; Dahan, 1997); muscle strengthening (e.g. gluteus medius, gluteus maximus and quadriceps muscles) (Fredericson *et al.*, 2000).

2.8.13 Manipulation:

Manipulation, is a Grade V joint mobilisation technique (Bergmann et al., 1993) that is characterised by a high velocity low amplitude thrust, that is imparted into a dysfunctional joint (especially when associated with soft tissue fibrosis, oedema, adaptive shortening of muscle, loss of joint flexibility, altered joint mechanics and joint instability locally or at a distance from the joint (Bergmann and Peterson, 2011)) with the aim of decreasing pain, normalisation of movement and alignment, decrease painful joint play and end feel resistance, decrease associated muscle hypertonicity, improved circulatory function and Kinematic chain effects of manipulation:

2.8.13.1 Decrease pain

Pain associated with a dysfunctional joint is thought to be decreased by the increased stimulation of the dysfunctional joint's mechanoreceptors (e.g. Golgi Tendon Organs, Annulospiral and Flowerspray endings, Ruffini end organs, which represent the Wyke Type I-III receptors) (Boal and Gillette, 2004; Leach, 2004), as a result of the manipulation applied (Wyke, 1985). The stimulation of these receptors is thought to override the smaller type C fibers (Wyke IV) (Boal and Gillette, 2004; Wyke, 1985) that carry pain sensations to the spinothalamic tract. This "gate control theory" thus reduces the patient's perceived pain (Gillette, 1987; Melzack and Wall, 1965). The reduction in pain allows for increased movement in the joint, which maintains a high level of stimulation of the mechanoreceptors, thus perpetuating a positive cycle in decreasing perceived pain (Boal and Gillette, 2004; Cohen *et al*., 1995).

In the context of ITBFS, the reduction in pain as a result of manipulation would improve the clinical symptoms associated with the syndrome. This effect may be exhibited to a greater extent when manipulating a joint that has the largest innervation. Therefore, in this study it would be expected that the combination group would have the largest reduction in pain, as a result of the greatest number of receptors being stimulated by the manipulation applied.

By contrast, an additional theory proposed the reduction of pain, as a result of the release of endorphins (Vernon *et al*., 1986), which is thought to assist with reducing the perception of pain at the level of the substantia nigra and supra spinal structures (Terrett and Vernon, 1984). This would be evident in this study if all participants improved to the same degree, irrespective of the joint that was manipulated.

2.8.13.2 Normalisation of movement and alignment

Normalisation of movement and restoration of alignment can be achieved through manipulative therapy by: reducing mechanical joint locking (Hyde and Gengenbach, 2007), decreasing adhesion formation (through decreased inflammatory cycle and increased movement) (Hyde and Gengenbach, 2007; Mayer and Gatchel, 1988), breaking down of formed adhesions (Hyde and Gengenbach, 2007; Evans, 2002; Shekelle, 1994; Kirkaldy-Willis, 1992; Mayer and Gatchel, 1988), freeing of meniscal tags (Hyde and Gengenbach, 2007; Evans, 2002; Shekelle, 1994; Giles, 1986), and aiding repair and healing through normalisation of joint nutrition (Bergmann and Peterson, 2011; Leach, 2004).

In synovial joints the above effects are usually present after a cavitation (popping sound) has been heard (Dagenais and Haldeman, 2011; Sandoz, 1981), however it is theorised that these effects also occur in fibro-cartilaginous joints without a cavitation sound (as these joints do not contain synovial fluid) (Moore and Dalley, 2006).

In this study on ITBFS, it would thus stand to reason that all manipulated joints would show improved ROM post manipulation. The superior tibio-fibular joint would thus be the most likely to directly impact on the ITBFS in participants.

2.8.13.3 Decrease painful joint play and end feel resistance

As a result of the normalisation of movement through manipulation, the joint's ability to move independent of voluntary muscle action increases. This allows the examiner to feel a natural spring in the manipulated joint either in its neutral position (joint play) or at its end ROM (end feel). This joint springing action is thought to assist in improving joint nutrition and thus, decrease degeneration and improve healing (Morris, 2006; Palmer, 1910).

2.8.13.5 Decrease associated muscle hypertonicity

Joint dysfunction is usually associated with protective muscle spasm. When the joint is manipulated, Korr (1975) theorised that the sudden stimulation of the mechanoreceptors results in a barrage of information to the spinothalamic tract via the Golgi Tendon Organs, Annulospiral and Flowerspray sensory nerve endings (Leach, 2004; Watts, 1976). This barrage results in the brain (Herzog, 1993), via the thalamus and rubropsinal tract, resetting the "gamma gain" or the sensitivity levels of these sensory nerve endings (Leach, 2004). Thus the manipulation not only directly affects the joint, but also addresses the abnormally close relationship between the origin and insertion points of the muscle, which are restored to their normal position (Suter *et al.*, 1994). This normalisation of the muscle length, results in additional normalisation of joint function

(Sandoz, 1981). In addition the normalisation of the muscle length and function allows for a decrease in metabolic waste build up and an increase in nutrient rich blood to the muscle thereby facilitating a decreased likelihood of continued muscle spasm and tenderness (Shambaugh, 1987).

2.8.13.6 Improved circulatory function

This is thought to be as a result of a twofold mechanism, the first being related to the effect of manipulation of the muscles surrounding the joint as described in the paragraph above. The second effect being related to stimulation of the autonomic nervous system. The latter is as a result of the stimulation of the “fright and flight” mechanism, whereby the body dispatches blood to the musculoskeletal structures in response to a perceived external stressor in order to deal with the perceived threat. This has been shown through the modifications in cutaneous changes related to texture, temperature and moisture (Bergmann and Peterson, 2011).

2.8.13.7 Kinematic chain effects of manipulation

The kinematic chain is a combination of joints that link to form a mobile complex unit that is either open (has a free terminal point (e.g. hand of the upper limb)) or closed (has a fixed terminal point (e.g. foot of the lower limb when the patient is weight bearing)) (Bergmann and Peterson, 2011). Within the kinematic chain, each of the joints has a functional contribution towards the effective use of the chain in order to achieve a particular purpose (Bergmann and Peterson, 2011; Grindstaff *et al.*, 2011; Paris, 1985). Therefore, when a joint displays a decrease in ROM as a result of dysfunction, the other joints in the chain are required to compensate for this lack of motion (Bergmann and Peterson, 2011; Grindstaff *et al.*, 2011). Thus, it is theorised that manipulation of a dysfunctional segment will restore normal motion to that joint (increasing movement) whilst concomitantly decreasing the hypermobility in associated joints within the kinematic chain allowing normal kinematic chain function (Brantingham *et al.*, 2012(b); Bergmann and Peterson, 2011; Brantingham *et al.*, 2009(b); Forbes, 2009; Collins *et al.*, 2004; Dananberg, 2004; Green *et al.*, 2001; Kavanagh, 1999; Reid, 1992).

Thus, by way of example: it has been suggested that after injury to the ankle, hypomobility occurs at the ipsilateral subtalar joint (Meadows, 2002; Greenman, 1996), talocrural joint (Denegar *et al.*, 2002; Green *et al.*, 2001), distal tibio-fibular joint

(Kavanagh, 1999; O'Brien and Vicenzino, 1998; Hetherington, 1996), and / or proximal tibio-fibular joint (Meadows, 2002; Greenman, 1996). If the hypomobility of the ankle joint complex is addressed, it reduces dysfunction (Meadows, 2002; Kavanagh, 1999; Lewit, 1999), including altered fibula motion (Meadows, 2002; Dananberg *et al.*, 2000; Johnson, 1989), resulting in increased dorsiflexion ROM (Drewes *et al.*, 2009) and improved joint mobility (Denegar *et al.* 2002). As these common impairments are known to alter joint mechanics during functional activities, such as walking or running, these altered mechanics will then revert to more normal mechanics (Drewes *et al.*, 2009; Monaghan *et al.*, 2006).

In the literature surrounding clinical trials in respect of ITBFS, Baer (1999) found that the use of manipulation, specifically of the sacroiliac joint and fibular head in the treatment of ITBFS is highly recommended. Sacroiliac joint manipulation has been advocated in the treatment of ITBFS and patients have responded favourably to sacroiliac joint and fibular head manipulation (Souza, 2001; Baer, 1999). However, there is significant paucity of literature indicating both the individual clinical effects of manipulating strategic joints within the lower limb kinematic chain and comparing this to a combination intervention (where more than one joint is manipulated in the kinematic chain).

Based on the review of the literature above, it is not surprising that most authors conclude that treatment currently needs to reside in a multimodal approach in order to be effective when treating ITBFS (Fredericson *et al.*, 2000; Reid, 1992). The reason for this is twofold, including

- The lack of a definitive understanding of the aetiology of ITBFS and
- The lack of definitive indicators in the literature for the use of any one treatment modality over another.

As a result, Fredericson *et al.* (2000) describe the treatment of ITBFS as requiring a number of intervention points, including: modification of physical activity, soft tissue massage, stretching and strengthening of affected muscle groups and anti-inflammatory medication. These are beneficial for patients who have a low mileage activity. In the treatment of athletes with higher mileage, or who are unable to completely cease from activity, a more intense treatment programme is frequently required. This usually includes: icing and anti-inflammatory medications, activity modification with reduced mileage until symptoms have subsided. The ensuing causal activity is replaced with another cardiovascular activity (e.g. swimming or elliptical cycling) to maintain fitness, which is followed by a rehabilitative protocol (Khaund and Flynn, 2005; Grady *et al*., 1986; McNicol *et al*., 1981; Noble, 1980).

To address these variances in treatment approaches, Hall (1997) conducted a study investigating the effectiveness of dry needling of the TFL and ITB combined with a stretching programme in the treatment of ITBFS. She found a statistically significant improvement in the group receiving the combination treatment compared to the group receiving a singular intervention for ITBFS. By contrast, Baer (1999) found that sacroiliac and superior tibio-fibular joint manipulation in addition to active release therapy (ART) of the TFL and ITB to be effective in the treatment of ITBFS.

In their review of literature, Hoskins *et al*. (2006), concluded that a holistic treatment option may include chiropractic care, where the chiropractor utilizes a wide range of treatments i.e.: dry needling, myofascial release techniques, electro-modalities, ischaemic compression, exercise therapy and orthotics in conjunction with their mainstay treatment of manipulation. Notwithstanding this, Ellis *et al*. (2007) advocated that there is an urgent need for further research in the form of randomized controlled clinical trials with regard to chiropractic specific procedures, performed in isolation, in the treatment of ITBFS. Therefore this research aimed to add to the literature by evaluating the effect of the individual treatments of the ankle (talocrural joint), superior tibio-fibular joint and sacroiliac joint by manipulation. Additionally, the study also combined these treatments to evaluate the effect of the combined therapy on the kinematic chain in the treatment.

2.9 Conclusion

Based on the review of the literature in this chapter, it is evident that ITBFS has both an uncertain origin and thus a pathogenesis which does not allow for any health care provider to develop effective and efficient protocols for providing the best and most appropriate care (Hyde and Gengenbach, 2007). It is therefore incumbent upon the various health care providers that see patients presenting with ITBFS to provide further research into both the aetiology and assessment of ITBFS as well as its treatment and prevention (Finch and Cook, 2013; Lavine, 2010; Hyde and Gengenbach, 2007; Fredericson and Wolf, 2005). Therefore, Chapter Three presents the methods and materials of this study. Chapter Four presents the results and the discussion of the results and Chapter Five presents the conclusions and recommendations.

Chapter Three
Methodology and Materials

3.1 Introduction

Chapter Three is a discussion surrounding the methods and materials used for this study and include a detailed description of the study design and protocols followed with respect to advertising, sampling, clinical procedures, intervention administered, measurement tools, and statistical analysis.

3.2 Study design and protocol

This was a prospective, randomized clinical trial based on a quantitative paradigm, designed to investigate the clinical effects (subjective and objective measures) of four different manipulative interventions in the treatment of ITBFS. In addition, the secondary measures served as an exploratory investigation into the relationship between clinical and biomechanical changes of the lower extremity in patients with ITBFS.

Based on this study design, this research was approved by the Durban University of Technology - Institutional Research and Ethics Committee (IREC 095/13) (Appendix A1), indicating that the research protocol satisfied the ethical requirements set out by the Medical Research Council for such studies. Furthermore, this approval indicates that the research protocol is also in line with the Declaration of Helsinki, 1975 ethical requirements (Johnson, 2005).

3.3 Advertising and recruitment

Participants were recruited through advertisements by means of pamphlets (Appendix B) and word-of-mouth. The pamphlets were emailed to the Chairpersons of the Running and other Recreational Clubs for their onward distribution to members (with permission from the Chairperson / Committee of the Club), and the pamphlets were attached to library notice boards, shopping centres and other areas of communal gathering, after permission had been obtained from the relevant persons in charge (Appendix C). Where possible, presentations to clubs and at other places of recreational activity were also made to recruit participants. This was done after obtaining permission from the club chairpersons (Appendix C).

3.4 Standard of acceptance

3.4.1 Telephonic Interview

Upon telephonic response, participants were interviewed to see whether they met the inclusion and exclusion criteria, using the following questions:

Table 3.1: Telephonic interview questionnaire and responses

	Question	Responses
1	Would you be willing to answer a few questions about yourself and the ITBFS that you are suffering from at the moment?	YES
2	Are you between the ages of 20-40 years?	YES
3	Do you experience burning pain over the lateral aspect of the knee that is felt during activity or after activity?	YES
4	Do you experience pain on the lateral aspect of the knee when going up or down a flight of stairs?	YES
5	Did you or are you currently: • Receiving any treatment for the ITBFS? • Using any anti-inflammatory or medication for ITBFS? • Receiving any surgical intervention to relief ITBFS?	 NO NO NO

Upon meeting the above telephonic inclusion criteria, an appointment was scheduled at the Durban University of Technology (DUT) Chiropractic Day Clinic (CDC).

3.5 Sample

3.5.1 Sample size

Initially, it was agreed to recruit 80 participants from the greater Durban area, 20 per group (with a minimum of 17 per group) (Esterhuizen, 2013), which would be sufficient to achieve an 81% power to detect a difference of -2.0 (post-pre difference on the Numerical Pain Rating Scale) between the null hypothesis, so that both group means are 6.0 and the alternative hypothesis that the mean of Group 2 is 8.0 with estimated group standard deviations (SD) of 2.0 and 2.0 and with a significance level (alpha) of $p > 0.05$ using a two-sided two-sample t-test (Esterhuizen, 2013).

However, nine months into the study, only 15 viable participants were converted into participants (of a total of 45 responses to the advertisements), and an application for amendment to the sample size was submitted to the IREC for review (Appendix A2). This was supported by statistical evaluation whereby Group sample sizes of a minimum of 10 were found to achieve 80.491% power to reject the null hypothesis of equal means when the population mean difference is $\mu 1 - \mu 2 = 6.0 - 8.0 = -2.0$ with a standard deviation for both groups of 1.5 and with a significance level (alpha) of $p > 0.05$ using a two-sided two-sample equal-variance t-test (Esterhuizen, 2014).

Although the IREC submission resulted in a move from parametric to non-parametric statistical analysis, the strength of the analysis was retained. With IREC's approval, the sample size was reduced from 80 to a minimum of 40, and the group numbers were reduced from 20 to 10 participants per group (Appendix A3).

3.5.2 Sample allocation and method

Suitable participants were recruited by self-selection (based on potential participant's response to advertisements) (Mouton, 1996). However, once the participants had met the inclusion criteria (and once they had completed the informed consent form (Appendix D) to formally be part of the study), they were then allocated into four groups by means of stratified sampling. The stratification was done by gender (Mouton, 1996) as indicated in Table 3.2.

Table 3.2 : Stratification table

	Gender	Group A	Group B	Group C	Group D	Total
Allocation	Males	10 (5)	10 (5)	10 (5)	10 (5)	40 (20)
	Females	10 (5)	10 (5)	10 (5)	10 (5)	40 (20)
Total		20 (10)	20 (10)	20 (10)	20 (10)	80 (40)

*The numbers in brackets represent the revised sample stratification.

The reason for the above sampling strategy (viz. stratified sampling), was based on two factors:

- Response to clinical outcomes has been noted to be different between males and females (Wiesenfeld-Hallin, 2005; Decker *et al.*, 2003; Wise *et al.*, 2002). Therefore, stratification was required to ensure that the groups are homogenous in this respect (Mouton, 1996).

- Anatomical differences with regards to the ITB have been noted between males and females (Ellen *et al.*, 1999; Reid, 1992; Lindenburg *et al.*, 1984). Therefore, it was suggested that studies stratify to negate their effect through appropriate applications (Park and Stefanyshyn, 2011). Therefore, this study utilised a sample that attempted to achieve homogeneity between the study groups by means of stratified sampling.

Since the larger proportions of respondents to this study were males, the IREC submission also included a request to retain the stratification of male versus females in equal numbers per group. However, with the emphasis on retaining equivalent numbers of each and not a set equal figure (as indicated in Table 3.2). A total of 48 participants were recruited, of which 62.5% were male and 37.5% were female, which were split equally between the four groups (see Chapter Four, Table 4.2).

In addition, all participants were screened for joint dysfunction and the region in which the dysfunction was found. This information was recorded and used for group allocation purposes (viz. ankle joint group, superior tibio-fibular joint group or sacroiliac joint group), with the combination group having two out of three joint dysfunctions (viz. sacroiliac joint and superior tibio-fibular joint, or sacroiliac joint and ankle joint, or superior tibio-fibular joint and ankle joint of inclusion).

3.5.3 Sample characteristics (inclusion and exclusion criteria)

Gender, ethnicity and occupation were not utilized as exclusion or inclusion criteria.

3.5.3.1 Inclusion criteria

- Participants had to be between the ages of 20 (the development of the condition does not seem to be as prevalent in ages younger than this (Lindenburg *et al.*, 1984; Noble *et al.*, 1982) and 40 (as patients older than this may have already developed degenerative changes within the knee (Kirkaldy-Willis and Burton, 1992).
- Symptomatic participants were required to be diagnosed with ITBFS from the following diagnostic criteria: the participant had to have point 1 and 2, with at least 1 of the other 5 points (Norris, 1998; Nicholas and Hershman, 1995; Noble *et al.*, 1982):

1. A positive Noble's compression test had to be present (lateral femoral pain when researcher applied pressure to it with his thumb (Magee, 2008)).

2. A positive Ober's test had to be present (Participant was in a side lying position with lower leg flexed at the hip and knee for stability. The researcher passively abducted and extended the participant's upper leg with the knee straight. The researcher slowly lowered the upper leg. If a contracture was present, the leg was expected to remain abducted and did not "fall" to the table (Magee, 2008)).

3. Burning pain over the lateral aspect of the knee that was experienced during activity or after activity.

4. Pain experienced whilst running or walking downhill.

5. Pain on the lateral aspect of the knee when ascending or descending a flight of stairs.

6. Localised tenderness over the lateral femoral condyle, approximately 2-4 cm superior to the lateral joint line of the knee.

7. Swelling and possible crepitus over Gerdy's tubercle.

- The participant had to agree to and sign the Letter of Information and Informed Consent Form (Appendix D).
- The participant was required to have had recurrent symptoms for no longer than two years.
- The participant had to have joint dysfunction in at least one of the areas of the study (viz. sacroiliac joint, superior tibio-fibular joint, or ankle joint).
- Potential participants on medication (viz. NSAIDs or painkillers, were required to voluntarily end their medication use at least three days "washout period" prior to inclusion in the study (Seth, 1999; Poul *et al.*, 1993).

3.5.3.2 Exclusion criteria

- Potential participants that had been conservatively (manual therapy, non-surgical, non-medicinal) treated for ITBFS (within the two week period prior to inclusion into the study) were not permitted to take part in this study.
- Any potential participants that required further investigations to confirm a diagnosis or who required exclusion of diagnoses that would require immediate or alternative treatment as the first line of intervention, were also excluded.
- Potential participants with a history of previous injury / injuries (requiring casting/bracing) and/or surgery to the knee and/or hip and / or foot and ankle joints

were also excluded, as this would have affected the biomechanical measures taken in this study.

- Any participants that displayed contraindications to manipulation were excluded (Byfield, 2012; Bergmann and Peterson, 2011).

3.6 Clinical procedure

At the first consultation, each participant was given their Letter of Information and Informed Consent Form (Appendix D), providing the participant with a detailed explanation of what the research entailed and what would be expected from them as participants. Participants were also made aware that they were free to withdraw from the research at any point in time as was indicated within the letter.

Participants then underwent a case history (Appendix E), a physical (Appendix F) and regional examinations for lumbar (Appendix G), hip (Appendix H), knee (Appendix I) and foot and ankle (Appendix J) regions, and were screened for the inclusion criteria. This information was recorded on the SOAPE note (Appendix K). The participants were then allocated to one of four groups that was categorised by the anatomical region that was manipulated as per the stratification table (refer to Table 3.2). Group A received an ankle joint manipulation; Group B received a superior tibio-fibular joint manipulation; Group C received a sacroiliac joint manipulation; Group D received a combination of any two manipulation interventions (viz. sacroiliac joint and / or, superior tibio-fibular joint and / or ankle joint). These techniques were applied as described by Byfield (2012) and Bergmann and Peterson (2011).

Each participant's involvement took place over a period of four weeks involving seven appointments (Brantingham *et al.*, 2012(b); Byfield, 2012; Bergman and Peterson, 2011; Brantingham *et al.*, 2009(a); Brantingham *et al.*, 2009(b)). Thus, each participant prescribed to 2 appointments per week for the first three (3) weeks, during which, they received their intervention (data was only collected at appointments 1, 3, 5, and 7) and a final appointment in week four for data collection with no intervention.

Table 3.3 : Outline of measurements and interventions protocols per Group

Week	Visit	Group A	Group B	Group C	Group D
1	1	History Physical + Orthopaedic Examination Measurements - VAS[1] - Algometer[2] - SKSQ[3] Intervention	History Physical + Orthopaedic Examination Measurements - VAS - Algometer - SKSQ Intervention	History Physical + Orthopaedic Examination Measurements - VAS - Algometer - SKSQ Intervention	History Physical + Orthopaedic Examination Measurements - VAS - Algometer - SKSQ Intervention
	2	Intervention	Intervention	Intervention	Intervention
2	3	Measurements - VAS - Algometer - SKSQ Intervention	Measurements - VAS - Algometer - SKSQ Intervention	Measurements - VAS - Algometer - SKSQ Intervention	Measurements - VAS - Algometer - SKSQ Intervention
	4	Intervention	Intervention	Intervention	Intervention
3	5	Measurements - VAS - Algometer - SKSQ Intervention	Measurements - VAS - Algometer - SKSQ Intervention	Measurements - VAS - Algometer - SKSQ Intervention	Measurements - VAS - Algometer - SKSQ Intervention
	6	Intervention	Intervention	Intervention	Intervention
4	7	Measurements - VAS - Algometer - SKSQ	Measurements - VAS - Algometer - SKSQ	Measurements - VAS - Algometer - SKSQ	Measurements - VAS - Algometer - SKSQ

3.7 Measurement tools

3.7.1 Subjective data

Subjective data was obtained from the Visual Analogue Scale (VAS) and Knee Score Questionnaire (KSQ) and recorded on the Data sheet (Appendix L):

3.7.1.1 Visual analogue scale (VAS)

The Visual Analogue Scale (VAS), represented on the Data sheet (Appendix L), was used to evaluate the participants' perception of their ITBFS pain. The VAS is a well-established outcome measure of pain intensity (Crossley *et al*., 2004; Price *et al*., 1994; Price *et al*., 1983; Merskey, 1973). It involved the use of an unmarked horizontal line 10 cm in length, to evaluate the participants' perception of pain based on a description at each end of the horizontal line; 0 at one end representing no pain and 100 at the other end representing pain at its worst (Yeomans and Liebenson, 1996). The VAS has a high level of responsiveness, reliability and validity (Crossley *et al*., 2004; Price *et al*., 1994; Price *et al*., 1983; Merskey,

[1] Visual analogue scale
[2] Pain pressure threshold algometer
[3] Subjective knee score questionnaire

1973). This permitted detection of clinically relevant changes, an essential measurement for clinical trials (Reading, 1980). A mean reduction in VAS of 20-25 mm (sub-acute to chronic patients) and 30-35 mm (acute patients) has been shown to represent a clinically important difference in pain severity (Lee *et al.*, 2003(a)). Based on this, a mean reduction of 20-25mm in VAS was considered a Minimally Clinical Important Distance (MCID) (Ostelo and de Vet, 2005 and Lee *et al.*, 2003(a)).

3.7.1.2 Knee scoring questionnaire (KSQ)

A Knee Score Questionnaire (KSQ) (Appendix M) (Yeomans, 2000), was used to evaluate subjective data provided by the participants' over a four week period with regards to the participants' perception of their ITBFS. The KSQ is a modified version from Noyes *et al.* (1984) original version, and includes the parameters/ headings: pain, swelling, stability, overall activity level, walking, stairs, and running, jumping and twisting. The headings are followed by subsequent questions related to the particular heading with each question carrying a weighted score. The score is totalled at the end of the questionnaire and converted to a percentage. The score rating is based on a positive outcome with improvement to form a direct link related to the participants' perception of their overall status. The KSQ is a well-established outcome measurement tool that can be used to subjectively identify the participants' status (Jenny and Diesinger, 2011; Garratt *et al.*, 2004; Yeomans and Liebenson, 1997; Yeomans and Liebenson, 1996; Noyes *et al.*, 1984). However, the MCID has not been determined for the KSQ, yet this instrument has continued to be used in assessing health outcomes in this study and so this deficiency must be addressed by future research (Garratt *et al.*, 2004).

3.7.2 Objective data

3.7.2.1 Algometer

According to Kinser *et al.* (2009), Williamson and Hoggart (2005), Fischer (1987) and Fischer (1986), the use of an algometer as an objective measurement tool has been found to be both valid and reliable. Pressure and pain threshold assessment by an algometer is a reliable measure of subjective pain (Potter *et al.*, 2006). The algometer was used to assess pressure and pain threshold over the ITB surface on the lateral aspect of the thigh (at the level just proximal to the Gerdy's tubercle and on the soft tissue of the ITB near the origin of inflammation, where the algometer would not place pressure on the bony prominence of the

Gerdy's tubercle). This was consistently the same in all participants irrespective of the intervention so that the actual symptomatic improvement of the ITBFS could be measured. The Wagner KDK20 Force Dial (Wagner Instruments, PO Box 1217, Greenwich, CT, 06836, USA) was used. The minimal clinically important difference was noted at 15% (O'Leary *et al*., 2007; Potter *et al*., 2006; Paungmali *et al*., 2003), or with regards to MCID, it was 1.77kg/cm^2 (Chesterton *et al*., 2007).

3.7.3 Other objective measurements

3.7.3.1 Leg length

This was measured by means of true leg length where a tape measure was used to find the distance from the anterior superior iliac spine (ASIS) to the medial malleolus on the same side. The participant lies supine with his / her pelvis level to the table. The measurement was done bilaterally which was compared with the ipsilateral reading (Magee, 2008). According to Magee (2008), a difference of 1cm to 1.3cm is considered normal. This measurement has been found to be reliable and valid in clinical practice (Boon *et al*., 2006), but has to date not been found to correlate with sidedness of ITBFS patients suffering with the syndrome (Boling *et al*., 2009; Brantingham *et al*. 2009(a); Noehren *et al*., 2007; Gross and Foxworth, 2003; Grady *et al*., 1986; McKenzie *et al*., 1985).

3.7.3.2 Quadriceps angle (Q angle) of the femur

This is usually measured by means of radiographs, but this is a very expensive procedure that unnecessarily exposes the participant to radiation (Smith *et al*., 2008). The Q angle was determined by using three anatomical landmarks: the ASIS, the midpoint of the patella and the centre of the tibial tubercle. The angle is determined by measuring the angle between the quadriceps ray and the patellar tendon ray from the perpendicular (Livingston and Spaulding, 2002). An angle greater than 15° for men and 20° for women is considered abnormal and increases the risk for overuse injuries such as ITBFS (Park and Stefanyshyn, 2011; Horton and Hall, 1989). There is, however, a debate concerning this test's reliability and validity as Piva *et al*. (2006) found this measure to have moderate values whereas Derek *et al*. (2000) and Emami *et al*. (2007) found that the Q angle measurement a very helpful tool in predicting general knee injuries.

3.7.3.3 Tibio-femoral angle

This angle was measured utilising three points: the ASIS, the midpoint of the patella and the midpoint of the ankle joint (talocrural joint). The tibio-femoral angle is formed at the knee joint and is measured with a goniometer (Fakoor *et al.*, 2010); any measurement greater than 8° from 180° was considered to be abnormal (Fakoor *et al.*, 2010; Arazi *et al.*, 2001).

3.7.3.4 Feiss line

Another measurement used was the Feiss line test (also known as the navicular drop test (weight bearing)). Here the researcher marks the apex of the medial malleolus and the plantar aspect of the first metatarsophalangeal joint while the patient is non-weight bearing. The researcher then palpates the navicular tuberosity. The level of the tuberosity in relation to the line joining the two previously made points is noted. The participant then stands with feet eight to 15 cm apart. The two points are checked to ensure that they still represent the apex of the medial malleolus and the plantar aspect of the MTP joint. The navicular is again palpated; the navicular tubercle normally lies on, or very close to the line joining the two points. If the navicular tubercle falls below the line; it is classified as a flatfoot (pes planus), whereas if it falls above the line it is noted as a high arched foot (pes cavus) (Magee, 2008). Rezeghi and Batt (2002) and Cashmere *et al*. (1999) indicate that this measure provides an accurate indication of the behaviour of the medial longitudinal arch; however, there is limited evidence for its relationship with other lower extremity conditions.

3.7.3.5 Leg-heel alignment

Here participants lie prone with the foot extending over the end of the examining table. The researcher placed a mark over the midline of the calcaneus at the insertion of the Achilles tendon. A second mark is made approximately one centimetre distal to the first mark and as close to the midline of the calcaneus as possible. A calcaneal line is made to join the two marks. Another two marks are made on the midline of the lower third of the leg. These two marks are joined, forming the tibial line, representing the longitudinal axis of the tibia. The subtalar joint is then placed in the neutral position and the two lines are observed. If the lines are parallel or in slight varus (2 – 8°), the leg-to-heel alignment is considered normal (Skinner, 1993). If the heel is inverted, the patient has a hindfoot varus; if the heel is everted, the patient has a hindfoot valgus (Magee, 2008). Again Cashmere *et al*. (1999), and Rezeghi and Batt (2002) indicated that this measure provides an accurate indication of the behaviour of the hindfoot; however, there is limited evidence for its relationship with other lower extremity conditions.

In a study of this type it is common practice to have a blinded assessor (someone who takes the measurements without knowing the interventions that the participants received); however for pragmatic (e.g. study duration and finances) reasons it was not possible to secure a blinded assessor for this study (Schultz, Altman and Moher, 2010).

3.8 Statistical analysis

Data was recorded on the Data Sheet (Appendix L) during consultations. This data was kept in the patient’s file and transferred to an Excel spread sheet prior to submission to a statistician. Following consultation with the research statistician, statistical analysis was conducted on the data using the latest version of SPSS version 22 (manufactured by SPSS Inc., 444N. Michigan Ave, Chicago, Illinois, 60611, USA).

“Drop out” participants had their data collected and kept for intent to treat analysis (Esterhuizen, 2013). Additionally, the reason for “drop out” was noted and commented on in the dissertation, and where a “drop out” was due to adverse side effects, it was reported via IREC procedures.

The intention to treat analysis was done to avoid the effect of “drop out” and reduce statistical analysis bias. Therefore, intention to treat analysis provided information about the initial treatment intent, not the treatment eventually administered. Any “drop outs” were replaced with new patients to ensure that at least 30 out of 40 patients completed the entire treatment process. However, everyone who began the treatment was considered to be part of the trial, whether they finished it or not.

Full application of intention to treat was performed where data existed up to and including measurements taken at time point three (beginning of week three) for all randomised patients (Esterhuizen, 2013). Missing data were inputed using the median for that group and the demographic data was collectively then presented in the form of graphs and tables (Esterhuizen, 2013).

Inferential statistical evaluation was aimed at measuring any significant changes occurring between the consultations, as well as between the four groups. Thus, non-parametric testing was used to analyse the Numerical Pain Rating Score (NRS), Algometer and the Knee Score Questionnaire readings.

Treatment effects were analysed by repeated measures ANOVA (to assess inter- and intra-group changes over time for continuous outcomes). Inter-group changes over time in ordinal variables were achieved using a non-parametric Friedman test. Pearson's correlation was used to assess intra-group correlations between changes in outcome measures over time. A two-tailed p value of <0.05 or a confidence interval of 95% was considered as statistically significant (Esterhuizen, 2013).

Chapter Four

Results and Discussion

4.1 Introduction

Chapter Four provides information on the statistical data that was collected during the course of the study. Subjective and objective readings were obtained through visits one through seven (and measurements one to four during the four week study period). The results are represented by graphs and tables with a short description accompanying each figure or table.

Subjective data collected was in the form of the Visual Analogue Scale (perception of pain) and the Knee scoring questionnaire.

Objective data was collected in the form of the Tibio-femoral angle, Leg length, and Quadriceps angle (Q Angle) of femur, Leg-heel alignment, Feiss line, and Algometer measurements.

All subjective and objective data collected was collectively recorded onto the Data sheet (Appendix L) before being captured on a spreadsheet.

4.2 Terms and abbreviations specific to this chapter

KSQ	Knee scoring questionnaire
LL L	Leg length left
LL R	Leg length right
MCID	Minimally Clinically Important Difference
N	Full sample size
n	Sample size per group. Sample in this case is defined as *"A subset of a population"* (Tropper, 1998)
p	*p*-Value: Means information is of statistical value or that which indicates the data is statistically significant (Hinton, 2001; Campbell and Machin, 1999; Wright, 1997; Bland, 1996; Swinscow, 1996)
Q angle	Quadriceps angle
r	Pearson's interclass correlation coefficient measures the bivariate relation of variables representing different measurement classes and is denoted as the Pearson's r (McGraw and Wong, 1996)
VAS	Visual analogue scale
>	Strict inequality meaning 'greater than"
<	Strict inequality meaning 'less than"
=	Used as a mathematical expression to indicate an equality

4.3 Data

Data collection occurred over a four-week period during which participants had to commit to two visits per week for the first three-weeks and one visit in the final week. During this time, primary – and secondary measures were taken at visits one, three, five and seven and recorded on to the Data Sheet (Appendix L).

4.3.1 Primary data (Outcome measures)

The primary data included and was collected from the following tools;

- VAS (perceived pain),
- KSQ, and
- Algometer.

All data was recorded on the Data Sheet (Appendix L), prior to data capturing.

4.3.2 Secondary data (Outcome measures)

- Case History (Appendix E):
  - Gender
  - Age
  - Leg involved
- Senior Physical Examination (Appendix F).
- Lumbar Regional Examination (Appendix G):
  - Leg length
- Hip Regional Examination (Appendix H).
- Knee Regional Examination (Appendix I):
- Foot and Ankle Regional Examination (Appendix J):
  - Feiss line
  - Leg-heel alignment

All data was recorded on the Data Sheet (Appendix L), prior to data capturing.

4.4 Review of objectives

The aim of the study was to determine the differences between:

1. ankle joint manipulation alone as well as
2. superior tibio-fibular joint manipulation alone versus
3. sacroiliac joint manipulation alone, versus
4. a combination of these three interventions in the treatment of ITBFS

The objectives were to measure the differences between the four interventions, if any, in terms of primary outcome measures, which were noted as clinical outcome measures (VAS, KSQ and Algometer) and secondary outcome measures, which were noted as biomechanical measures (Leg length, Q-angle, Tibio-femoral angle, Feiss line and Leg-heel alignment), with regards to the following:

1. To determine the effect of ankle joint manipulation in the treatment of ITBFS.
2. To determine the effect of superior tibio-fibular joint manipulation in the treatment of ITBFS.
3. To determine the effect of sacroiliac joint manipulation in the treatment of ITBFS.
4. To determine the effect of a combination of these three treatments in the treatment of ITBFS.

5. To compare a trend amongst the four different groups in terms of the findings and to determine the relative effect of lower extremity manipulation in the treatment of ITBFS.

4.5. Response rate

A total of 102 people showed an interest in the study. Of these 102 people, only 48 people could be converted into participants, with the remaining 54 people excluded for the following reasons:

- 22 potential participants that could not participate due to work commitments or other personal reasons, and;
- 32 potential participants that were excluded based on the exclusion criteria.

The 48 participants included were spread across the four groups as follows:

- Group A had a total of 14 participants at the end of the study, of which four dropped out (converted by intention to treat analysis). This left 10 participants who completed the four-week intervention study.
- Group B had a total of 11 participants at the end of the study, of which two dropped out (converted by intention to treat analysis). This left nine participants who completed the four-week intervention study.
- Group C had a total of 12 participants at the end of the study, of which two dropped out (converted by intention to treat analysis). This left 10 participants who completed the four-week intervention study.
- Group D had a total of 11 participants at the end of the study, of which one dropped out (converted by intention to treat analysis). This left 10 participants who completed the four-week intervention study.
- None of the dropouts noted in the consort diagram was due to adverse events or worsening of their condition. The participants withdrew for various reasons including but not limited to work commitment, training schedules, personal reasons and seeking less limited interventions.

The study aimed to attract a large population sample size so as to rule out any form of bias related to sampling procedures (Mouton, 1996). All dropouts were replaced so as to achieve a minimum of an 80% completion rate (See Figure 4.1).

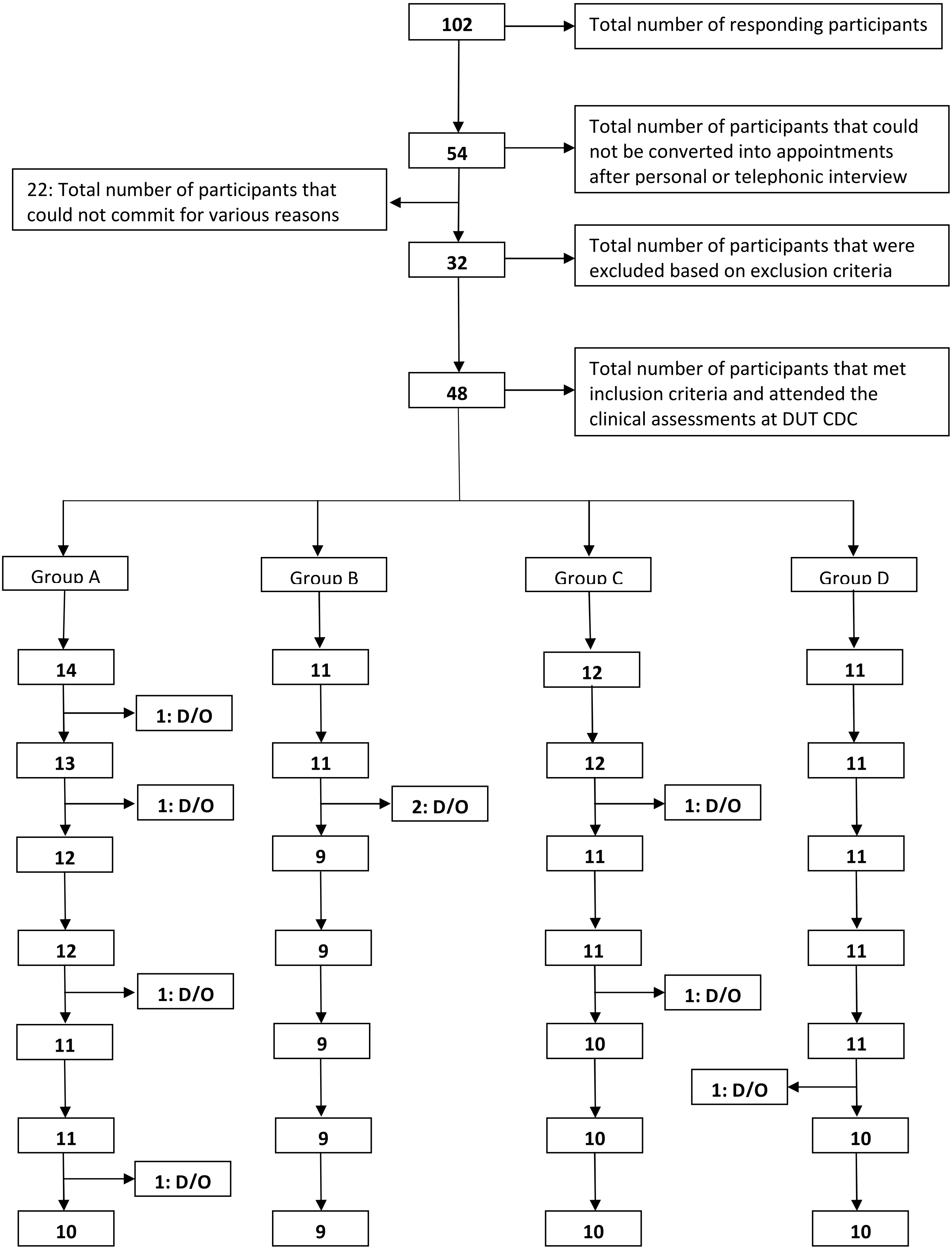

Figure 4.1: Consort diagram indicating the progression and dropouts of participant through the course of the research process (Schultz, Altman and Moher, 2010)

4.6 Demographic data

4.6.1 The sample characteristics

The study took place over an 11-month period. The majority of participants were recruited from sports events held across the greater Durban area. The sample size of this study consisted of 48 participants. With reference to Section 3.4.1 (sample size), the minimum required number of data sets (complete or completed through intention to treat) for this study was 40 (Appendix A3) which was in accordance with the recommendation from the statistician (Esterhuizen, 2014). Participants were placed into one of four groups according to the randomized table (Chapter 3: Table 3.2).

4.6.2 The comparison of age between the four treatment groups

Table 4.1: Age

	Group A		Group B		Group C		Group D		Total		*p* value
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	
Age	27.5	4.2	28.2	5.0	31.1	5.6	31.3	6.4	29.4	5.4	0.188

4.6.3 Gender and sidedness of ITB presentation between the four treatment groups

Table 4.2: Gender and Side of ITB

		Group										*p* value
		A		B		C		D		Total		
		n	%	*n*	%	n	%	*n*	%	*N*	%	
Gender	Male	8	57.1%	5	45.5%	9	75.0%	8	72.7%	30	62.5%	0.419
	Female	6	42.9%	6	54.5%	3	25.0%	3	27.3%	18	37.5%	
	Total	**14**	**100.0%**	**11**	**100.0%**	**12**	**100.0%**	**11**	**100.0%**	**48**	**100.0%**	
Side of ITB	Right	10	71.4%	5	45.5%	5	41.7%	6	54.5%	26	54.2%	0.428
	Left	4	28.6%	6	54.5%	7	58.3%	5	45.5%	22	45.8%	
	Total	**14**	**100.0%**	**11**	**100.0%**	**12**	**100.0%**	**11**	**100.0%**	**48**	**100.0%**	

Table 4.1 reflects that the participants were between 23.3 and 37.7 years of age (with the mean ranging between 27.5 to 31.3 years of age). This is congruent with the literature that suggests that ITBFS affects individuals between the ages of 20 and 40 years of age (Noble

et al., 1982; Noble, 1980). This also agrees with the literature (Lindenburg *et al*., 1984), which notes that ITBFS in South Africa (eThekwini Municipality) does not seem to be prevalent in younger populations (less than 18 years of age) or in older populations (older than 45 years of age). More recent results obtained by Shivananda's *et al*. (2014) also indicated an age range of 19 to 21 years with an average age of 20 years. These subtle differences may be directly as a result of the differences in the inclusion criteria for more recent clinical trials (Shivananda *et al*., 2014) as opposed to the previous epidemiological studies (Lindenburg *et al*., 1984; Noble *et al*., 1982; Noble, 1980). This would, therefore, suggest that none of the participants in this research seem to have ITBFS that may be secondary to degenerative changes (e.g. in the knee and / or ankyloses of the sacroiliac joints) as suggested by Kirkaldy-Willis and Burton (1992).

Of the 48 participants, male participants accounted for 30 adults (62.5%), and female participants accounted for 18 adults (37.5%). The results of the gender distribution are not dissimilar to those obtained by Turnbull (2010), although it is recognised that the stratification in this study would have potentially affected the differences (viz. this study had a 17% increase in females compared to Turnbull's (2010) study). This tendency towards male gender may also be as a result of the differences in running kinematics and kinetics, which have been shown to be different in males and females (Decker *et al*., 2003). These results, are however, different to some international studies which suggest that there are fewer males than females (Beers *et al*., 2008), and yet congruent with others (Shivananda *et al*., 2014; Messier *et al*., 1995; Noble *et al*., 1982; Orava, 1978). These latter differences may be as a result of the methodology within each of these studies, which include stratification, study type and / or advertising and region of advertising.

Notwithstanding the above discussion, the results of this study, with regards to patient demographics, were not dissimilar between the groups and there was no significant difference noted between the groups in terms of any of the demographic variables (age, gender and sidedness of the ITB) (all $p>0.05$). As a result of the baseline demographics not being significantly different between the four treatment groups, it suggests that the randomisation process and stringent application of the inclusion and exclusion criteria resulted in group homogeneity (Mouton, 1996). Thus, the lack of differences between the groups allowed for comparison between the treatment groups (Mouton, 1996). Therefore, all measurements post visit one, three, five and seven could be considered to be more directly related to the treatment itself and not due to the varying baseline demographic differences between the groups. The significance of this is that the results achieved are based purely on the treatment effect and that no controlling for demographic variances was needed in the statistical analysis.

From the above discussion, the only limitation in the interpretation of the results that may be considered is the effect of leg-dominance on the presentation of ITBFS (Ruedl *et al*., 2012). Considering that the right and left presentations of ITBFS were almost equal (54.2% and 45.8%), it would seem unlikely that leg-dominance induced ITBFS would have been influenced by gender, as suggested by Ruedl's *et al*. (2012) study, where females were found to be more likely to sustain an injury on their non-dominant leg and males more likely to sustain an injury to their dominant leg. For this research, the equality of left to right legs may be as a result of the stratification, whereby similar numbers of each gender were allocated to each of the groups, which contrasts with Ruedl's *et al*. (2012), Flanigan's *et al*. (2010) and Kannus's *et al*. (1999) studies. It is suspected that in the population group under study, road camber may also have played a role in the ITBFS presentation. This data was however not collected and it is therefore suggested that future studies consider including this information in their data collection in order to determine whether camber does play a significant role in the presentation and treatment of ITBFS patients.

4.7 The intra-group analysis

The intra-group analysis was conducted utilising the following primary outcome measurement tools:

- The Visual Analogue Scale (VAS) (Appendix L) was used to evaluate the subjective data provided by the participants' perception of their ITBFS pain. The VAS is a well-established outcome measure of pain intensity (Crossley *et al*., 2004; Price *et al*., 1994; Price *et al*., 1983; Merskey, 1973).

- A Knee Score Questionnaire (KSQ) (Yeomans, 2000) was used to evaluate subjective data provided by the participants' over a four-week period with regards to their perception of their ITBFS in terms of activity limitation. The KSQ is a modified version from Noyes's and Barber-Westin (1997) questionnaire and includes the following parameters / headings: pain, swelling, stability, overall activity level, walking, ascending or descending stairs, and running, jumping and twisting. The KSQ is a well-established outcome measurement tool that can be used to subjectively reflect the participant's pain threshold (Jenny and Diesinger, 2011; Garratt *et al*., 2004; Yeomans and Liebenson, 1997; Yeomans and Liebenson, 1996; Noyes and Barber-Westin, 1997). However, the MCID has not been determined for the KSQ, yet this instrument has continued to be used in assessing health outcomes in this study and so this deficiency must be addressed by future research (Garratt *et al.*, 2004).

The objective data was analysed using readings obtained from the algometer, which according to Kinser *et al*. (2009), Potter *et al.*, 2006, Williamson and Hoggart (2005), Fischer (1987) and Fischer (1986) is a reliable objective measurement tool, and can be considered valid.

These measures were supplemented with secondary outcome measures;

- Tibio-femoral angle,
- Q angle,
- Leg length,
- Feiss line, and
- Leg-heel alignment.

These results are presented per Group (A, B, C, and D) with the secondary (biomechanical) outcome measures being presented first and the primary (clinical) outcomes measures being discussed last. The reason for this reverse presentation is that the influence of biomechanical factors on the clinical outcome measures can only be considered and discussed with the clinical outcome measures, if the biomechanical measures are presented prior to the clinical measures.

4.8 To assess the intra-group changes over time in the ankle intervention group (Group A) with regard to the secondary and primary outcome measures

4.8.1 Effect of the ankle interventions

The objective was to determine the effect of an ankle joint manipulation in the treatment of ITBFS, which was represented in this study as Group A.

4.8.1.1 Tibio-femoral angle[4]

There was no statistically significant change over time according to Wilk's Lambda test (*p*=0.369)[5] in the tibio-femoral angle when manipulating the ankle joint. The graph indicates that a change did occur after measurement one with a downward trajectory, up to measurement three, before it plateaued.

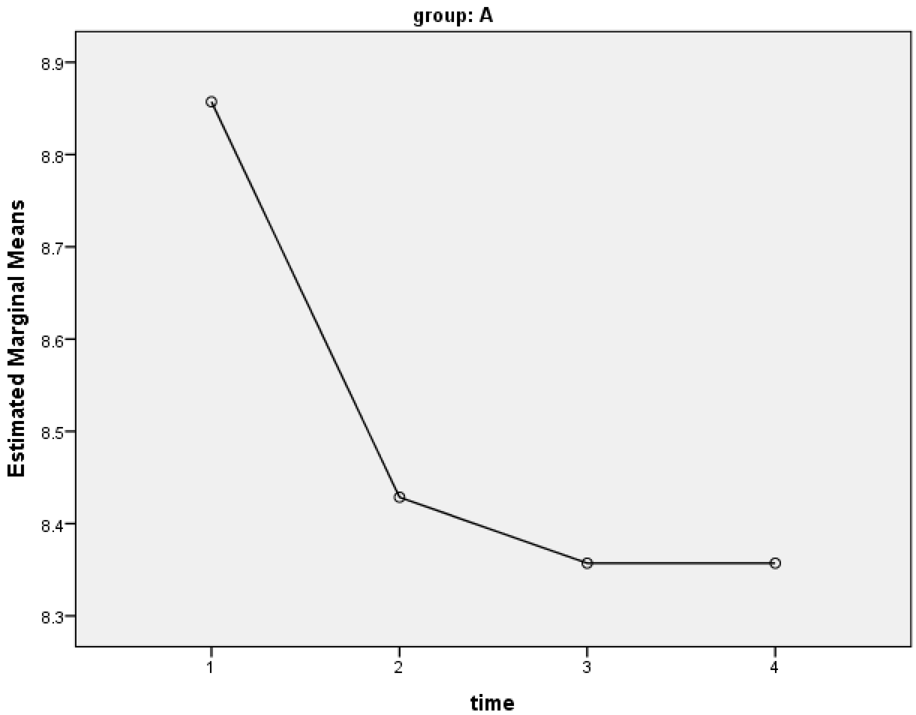

Figure 4.2: Profile plot for tibio-femoral angle over time following ankle joint manipulation (Group A)

[4] ***X axis = time: 1 – Visit one baseline reading; 2 – Visit three; 3 – Visit five; 4 – Visit seven (applicable to all figures)***

[5] ***Wilks Lambda results are inversely proportional to the outcome i.e. the lower the Wilks lambda scores, the higher/ greater improvement made in terms of readings (Esterhuizen, 2015) (applicable to all the references to Wilks Lambda).***

The decrease in the tibio-femoral angle (although small) seems to suggest that manipulation of the ankle results in a change in the biomechanics of the lower extremity. This change facilitated by manipulation seems to suggest that in patients with ITBFS the talus acts as the key stone of the talocrural joint and allows it to move more fully into its mortise (Reid *et al.*, 2007; Denegar *et al.*, 2002). This may lead to the tibia and fibula having to accommodate a greater portion of the talus in the mortise joint. This results in rotatory accommodation around the axes of these two long bones in order to have congruence between themselves and the talus (Landrum *et al.*, 2008; Vicenzino *et al.*, 2006; Denegar *et al.*, 2002). This rotation seems to result in an approximation of the femur to the tibia (medially), decreasing the medial knee compartment with a concomitant increase in the lateral knee compartment (suggesting the possibility of increased external rotation of the tibia as a result of the manipulation). This opening of the lateral knee compartment may then assist in stretching the vastus lateralis (and its pull on the ITB), which releases pressure as it passes over the knee, therefore providing relief from the tightness of the lateral thigh musculature and the ITB which is associated with the ITBFS.

This change in the knee biomechanical alignment may also be facilitated more directly at the lateral knee compartment by the effects of the ankle joint manipulation on the proximal and distal ends of the fibula (Landrum *et al.*, 2008; Vicenzino *et al.*, 2006; Whitman *et al.*, 2005; Collins *et al.*, 2004; Green *et al.*, 2001; Pellow and Brantingham, 2001; O'Brien and Vicenzino, 1998; Mulligan, 1995). This may have allowed for greater superior to inferior motion of the fibula, which has pulled on its distal insertion and stretched the ITB. This then has allowed for the normalisation of the tibio-femoral angle and thus tibio-femoral alignment.

These results imply that by manipulating the ankle joint the biomechanical shift that occurs over time could result in a reduced need for shock absorption by the knee, putting the emphasis back on the foot as the main shock absorber and a major impact distributor up the kinematic chain (Reid *et al.*, 2007; Decker *et al.*, 2003).

However this discussion must be contextualised with regards to the small sample size and therefore interpreted with caution.

4.8.1.2 Leg length of right leg (LL R)

When manipulating the ankle joint there was no statistically significant change over time according to Wilk's Lambda test (*p*=0.205) for leg length change in the right leg.

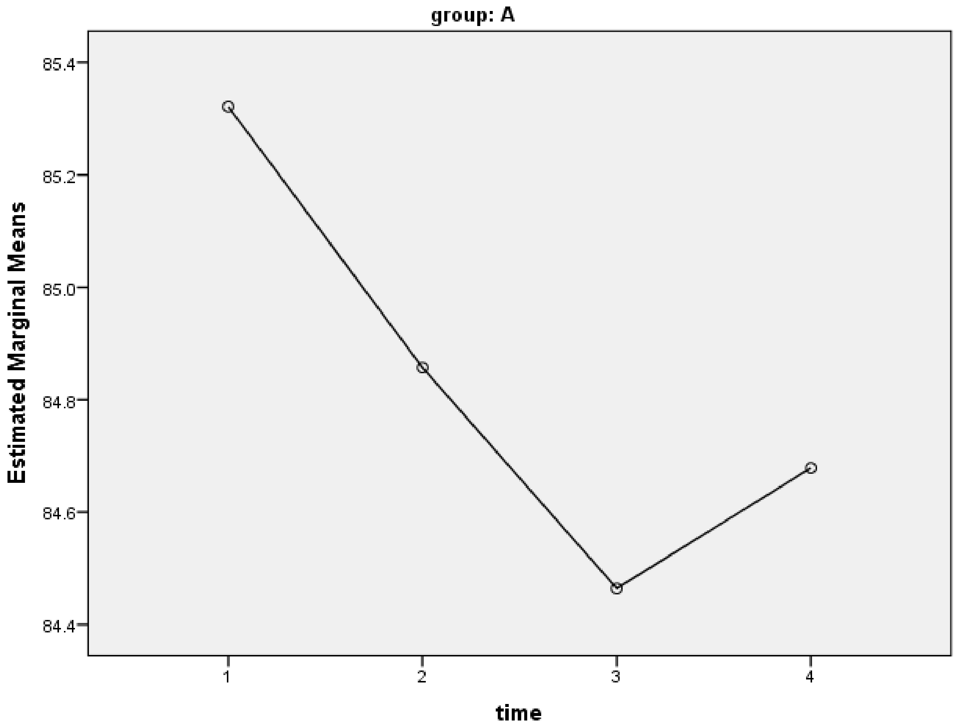

Figure 4.3: Profile plot for leg length of right leg over time following ankle joint manipulation (Group A)

4.8.1.3 Leg length of left leg (LL L)

As seen with the right leg length measurements, there was no statistically significant change over time (*p*=0.479) in the leg length of the left leg following manipulation of the ankle joint. As with the right leg, there was a downward trajectory, however, the final readings showed a plateau (in the same period as the right leg length increased).

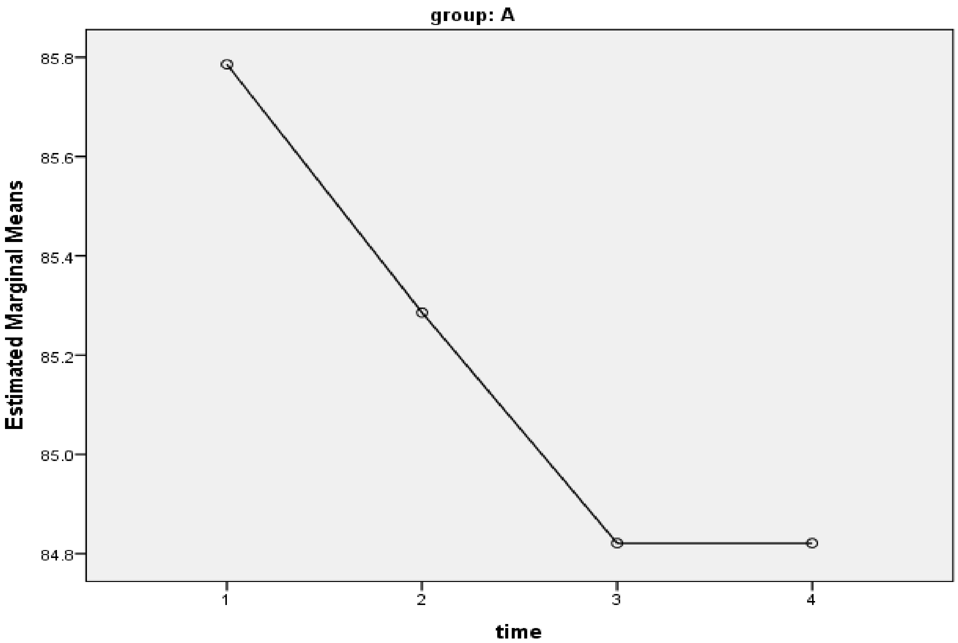

Figure 4.4: Profile plot for leg length of left leg over time following ankle joint manipulation (Group A)

From the above results, it seems to suggest that there is a marginal non-significant change in the leg length recorded over the treatment period in the ankle joint manipulation group (Group A), with a decrease in the leg length. Although clinically not significant, this suggests improved congruence of the talus in the mortise joint, formed by the crura of the tibia and fibula respectively (Denegar *et al*., 2002).

This minor change may indicate three possibilities:

1. That after manipulation, the ankle joint with improved ROM, is better able to deal with ground reactive forces in running by being better able to absorb shock, therefore allowing for better interaction between the muscles, periarticular tissue and arthrokinematics (Landrum *et al*., 2008; Vicenzino *et al*., 2006; Whitman *et al*., 2005; Collins *et al*., 2004; Guenther and Blickhan, 2002; Green *et al*., 2001; Pellow and Brantingham, 2001; O'Brien and Vicenzino 1998; Neely, 1998; Gross 1995). This decreases the need for the remainder of the lower limb joints and muscles to assist with compensation (Decker *et al*., 2003; Zhang *et al*., 2000; McNitt-Gray, 1993).

2. That after manipulation, the ankle joint with improved ROM is able to influence lower limb angular velocities particularly at the knee, therefore potentially reducing the likelihood of injury at the knee (Decker *et al*., 2003; Guenther and Blickhan, 2002).

3. That after manipulation of the ankle joint, there is limited need for the knee (predominant shock absorber in females (Decker *et al.*, 2003)) hip or sacroiliac joint to utilise flexion positions to absorb the shock during running. This limits the need for the body to compensate with muscular and / or ligamentous adaptations that would support this altered shock absorption position. This has relevance in terms of leg length in that unequal loading or excessive loading of the musculature may predispose the patient to acute injury, repetitive strain or compensations that causes asymmetry and leg length changes (as seen with ITBFS) (Novacheck, 1998).

The above assertions support the work of Visser *et al.* (1990), who indicated that when optimal joint angles were achieved, optimal muscle lengths were also attained and hence optimal function (Costain and Hackney, 1998). This explains why participants' in this intervention group showed some improvement in leg length, albeit statistically insignificant. This is in line with the suggestions made by Blustein and D'Aminco (1985), who stated that symmetry and good alignment resulted in increased muscle balance and efficiency, and decreased stress and fatigue.

As a result of the above discussion in terms of leg length, this suggests a change as a result of ankle joint manipulation, which increases the range of ankle joint motion (Brantingham *et al.*, 2012(b); Brantingham *et al.*, 2009(b)), which indicates that ankle dorsiflexion and plantarflexion changes occur. These outcomes should be correlated with changes in the clinical presentation of ITBFS so as to determine more accurately whether the trend described in this section above is supported more conclusively by clinical data.

4.8.1.4 Quadriceps angle (Q angle) of femur

There was no statistically significant change over time according to the Wilk's Lambda test (p=0.763) in the Q angle following ankle joint manipulation. The graph indicates an increase with an upward trajectory after measurement one, followed by a downward trajectory between measurement two and three before it plateaus to measurement four.

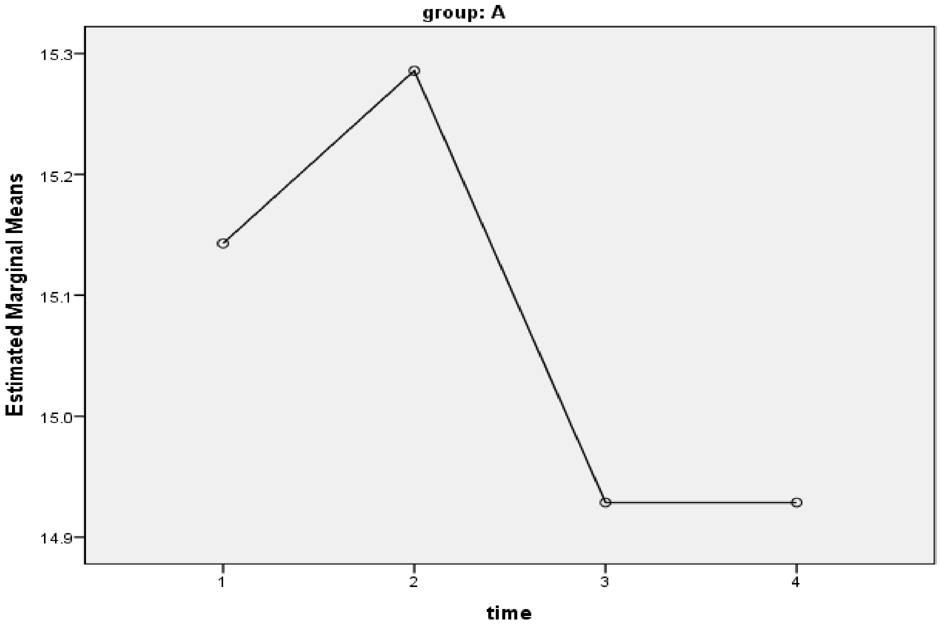

Figure 4.5: Profile plot for Q angle over time following ankle joint manipulation (Group A)

The above results indicate that there is an initial increase of the Q angle, followed by a decrease following manipulation of the ankle joint. This is not unexpected with biomechanical change (as discussed in Section 4.8.1.1), as the alignment and symmetry of the lower limb changes in reaction to the intervention (Brantingham *et al.*, 2012(b); Brantingham *et al.*, 2009(b); Subotnick, 1999).

This result is in keeping with the work of Jernick and Heifitz (1979), and Buchbinder *et al.* (1979), who indicated that dysfunction in the foot and ankle complex may predispose to chondromalacia patella, due to Q angle changes. They suggest along with Huberti and Hayes (1984) that increased or decreased Q angles (viz. asymmetry and its effect on the quadriceps's muscle vector pull on the patella) may lead to chondromalacia patella. This mechanism is similarly seen in the relationship between the Q angle and ITBFS, where Fredericson *et al.* (2006) indicated that an increased Q angle is likely to cause lateral deviation of the patella during quadriceps muscle contraction. This increases the ability of the stronger vastus lateralis (as opposed to the weaker vastus medialis) to retain the patella's position more laterally (Dippenaar *et al.*, 2008). This is also consistent with the assertion by Jernick and Heifitz (1979) as well as Buchbinder *et al.* (1979), that showed increased pronation with decreased dorsiflexion increases internal tibial rotation, which results in an increased Q-angle and therefore a higher likelihood of ITBFS (Brantingham *et al.*, 2012(b); Brantingham *et al.*, 2009(b); Landrum *et al.*, 2008; Vicenzino *et al.*, 2006; Whitman *et al.*, 2005; Collins *et al.*, 2004; Green *et al.*, 2001; Pellow and Brantingham, 2001;

O'Brien and Vicenzino, 1998; Huberti and Hayes, 1984). Therefore manipulation of the ankle joint in this study, is consistent with the literature indicating that increased dorsiflexion ROM of the ankle joint is likely to result in the opposite biomechanical changes (external rotation of the tibia and thus approximation of the origin and insertion of the tibia) that affects the Q angle and may improve the clinical outcomes for the patient suffering with ITBFS. However this discussion must be contextualised with regards to the small sample size and therefore interpreted with caution.

4.8.1.5 Feiss line

There was no statistically significant change in the Feiss line over time (p=0.392) following ankle joint manipulation. The Feiss line is a valid and reliable structural measure as a result of a dynamic process (weight bearing pronation and supination) between the hindfoot and the forefoot (Sporndly-Nees *et al.*, 2011; Neely 1998). Thus, although the Feiss line may show particular medial arch positions, the small changes that were seen preclude it as a predominant cause of a functional leg length inequality (Lun *et al.*, 2004). These small changes in the Feiss line may indicate that the ROM of the ankle joint (hindfoot) is more important in alleviating ITBFS in patients meeting the inclusion criteria for this study. These outcomes are consistent with Warren and Jones (1987) and Cowan *et al.* (1993), who suggest that biomechanical functioning as compared to static measures is more accurate in determining possible overuse pathologies.

4.8.1.6 Leg-heel alignment

Very minor change (0.1º) occurred over time in the Leg-heel alignment following manipulation of the ankle joint. Therefore, it is possible that the same discussion that centred on the Feiss line would be applicable to the Leg-heel alignment, with the exception of the hindfoot-forefoot analogy and the inclusion of subtalar-talocrural joint compensations, which are not amplified by the short distance between the talocrural and subtalar joints (Deneger *et al.*, 2002). This states that the subtalar joint is responsible for adaptation of the foot to the ground whereas the talocrural joint is actually responsible for adaptation of the foot to the ankle (Lopez-Rodriques *et al.*, 2007; Sugimoto *et al.*, 1997).

4.8.1.7 Knee score questionnaire (KSQ)

There was a highly statistically significant change over time ($p<0.001$) in the KSQ in Group A. The average change was approximately a 12.5% improvement. However, comment cannot be made on whether the average change over time is clinically important due to a paucity of literature with regards to the MCID for the KSQ, as this has not been determined yet for the KSQ.

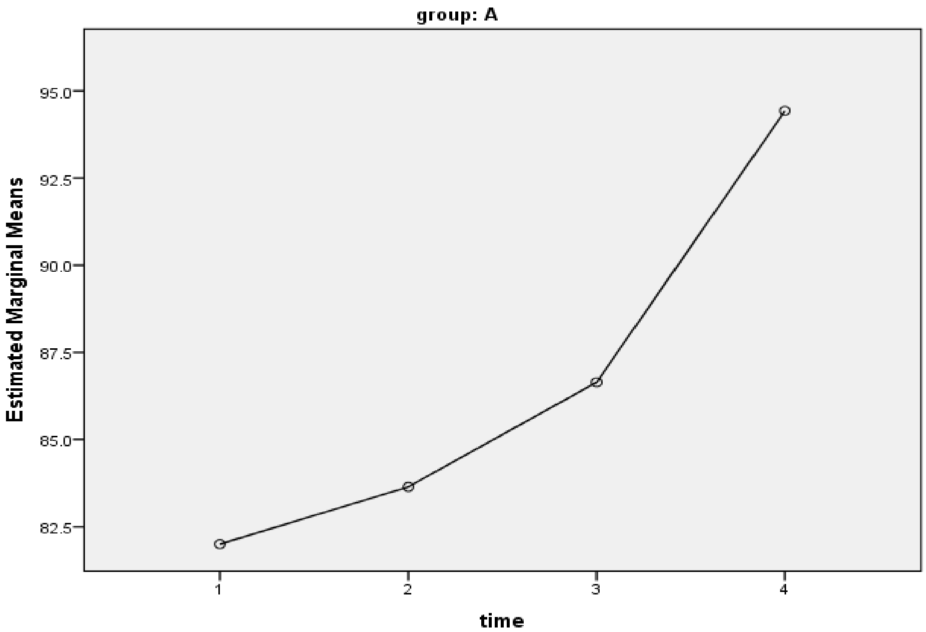

Figure 4.6: Profile plot for KSQ over time following ankle joint manipulation (Group A)

The results obtained in this study showed that those participants that received ankle manipulation improved in terms of their subjective evaluation of pain, swelling, stability and overall activity level in relation to their previous ITBFS-induced limitations. In congruence with the aforementioned discussions (Sections 4.8.1.1 – 4.8.1.6), the participants' benefit was statistically significant. It is therefore plausible to suggest that manipulation of the ankle joint complex does result in perceived clinical change, which seems to be related to small changes in the:

1. Tibio-femoral angle,
2. Leg length and
3. Q angle on the ipsilateral side to the ITBFS, with no or limited input from changes in the Feiss line and Leg-heel alignments respectively.

It should, however, also be considered that the collective change that has occurred in all these alignment measures might have resulted in the overall change in the participants' perceived improvement of their pain over time (Neely, 1998). Further research, with larger sample sizes, is required to confirm how the alignment changes may effect perceived clinical changes as shown by the KSQ.

4.8.1.8 Algometer

There was no statistically significant change over time in algometer measurements according to the Wilk's Lambda test (p=0.319) following manipulation of the ankle joint. The graph that follows indicates an increase in tenderness with a downward trajectory after measurement one, and a steady upward trajectory (decreased sensitivity) following measurements two through four. This indicates that participants did experience an improvement with regards to pain pressure threshold.

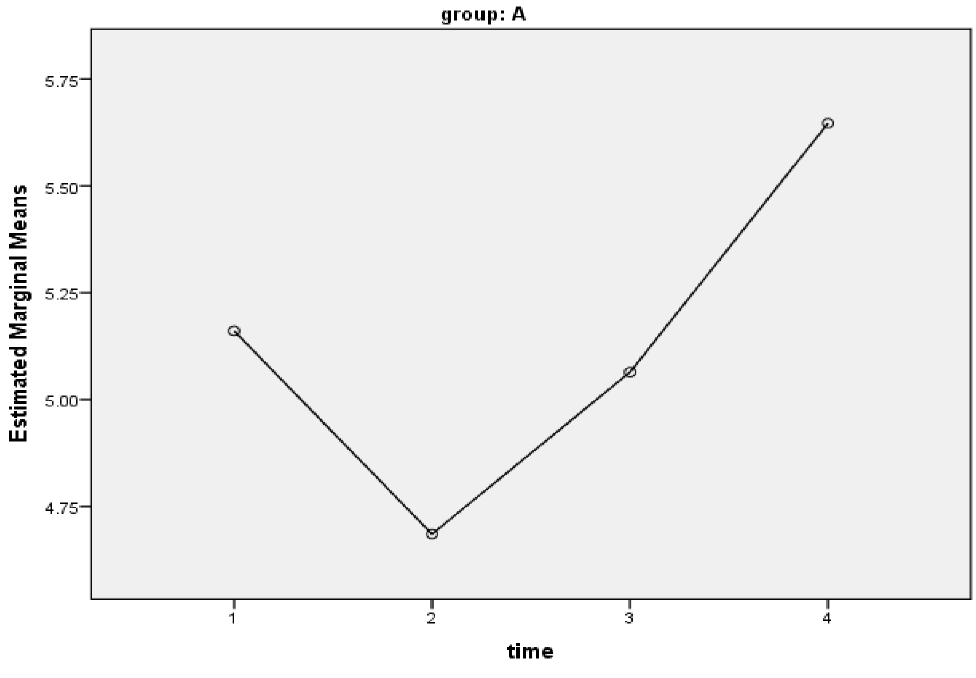

Figure 4.7: Profile plot for algometer over time following ankle joint manipulation (Group A)

The algometer reflects the pain pressure threshold of soft tissue structures (Kinser *et al.*, 2009; Williamson and Hoggart, 2005; Fischer, 1986). For this study, the point at which the algometer measures were taken was 2.5cm above the LFE on the ipsilateral limb of the ITBFS. This is near the location of trigger points 1 and 2 of the vastus lateralis muscle portion of the quadriceps femoris muscle (Chaitow and DeLany, 2002; Travell and Simons 1983).

The above results are congruent with the outcomes obtained for the Q angle followed by a decrease. A biomechanical change (which results from alignment and / or symmetry of the lower limb change) after an intervention may initially lead to a reactive muscle spasm (Travell and Simons 1983) before the altered biomechanics are accepted, and the reactive muscle activity settles (Brantingham *et al*., 2012(b); Brantingham *et al*., 2009(b); Subotnick, 1999). This settling muscle activity would allow the participant to tolerate the increased algometer pressure at subsequent readings (Kinser *et al*., 2009; Williamson and Hoggart, 2005; Fischer, 1986). This explanation is consistent with muscle loading changes that occur as biomechanical changes occur (Chaitow and DeLany, 2002; Travell and Simons 1983), and the reduced sensitivity that muscles would display (Robergs and Roberts, 1997).

These changes may however not be reflected in the KSQ (Section 4.8.1.7), as the increased movement available in the ankle joint as well as the changes in mechanical loading (and even perhaps in activity), may result in the activation of greater numbers of mechanoreceptors (Vernon and Mrozek, 2005; Suter *et al*., 2000; Hopkins and Ingersoll, 2000; William, 1997). This leads to decreased perceived pain (Melzack and Wall, 1965) and increased activity (Hillermann *et al*., 2006), allowing the participant to not perceive and therefore record the subtle changes that occur within the quadriceps femoris muscle as a result of the effect of the ankle manipulation on the Q angle.

4.8.1.9 Visual analogue scale (VAS)

There was a highly significant change over time according to the Wilk's Lambda test (p<0.001) in the VAS following manipulation of the ankle joint. A mean reduction in VAS of 20-25mm (sub-acute to chronic patients) and 30-35mm (acute patients) has been shown to represent a clinically important difference in pain severity (Lee *et al*., 2003(a)). Based on this, a mean reduction of 20-25mm in VAS was considered as a MCID. This measurement agrees with Ostelo and de Vet (2005) and Lee's *et al*. (2003(a) studies.

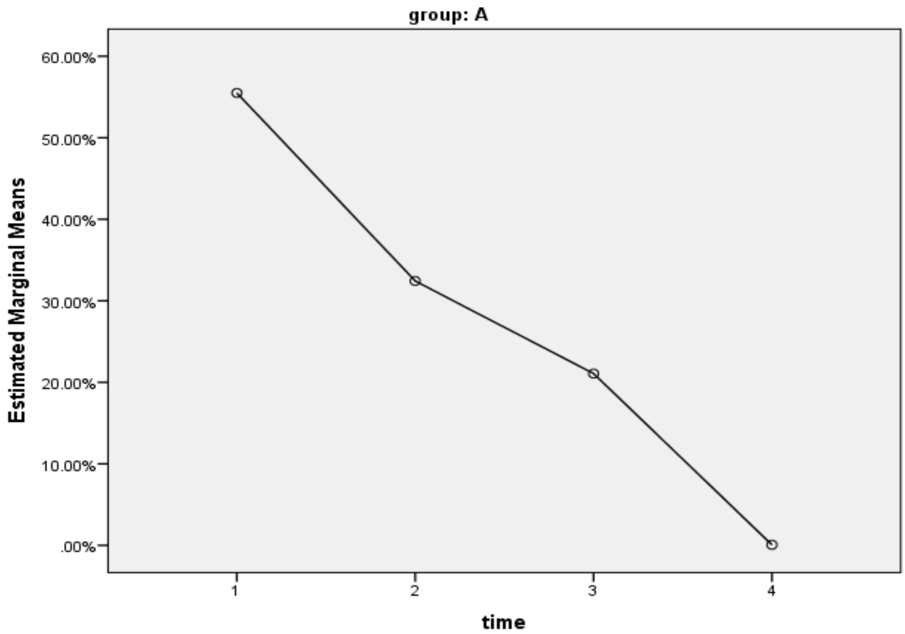

Figure 4.8: Profile plot for VAS over time following ankle joint manipulation (Group A)

The outcomes of the VAS are not unexpected, based on the discussion presented in Section 4.8.1.8, in which it was stated that:

1. Increased ROM in the ankle joint resulted in increased mechanoreceptive stimulation and therefore decreased pain (Vernon and Mrozek, 2005; Hopkins and Ingersoll, 2000; Suter *et al*., 2000; William, 1997).

2. The changes in the biomechanics of the lower extremity (as evidenced by the changes in the Q angle) further changes the mechanoreceptive and proprioceptive input from the lower extremity, which further reduces pain (Moayedi and Davis, 2013; Melzack and Wall, 1965).

3. The effects of the changes in the quadriceps femoris muscle are only for an initial period and not sufficient to be reported as overt pain but rather as muscle stiffness (Chaitow and DeLany, 2002; Travell and Simons 1983). As such MTPs may be better tolerated than the pain of ITBFS origin, which is inflammatory in nature and possibly more severe (Lavine, 2010; Fredericson *et al*., 2000; Orchard *et al*., 1996; Holmes *et al*., 1993; Grady *et al*., 1986; Lindenburg *et al*., 1984; Noble *et al*., 1982; Williams, 1980). Thus, with the participant changing the type of pain, there may be an initial perception that the ITBFS is improving, when in fact the symptoms of pain may be totally unrelated.

4.8.1.10 Pearson's correlation

Table 4.3: Correlations between primary and secondary outcome measures for the ankle intervention (Group A)

		Change tibio-femoral angle	Change Leg Length (Right)	Change Leg Length (Left)	Change Q-angle	Change Feiss line	Change KSQ	Change Algometer	Change VAS
Change tibio-femoral angle	Pearson Correlation	1	0.378	0.482	0.026	-0.353	0.332	0.308	0.076
	Sig. (2-tailed)		0.183	0.081	0.930	0.216	0.246	0.284	0.796
	N	14	14	14	14	14	14	14	14
Change Leg Length (Right)	Pearson Correlation	0.378	1	0.967**	-0.210	0.557*	0.028	0.466	0.465
	Sig. (2-tailed)	0.183		0.000	0.471	0.039	0.923	0.093	0.094
	N	14	14	14	14	14	14	14	14
Change Leg Length (Left)	Pearson Correlation	0.482	0.967**	1	-0.093	0.413	0.153	0.490	0.419
	Sig. (2-tailed)	0.081	0.000		0.751	0.142	0.602	0.075	0.136
	N	14	14	14	14	14	14	14	14
Change Q-angle	Pearson Correlation	0.026	-0.210	-0.093	1	-0.410	0.163	0.131	-0.578*
	Sig. (2-tailed)	0.930	0.471	0.751		0.146	0.578	0.655	0.030
	N	14	14	14	14	14	14	14	14
Change Feiss line	Pearson Correlation	-0.353	0.557*	0.413	-0.410	1	-0.226	0.063	0.294
	Sig. (2-tailed)	0.216	0.039	0.142	0.146		0.436	0.832	0.308
	N	14	14	14	14	14	14	14	14
Change KSQ	Pearson Correlation	0.332	0.028	0.153	0.163	-0.226	1	0.340	-0.403
	Sig. (2-tailed)	0.246	0.923	0.602	0.578	0.436		0.234	0.153
	N	14	14	14	14	14	14	14	14
Change Algometer	Pearson Correlation	0.308	0.466	0.490	0.131	0.063	0.340	1	-0.058
	Sig. (2-tailed)	0.284	0.093	0.075	0.655	0.832	0.234		0.844
	N	14	14	14	14	14	14	14	14
Change VAS	Pearson Correlation	0.076	0.465	0.419	-0.578*	0.294	-0.403	-0.058	1
	Sig. (2-tailed)	0.796	0.094	0.136	0.030	0.308	0.153	0.844	
	N	14	14	14	14	14	14	14	14

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

From the Correlation Table (Table 4.3), it can be seen that the only significant relationships are the following:

1. Change in the right leg length in relation to the change in the left leg length (positive relationship).
   This implies that the degree of change in one leg was mirrored by the degree of change in the other leg. This is consistent with the discussion in these sections (A and B).

2. Change in the right leg length and changes in the Feiss line (positive relationship).
   This would imply that the degree of change in the Feiss line mirrors the degree of change in the right leg length. Due to the changes in the Feiss line being very small, it was not possible to create a graph outlining its degree of change (Section 4.8.1.6). However, the outcomes of the correlation seem to suggest that the change in the mechanics of the right foot of patients in this group were related to changes in the Feiss line. This outcome may be related to the athlete's leg dominance, increased load on the foot and ankle and thus increased compensation in both the forefoot and the hindfoot. As was previously suggested, this requires further study.

3. Changes in the Q angle and changes in the VAS (negative relationship).
   This suggests that as the Q angle increases, this leads to a decrease in the VAS, as compared to a decreased change in the Q angle leading to an increased change in the VAS. The latter is seen in this study, where a small increase in the Q angle leads to a rapid, significant decrease in the VAS (i.e. a large change).

Therefore, these correlations re-enforce the discussions regarding leg length (Sections 4.8.1.2 and 4.8.1.3) as well as the discussion of the improved functional ability being related to decreased pain (Section 4.8.1.7).

4.8.1.11 Summary / discussion on objective one

Based on the intra-group results presented (Sections 4.8.1.1 to 4.8.1.9), the following table (Table 4.4) summarises the outcomes that were obtained for those participants with ITBFS who received ankle joint manipulation.

Table 4.4: Summary table for the ankle intervention (Group A)

Measurements	Significant Difference[6]	Change
Tibio-femoral angle	None	↓
LL R you have left a space	None	↓
LL L ditto	None	↓
Q angle	None	↓
Feiss line	None	None
Leg-heel alignment	None	Minimal
KSQ	Significant	↑
Algometer	None	↑
VAS	Significant	↓

Based on the results obtained from Group A, it appears that hypomobility of the ankle joint plays a role in participants developing ITBFS. This concurs with the assertions that abnormal restrictive barriers to accessory movement (decreasing the ability of the talus to move into the talocrural joint (Denegar *et al.*, 2002)), can cause changes in the normal pattern of movement around the instantaneous axis of rotation (IAR) of the ankle joint, and therefore change the biomechanics of the lower extremity (Fujii *et al.*, 2010; Bogduk, 1997; White and Panjabi, 1990; Sammarco *et al.*, 1973). This also supports the work of Wolfe *et al.* (2001), Baumhauer *et al.* (1995), Kannus and Renstrom (1991) and Milgrom *et al.* (1991), who suggested that ankle injury is likely to cause local and more global mechanical dysfunction (Landrum *et al.*, 2008; Vicenzino *et al.*, 2006; Whitman *et al.*, 2005; Collins *et al.*, 2004; Denegar and Miller, 2002; Green *et al.*, 2001; Pellow and Brantingham, 2001; O'Brien and Vicenzino, 1998).

The ankle intervention in this study was aimed at improving the mechanics at the ankle joint by decreasing hypomobility at the talocrural joint (Denegar *et al.*, 2002; Green *et al.*, 2001) and distal tibio-fibular joint (Kavanagh, 1999; O'Brien and Vicenzino, 1998; Hetherington,

[6] Statistically there was no significant difference reported, although changes / trends over time did occur.

1996). The resulting increased ankle dorsiflexion and joint mobility, positively affected lower limb biomechanics (Drewes, *et al.* 2009; Landrum *et al.*, 2008; Monaghan *et al.*, 2006; Vicenzino *et al.*, 2006; Whitman *et al.*, 2005; Collins *et al.*, 2004; Denegar, *et al.* 2002; Green *et al.*, 2001; Pellow and Brantingham, 2001; O'Brien and Vicenzino, 1998).

From the results obtained, there seems to be a positive trend for statistically significant levels of improvement (in VAS and KSQ), which suggests clinical improvement for patients. This suggests that ankle manipulation has an effect on decreasing the aberrant leg biomechanics that have an effect on predisposing the patient to ITBFS. As a result, it is important that clinicians consider this joint when evaluating patients presenting with ITBFS.

Limitations to a more generalised conclusion are not possible in that:

- The numbers of the sample for this group in this study were small. Therefore, it is suggested that a study with a larger sample size is carried out in the future.

- The time period of the clinical trial was only four weeks, with final measurements taken a week after the final treatment. It is therefore, only possible to state that the outcomes are related to short-term effects of the clinical intervention and as such medium or long term outcomes were not established. Therefore, a study similar to this one, with a one month, six month and twelve month follow-up is recommended.

- Lastly, because the biomechanical chain is responsive to change, thereby allowing for compensation, it is likely that any one participant may have presented with more than one restriction throughout the lower limb kinematic chain. The allocation of the participants was also made based on the severity of the restrictions found, with the result that participants in the ankle joint group (Group A) had the most severe restriction in the ankle joint (which did not preclude restrictions elsewhere). This is another factor that may have hampered the outcome of this group's results, as not all biomechanical dysfunctions would have been addressed. A future study may wish to consider having a pure ankle joint complex group (viz. only the ankle joint is restricted) and compare this to a group in which both an ankle joint restriction and another joint in the kinematic chain are involved; in order to determine the effect of multiple restrictions on the outcome of the clinical measures used in this study.

4.9 To assess the intra-group changes over time in the superior tibio-fibular intervention group (Group B) with regard to the secondary and primary outcome measures

4.9.1 Effect of the superior tibio-fibular interventions

The objective was to determine the effect of a Superior tibio-fibular joint manipulation in the treatment of ITBFS, which was represented in this study as Group B.

4.9.1.1 Tibio-femoral angle

There was no statistically significant change over time according to Wilk's Lambda test (p=0.405) in the tibio-femoral angle when manipulating the superior tibio-fibular joint. The graph that follows indicates an overall downward trajectory after measurement one, with a slight subsequent upward trajectory between measurement two and three, before it plateaus to measurement four.

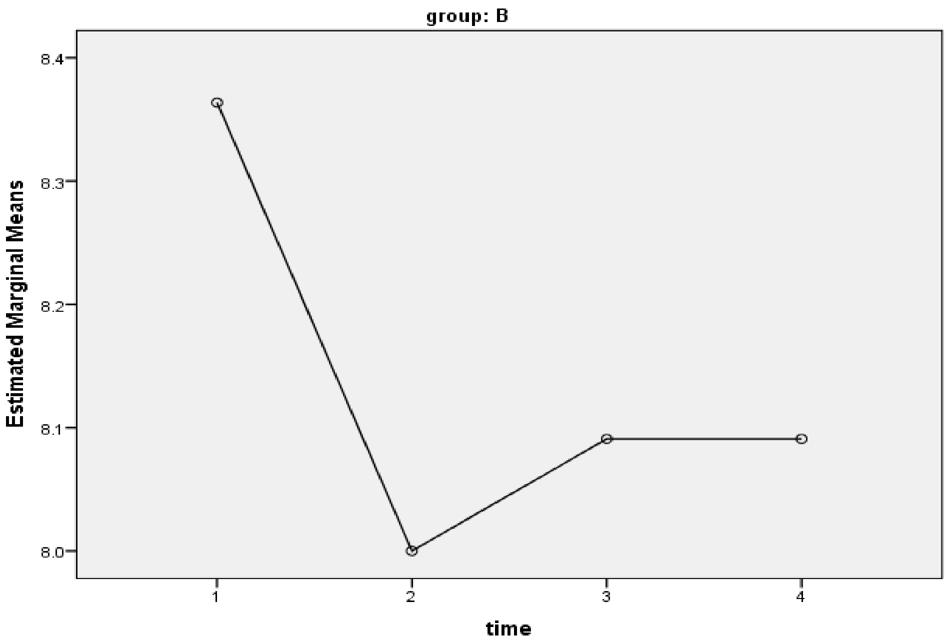

Figure 4.9: Profile plot for tibio-femoral angle over time following superior tibio-fibular joint manipulation (Group B)

The decrease in the tibio-femoral angle (although small) seems to suggest that manipulation of the superior tibio-fibular joint results in some functional change in the biomechanics of the lower extremity.

This change facilitated by manipulation seems to suggest that patients with ITBFS react in one of two ways to manipulation:

1. Manipulation has an effect of decreasing the hypertonicity of the muscles that insert over the region of the joint (TFL via the ITB and peronei), via a process of reducing arthrogenic muscle inhibition (Pickar, 2002; Hopkins and Ingersoll, 2000; Suter *et al.*, 2000) or through inhibitory neurological reflexes (Leach, 2004; Pickar, 2002; Indahl *et al.*, 1997).

2. Manipulation results in a biomechanical change (Pickar, 2002), where there is a shift in the weight bearing capacity (centre of gravity) from the fixed fibula back to the tibia (Sharma *et al.*, 2001). This subtle shift (the movement is not large as a result of the structure of the articulating surfaces), causes a decrease in the tibio-femoral angle (Freeman and Pinskerova, 2005; Bonaldi *et al.*, 1998). This results in an approximation of the femur to the tibia (medially), decreasing the medial knee compartment with a concomitant increase in the lateral knee compartment (Sharma *et al.*, 2001; Bruns *et al.*, 1994; McKellop *et al.*, 1994). The opening of the lateral knee compartment then further enforces this mechanical change by assisting in stretching the vastus lateralis (Chaitow and DeLany, 2002; Travel and Simons, 1983). This occurs by decreasing the pull on the ITB (of the dysfunctional fibula) and the tightness of the lateral thigh musculature and fascia, which decreases the associated signs and symptoms of ITBFS (Fredericson *et al.*, 2006; Bonaldi *et al.*, 1998).

3. Manipulation of the superior tibio-fibular joint would also directly result in effects at the distal end of the fibula (Landrum *et al.*, 2008; Vicenzino *et al.*, 2006; Whitman *et al.*, 2005; Collins *et al.*, 2004; Denegar, *et al.* 2002; Green *et al.*, 2001; Pellow and Brantingham, 2001; O'Brien and Vicenzino, 1998; Mulligan, 1995), which may allow for greater inferior to superior motion of the fibula as a whole (Bergmann and Petersen, 2011; Bergman *et al.*, 1993). Therefore, decreasing the pull on the ITB and thus allowing for the normalisation of the tibio-femoral alignment and consequently the tibio-femoral angle.

The above changes may occur singularly or in combination (Leach, 2004; Pickar, 2002).

4.9.1.2 Leg length of right leg (LL R)

When manipulating the superior tibio-fibular joint there was no statistically significant change over time according to Wilk's Lambda test (*p*=0.405) for leg length change in the right leg. Although not significant, the change in the graph indicates a downward trajectory after measurement one and a plateau effect after measurement two.

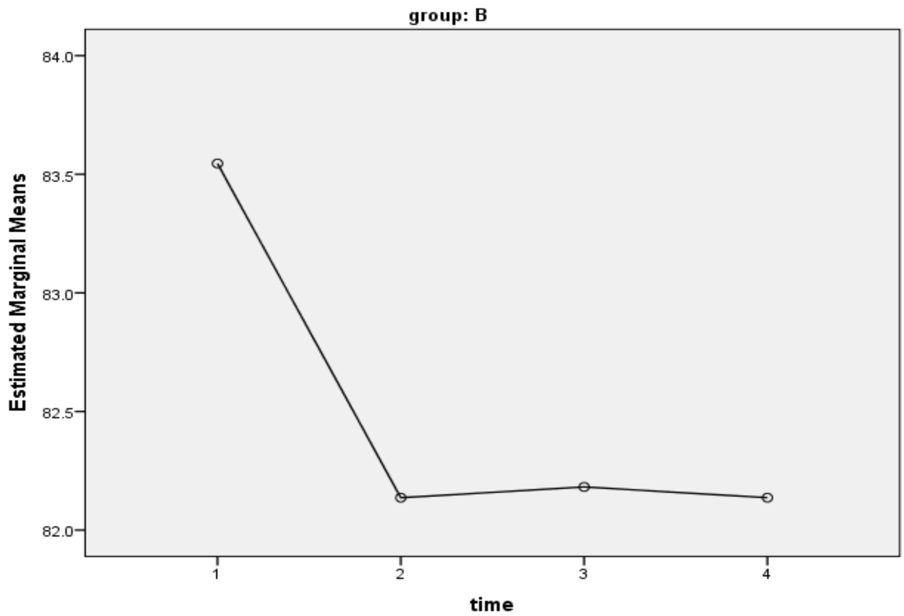

Figure 4.10: Profile plot for leg length of right leg over time following superior tibio-fibular joint manipulation (Group B)

4.9.1.3 Leg length of left leg (LL L)

As seen with the right leg length measures, there was no statistically significant change over time in the left leg length measures of participants according to the Wilk's Lambda test (*p*=0.405), when manipulating the superior tibio-fibular joint. As with the graph in Section 4.9.1.2, the following graph represents measurement outcomes in respect of the left leg, and presents similarly.

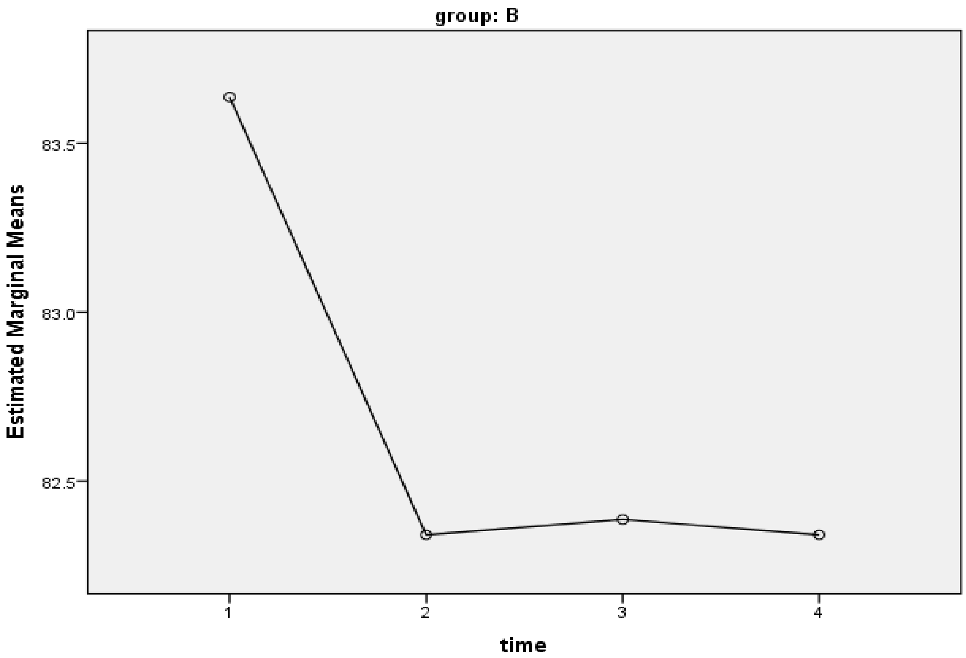

Figure 4.11: Profile plot for leg length of left leg over time following superior tibio-fibular joint manipulation (Group B)

Not dissimilar to Group A (ankle joint manipulation), it is seen in the right and left leg length measures, that manipulation of the superior tibio-fibular joint reduces the length of the legs as measured in this study (see Section 3.4.5 for explanation thereof).

As previously discussed, it is likely that manipulation of the superior tibio-fibular joint had an effect on the distal tibio-fibular joint and thus improved the alignment in the talocrural joint (Landrum *et al*., 2008; Vicenzino *et al*., 2006; Whitman *et al*., 2005; Collins *et al*., 2004; Denegar, *et al*. 2002; Green *et al*., 2001; Pellow and Brantingham, 2001; O'Brien and Vicenzino, 1998). This improved alignment would have resulted in potential shortening of the leg as the talus was better able to move into the crura provided by the tibia and fibula respectively (Fujii *et al*., 2010).

This improved alignment would have been responsible for the improved dorsiflexion at the ankle joint (Landrum *et al*., 2008; Vicenzino *et al*., 2006; Whitman *et al*., 2005; Collins *et al*., 2004; Denegar, *et al*. 2002; Green *et al*., 2001; Pellow and Brantingham, 2001; O'Brien and Vicenzino, 1998). These changes in the functioning of the ankle joint (Section 4.8.1.11) are further supported by the work of Wolfe *et al*. (2001), Bogduk (1997), Baumhauer *et al*. (1995), Kannus and Renstrom (1991) and Milgrom *et al*. (1991), White and Panjabi (1990) and Sammarco *et al*. (1973).

4.9.1.4 Quadriceps angle (Q angle) of femur

The graph indicates that there was no statistically significant change over time in the Q angle of the femur according to the Wilk's Lambda test (p=0.441) when manipulating the superior tibio-fibular joint. An overall decrease occurred with a downward trajectory from measurement one to measurement two, after which it plateaued.

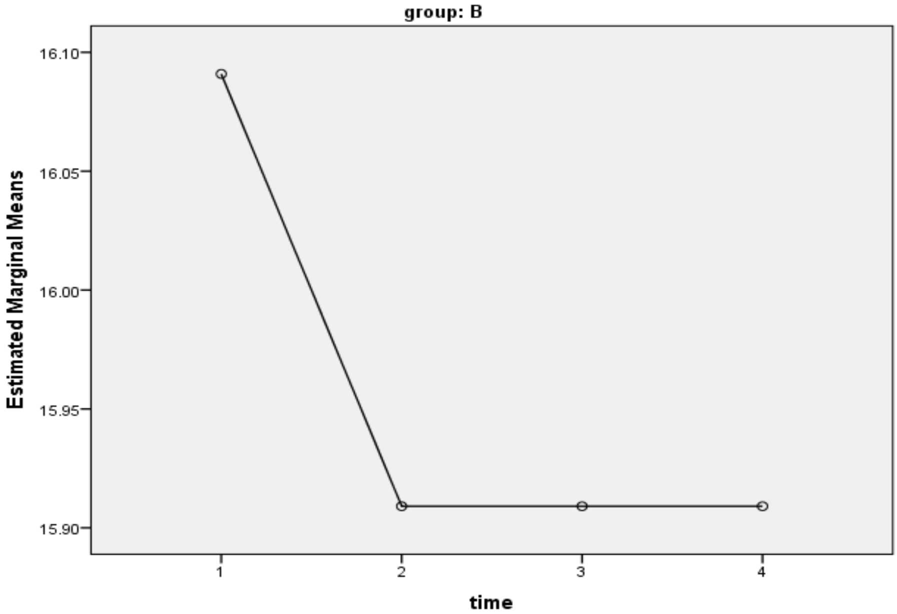

Figure 4.12: Profile plot for Q angle over time following superior tibio-fibular joint manipulation (Group B)

In much the same manner as the tibio-femoral angle changes following manipulation of the superior tibio-fibular joint (Section 4.9.1.1); the manner in which manipulation of the superior tibio-fibular joint changes the Q angle may be related to:

1. Manipulation having an effect of decreasing the hypertonicity of the muscles (quadriceps femoris muscle) that insert via the ITB over the region of the superior tibio-fibular joint (Hillermann *et al.*, 2006; Suter *et al.*, 2000). This may occur via the process of reducing arthrogenic muscle inhibition (Pickar, 2002; Hopkins and Ingersoll, 2000; Suter *et al.*, 2000) or through inhibitory neurological reflexes (Leach, 2004; Pickar, 2002; Indahl *et al.*, 1997).

2. Manipulation results in a biomechanical change (Pickar, 2002), where there is a shift in the weight bearing capacity from the fixed fibula, back to the tibia (Sharma *et al.*, 2001). As previously explained, this subtle shift results in opening of the lateral knee

compartment, reducing pressure on this compartment and thus the pull on the ITB that is linked to the capsule, retinaculum and the lateral collateral ligaments (Standring, 2009; Moore and Dalley, 2006). This is supported by Johnson (1989), who indicated that superior tibio-fibular dysfunction was a component of lateral facet syndrome of the knee. This is associated with tight lateral musculature and a tight retinaculum and a laterally displaced patella, which increases the likelihood of signs and symptoms associated with ITBFS (Fredericson *et al.*, 2006). Therefore, manipulation of the superior tibio-fibular joint would as a consequence assist in decreasing the likelihood of lateral facet syndrome (Johnson, 1989), thereby improving patella function with a resultant clinical improvement of ITBFS, or alternatively result in a decrease in the downward pull of the ITB, hence also decreasing the clinical signs and symptoms of ITBFS.

Both of the above mechanisms would alleviate either a muscular or a ligamentous pull of the patella laterally as well as decreasing the downward pull on the ITB, thus decreasing the ITBFS symptoms and changing the signs, which would include a decrease in the Q angle.

4.9.1.5 Feiss line

There was no statistically significant change in the Feiss line over time according to the Wilk's Lambda test (p=1.000) following superior tibio-fibular joint manipulation. It was previously noted that the Feiss line is a valid and reliable structural measure as a result of a dynamic process (weight bearing pronation and supination) (Sporndly-Nees *et al.*, 2011; Neely 1998). It is unlikely that a more proximal change in biomechanics was likely to affect the Feiss line as a result of superior tibio-fibular joint manipulation. This is particularly true if the superior tibio-fibular joint manipulation had no effect on tibial internal rotation, which is unlikely as talocrural joint manipulation also revealed no statistically significant changes.

Thus, the lack of change in the Feiss line and therefore medial arch position as a result of superior tibio-fibular joint manipulation may indicate that its effect on the ROM of the superior tibio-fibular joint is more important in alleviating ITBFS than its potential to change foot supination / pronation. This however requires further study.

4.9.1.6 Leg-heel alignment

No statistically significant difference in leg-heel alignment over time was observed when manipulating the superior tibio-fibular joint, which is consistent with previous discussion (Section 4.8.1.6).

4.9.1.7 Knee scoring questionnaire (KSQ)

There was a highly significant change over time according to the Wilk's Lambda test (p=0.009) in the KSQ in Group B. The average change was approximately an 18.5% improvement. Comment cannot be made on whether the average change over time is clinically important due to a paucity of literature in this regard.

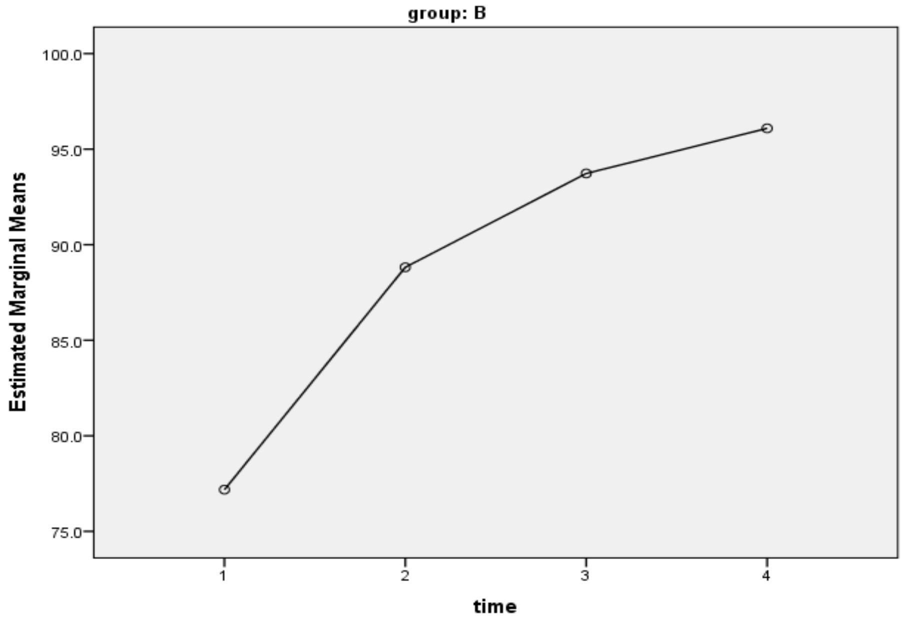

Figure 4.13: Profile plot for KSQ over time following superior tibio-fibular joint manipulation (Group B)

The results obtained in this study showed that those participants that received superior tibio-fibular joint manipulation improved in terms of their subjective evaluation of pain, swelling, stability and overall activity level in relation to their ITBFS. The outcomes obtained here show that the participants received a statistically significant benefit. It is therefore plausible to suggest that manipulation of the superior tibio-fibular joint does result in perceived clinical change, which seems to be related to change in the:

1. Tibio-femoral angle (this may be a direct result of the manipulation at the mid-point of the tibio-femoral angle),

2. Leg length (this may be as an indirect result of the effect of the manipulation on the talocrural joint and alignment of the talus in this joint), and;

3. Q angle on the ipsilateral side to the ITBFS (this may be a direct result of the manipulation at the mid-point of the tibio-femoral angle), with no or limited input from changes in the Feiss line and Leg-heel alignments respectively.

It should however also be considered that the collective change that occurred in all these alignment measures might have resulted in the overall change in the perceived improvements of the participants over time (Neely, 1998). Further research, with larger sample sizes, is required to confirm how the alignment changes may reflect perceived clinical changes as shown by the KSQ.

4.9.1.8 Algometer

There was no statistically significant change over time in the algometer readings according to the Wilk's Lambda test (p=0.290) when manipulating the superior tibio-fibular joint. The following graph indicates an overall increase with no trajectory change between measurement one and two. An upward trajectory is noticed between measurement two and measurement four (indicating decreased sensitivity and increased kilograms per square centimetre of applied pressure). This indicated that participants did experience an improvement with regards to pain pressure threshold.

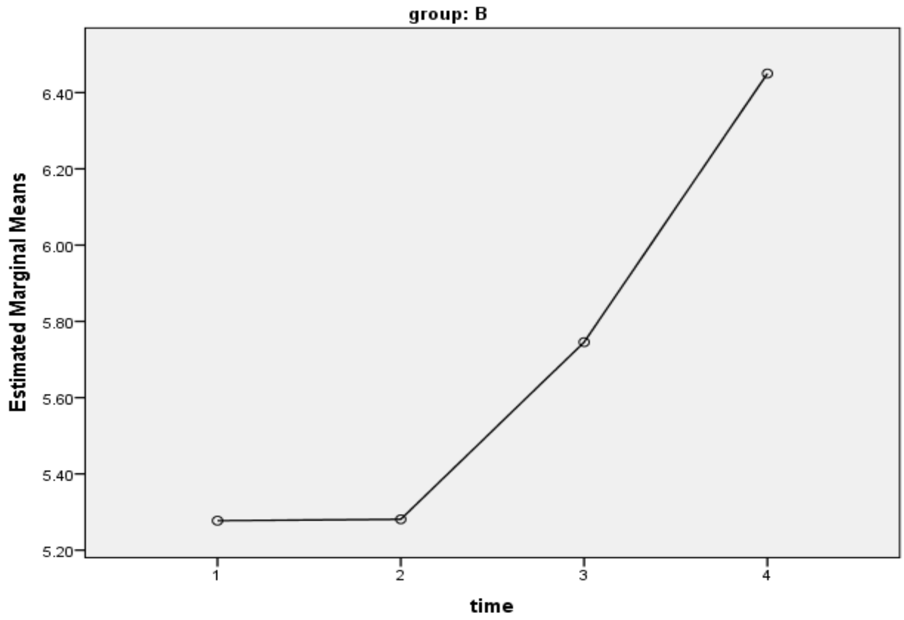

Figure 4.14: Profile plot for algometer over time following superior tibio-fibular joint manipulation (Group B)

The algometer reflects pain pressure threshold of soft tissue structures (Kinser *et al.*, 2009; Williamson and Hoggart, 2005; Fischer, 1986). For this research it was used as a tool to measure change in the presentation of ITBFS. Thus, the anatomical location of application was 2.5cm above the LFE on the ipsilateral limb of the ITBFS. This is near the location of trigger points 1 and 2 of the vastus lateralis (Chaitow and DeLany, 2002; Travell and Simons 1983) muscle portion of the quadriceps femoris muscle.

The above results are congruent with the outcomes obtained for the Q angle, in which there was a decrease after measurement one, followed by a plateau after measurements two, three and four. A biomechanical change (which results from alignment and / or symmetry of the lower limb change) after an intervention may initially cause a protective reactive muscle spasm before the altered biomechanics are accepted as biomechanically normal (Brantingham *et al.*, 2012(b); Brantingham *et al.*, 2009(b); Subotnick, 1999). Alternatively, because the muscles are now relaxed and able to function optimally post manipulation (Leach, 2004), it may be that they are predisposed to higher levels of fatigue, which may result in a form of delayed onset muscle stiffness (DOMS) (Cheung *et al.*, 2003). Both these outcomes would have led to immediate muscle tenderness, which would not have reflected as an improvement after measurement two. However, the settling of the biomechanical changes or the DOMS that would have occurred during the succeeding weeks would have enabled the participant to tolerate a higher algometer pressure at subsequent measurements (Kinser *et al.*, 2009; Williamson and Hoggart, 2005; Fischer, 1986). This explanation is again consistent with muscle loading changes that occur as biomechanical changes (Chaitow and DeLany, 2002; Travell and Simons 1983), and the sensitivity that muscles would display at the various time points during the change (Robergs and Roberts, 1997).

These changes may however not be reflected in the KSQ (Section 4.9.1.7), as the increased movement available in the superior tibio-fibular joint as well as the changes in mechanical loading, and even perhaps during activity, may result in the activation of greater numbers of mechanoreceptors (Vernon and Mrozek, 2005; Hopkins and Ingersoll, 2000; Suter *et al.*, 2000; William, 1997). This would decrease perceived pain, which would enable the participant to increase their activity (Hillermann *et al.*, 2006; Melzack and Wall, 1965).

4.9.1.9 Visual analogue scale (VAS)

There was a highly significant change over time according to the Wilk's Lambda test (p<0.001) in the VAS following superior tibio-fibular joint manipulation. Participants also had a clinically significant change in their perception of pain as recorded on the VAS over the four measurement time points.

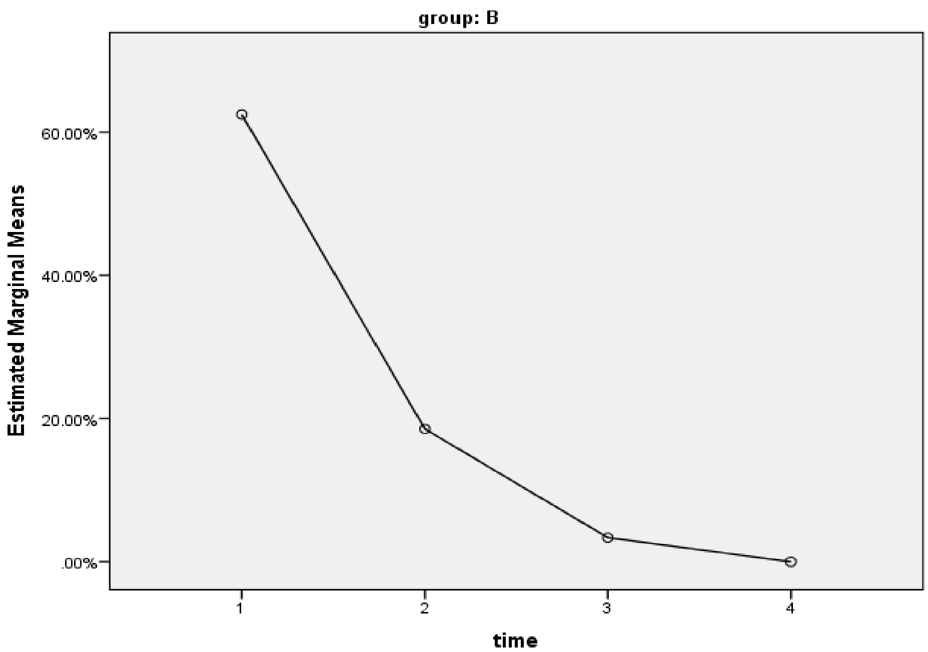

Figure 4.15: Profile plot for VAS over time following superior tibio-fibular joint manipulation (Group B)

The outcomes of the VAS are not unexpected, based on:

1. Increased ROM in the superior tibio-fibular joint may result in increased mechanoreceptive stimulation and therefore decreased pain perception (Vernon and Mrozek, 2005; Suter *et al*., 2000; Hopkins and Ingersoll, 2000; William, 1997). Thus, it could be expected that the VAS would decrease over the measurement period.

2. The changes in the biomechanics of the lower extremity (as evidenced by the changes in the Q angle for example (Section 4.9.1.4)) further change the mechanoreceptive and proprioceptive input from the lower extremity (i.e. ankle, tibio-femoral and hip joints) further reducing pain (Moayedi and Davis, 2013; Melzack and Wall, 1965).

3. The effects of the changes in the quadriceps femoris muscle are only for an initial period (possibly at the point of manipulation) and not sufficient for the participant to report it as overt pain (e.g. DOMS) (Cheung *et al*., 2003; Chaitow and DeLany, 2002; Travell and Simons 1983). Additionally, MFTPs are tolerated to a greater degree than the pain of ITBFS origin, which is usually inflammatory in nature and possibly more severe (Lavine, 2010; Fredericson *et al*., 2000; Orchard *et al*., 1996; Holmes *et al*., 1993; Grady *et al*., 1986; Lindenburg *et al*., 1984; Noble *et al*., 1982; Williams, 1980). Thus with the patient changing the type of pain there may be an initial perception that the ITBFS is improving, when in fact the symptoms of pain may be totally unrelated.

4.9.1.10 Pearson's correlation

Table 4.5: Correlations between primary and secondary outcome measures for the superior tibio-fibular intervention (Group B)

		Change tibio-femoral angle	Change Leg Length (Right)	Change Leg Length (Left)	Change Q-angle	Change Feiss line	Change KSQ	Change Algometer	Change VAS
Change tibio-femoral angle	Pearson Correlation	1	0.646*	0.633*	0.214	.[c]	-0.557	0.375	0.198
	Sig. (2-tailed)		0.032	0.036	0.527	.	0.075	0.255	0.560
	N	11	11	11	11	11	11	11	11
Change Leg Length (Right)	Pearson Correlation	0.646*	1	1.000**	-0.518	.[c]	-0.743**	0.212	0.300
	Sig. (2-tailed)	0.032		0.000	0.103	.	0.009	0.532	0.370
	N	11	11	11	11	11	11	11	11
Change Leg Length (Left)	Pearson Correlation	0.633*	1.000**	1	-0.522	.[c]	-0.757**	0.214	0.301
	Sig. (2-tailed)	0.036	0.000		0.099	.	0.007	0.528	0.369
	N	11	11	11	11	11	11	11	11
Change Q-angle	Pearson Correlation	0.214	-0.518	-0.522	1	.[c]	0.132	0.049	-0.209
	Sig. (2-tailed)	0.527	0.103	0.099		.	0.698	0.885	0.538
	N	11	11	11	11	11	11	11	11
Change Feiss line	Pearson Correlation	.[c]	.[c]	.[c]	.[c]	.[c]	.[c]	.[c]	.[c]
	Sig. (2-tailed)	.	.	.	.		.	.	.
	N	11	11	11	11	11	11	11	11
Change KSQ	Pearson Correlation	-0.557	-0.743**	-0.757**	0.132	.[c]	1	-0.441	-0.258
	Sig. (2-tailed)	0.075	0.009	0.007	0.698	.		0.174	0.443
	N	11	11	11	11	11	11	11	11
Change Algometer	Pearson Correlation	0.375	0.212	0.214	0.049	.[c]	-0.441	1	-0.172
	Sig. (2-tailed)	0.255	0.532	0.528	0.885	.	0.174		0.612
	N	11	11	11	11	11	11	11	11
Change VAS	Pearson Correlation	0.198	0.300	0.301	-0.209	.[c]	-0.258	-0.172	1
	Sig. (2-tailed)	0.560	0.370	0.369	0.538	.	0.443	0.612	
	N	11	11	11	11	11	11	11	11

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

c. Cannot be computed because at least one of the variables is constant.

From the correlation table (Table 4.5), it can be seen that the only significant relationships are the following:

1. Change in the leg length on the right in relation to the change of the length of the left leg (positive relationship).
   This implies that the degree of change in one leg was mirrored by the degree of change in the other leg. This is consistent with the discussion in these previous sections.

2. Change in the length of the right leg to the tibio-femoral angle as well as the length of the left leg to the tibio-femoral angle.
   This would imply that the degree of change in the tibio-femoral angle mirrors the degree of change in the leg lengths bilaterally. Hence with a decrease in the change in the leg length, there is a decrease in the change of the tibio-femoral angle and vice-versa. This would support the assertions that increased incongruence at the talocrural joint and thus perceived increases in leg length are associated with a larger tibio-femoral angle. This would concur with the literature which has found a tentative association between increases in the tibio-femoral angle and the increased likelihood of ITBFS (Fujii, *et al*., 2010; Landrum *et al*., 2008; Vicenzino *et al*., 2006; Hannon, 2006; Whitman *et al*., 2005; Collins *et al*., 2004).

3. Changes in the right and left leg lengths and the KSQ.
   This outcome would suggest that the degree to which the KSQ increases is likely to be associated with a smaller change in leg lengths, as compared to decreased change in the KSQ being associated with greater change in the leg lengths. According to the participants' reported findings in the KSQ, the former outcome is seen in this study, where a small change (decrease) in the leg length seems to be associated with increased functional ability. This seems to re-inforce the assertion that talocrural joint congruency is important in establishing normal function in the rotation of the tibia, thus alleviating ITBFS. A study similar to this study is necessary with the addition of the measures of ankle plantarflexion and dorsiflexion (see Section 4.8.1.3).

Therefore these correlations re-enforce previous discussions (Sections 4.8.1.2 and 4.8.1.3), as well as the discussion on improved functional ability being related to decreased pain (Section 4.8.1.7).

4.9.1.11 Summary / discussion on objective two

Table 4.6: Summary table for the superior tibio-fibular intervention (Group B)

Superior Tibio-Fibular Intervention (Group B)			Ankle Intervention (Group A)		
Measurements	**Significant Difference[7]**	**Change**	**Measurements**	**Significant Difference**	**Change**
Tibio-femoral angle	None	↓	**Tibio-femoral angle**	None	↓
LL R	None	↓	**LL R**	None	↓
LL L	None	↓	**LL L**	None	↓
Q angle	None	↓	**Q angle**	None	↓
Feiss line	None	None	**Feiss line**	None	None
Leg-heel alignment	None	None	**Leg-heel alignment**	None	Minimal
KSQ	Significant	↑	**KSQ**	Significant	↑
Algometer	None	↑	**Algometer**	None	↑
VAS	Significant	↓	**VAS**	Significant	↓

It is of interest to note that manipulation of both the ankle joint and the superior tibio-fibular joint on the side ipsilateral to the ITBFS seems to have a very similar outcome in terms of the trends (as seen the columns labelled 'Change') seen in both groups as well as in terms of the significant clinical outcomes (KSQ and VAS). These outcomes seem to suggest that the superior tibio-fibular joint may be a key factor when addressing ITBFS, as it is affected directly by both ankle joint and superior tibio-fibular joint manipulation. It further suggests that the runner's leg length or the camber of the road has a role to play in a dysfunctional superior tibio-fibular joint, and thus its effect on the development of ITBFS. This may also be the reason that literature reports high numbers of lower leg injuries in runners (Ellapen *et al.*, 2013; van Middelkoop *et al.*, 2007; Hreljac and Ferber, 2006; Lun *et al.,* 2004; Renström and Peterson, 2003; Wen *et al.*, 1997; James *et al.*, 1978). In addition, these changes in the superior tibio-fibular joint may also have an effect on the shock absorption capacity of the ankle joint, which if aberrant, places more pressure on the knee, predisposing it to dysfunction and making it the most common injury in runners (Ellapen *et al.*, 2013; Chang *et al.*, 2012; Larson *et al.*, 2011; van Gent *et al.*, 2007; Puckree *et al.*, 2007; van Middelkoop *et al.*, 2007; Hreljac and Ferber, 2006; Noakes, 2003; Renström and Peterson, 2003; Taunton *et al.*, 2003; Taunton *et al.*, 2002; Steinacker *et al.*, 2001; Satterthwaite *et al.*, 1996).

[7] Statistically there was no significant difference reported, although changes / trends over time did occur.

4.10 To assess the intra-group changes over time in the sacroiliac intervention group (Group C) with regard to the secondary and primary outcome measures

4.10.1 Effect of the sacroiliac interventions

The objective was to determine the effect of a sacroiliac joint manipulation in the treatment of ITBFS, which was represented in this study as Group C.

4.10.1.1 Tibio-femoral angle

There was no statistically significant change over time according to the Wilk's Lambda test (*p*=0.094) in the tibio-femoral angle following sacroiliac joint manipulation. The following graph indicates an overall increase with an upward trajectory after measurement one, followed by a slight downward trajectory between measurement two and measurement three before it plateaus.

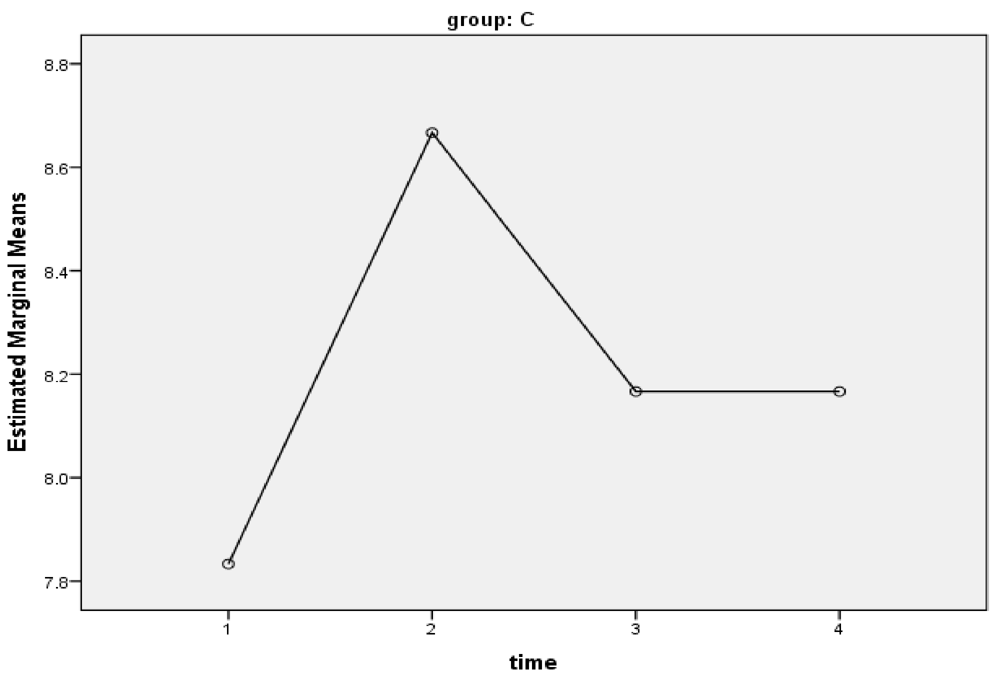

Figure 4.16: Profile plot for tibio-femoral angle over time following sacroiliac joint manipulation (Group C)

When working from a fixed limb, the attachments of the quadriceps femoris and the biceps femoris muscles to the pelvic ring (in particular the superior pubic rami / anterior superior and inferior iliac spines as well as the ischial tuberosity) are responsible for rotating the pelvis around the x-axis either positively or negatively (Standring, 2009; Moore and Dalley, 2006; Levangie and Norkin, 2001). This motion would require that the pelvic articulations with the spine (viz. the sacroiliac joints) allow for the movement created by these muscles (Morris, 2006). However, this also creates shear and torque forces through the sacroiliac joints, leading to joint impaction and thus joint dysfunction with an associated impact on the function of muscles that normally move the joint (Bergman and Petersen, 2011). As both these muscle groups attach to the ITB and influence its tautness or flexibility, it is therefore important to consider sacroiliac joint dysfunction as a possible factor that has an impact on the ITBFS (Baer, 1999; Ellen *et al*., 1999; Reid, 1992; Lindenburg *et al*., 1984).

According to the results shown in Figure 4.16, spinal joint mobilization and manipulation has an immediate effect on muscle activation, both near and distant to the site of intervention (Grindstaff *et al*., 2011; Hillermann *et al*., 2006; Dishman and Bulbulian, 2002; Dishman *et al*., 2001). Therefore the outcomes of this study with regards to the tibio-femoral angle are not unexpected, in that manipulation of the sacroiliac joint would result in muscle relaxation (Leach, 2004; Dishman and Bulbulian, 2002; Dishman *et al*., 2001). This relaxation effect results in changes in the axis of rotation of the pelvis which disturbs the balance of the hip, which would leave the coronal plane muscles responsible for maintaining hip stability (Robergs and Robert, 1997; Norkin and Levangie, 1992). This would result in an increase in the tibio-femoral angle as the stronger adductor muscle group would pull the knee more medially (Levangie and Norkin, 2001).

The subsequent biomechanical changes in the lower limb as a result of the manipulation will then settle as the treatment continues, as balance between the antagonist muscles and co-ordination of the agonist muscles re-establishes itself. Hence, the initial increase is followed by a decrease in the angle and then a plateau. Of interest in the sacroiliac joint manipulation group, is that the tibio-femoral angle, unlike in the groups where manipulations were performed on the ankle and superior tibio-fibular joints is actually greater at the end of the trial than it was at the beginning.

4.10.1.2 Leg length of right leg (LL R)

When manipulating the sacroiliac joint there was no statistically significant change over time in the right leg length according to the Wilk's Lambda test (p=0.462). The following graph indicates a decrease in leg length with a downward trajectory after measurement one, with a slight upward trajectory following measurement two and a subsequent downward trajectory after measurement three.

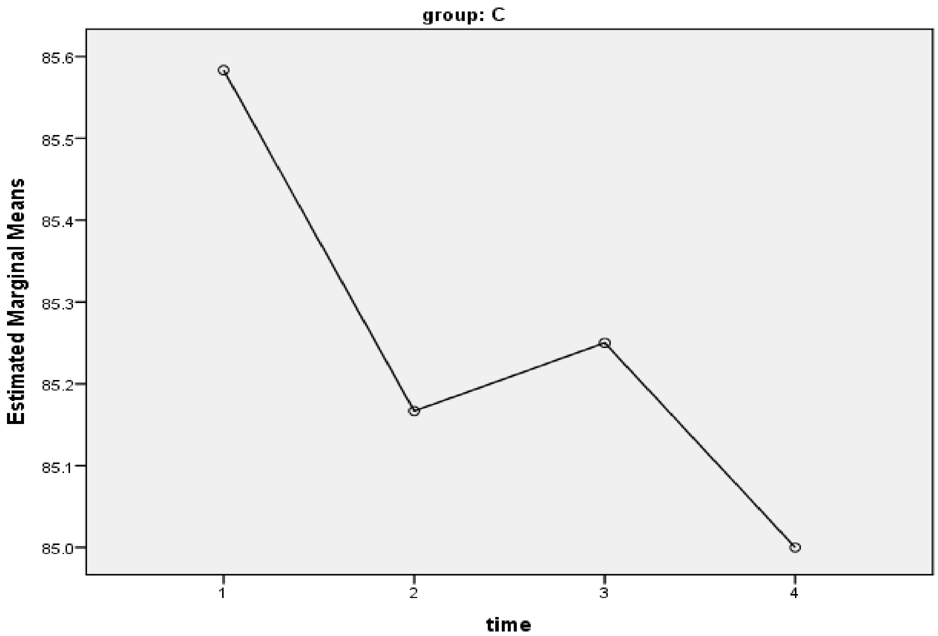

Figure 4.17: Profile plot for leg length of right leg over time following sacroiliac joint manipulation (Group C)

4.10.1.3 Leg length of left leg (LL L)

As observed with the right leg length measurements, there was no statistically significant change over time according to the Wilk's Lambda test (p=0.234) in the leg length measurements of the left leg when manipulating the sacroiliac joint. As with the right leg, there was an overall decrease with a downward trajectory, however the effect is much less in the left leg as compared to the right leg.

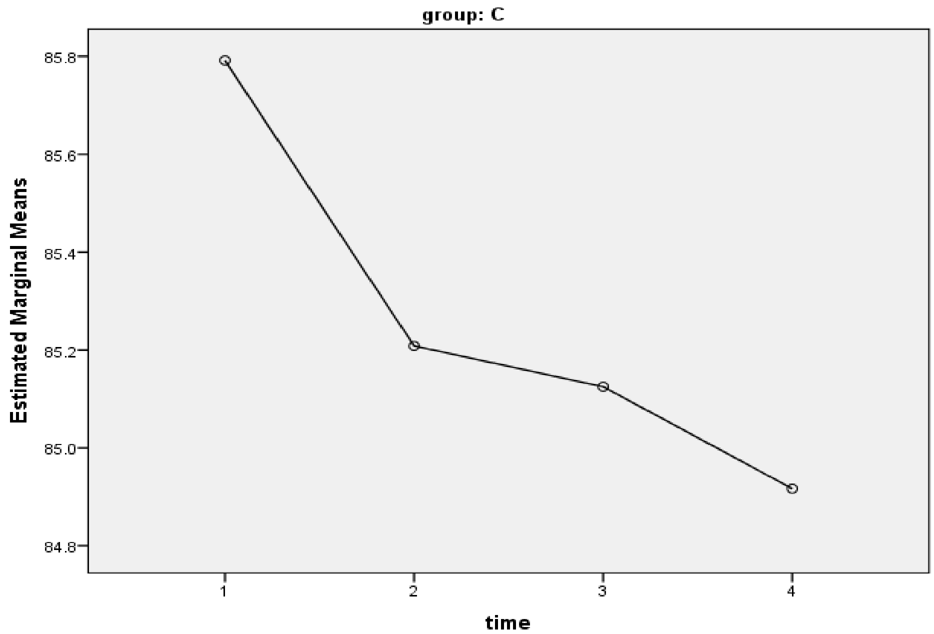

Figure 4.18: Profile plot for leg length of light leg over time following sacroiliac joint manipulation (Group C)

The right and left leg measurements, like those of the ankle joint and superior tibio-fibular joint decreased over the duration of the study.

This is consistent with the literature regarding the association between pelvic rotation and its effect on leg length, as well as the assertion that dysfunctional joints (as described for the ankle joint manipulation group) inhibit the ability of joints to lie in congruent planes. This affects the ability of the osseous kinematic chain to achieve optimal position and therefore length. In the context of running these abnormal biomechanics are further enhanced by incorrect running technique (Noakes, 1992) and road camber (Sutker, 1985; Lindenburg *et al.*, 1984).

4.10.1.4 Quadriceps angle (Q angle) of femur

There was no statistically significant change over time in the Q angle of the femur according to Wilk's Lambda test (*p*=0.561) when manipulating the sacroiliac joint. The graph that follows indicates an overall decrease with an upward trajectory following measurement one. Subsequent measurements (two, three, and four) followed a downward trajectory.

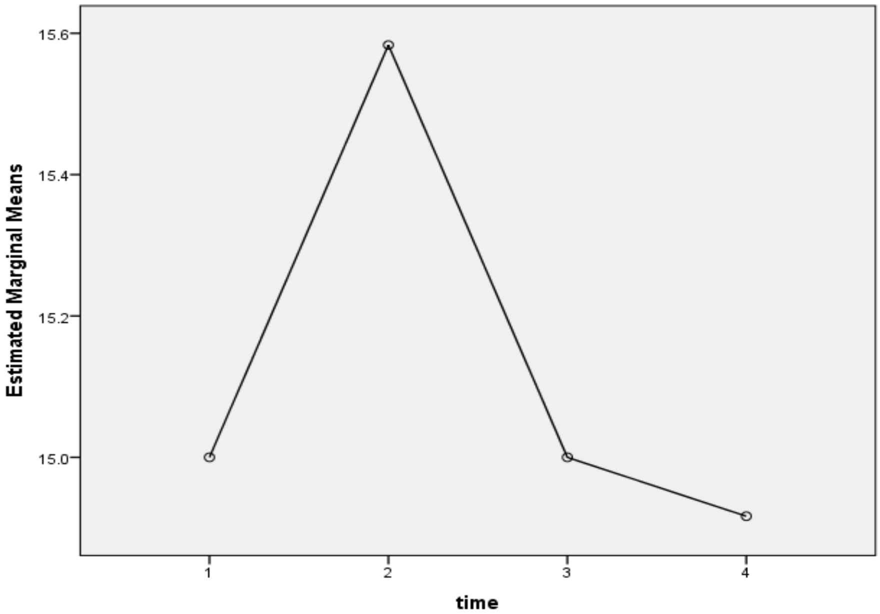

Figure 4.19: Profile plot for Q angle over time following sacroiliac joint manipulation (Group C)

The discussion regarding the tibio-femoral angle (Section 4.10.1.1) refers with particular reference to the attachments of the quadriceps femoris and the biceps femoris muscles to the pelvic ring, which are responsible for rotating the pelvis around the x-axis (Standring, 2009; Moore and Dalley, 2006; Levangie and Norkin, 2001). The resultants shear and torque forces that pass through the sacroiliac joints results in impaction of the joints, which can lead to joint dysfunction (Bergman and Petersen, 2011). Also with both these muscle groups influencing the ITB's tautness or flexibility, it is important to consider sacroiliac joint dysfunction as a possible factor influencing ITBFS (Baer, 1999; Ellen *et al*., 1999; Reid, 1992; Lindenburg *et al*., 1984). As a result, the effects of sacroiliac joint mobilization and manipulation have been shown to have an immediate effect on muscle activation (Grindstaff *et al*., 2011; Hillermann *et al*., 2006; Dishman and Bulbulian, 2002; Dishman *et al*., 2001).

Therefore, the outcomes of this study with regards to the Q angle are not unexpected, in that manipulation of the sacroiliac joint results in muscle relaxation (Leach, 2004; Dishman and Bulbulian, 2002; Dishman *et al*., 2001). This relaxation effect results in changes in the sagittal plane and therefore disturbs the balance of the hip, as the coronal plane muscles controlling the hip responsible for maintaining stability (Robergs and Robert, 1997; Norkin and Levangie, 1992). This results in an increased Q angle as the stronger adductor muscle group pulls the knee more medially (Levangie and Norkin, 2001). The subsequent biomechanical changes in the lower limb as a result of the manipulation then settle as the treatment continues, as balance between the antagonist muscles and co-ordination of the agonist muscles re-establishes itself. Hence the initial increase is followed by a decrease in the Q angle.

In the sacroiliac joint manipulation group, the Q angle (like the groups where manipulations were performed on the ankle joint (Group A) and superior tibio-fibular joint (Group B)), is actually smaller at the end of the trial than it was at the beginning.

However, this outcome creates contradiction within the sacroiliac joint manipulation group, as it seems odd that there is an overall decrease in the Q angle but an increase in the tibio-femoral angle. Particularly when considering that the anatomical points of reference for these angles (at least for the superior line forming the angle) are the same or at least consistent (ASIS and mid-point of the patella) (Fakoor *et al*., 2010; Smith *et al*., 2008; Livingstone and Spaulding, 2002; Arazi *et al*., 2001).

After consideration, it was deemed possible that in participants with ITBFS and thus displaying a tight ITB that this was as a result of an internal tibial rotation. This internal tibial rotation dysfunction position seems to be addressed in the ankle and superior tibio-fibular manipulation groups either directly or indirectly by changing the dynamics of the talocrural joint. Thus, external rotation of the tibia, and the ITB being brought closer to its insertion, results in relief from the load on the fascial band. The effect of addressing this dysfunction has the ability to change the second line of reference in the Q angle (Smith *et al*., 2008; Livingstone and Spaulding, 2002). However, this would not affect the second line in the tibio-femoral angle, as the last point on the anterior part of the talus would not be affected by the change in rotation of the tibia (Fakoor *et al*., 2010; Arazi *et al*., 2001). It is not possible to produce these effects through manipulation of the sacroiliac joint. This assertion however is only arrived at through deductive reasoning and therefore it would be a hypothesis that would require further testing.

4.10.1.5 Feiss line

There was no statistically significant change in the Feiss line over time according to Wilk's Lambda test (p=1.000) following sacroiliac joint manipulation. As the Feiss line is a valid and reliable structural (non-functional) measure of the result of a dynamic process (weight bearing pronation and supination) (Sporndly-Nees *et al*., 2011; Neely 1998), it is unlikely that a more proximal change in biomechanics will affect this line. This is particularly true if the sacroiliac manipulation had no effect on tibial rotation.

4.10.1.6 Leg-heel alignment

No statistically significant difference in leg-heel alignment over time was observed when manipulating the sacroiliac joint, which is consistent with the previous discussion and supports the assertions presented in Section 4.10.1.4.

4.10.1.7 Knee scoring questionnaire (KSQ)

There was no statistically significant change over time in the KSQ according to the Wilk's Lambda test (*p*=0.493) following sacroiliac joint manipulation. The graph that follows indicates an overall increase even though the difference between measurement one and two showed an initial downward trajectory. This was followed by subsequent upward trajectories after measurements two and three. This could be interpreted as there being no significant change over time, although participants did experience an improvement clinically.

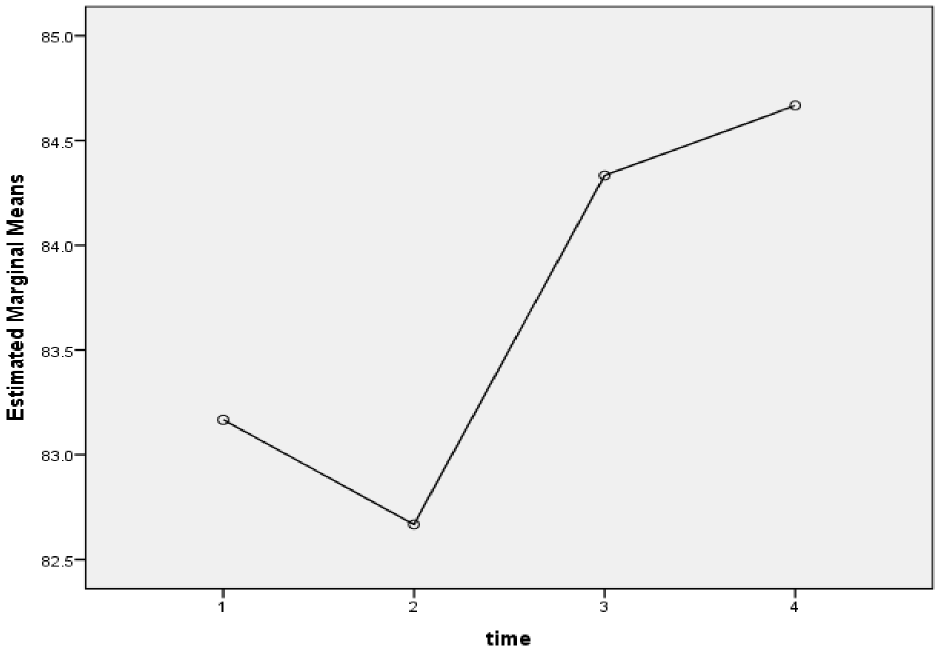

Figure 4.20: Profile plot for KSQ over time following sacroiliac joint manipulation (Group C)

The results obtained in this study suggest that the ITBFS participants that received sacroiliac joint manipulation improved in terms of their subjective evaluation of pain, swelling, stability and overall activity level. However, in contrast to Groups A and B, the change over time was not significant.

This is incongruent with previous discussion (Sections A and B), the outcomes obtained here suggest that the participants did not receive a significant benefit from manipulation of the sacroiliac joint. In considering this outcome, it is also of interest to note that the only difference between Groups A, B and C is the lack of significance in the KSQ outcome and the decrease versus increase in the tibio-femoral angle respectively. This would suggest that the internal tibial rotation hypothesis (presented in Section 4.10.1.4) may also play a role in the manner in which the participants in this study reported their perceived changes on the KSQ. It is therefore suggested that the impact of tibial rotation be investigated with regards to the effect that this has on the functional ability of the knee and hence the reduction of knee symptoms in patients with ITBFS.

4.10.1.8 Algometer

There was no statistically significant change over time in the algometer readings when manipulating the sacroiliac joint, according to the Wilk's Lambda test (p=0.987). The graph indicates an overall increase with an upward trajectory after measurement one, followed by a downward trajectory after measurement two, and a slight upward trajectory after measurement three. This indicates that participants did experience an improvement with regards to pain pressure threshold, this was statistically not significant.

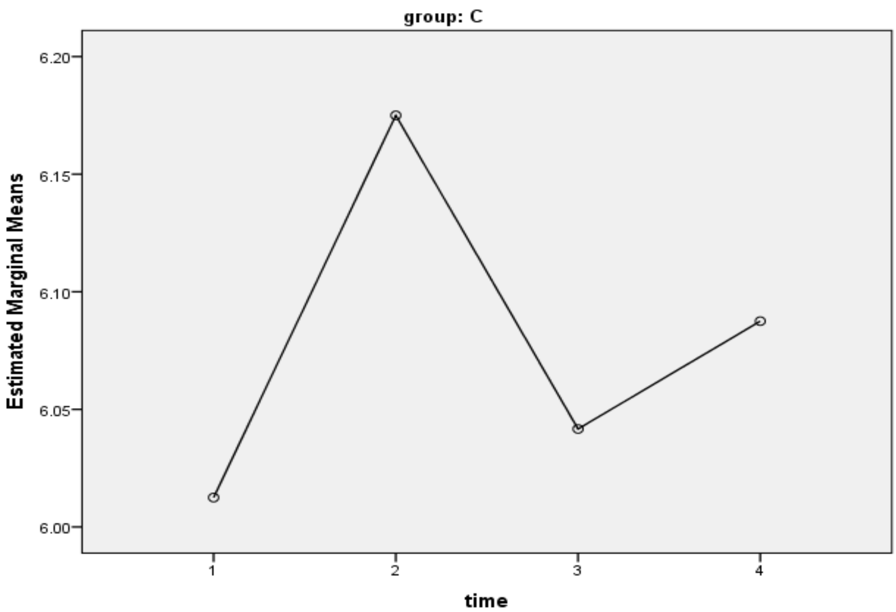

Figure 4.21: Profile plot for algometer over time following sacroiliac joint manipulation (Group C)

As for the previous two joints, the algometer reading was taken about 2.5cm above the LFE on the ipsilateral limb of the ITBFS.

The above results are not congruent with the changes seen in Groups A and B. They have some similarities to changes in the Q angle and leg length in Group C, but contrast with the changes in the tibio-femoral angle in Group C in terms of the trends seen in Groups A and B. This seems to support the assertion that manipulation of the sacroiliac joint is limited in its ability to address the full biomechanical chain changes that seem to be associated with ITBFS. This indicates that although patients perceive a sudden decrease in tenderness of the region around the ITB, the decrease in tenderness does not persist. This suggests that there is fundamental underlying biomechanical dysfunction that is not addressed by this form of intervention in isolation. Even with this outcome it is suggested that this hypothesis be tested in a future study.

4.10.1.9 Visual analogue scale (VAS)

There was a highly significant change over time according to the Wilk's Lambda test (*p*<0.001) in the VAS when manipulating the sacroiliac joint. Participants also had a clinically significant change in their perception of pain as recorded on the VAS.

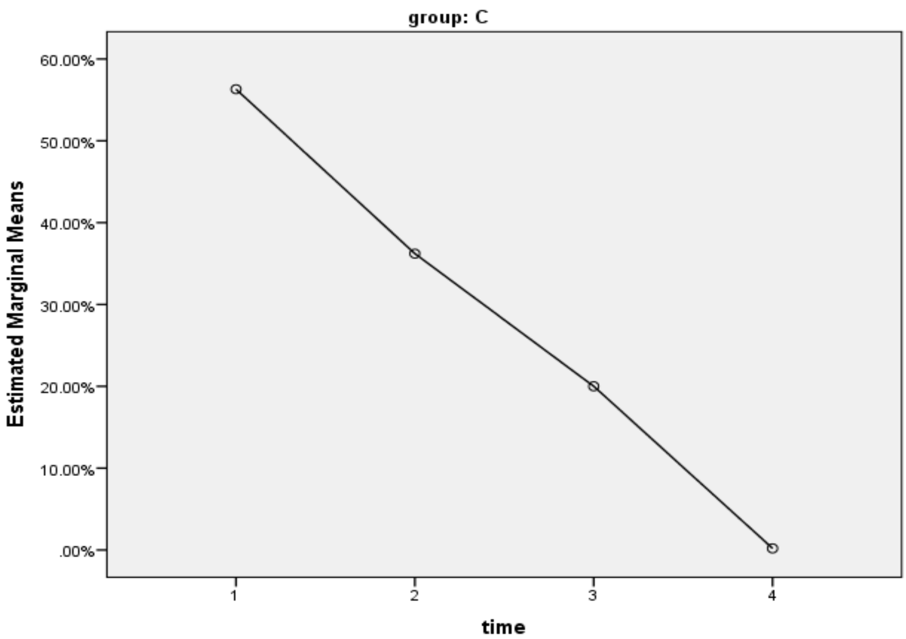

Figure 4.22: Profile plot for VAS over time following sacroiliac joint manipulation (Group C)

The outcomes of the VAS are not unexpected, based on the discussions presented in Section 4.8.1.8. Further to this:

1. The increased ROM in the sacroiliac joint may have resulted in increased mechanoreceptive stimulation and therefore decreased pain (Vernon and Mrozek, 2005; Hopkins and Ingersoll, 2000; Suter *et al*., 2000; William, 1997). This is more so true of the sacroiliac joint than any other joint manipulated in this study, as the innervation to the anterior and posterior parts of this joint, ranges from L2 through S1 innervation compared to the superior tibio-fibular joint, which is limited to L4 innervation and the ankle joint, which is limited to L4-S2 innervation (Haldeman, 2005; Kasunich, 2003; Chaitow and Delany 2002; Peterson and Bergman, 2002; Gatterman, 1990; Bernard and Kirkaldy-Willis, 1987). Therefore, the degree of mechanoreceptive stimulation is greater and the trajectory of decline in the VAS readings is more linear than in the other joints manipulated.

2. By contrast, the changes in the biomechanics of the lower extremity (as discussed in Sections 4.10.1.1 – 4.10.1.6) indicate that the pain reduction as a result of biomechanical change is limited. Therefore, the supplementary reduction in pain through point one above seems to allow for similar decreases in pain when compared to other groups, but does not seem to affect the functional ability of the lower extremity (as recorded in the KSQ).

4.10.1.10 Pearson's Correlation

Table 4.7: Correlations between primary and secondary outcome measures for the sacroiliac intervention (Group C)

		Change tibio-femoral angle	Change Leg Length (Right)	Change Leg Length (Left)	Change Q-angle	Change Feiss line	Change KSQ	Change Algometer	Change VAS
Change tibio-femoral angle	Pearson Correlation	1	-0.598*	-0.721**	0.059	.[d]	0.184	0.438	-0.334
	Sig. (2-tailed)		0.040	0.008	0.856	.	0.566	0.155	0.289
	N	12	12	12	12	12	12	12	12
Change Leg Length (Right)	Pearson Correlation	-0.598*	1	0.947**	0.215	.[d]	-0.187	-0.181	0.063
	Sig. (2-tailed)	0.040		0.000	0.502	.	0.560	0.573	0.846
	N	12	12	12	12	12	12	12	12
Change Leg Length (Left)	Pearson Correlation	-0.721**	0.947**	1	0.135	.[d]	-0.212	-0.213	0.094
	Sig. (2-tailed)	0.008	0.000		0.675	.	0.509	0.506	0.770
	N	12	12	12	12	12	12	12	12
Change Q-angle	Pearson Correlation	0.059	0.215	0.135	1	.[d]	0.223	0.203	-0.255
	Sig. (2-tailed)	0.856	0.502	0.675		.	0.487	0.528	0.424
	N	12	12	12	12	12	12	12	12
Change Feiss line	Pearson Correlation	.[d]	.[d]	.[d]	.[d]	.[d]	.[d]	.[d]	.[d]
	Sig. (2-tailed)	.	.	.	.		.	.	.
	N	12	12	12	12	12	12	12	12
Change KSQ	Pearson Correlation	0.184	-0.187	-0.212	0.223	.[d]	1	0.559	0.401
	Sig. (2-tailed)	0.566	0.560	0.509	0.487	.		0.059	0.197
	N	12	12	12	12	12	12	12	12
Change Algometer	Pearson Correlation	0.438	-0.181	-0.213	0.203	.[d]	0.559	1	-0.176
	Sig. (2-tailed)	0.155	0.573	0.506	0.528	.	0.059		0.584
	N	12	12	12	12	12	12	12	12
Change VAS	Pearson Correlation	-0.334	0.063	0.094	-0.255	.[d]	0.401	-0.176	1
	Sig. (2-tailed)	0.289	0.846	0.770	0.424	.	0.197	0.584	
	N	12	12	12	12	12	12	12	12

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

d. Cannot be computed because at least one of the variables is constant.

From the correlation table (Table 4.7), it can be seen that the only significant relationships are the following:

1. Change in the participant's right leg length in relation to the change of the length of the left leg (positive relationship).
   This implies that the degree of change in one leg was mirrored by the degree of change in the other leg. This is consistent with the discussion in previous sections.

2. Change in the participant's right leg length to the tibio-femoral angle as well as the left leg length to the tibio-femoral angle.
   This would imply that the degree of change in the tibio-femoral angle mirrors the degree of change in the leg lengths bilaterally. Hence, with a decrease in the change in the participants' leg lengths, there was a decrease in the change of their tibio-femoral angle. Similarly, a change in the participants' tibio-femoral angle, there was a corresponding change. This would support the assertions that pelvic tilt and not talocrural joint congruency are responsible for increases in leg length, which are associated with a larger tibio-femoral angle. This would concur with the literature which has found a tentative association between increases in the tibio-femoral angle and the increased likelihood of ITBFS (Fujii, *et al.*, 2010; Hannon, 2006; Landrum *et al.*, 2008; Vicenzino *et al.*, 2006).

Therefore, these correlations re-enforce the discussions in Sections 4.10.1.1, 4.10.1.3 and 4.10.1.3.

4.10.1.11 Summary / discussion on objective three

Table 4.8: Summary table for the sacroiliac intervention (Group C)

Sacroiliac Intervention (Group C)			Superior Tibio-Fibular Intervention (Group B)			Ankle Intervention (Group A)		
Measurements	**Significant Difference[8]**	**Change**	**Measurements**	**Significant Difference[9]**	**Change**	**Measurements**	**Significant Difference**	**Change**
Tibio-femoral angle	None	↑	**Tibio-femoral angle**	None	↓	**Tibio-femoral angle**	None	↓
LL R	None	↓	**LL R**	None	↓	**LL R**	None	↓
LL L	None	↓	**LL L**	None	↓	**LL L**	None	↓
Q angle	None	↓	**Q angle**	None	↓	**Q angle**	None	↓
Feiss line	None	None	**Feiss line**	None	None	**Feiss line**	None	None
Leg-heel alignment	None	None	**Leg-heel alignment**	None	None	**Leg-heel alignment**	None	Minimal
KSQ	None	↑	**KSQ**	Significant	↑	**KSQ**	Significant	↑
Algometer	None	↑	**Algometer**	None	↑	**Algometer**	None	↑
VAS	Significant	↓	**VAS**	Significant	↓	**VAS**	Significant	↓

[8] Statistically there was no significant difference reported, although changes / trends over time did occur.
[9] Statistically there was no significant difference reported, although changes / trends over time did occur.

It is of interest to note that manipulation of both the ankle joint and the superior tibio-fibular joint on the side ipsilateral to the ITBFS seems to have a dissimilar outcome in terms of the trends seen in Group C (sacroiliac joint manipulation).

This outcome suggests that tibial rotation may be a key factor when addressing ITBFS through manipulation of the ankle joint and the superior tibio-fibular joint. Both these forms of manipulation and the manner in which they are applied seem to have an effect on tibial rotation, which allows for simultaneous and synchronised changes to the tibio-femoral angle and the Q-angle. This is not the case with the sacroiliac joint manipulation group, where it is evident that there may be changes in the thigh, hip and pelvic mechanics, which may result in similar changes to the upper line of the tibio-femoral angle and the Q angle (Fakoor *et al*., 2010; Smith *et al*., 2008; Livingstone and Spaulding, 2002; Arazi *et al*., 2001), and only the lower line in the Q angle but not in the tibio-femoral angle. This is because the lower end of the second line in the Q-angle is the patella ligament which is likely to be more mobile and have position changes with tibial rotatory movements (through the pull of the quadriceps femoris muscle group) (Smith *et al*., 2008; Lee *et al*., 2003(b); Livingstone and Spaulding, 2002) as opposed to the static osseous structure of the ankle which is utilised as a point for the tibio-femoral line (Fakoor *et al*., 2010; Arazi *et al*., 2001).

This assertion would imply that in treating ITBFS, treatment directed at the lower end of the kinematic chain would be more beneficial for these patients, as it seems to address potential compensatory mechanics found as a causative agent or as a consequence of ITBFS (Hoskins *et al*., 2006; Haldeman, 2005; Kasunich, 2003; Chaitow and Delany, 2002; Peterson and Bergman, 2002; Suter *et al*., 2000; Gatterman, 1990; Bernard and Kirkaldy-Willis, 1987). In either event, the increased shock absorption ability post manipulation through the lower kinematic chain joints seems to decrease pressure on the knee in terms of shock absorption, and this aids in reducing the perceived symptoms of ITBFS, which is in contrast to manipulation of the sacroiliac joint which has often been cited as essential in athletes (Hoskins *et al*., 2006; Haldeman, 2005; Kasunich, 2003; Chaitow and Delany, 2002; Peterson and Bergman, 2002; Suter *et al*., 2000; Gatterman, 1990; Bernard and Kirkaldy-Willis, 1987). Therefore this study agrees with Hyde and Gengenbach (2007) that one should not manipulate the sacroiliac joint, and should it be necessary, only in lateral recumbent patient position.

4.11 To assess the intra-group changes over time in the combination intervention group (Group D) with regard to the secondary and primary outcome measures

4.11.1 Effect of the Combination interventions

The objective was to determine the effect of a combination of the three treatments (viz. ankle joint manipulation, superior tibio-fibular joint manipulation and sacroiliac joint manipulation) in the treatment of ITBFS, which was represented in this study as Group D. It is important to note that for this combination group, each participant received a manipulation to two of the three joints as represented in Groups A to C. This was determined by the two most severely restricted joints of the three assessed. The majority of the participants in this group received a sacroiliac manipulation with either a talocrural manipulation or a superior tibio-fibular manipulation.

4.11.1.1 Tibio-femoral angle

There was no statistically significant change over time in the tibio-femoral angle when using combination treatments, according to the Wilk's Lambda test (p=0.105). The graph that follows indicates an overall increase with a downward trajectory after measurement one and followed with a larger subsequent upward trajectory between measurement two and measurement three before a slight downward trajectory to measurement four.

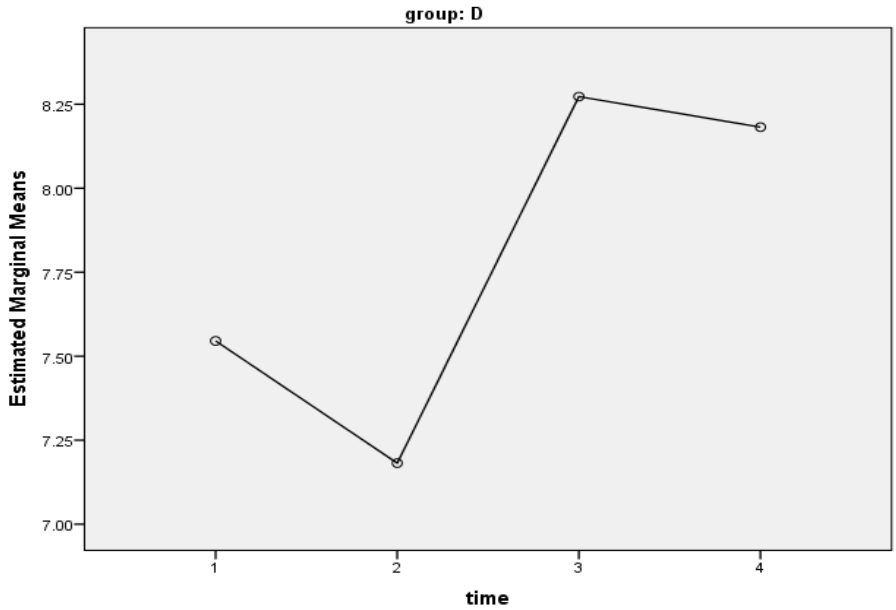

Figure 4.23: Profile plot for tibio-femoral angle over time following combination treatment (Group D)

In keeping with an ankle joint or superior tibio-fibular joint manipulation, the participants in this group reported an initial decrease in the tibio-femoral angle. However, in keeping with sacroiliac joint manipulation, the overall outcome of this group indicated that the tibio-femoral angle increased in degrees (but not to the same extent).

Based on the discussions for the previous groups (A, B and C), it seems evident that:

1. With the participants having received a sacroiliac joint manipulation and with the concomitant relaxation (Hillermann *et al.*, 2006; Morris, 2006) of the external rotators (e.g. piriformis) (Standring, 2009; Moore and Dalley, 2006), it is likely that the hip joint (and hence femur) re-establishes the normal internal – external rotation position. This would require the femur to internally rotate (Subotnick, 1999).

2. By contrast, manipulation of the talocrural or the superior tibio-fibular joints, there is an increased likelihood that the talocrural joint becomes congruent, allowing for external rotation of the tibia (Landrum *et al.*, 2008; Vicenzino *et al.*, 2006; Denegar *et al.*, 2002). This external rotation allows the talus to fit more snugly into the talocrural joint (Levangie and Norkin, 2001).

The internal femoral rotation with the external rotation of the tibia results in the medial femoral condyle (being the longer of the two femoral condyles), rotating on its axis. This requires that the knee accommodates by means of creating a genu valgum position to attenuate the opposing forces (Noehren *et al*., 2007; Johal *et al*., 2005; Lee *et al*., 2003(b); Neely, 1998). The genu valgum position decreases the bowing of the ITB over the LFE, which reduces the point of friction (Strauss *et al*., 2011; Fredericson *et al*., 2000; Reid, 1992) or the compression of the fat pad (Fairclough *et al*., 2006), that results in an alleviation of the ITBFS symptoms.

The result of the opposing forces thus results in an increase in the tibio-femoral angle (Johal *et al*., 2005; Lee *et al*., 2003(b)) and the Q angle (Johal *et al*., 2005; Lee *et al*., 2003(b)), with a possible shortening of the ipsilateral limb of the sacroiliac joint that was manipulated and a relative increase in the limb that was not manipulated (contralateral to the ITBFS limb) (Bergmann and Peterson, 2011; Brantingham *et al*., 2009(b); Morris, 2006; Haldeman, 2005). The latter would have resulted from the induced pelvic obliquity (Bergmann and Peterson, 2011; Brantingham *et al*., 2009(b); Morris, 2006; Haldeman, 2005; Hageman and Blanke, 1986) created by the cork-screw motion of the knee, resulting in a shorter limb and thus the need for compensation (Johal *et al*., 2005; Lee *et al*., 2003(b)). These assertions can however only be supported by the measures discussed below.

4.11.1.2 Leg length of right leg (LL R)

There was no statistically significant change over time according to the Wilk's Lambda test (p=0.931) in the right leg length when combining treatments. The graph that follows indicates an increase in leg length with an upward trajectory after measurement one through measurement three, and a slight downward trajectory following measurement three to measurement four.

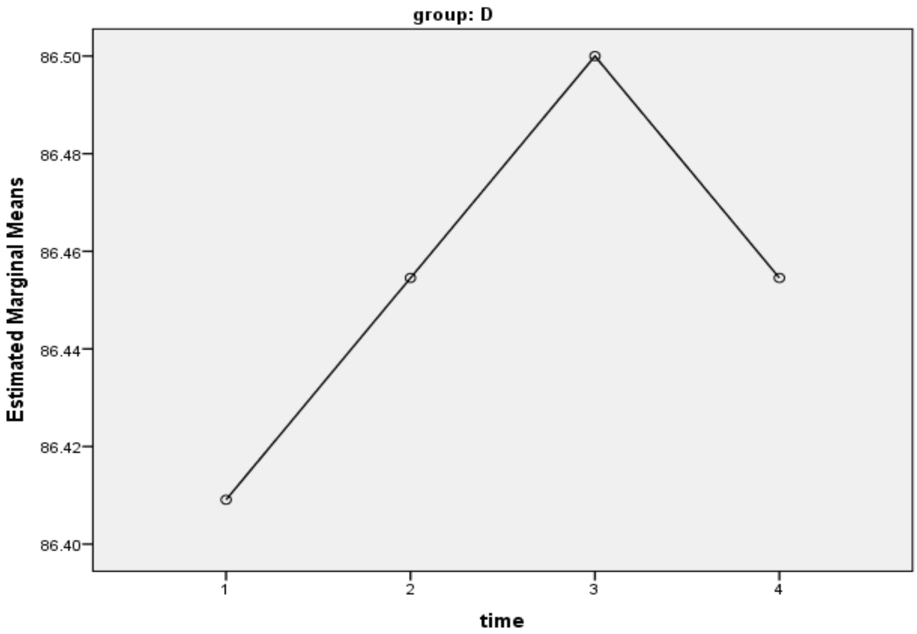

Figure 4.24: Profile plot for leg length of right leg over time following combination treatment (Group D)

4.11.1.3 Leg length of left leg (LL L)

When combining treatments there was no statistically significant change over time according to the Wilk's Lambda test (*p*=0.768) in the left leg length. The following graph indicates a decrease in leg length with a straight line trajectory after measurement one through measurement three, with a large downward trajectory following measurement three to measurement four.

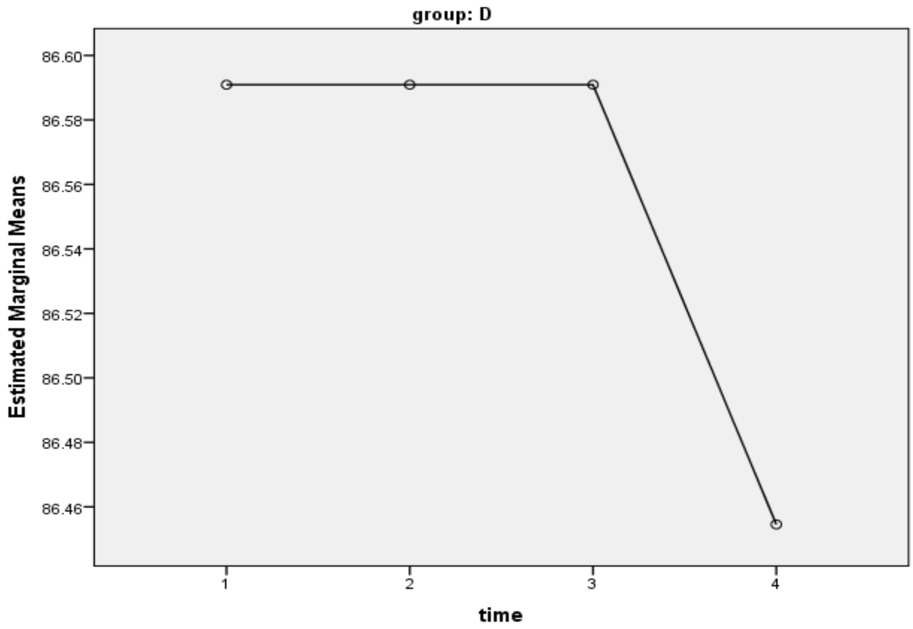

Figure 4.25: Profile plot for leg length of left leg over time following combination treatment (Group D)

Based on the outcomes of the leg length presented here and the discussion in section 4.11.1.1 regarding tibio-femoral angle, it seems plausible that changes in tibial internal rotation could be applicable to the participants in this group. This is particularly true as the right leg length increased overall and the left leg length decreased overall. This assertion however requires further testing as this study did not note how many participants were manipulated on the right versus the left leg per group. Additionally, it must be noted that running mechanics were not noted in this study and it is advised that these also be considered in future studies in order to determine their impact on the changes in the leg length, particularly in patients that receive multiple manipulations (as would possibly be the case in clinical practice).

4.11.1.4 Quadriceps angle (Q angle) of femur

There was no statistically significant change over time in the Q angle of the femur when combining treatments, according to the Wilk's Lambda test (*p*=0.789). The graph that follows indicates a downward trajectory following measurement one, with subsequent measurements (two, three, and four) following an upward trajectory.

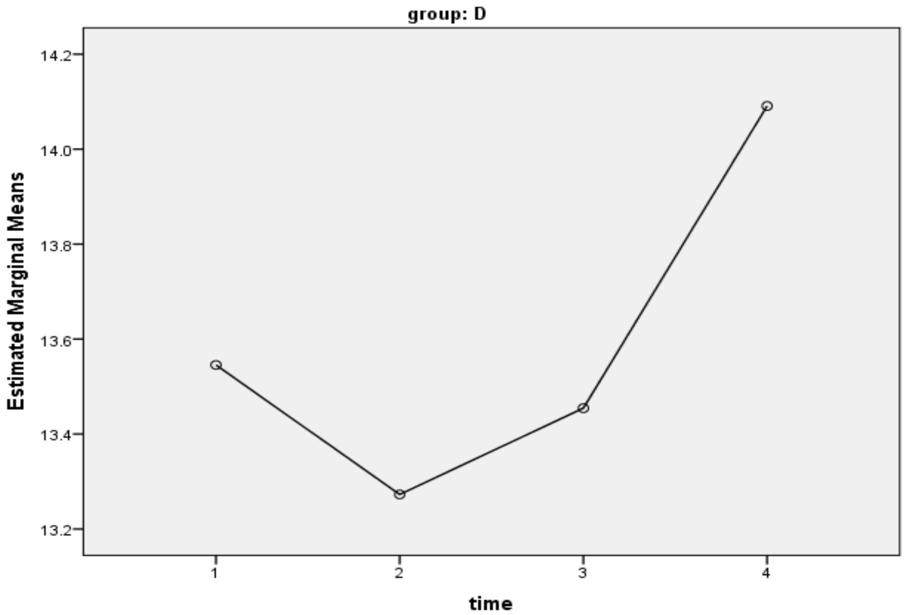

Figure 4.26: Profile plot for Q angle over time following combination treatment (Group D)

The outcomes for the Q angle support the assertions in Section 4.11.1.1, in which there was a discussion about the changes in the lower limb biomechanics associated with the tibio-femoral angle. These changes as proposed and supported by the literature would also have increased the Q angle over time. Therefore, these proposed changes seem to be validated by the outcomes obtained for this intervention group (Group D).

4.11.1.5 Feiss line

There were no statistically significant difference in the Feiss line over time according to the Wilk's Lambda test (p=1.000) when combining treatments. This is similar to the discussions presented in Section 4.10.1.5, where it was indicated that there may be no effect from the sacroiliac joint manipulation. In addition, it was seen that the superior tibio-fibular joint manipulation had no effect on the Feiss line, where the ankle joint manipulation group had a very small effect. As a result, no change for Group D was likely.

4.11.1.6 Leg-heel alignment

There were no statistically significant differences in leg-heel alignment over time when combining treatments. This is similar to the discussions presented in Section 4.10.1.6, where it was indicated that there may be no effect from sacroiliac joint manipulation. In addition, it was seen that the superior tibio-fibular joint and ankle joint manipulation groups had no effect on changes in the leg-heel alignment. As a result, no change for Group D was likely.

4.11.1.7 Knee scoring questionnaire (KSQ)

There was a highly significant change over time in the KSQ according to the Wilk's Lambda test (*p*=0.006) in Group D. The average change was approximately a 28% improvement. Comment cannot be made on whether the average change over time is clinically important due to a paucity of literature in this regard. The graph indicates an overall increase with an upward trajectory following measurement one to two. Following measurement two, there was a slight downward trajectory followed by a subsequent upward trajectory through measurement three and four.

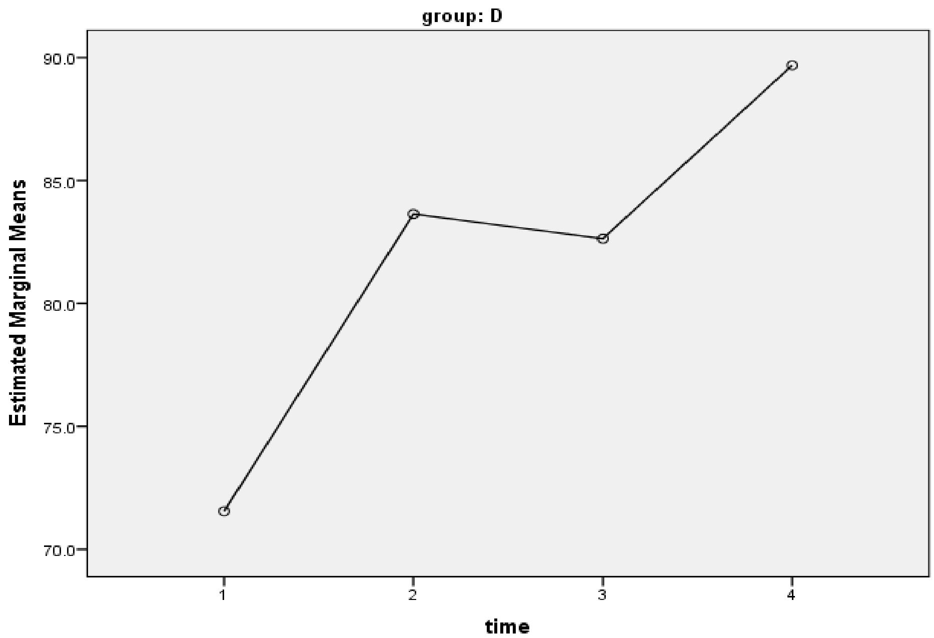

Figure 4.27: Profile plot for KSQ over time following combination treatment (Group D)

In terms of the KSQ, the individual groups showed the following:

- Significant improvement in Group A: ankle joint manipulation.
- Significant improvement in Group B: superior tibio-fibular joint manipulation.
- Non-significant improvement in Group C: sacroiliac joint manipulation.

Given these results, the outcome of the combination group (Group D) seemed to be related to manipulation of the lower joints (ankle and superior tibio-fibular) as opposed to the sacroiliac joint manipulation. However, consideration also needs to be given to the cumulative effect of the ankle joint and superior tibiofibular joint versus sacroiliac joint manipulations administered in this group, which may have resulted in a greater functional / biomechanical change when compared to any of the single manipulation groups. Thus, resulting in the significant change achieved on the KSQ in this group (Group D).

4.11.1.8 Algometer

There was no significant change over time in algometer readings according to the Wilk's Lambda test (*p*=0.80) when combining treatments. The graph that follows indicates an upward trajectory between measurements one through four (indicating decreased sensitivity and increased kilograms per square centimetre of applied pressure). This indicates that participants did experience an improvement with regards to pain pressure threshold, but this was not statistically significant.

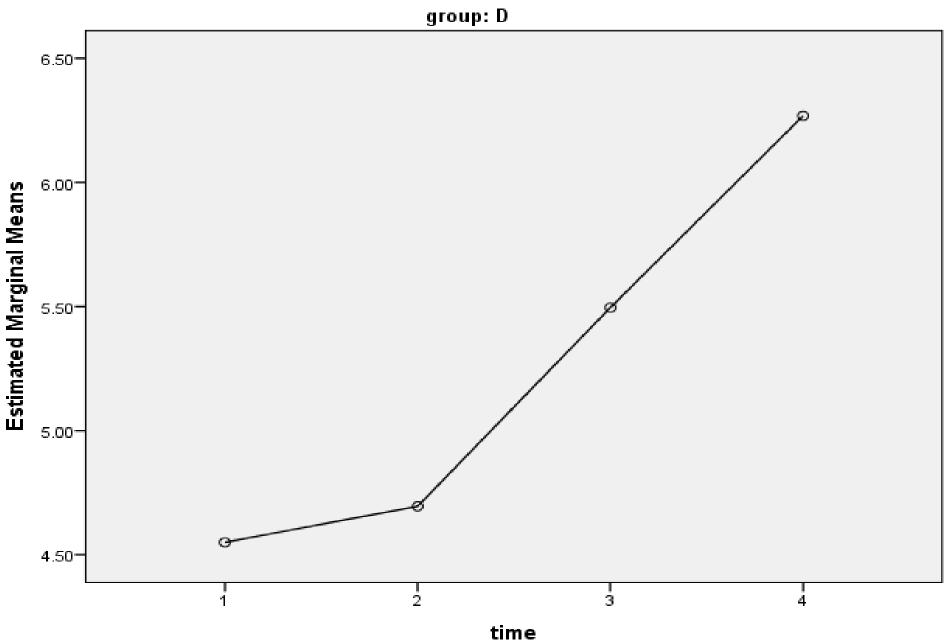

Figure 4.28: Profile plot for algometer over time following combination treatment (Group D)

In line with all the other groups in this study, it is anticipated that the changes that are responsible for the KSQ significant difference, place increased strain on the muscles of the quadriceps femoris group. This increased stress is in line with the proposed and discussed biomechanical changes of tibio-femoral angle (Section 4.11.1.1). These stressors are more likely to activate muscles that have been inactive or have been inactivated by arthrogenic muscle inhibition, which results in these muscles reacting to overload through the development of myofascial trigger points, delayed onset muscle soreness and / or a combination of these (Chaitow and DeLany, 2002; Travell and Simons 1983). As a result, the changes in the algometer do not necessarily reflect the changes in the KSQ, because although the muscles are more active and provide for increased functional ability, the muscles have a slower pace at improving on sensitivity as they adjust to the new loads placed on them.

4.11.1.9 Visual analogue scale (VAS)

There was a significant change over time in the VAS when combining treatments, according to the Wilk's Lambda test ($p<0.002$). The current study outcomes suggest that participants had a clinically significant change in their perception of pain as recorded on the VAS.

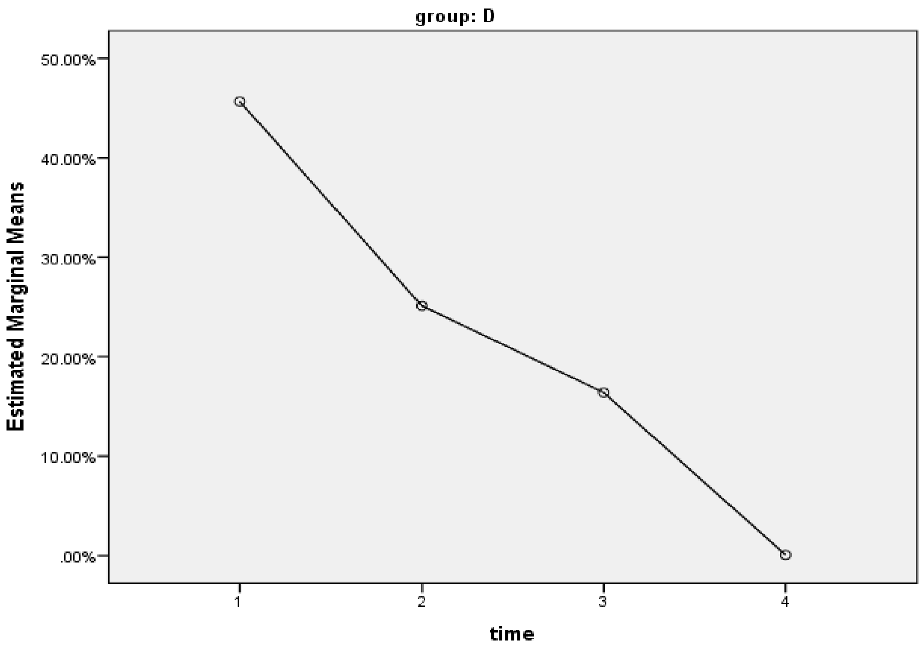

Figure 4.29: Profile plot for VAS over time following combination treatment (Group D)

The changes in the VAS reflect the changes in the KSQ, as the improved functional ability (reflected in the KSQ) implies that there is a greater number of firing mechanoreceptors within the lower limb that overrides the pain / discomfort that is represented by the slower change in the algometer over time (Melzack and Wall, 1965). In addition, the participants initially reported on the sharp, inflammatory type pain associated with the ITBFS, which conflicts with the lesser, dull and perhaps achy pain from the changing muscle dynamics (Fredericson and Wolf, 2005; Chaitow and DeLany, 2002; Travell and Simons 1983).

4.11.1.10 Pearson's Correlation

Table 4.9: Correlations between primary and secondary outcome measures for the combination intervention (Group D)									
		Change tibio-femoral angle	Change Leg Length (Right)	Change Leg Length (Left)	Change Q-angle	Change Feiss line	Change KSQ	Change Algometer	Change VAS
Change tibio-femoral angle	Pearson Correlation	1	0.249	-0.006	0.238	.[b]	0.479	0.332	0.243
	Sig. (2-tailed)		0.461	0.985	0.480	.	0.136	0.318	0.471
	N	11	11	11	11	11	11	11	11
Change Leg Length (Right)	Pearson Correlation	0.249	1	0.659*	0.230	.[b]	-0.163	0.130	-0.233
	Sig. (2-tailed)	0.461		0.028	0.497	.	0.632	0.702	0.490
	N	11	11	11	11	11	11	11	11
Change Leg Length (Left)	Pearson Correlation	-0.006	0.659*	1	0.088	.[b]	-0.086	-0.029	0.012
	Sig. (2-tailed)	0.985	0.028		0.798	.	0.802	0.932	0.972
	N	11	11	11	11	11	11	11	11
Change Q-angle	Pearson Correlation	0.238	0.230	0.088	1	.[b]	-0.371	-0.187	0.321
	Sig. (2-tailed)	0.480	0.497	0.798		.	0.261	0.583	0.336
	N	11	11	11	11	11	11	11	11
Change Feiss line	Pearson Correlation	.[b]	.[b]	.[b]	.[b]	.[b]	.[b]	.[b]	.[b]
	Sig. (2-tailed)	.	.	.	.		.	.	.
	N	11	11	11	11	11	11	11	11
Change KSQ	Pearson Correlation	0.479	-0.163	-0.086	-0.371	.[b]	1	0.498	-0.174
	Sig. (2-tailed)	0.136	0.632	0.802	0.261	.		0.119	0.609
	N	11	11	11	11	11	11	11	11
Change Algometer	Pearson Correlation	0.332	0.130	-0.029	-0.187	.[b]	0.498	1	-0.346
	Sig. (2-tailed)	0.318	0.702	0.932	0.583	.	0.119		0.298
	N	11	11	11	11	11	11	11	11
Change VAS	Pearson Correlation	0.243	-0.233	0.012	0.321	.[b]	-0.174	-0.346	1
	Sig. (2-tailed)	0.471	0.490	0.972	0.336	.	0.609	0.298	
	N	11	11	11	11	11	11	11	11

*. Correlation is significant at the 0.05 level (2-tailed).
b. Cannot be computed because at least one of the variables is constant.

Based on the outcomes of the individual intervention groups versus the combination intervention group and the differences in the dynamic biomechanical changes in these respective groups, it is not unexpected that this group had fewer significant correlations and that the only correlation that was significant in terms of Pearson's correlation was that of leg length.

4.11.1.11 Summary / Discussion on objective four

Table 4.10: Summary table for the combination intervention (Group D)

Combination Intervention (Group D)			Sacroiliac Intervention (Group C)			Superior Tibio-Fibular Intervention (Group B)			Ankle Intervention (Group A)		
Measurements	**Significant Difference**[10]	**Change**	**Measurements**	**Significant Difference**[11]	**Change**	**Measurements**	**Significant Difference**[12]	**Change**	**Measurements**	**Significant Difference**	**Change**
Tibio-femoral angle	None	↑	**Tibio-femoral angle**	None	↑	**Tibio-femoral angle**	None	↓	**Tibio-femoral angle**	None	↓
LL R	None	↑	**LL R**	None	↓	**LL R**	None	↓	**LL R**	None	↓
LL L	None	↓	**LL L**	None	↓	**LL L**	None	↓	**LL L**	None	↓
Q angle	None	↑	**Q angle**	None	↓	**Q angle**	None	↓	**Q angle**	None	↓
Feiss line	None	None	**Feiss line**	None	None	**Feiss line**	None	None	**Feiss line**	None	None
Leg-heel alignment	None	None	**Leg-heel alignment**	None	None	**Leg-heel alignment**	None	None	**Leg-heel alignment**	None	Minimal
KSQ	Significant	↑	**KSQ**	None	↑	**KSQ**	Significant	↑	**KSQ**	Significant	↑
Algometer	None	↑	**Algometer**	Nine	↑	**Algometer**	None	↑	**Algometer**	None	↑
VAS	Significant	↓	**VAS**	Significant	↓	**VAS**	Significant	↓	**VAS**	Significant	↓

Table 4.10 represents a summary of the findings in schematic form, allowing the comparison between the groups.

[10] Statistically there was no significant difference reported, although changes / trends over time did occur.
[11] Statistically there was no significant difference reported, although changes / trends over time did occur.
[12] Statistically there was no significant difference reported, although changes / trends over time did occur.

4.12 To compare a trend amongst the four different groups in terms of the findings and to determine the relative effect of lower extremity manipulation in the treatment of ITBFS.

4.12.1 Comparison of the four interventions groups

To determine which group had the greatest change over time for each of the measures, the four groups were compared to determine whether any one group had a greater advantage in improving a participant's symptoms.

4.12.1.1 Tibio- femoral angle

There was a significant difference in change over time in the tibio-femoral angle between the groups according to the Wilk's Lambda test (*p*=0.001).

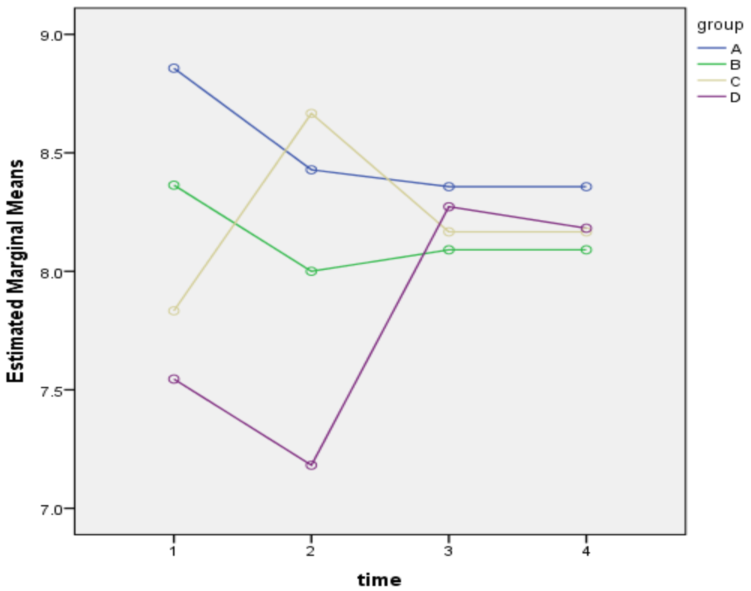

Figure 4.30: Comparison profile plot for tibio-femoral angle over time between the four groups

From Figure 4.30, it would seem that the combination group has the greatest ability to change the tibio-femoral angle. However, this change is associated with an increase in the tibio-femoral angle. This increased tibio-femoral angle (increased knee valgum) although potentially a positive factor for improvement in ITBFS at the knee, has a predilection for increased medial knee strain and greater trochanteric involvement in ITB irritation. Consequently, this may result in a possible increased stretch of the ITB over the greater trochanter, whereas a decrease in the angle would add less strain to the ITB as it passes over the hip and therefore, less insertional pull as it passes over the LFE. The latter was observed in Group A (ankle joint manipulation group) and Group B (superior tibio-fibular manipulation group manipulation group), who displayed the greatest decrease in the angle.

4.12.1.2 Leg length of right leg (LL R)

There was no statistically significant difference in change over time between the groups (p=0.335) in right leg length measurement.

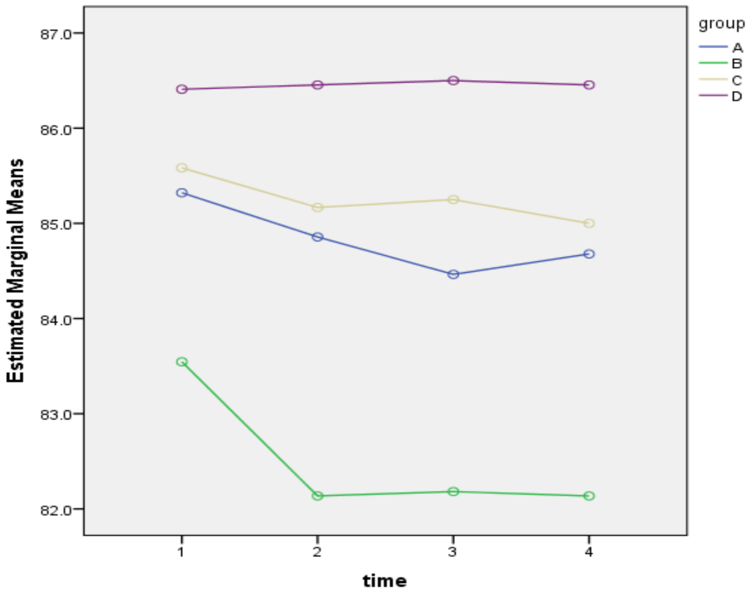

Figure 4.31: Comparison profile plot for leg length of right leg over time between the four groups

4.12.1.3 Leg length of left leg (LL L)

There was no statistically significant difference in change over time between the groups according to the Wilk's Lambda test (p=0.773) in the left leg length measurement.

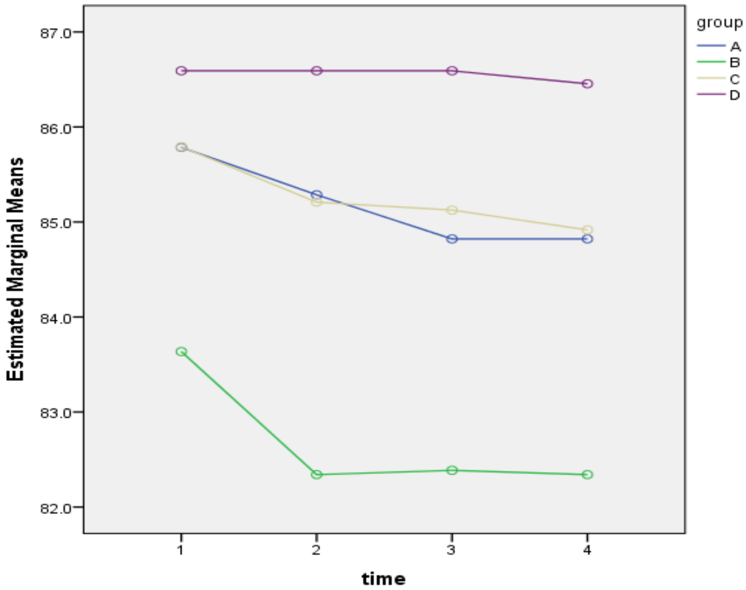

Figure 4.32: Comparison profile plot for leg length of left leg over time between the four groups

In terms of the effect of manipulation on leg length changes, it would seem that the superior tibio-fibular joint manipulation results in the greatest degree of change. This may be attributed to the previous discussion where it was suggested that the superior tibio-fibular joint has the ability to adapt the mechanics of the talocrural joint, without also affecting the foot's ability to react to ground reactive forces (as would be the case in the ankle joint manipulation group). Therefore from a mechanical point of view, the superior tibio-fibular joint has the greatest ability to change the leg length when considering the lower kinematic chain.

The sacroiliac joint has been cited as a possible factor that influences leg length with joint dysfunction (Gurney, 2002; Cummings *et al.*, 1993; Schuit *et al.*, 1989; Cibulka and Koldenhoff, 1986; Subotnick, 1981; Greenman, 1979), and several articles have suggested the use of leg length as a means to determine sacroiliac joint dysfunction (Bergmann and Peterson, 2011; Morris, 2006; Cohen, 2005; Haldeman, 2005; Vleeming *et al.*, 2001; Bernard and Kirkaldy-Willis, 1987). However, in this study when compared to the lower kinematic chain manipulation groups (A and B), the degree of change attributed to the sacroiliac joint is less than that which was affected by the ankle and superior tibio-fibular joint manipulations.

4.12.1.4 Quadriceps angle (Q angle) of femur

There was no statistically significant difference in change over time between the groups in the Q angle of the femur, according to the Wilk's Lambda (p=0.863).

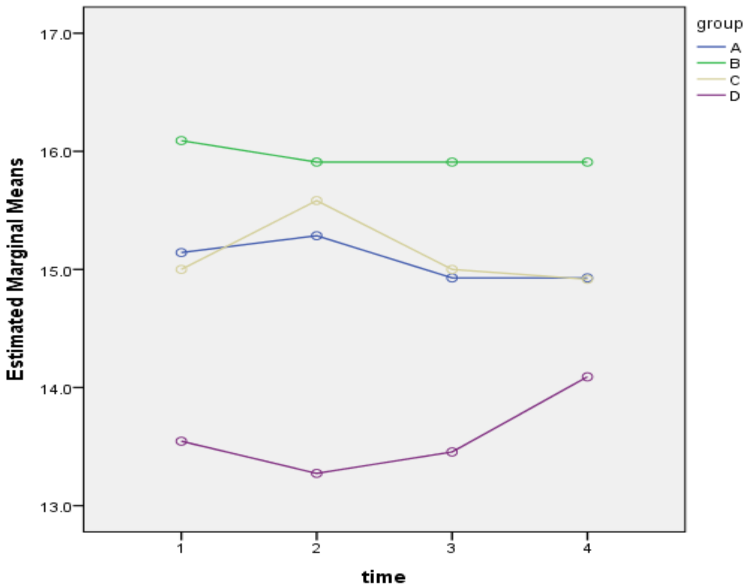

Figure 4.33: Comparison profile plot for Q angle over time between the four groups

The discussion as presented under Section 4.12.1 would be similar to that which affects the Q angle, with the same clinical outcome. This suggests that the Q angle is most affected by the combination group (Group D) in a negative manner, with the potential of increasing the discomfort in the participant in the longer term (even though the short term measures in this study suggest that there is clinical improvement). By contrast, the ankle joint and superior tibio-fibular joint manipulation seem to have the ability to decrease the Q angle and therefore align the mechanics of the lower limb to a more anatomically correct position, which allows for both clinical improvement and decreases the chance of longer term overuse syndromes.

4.12.1.5 Feiss line and Leg-heel alignment

There were no statistically significant changes noted over time in the Feiss line and leg-heel alignment readings between the four groups. Further to this the correlations between groups were not significant as the correlations were nonexistent because of lack of change over time (which would make the change values 0 or close to 0) (Esterhuizen, 2015).

4.12.1.6 Knee scoring questionnaire (KSQ)

There was a significant difference in change over time in the KSQ between the groups according to the Wilk's Lambda test (p=0.004).

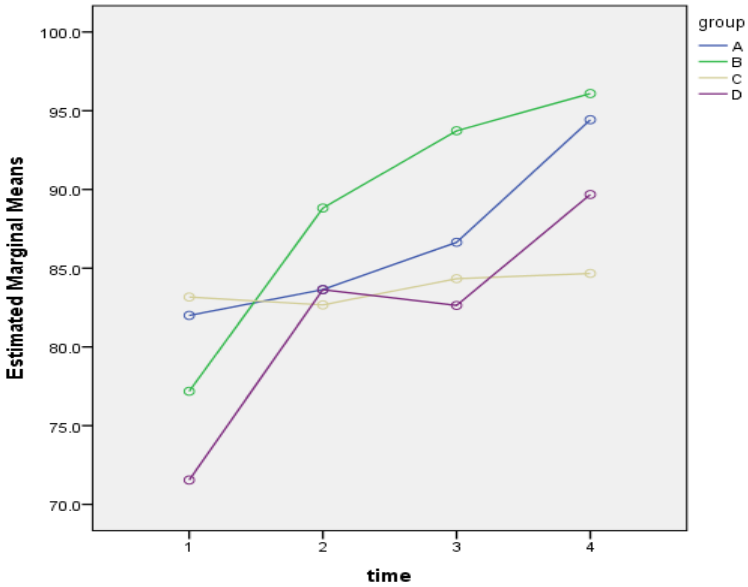

Figure 4.34: Comparison profile plot for KSQ over time between the four groups

From Figure 4.34, it would seem that the more specific the manipulation is to the knee joint (e.g. superior tibio-fibular joint) or the greater the degree to which it is able to affect both the ground reactive force and changes in the lower limb biomechanics (combination group), the greater the likelihood that the participant would improve over the other manipulation combinations. This re-enforces the assertion that manipulation of the lower kinematic chain is important in dealing with patient's clinical symptoms and functional ability in treating ITBFS.

4.12.1.7 Algometer

There was no significant difference in change over time between the groups in the algometer readings, according to the Wilk's Lambda test (*p*=0.609).

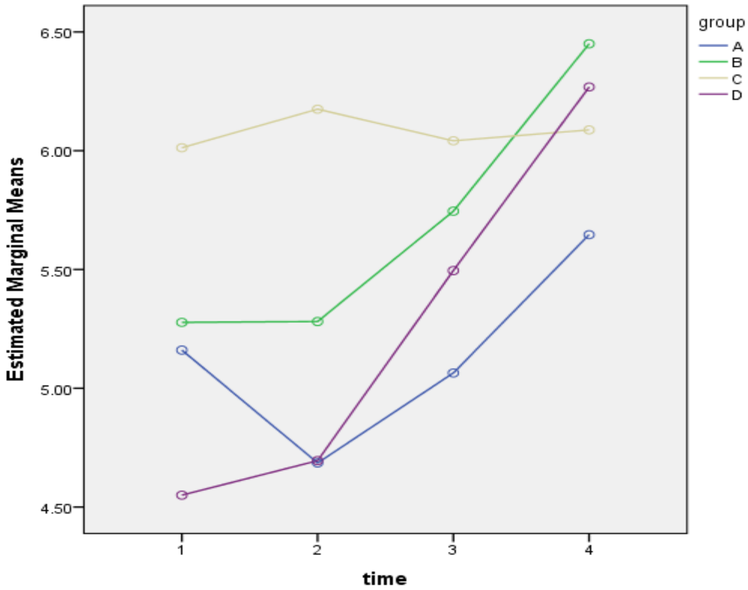

Figure 4.35: Comparison profile plot for algometer over time between the four groups

The trend here suggests that the combination group achieves the quickest response in terms of the sensitivity to kilograms per square centimetre. Therefore, changes in the muscle (vastus lateralis muscle), suggests that the effect of the sacroiliac joint manipulation in overriding arthrogenic muscle inhibition, in addition to the direct muscle changes, provides the best outcome for muscle tenderness improvement. This is in contrast to ankle joint manipulation, which seems to provide the best functional outcome in terms of improvement, but does not reflect the same rate of change in muscle tenderness. Therefore, in patients that are treated with ankle joint manipulations, the patient should expect a longer recovery rate than those that are treated with a combination of manipulations for ITBFS.

4.12.1.8 Visual analogue scale (VAS)

There was no significant difference in change over time in the VAS between the groups according to the Wilk's Lambda test (p=0.111).

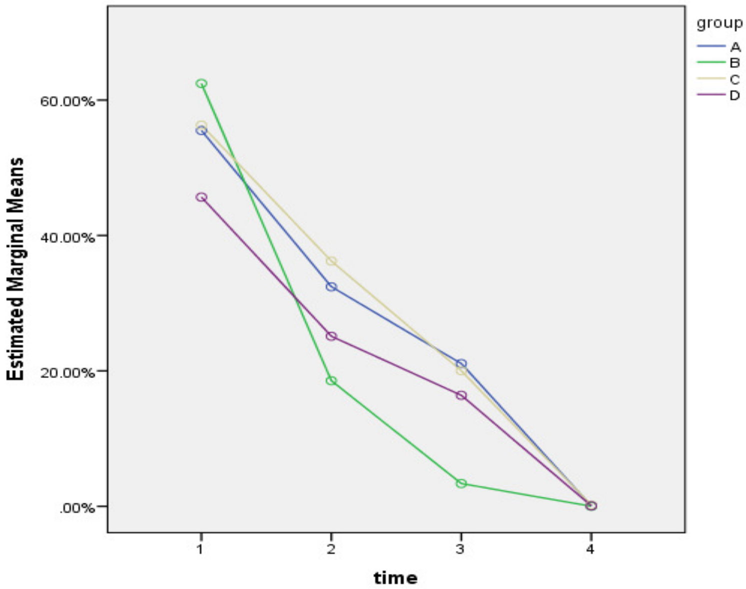

Figure 4.36: Comparison profile plot for VAS over time between the four groups

In terms of the classic lateral knee pain that is experienced by ITBFS sufferers, Figure 4.36 suggests that all patients receiving any intervention would improve to become asymptomatic. The group that has the greatest trajectory for improvement is Group B, which is the superior tibio-fibular joint group. This implies that the most direct manipulative therapy is best able to reduce the lateral knee pain at the quickest rate. However, the other interventions are not dissimilar but patients would have to be warned that they would not receive immediate and sudden relief.

4.13 Overall summary and review of objectives

The *aim* of the study was to determine the differences of superior tibio-fibular joint manipulation alone versus sacroiliac joint manipulation alone, versus subtalar joint manipulation alone as well as a combination of the three interventions in the treatment of ITBFS.

The *objectives* were to measure the differences between the four interventions, if any, in terms of primary clinical outcome measures:

- Visual analogue scale,
- Knee score questionnaire and
- Algometer

and secondary biomechanical outcome measures:

- Leg length,
- Q angle,
- Tibio-femoral angle,
- Feiss line and
- Leg-heel alignment.

The objectives were: -

- To determine the effect of ankle joint manipulation in the treatment of ITBFS.
- To determine the effect of superior tibio-fibular joint manipulation in the treatment of ITBFS.
- To determine the effect of sacroiliac joint manipulation in the treatment of ITBFS.
- To determine the effect of a combination of these three treatments in the treatment of ITBFS.

In the context of the results and the Null Hypothesis following from the objectives:

The only significantly different outcomes between the groups were the tibio-femoral angle and the KSQ.

- That Group D (Combination treatment) did not perform better than Group A (Ankle joint manipulation group)

  The null hypothesis is accepted for all outcome measures with the exception of the tibio-femoral angle.

- That Group D (Combination treatment) did not perform better than Group B (Superior tibio-fibular joint manipulation group)

  This null hypothesis is not rejected for all outcome measures with the exception of the tibio-femoral angle.
- That Group D (Combination treatment) did not perform better than Group C (Sacroiliac joint manipulation group)

  This null hypothesis is not rejected for all outcome measures with the exception of the tibio-femoral angle.

Chapter Five

Conclusion and Recommendations

5.1 Conclusion

Based on the premise that ITBFS has been associated with biomechanical changes in the lower extremity (Reid, 1992), this study aimed to determine the relative effectiveness of ankle joint manipulation versus superior tibio-fibular joint manipulation versus sacroiliac joint manipulation versus combination manipulative intervention utilising any two of the three joint complexes.

Therefore, this study comprised 48 participants spread over four groups (Ankle joint manipulation (Group A) N=14; Superior tibio-fibular joint manipulation (Group B) N=11; Sacroiliac joint manipulation (Group C) N=12; Combination treatment (Group D) N=14), who met the inclusion criteria and agreed to participate in the study that required six treatments within three weeks with a follow up seventh consultation for data measurement only in week four.

The results revealed that all four groups performed similarly (in other words, there was no significant difference), with the exception of the tibio-femoral angle which was significantly different across the groups. This significance however, correlated with an increased tibio-femoral angle which was not an expected outcome, as this has been associated with an increased risk for ITBFS, particularly in female patients.

In terms of the comparative trends between the groups, it was found that the effect of ankle joint and superior tibio-fibular joint manipulation were better at reducing the tibio-femoral angle and the Q angle. Therefore, allowing for improved limb alignment along with significantly improved KSQ scores and pain measures and trends for improvement in the algometer without significance. The sacroiliac joint group (Group C) performed the worst with increasing tibio-femoral angles with the only significant measure being that of pain reduction (no significant changes in the KSQ and the algometer measures). By contrast, the intervention offered to the combination group's (Group D) participants increased their tibio-femoral angle (significantly) and Q angles and allowed for significant improvement in the KSQ and pain readings. However, the athlete's long-term functional ability was questioned in terms of maintaining the biomechanical changes, which occurred in the combination group, as these changes are suggestive of increased likelihood of early degenerative changes in the patella-femoral and the tibio-femoral joints. This latter assertion would however require further investigation.

Based on the discussion in this study, there are several recommendations and these will now be discussed in each of the sections below.

5.2 Recommendations

This section summarises the recommendations that arose out of this study.

5.2.1 Future studies: methodology

- It is suggested that future studies structured similarly to this clinical trial, consider an increased sample size with due consideration for Age, Gender, Sidedness, Leg length, Tibio-femoral angle, Quadriceps angle, Feiss line and Leg-heel alignment. It is however suggested that significant investment in various different advertising and recruitment strategies be considered prior to the onset of the study.

- To increase the age range (with radiographs to exclude other knee pathologies) or have stratifications that include older participants, so that concomitant pathologies (e.g. early knee osteoarthritis) can be controlled for.

- The use of two clinical assessors (researcher and an independent person) to confirm the location of joint restrictions, so that only agreed upon joint restrictions be manipulated.

- The use of a blinded research assistant to take the clinical and biomechanical measurements, so that they are blinded to treatment received and that the researcher is blinded to the outcomes until the end of the study period.

- The inclusion of plantarflexion and dorsiflexion of the ankle joint should be considered as an additional biomechanical measure as this may add to the understanding of the changes in the biomechanical chain of the lower extremity.

- The inclusion of a more dynamic tool to measure the extremes of pronation and supination during the gait cycle may reveal more in terms of the dynamic nature of running as compared to the use of a static measure such as the Feiss line.

- A follow up after one month, six months or twelve month period following the last intervention, to determine whether the changes seen within the four week period of this study maintain their effect over this time period.

5.2.2 Future studies: questions that need investigation

Future studies need to consider whether the following factors may have had an outcome in this study:

- Training schedules,
- Road camber, and / or
- Leg dominance.

In a future study, it would be interesting to compare specifically stratified groups in terms of the combination intervention – viz.:

- Sacroiliac and ankle joint manipulation group
- Sacroiliac and superior tibio-fibular joint manipulation group
- Ankle and superior tibio-fibular joint manipulation group

Additionally, in a future study, it might be of interest to look at how the participants respond when comparing the treatment of an agreed upon restriction (primary restriction) as compared to a secondary restriction to determine if there is a clinical difference in the outcome obtained.

A study of a similar nature in the future may benefit from assessing the relationship of the tibio-femoral angle and the Q angle, to determine whether a fixed relationship exists between these two measures. This would assist in understanding which changes are likely to yield improved clinical outcomes for the patient.

In a similar manner, it would be interesting to understand the relationship between the tibial rotation on the tibio-femoral and the Q angles. This understanding may promote a clearer understanding of the relationship between the known x-axis rotation of the ankle complex and its effect via the y-axis rotation of the tibia on the tibio-femoral and the Q angles, and thus the outcome in effectively treating patients with ITBFS.

5.2.3 Clinical recommendations

It would seem from the outcomes of this study that the practitioners should first consider the distal extremity joints and their functionality before addressing more proximal consequences of ITBFS (at least in the short-term) to achieve outcomes that are clinically effective and with limited potential for longer term complications.

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Institutional Research Ethics Committee
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P O Box 1334, Durban, South Africa, 4001

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www.dut.ac.za

25 November 2013

IREC Reference Number: **REC 73/13**

Mr J A Botes
27 Povall Road
6 Lyngate
Musgrave
Durban
4001

Dear Mr Botes

The effect of four different manipulative techniques on Iliotibial Band Friction Syndrome (ITBFS) in terms of primary and secondary outcome measures

I am pleased to inform you that Full Approval has been granted to your proposal REC 73/13. You are requested to ensure the following:

- All telephonic interviews are to be recorded and stored as part of the documentation.

The Proposal has been allocated the following Ethical Clearance number **IREC 095/13**. Please use this number in all communication with this office.

Approval has been granted for a period of one year, before the expiry of which you are required to apply for safety monitoring and annual recertification. Please use the Safety Monitoring and Annual Recertification Report form which can be found in the Standard Operating Procedures [SOP's] of the IREC. This form must be submitted to the IREC at least 3 months before the ethics approval for the study expires.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC SOP's. In addition, you will be responsible to ensure gatekeeper permission.

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

Yours Sincerely

[redacted]

Prof J K Adam
Chairperson: IREC

Appendix A2

APPLICATION FOR APPROVAL OF AMENDMENT	
To be completed by the principal investigator/researcher in accordance with the Standard Operating Procedure for the fREe.	
Title of the study: The effect of four different manipulative techniques on Iliotibial Band Friction Syndrome (ITBFS) in terms of primary and secondary outcome measures.	
Institution: DUT	Date: 23/09/2014
Name and qualification of principal investigator/researcher: Jacques Andre Botes (B. Tech: Chiropractic)	Name and qualification of supervisor(s): Dr Horace White (M.Tech: Chiropractic) Dr Charmaine Korporaal (M.Tech: Chiropractic, CCFC,CCSP,ICSSD)
Name of qualification: M. Tech: Chiropractic	Student Number: 20616362
Ethical approval number: REC 73/13; IREC095/13	Research site: DUT
Nature of amendment: Recommendation for methodological amendments to study. 1. **Reduction in total samRle size {therefore, numbers Rer groue}:** Currently the total sample size of participants required is 80, divided into 4 groups of 20 participants each. A reduction in the total sample size of participants from 80 to 40 is recommended, allowing for 10 participants per group. 2. **Male versus female ratio:** Currently the male to female ratio is 10:10 per group. Recommendation made to keep focus on female versus female ratio per group the same, which is currently 3:3, rather than male versus female. • **Please see attached letter {Aeeendix A} and statistician's reeort {AReendix D} for relevant references and reference list.**	
Effect on risk benefit profile of participants: None, there are no changes to the letter of informed consent or patient procedure.	

Please submit the following documentation:

- Approved proposal: Attached as Appendix B
- Changes to letter of information and consent: None, but altered Advert appended (Appendix C)
- Any other relevant documentation: Attached letter of motivation with relevant reference list as (Appendix A); Statistician's report (Appendix D); Summary of PGSa/PGSb (Appendix E); Support letter from an external Chiropractor (Appendix F)

Signature:	**Date:**
Researcher:	
Supervisor:	
Head of Department:	

TO *BE COMPLETED BY THE CHAIR OF THE IREC.*

Date received:	Review required:	
	Expedited	**Full** committee

To *be completed by the chairperson* of *the IREC*

The amendment is:	Yes	No	N/A
Approved - there are no evident grounds for concern or further investigation.			
Approved subject to minor changes			
Needs to be re-submitted after recommendations are met			
Approved however a site inspection is recommended.			
Denied (please see attached)			

Signature:	**Date:**
Chairperson of IREC	

DUT
DURBAN
UNIVERSITY OF
TECHNOLOGY

Institutional Research Ethics Committee
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17 November 2014

Mr J A Botes
27 Povall Road
6 Lyngate
Musgrave
Durban
4001

Dear Mr Botes

Application for Amendment of Approved Research Proposal

The effect of four different manipulative techniques on Iliotibial Band Friction Syndrome (ITBFS) in terms of primary and secondary outcome measures

I am pleased to inform you that your application for amendment to the sample size and the male versus female ratio of your research proposal have been Approved.

Yours Sincerely

[redacted]

Professor J K Adam
Chairperson: IREC

APPENDIX B

ITB

RESEARCH

DO YOU SUFFER FROM ILIOTIBIALBAND SYNDROME

(Pain on the outside (lateral) aspect of the knee)

AND

ARE BETWEEN THE AGES OF 20-40

RESEARCH IS CURRENTLY BEING CARRIED OUT BY THE DURBAN UNIVERSITY OF TECHNOLOGY AT THE CHIROPRACTIC DAY CLINIC

TREATMENT

IS AVAILABLE TO THOSE WHO QUALIFY TO TAKE PART IN THIS STUDY

FOR FURTHUR INFORMATION or PRESENTATION CONTACT:

JACQUES BOTES

031 3732205/ 2512 OR 084 911 9218

APPENDIX C

27 Povall Road
6 Lyngate
Musgrave
Durban
4001

Name of Company

Request for permission to advertise for Research Participants

Dear Sir/ Mam,

I am a 5th-year Chiropractic student (student #: 20616362) at Durban University of Technology (DUT) in South Africa. In order for us to complete and graduate we need to complete a comprehensive thesis/ research study that is supported and supervised by dedicate professionals, the department of Chiropractic and Durban University of Technology (DUT).

My research project is an investigative study into the effect of four different manipulative techniques on Iliotibial band friction Syndrome (ITBFS). This is a prospective, randomized clinical trial designed to determine the differences of superior tibio-fibular joint manipulation alone versus sacroiliac joint manipulation alone, versus subtalar joint manipulation alone as well as a combination of the three interventions in the treatment of ITBFS.

The objectives for the study as determined by measuring the differences between the four interventions, if any, in terms of subjective and objective findings with regards to the following:

- To determine the effect of superior tibio-fibular manipulation in the treatment of ITBFS.
- To determine the effect of sacroiliac manipulation for ITBFS in the treatment of ITBFS.
- To determine the effect of ankle joint complex manipulation in the treatment of ITBFS.
- To determine the effect of a combined manipulation in the treatment of ITBFS.
- Compare trend amongst groups in terms of those findings and determine the relative effect of lower extremity manipulation for treatment of ITBFS.

I, Jacques Botes herewith kindly request for permission to advertise my research study within/ on your premises.

Kind Regards,

Jacques Botes

____

Permission Granted: **Yes** **No**

I, __________________________________, hereby give permission for Jacques Botes to advertise his research study within/ on our premises, signed at ____________________________, on the ___________________________ 2013.

Signed:

____

APPENDIX D

Letter of information and informed consent

DEAR PARTICIPANT

Welcome to my research project.

TITLE OF RESEARCH STUDY:

An investigative study into the effect of four different manipulative techniques on Iliotibial band friction Syndrome (ITBFS).

Principal investigator:	Jacques Botes - 0827000134
Co-Investigators:	Dr Horace White ((M-Tech Chiropractic) – 031 4642490; Dr C. Korporaal (M-Tech Chiropractic, CCFC, CCSP, ICSSD) – 0832463562

Introduction and Purpose of the study:

You have been selected to take part in a study that investigates the effect of different manipulation protocols. This will help determine which of the following will allow you to get better: superior tibio-fibular joint manipulation alone versus sacroiliac joint manipulation alone, versus subtalar joint manipulation alone or a combination of the three interventions in the treatment of ITBFS. The treatment protocol that you will receive aims to reduce your symptomatic pain which you are currently experiencing and to aid you in your recovery and return to a pain free activity.

Outline of the procedures:

All suitable participants, including you will be recruited by convenience sampling. However once the participants meet the inclusion criteria they will be allocated into four groups by means of stratified sampling. The stratification will be done by an age and gender method. Each group will receive a standard clinical treatment including superior tibio-fibular joint manipulation, sacroiliac joint manipulation, subtalar joint manipulation or a combination of the three interventions.

Risks/discomforts and Benefits

The treatment is safe and is unlikely to cause any adverse effects. However, you may feel transient stiffness or discomfort post treatment as is evident with any manual therapy, which should resolve without further complication to the patient. However, should the discomfort persist in any way, than you must please report this to me immediately so that I can take the appropriate action. The treatment aims to decrease the subject's symptomatic pain experienced due to the condition and to aid them in returning to their normal daily activity.

Reason(s) why the subject may withdraw or be withdrawn from the study:

In the event that the subject does not meet the inclusion criteria or infringes on the exclusion criteria of the study, the subject will be withdrawn. Your participation in this study is voluntary and refusal to participate will not result in any adverse consequences. You are free to withdraw from the study at any time.

Remuneration:
You will not be awarded any remuneration for taking part in this study.

Cost of study:
Your participation in this research is free of charge, but should the participant wants further treatment upon completion of the study, a normal consultation fee/ rate will apply.

Confidentiality:
Your personal information will remain confidential by the use of a coding system for data analysis and reporting and kept in the Chiropractic Day Clinic for 15 years, after which it will be shredded. All the results will be made available in the Durban University of Technology library in the form of a dissertation, but no personal information will be melted.

Should there be a research related injury: The D.U.T Clinic Protocol will be followed and the injury would also need to be reported to the Health Research and Ethics Committee, so please ensure that you advise me of any such problems.

Persons to contact in the event of any Problems or Queries:

Research: Mr Jacques Botes	Tel: 031 373 2205
Supervisor: Dr H. White (M.Tech: Chiropractic)	Tel: 031 373 2611
Co-supervisor:Dr C. Korporaal (M.Tech: Chiropractic)	Tel: 031 373 2611
IREC Research Administrator (IREC)	Tel: 031 373 2900

Statement of Agreement to Participate in the Research Study:

I, ...Subject's full name ....(ID number) have read this document in it is entirely and understand its contents. Where I have had any questions or queries, these have been explained to me by Natasha Coetzee to my satisfaction. Furthermore, I fully understand that I may withdraw from this study at any stage without any adverse consequences and my future health care will not be compromised. I, therefore, voluntarily agree to participate in this study.

Subject's name (print) ....
Subject's signature. ....Date..

Researcher's name (print) ....
Researcher's signature ....Date..

Witness name (print) ....
Witness signature ....Date...

APPENDIX E

DURBAN UNIVERSITY OF TECHNOLOGY
CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient: ______________________________ Date: __________

File # __________ Age: __________

Sex: __________ Occupation: ______________________________

Intern: ______________________________ Signature: ______________________________

FOR CLINICIANS USE ONLY:
Initial visit
Clinician: Signature:

Case History:

Examination:
Previous: Current:

X-Ray Studies:
Previous: Current:

Clinical Path. lab:
Previous: Current:

CASE STATUS:

PTT: Signature: Date:

CONDITIONAL:
Reason for Conditional:

Signature: Date:

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

Case Summary signed off: Date:

Intern's Case History:

1. Source of History:

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

3. Present Illness:

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

4. Other Complaints:

5. Past Medical History:

< General Health Status

< Childhood Illnesses

< Adult Illnesses

< Psychiatric Illnesses

< Accidents/Injuries

< Surgery

< Hospitalizations

6. Current health status and life-style:

< Allergies

< Immunizations

< Screening Tests incl. x-rays

< Environmental Hazards (Home, School, Work)

< Exercise and Leisure

< Sleep Patterns

< Diet

< Current Medication
Analgesics/week:

< Tobacco

< Alcohol

< Social Drugs

7. Immediate Family Medical History:

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

8. Psychosocial history:

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

9. Review of Systems:

< General

< Skin

< Head

< Eyes

< Ears

< Nose/Sinuses

< Mouth/Throat

< Neck

< Breasts

< Respiratory

< Cardiac

< Gastro-intestinal

< Urinary

< Genital

< Vascular

< Musculoskeletal

< Neurologic

< Haematologic

< Endocrine

< Psychiatric

APPENDIX F
Durban University of Technology
PHYSICAL EXAMINATION: SENIOR

Patient Name : ______________________ **File no :**__________ **Date :**________
Student : **Signature :**

VITALS:				
Pulse rate:			Respiratory rate:	
Blood pressure:	R	L	Medication if hypertensive:	
Temperature:			Height:	
Weight:	Any recent change? Y / N		If Yes: How much gain/loss	Over what period

GENERAL EXAMINATION:		
General Impression		
Skin		
Jaundice		
Pallor		
Clubbing		
Cyanosis (Central/Peripheral)		
Oedema		
Lymph nodes	Head and neck	
	Axillary	
	Epitrochlear	
	Inguinal	
Pulses		
Urinalysis		

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

Clinician: **Signature :**

APPENDIX G
REGIONAL EXAMINATION - LUMBAR SPINE AND PELVIS

Patient:_________________________________ File#:______Date:_________
Intern\Resident:__________________________ Clinician:__________________

STANDING:

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

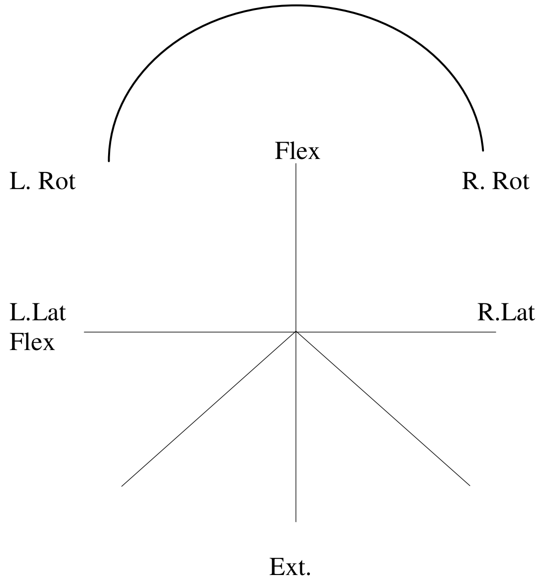
Minor's Sign
Muscle tone
Spinous Percussion
Scober's Test (6cm)
Bony and Soft Tissue Contours

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°
Flex



Which movt. reproduces the pain or is the worst?

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

SUPINE:

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

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

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

SITTING:

Spinous Percussion
Valsalva

Lhermitte

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

Slump 7 test	**L**										
	R										

LATERAL RECUMBENT:	**L**	**R**
Ober's		
Femoral n. stretch		
SI Compression		

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

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

NON ORGANIC SIGNS:

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

NEUROLOGICAL EXAMINATION

Fasciculations

Plantar reflex

level	**Tender?**	**Dermatomes**		**DTR**		
		L	R		L	R
T12				Patellar		
L1				Achilles		
L2						
L3				Proproception		
L4						
L5						

S1						
S2						
S3						

MYOTOMES

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

BASIC THORACIC EXAM

History
Passive ROM
Orthopedic

BASIC HIP EXAM

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

MOTION PALPATION AND JOINT PLAY

Upper Thoracics		
Lumbar Spine		
Sacroiliac Joint		
	L	R

APPENDIX H

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

▪ **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 (30-50°)		
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 & location*)			
1.	Level		
2.	Location		

JOINT PLAY MOVEMENTS		Right	Left
1.	Caudal glide (long axis traction superior – inferior)		
2.	Compression@ 90^{o} (inferior – superior)		
3.	Medial ➢ lateral @ 180^{o} / @ 90^{o}		
4.	Lateral ➢ medial @ 180^{o} / @ 90^{o}		
5.	Internal rotation		
6.	External rotation		
7.	Anterior ➢ posterior		
8.	Posterior ➢ anterior		
9.	Quadrant (scouring) test		

SPECIAL TESTS			Right	Left
1.	Patrick FABER Test			
2.	Trendelenberg Test			
3.	Craig's Test			
4.	Leg Length	Actual		
		Apparent		
5.	Sign of the Buttock			
6.	Thomas Test (hip flexion contracture)			
7.	Rectus Femoris Contracture Test			
8.	Iliopsoas contracture Test			
9.	Ely's Test (rectus femoris hypertonicity)			
10.	Ober's Test (ITB contracture)			
11.	Noble Compression Test (ITB Friction Syndrome)			
12.	Piriformis Test			
13.	Hamstrings	Hamstring Contracture Test		
		Tripod Test		

APPENDIX I

DURBAN UNIVERSITY OF TECHNOLOGY
KNEE REGIONAL EXAMINATION

Patient:____________________ File:__________ Date:__________
Intern:____________________ Signature:____________________
Clinician:____________________ Signature:____________________

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

A. Anterior view
Genu Varum:__________
Genu Valgum:__________
Patellar position:__________
Tibial Torsion:__________
Skin:__________
Swelling:__________

B. Lateral view
Genu Recurvatum:__________
Patella Alta:__________
Patella Baja:__________
Skin:__________

C. Posterior view
Swelling:__________
Skin:__________

D. General
Movement symmetry:__________
Structures symmetry:__________

! **ACTIVE MOVEMENTS**
Flexion (0 - 135E)__________
Extension (0 - 15E)__________
Medial Rotation (20 - 30E)__________
Lateral rotation (30 - 40E)__________

! **PASSIVE MOVEMENTS**
Tissue approx__________
Bone-bone__________
Tissue stretch__________
Tissue stretch__________
Patellar movement__________

! **RESISTED ISOMETRIC MOVEMENTS**
Knee: Flexion:__________
Extension:__________
Internal rotation:__________
External rotation:__________

Ankle: Plantarflexion__________
Dorsiflexion__________

! **LIGAMENTOUS ASSESSMENT**

One-Plane Medial Instability
Valgus stress (abduction)
Extended__________
Resting Position__________

One-Plane Lateral Instability
Varus stress (adduction)
Extended__________
Resting Position__________

One-Plane Anterior Instability
Lachman Test (0-30°)__________
Anterior Drawer Sign __________

One-Plane Posterior Instability
Posterior "sag" Sign__________
Posterior Drawer Test__________

Anterolateral Rotatory Instability
Slocum Test__________
Macintosh Test__________

Anteromedial Rotatory Instability
Slocum Test__________

Posterolateral Rotatory Instability
Jacob __________
Hughston's Drawer Sign__________
Reverse pivot shift test__________

Posteromedial Rotatory Instability
Hughston's Drawer Sign__________

TESTS FOR MENISCUS INJURY

McMurray________________________ Anderson med-lat grind______________________

"Bounce Home"___________________ Apley=s________________________________

! **PLICA TESTS**

Mediopatellar Plica _________________ Hughston's Plica_____________________________

Plica "Stutter"______________________________________

! **TESTS FOR SWELLING**

Brush/Stroke Test _________________ Patellar Tap Test____________________________

! **TESTS FOR PATELLA FEMORAL PAIN SYNDROME**

Clarke's Sign ______________________ Passive patella tilt test________________________

Waldron test____

! **OTHER TESTS**

Wilson's__________________________ Quadriceps Contusion Test___________________

Fairbank's________________________ Leg Length Discrepancy______________________

Noble Compression_________________________________

! **JOINT PLAY**

Movement of the tibia on the femur P | A:______________ A | P:______________

Translation of the tibia on the femur M | L:______________ L M:______________

Long axis distraction of the tibiofemoral joint _

Inf, sup, lat, + med glide of the patella ___________________________________

Movement of the inf. tibiofibular joint A | P:______________P | A:__________________

Movement of the sup. tibiofibular joint A | P:______________P | A:__________________

Movement of the sup. tibiofibular joint S | I :______________ I | S__________________

! **PALPATION**

Tenderness____________________________ Swelling___________________________

Joint line_____________________________ Nodules/exostoses___________________

Ligaments_____________________________ Muscles: thigh:________________________

Patella:_______________________________ Leg :___________________________

Patella tendon:_________________________ Popliteal artery:________________________

Bursae:_______________________________

! **REFLEXES AND CUTANEOUS DISTRIBUTION**

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

! **DERMATOMES**

	R	L		R	L
L2			S1		
L3			S2		
L4			S3		
L5					

07/02/2007

APPENDIX J

Foot and ankle regional examination

Patient:______________________________ File no:__________ Date:________

Intern / Resident__________________________ Signature:______________________

Clinician:__________________________ Signature:__________________________

Observation
Gait analysis (antalgic limp,toe off, arch, foot alignment, tibial alignment).
____
____
Swelling____
Heloma dura / molle____
Skin____
Nails____
Shoes____
Contours (achilles tendon, bony prominences)______________________________

Active movements

Weight bearing:	**R**	**L**	***Non weight bearing:***	**R**	**L**
Plantar flexion			50°		
Dorsiflexion			20°		
Supination					
Pronation					
Toe dorsiflexion			40°(mtp)		
Toe plantar flexion			40° (mtp)		
		Big toe dorsiflexion (mtp) (65-70°)			
		Big toe plantar flexion (mtp) 45°			
		Toe abduction + adduction			
		5° first ray dorsiflexion			
		5° first ray plantar flexion			

Passive movement motion palpation (Passive ROM quality, ROM overpressure, joint play)

	R	**L**		**R**	**L**
Ankle joint: *Plantarflexion*			Subtalar joint: *Varus*		
Dorsiflexion			*Valgus*		
Talocrural: *Long axis distraction*			Midtarsal:*A-P glide*		
First ray: *Dorsiflexion*			*P-A glide*		
Plantarflexion			*rotation*		
Circumduction of forefoot on fixed rearfoot			Intermetatarsal glide		
			Tarso metatarsal joints: *A-P*		
Interphalangeal joints: *L/A dist*			Metatarsophalangeal dorsiflexion (with associated plantar flexion of each toe		
A-P glide					
lat and med glide					
rotation					

Resisted Isometric movements

	R	L		R	L
Knee flexion			Pronation (eversion)		
Plantar flexion			Toe extension (dorsiflexion)		
Dorsiflexion			Toe flexion (plantar flexion)		
Supination (inversion)					

Neurological

	R	L
Dermatomes		
Myotomes		
Reflexes		
Balance/proprioception		

Special tests

	R	L
Anterior drawer test		
Talar tilt		
Thompson test		
Homan sign		
Tinel's sign		
Test for rigid/flexible flatfoot		
Kleiger test (med. deltoid)		

Alignment

	R	L
Heel to ground		
Feiss line		
Tibial torsion		
Heel to leg (subtalar neutral)		
Subtalar neutral position:		
Forefoot to heel (subtalar & Midtarsal neutral)		
First ray alignment		
Digital deformities		
Digital deformity flexible		

Palpation

Anteriorly	R	L
Medial maleoli		
Med tarsal bones, tibial (post) artery		
Lat.malleolous, calcaneus, sinus tarsi, and cuboid bones		
Inferior tib/fib joint, tibia, mm of leg		
Anterior tibia, neck of talus, dorsalis pedis artery		

Posteriorly

Calcaneus, Achilles tendon, Musculotendinous junction		

Plantarily

Plantar muscles and fascia		
Sesamoids		

APPENDIX K
DURBAN UNIVERSITY OF TECHNOLOGY

Patient Name: ***File #:*** ***Page:***

Date: ***Visit:*** ***Intern:***
Attending Clinician: ***Signature:***

S: ***Numerical Pain Rating Scale (Patient)*** ***Intern Rating*** ***A:***
Least 0 1 2 3 4 5 6 7 8 9 10 Worst

0: ***P:***

E:

Special attention to: ***Next appointment:***

Date: ***Visit:*** ***Intern:***
Attending Clinician: ***Signature:***

S: ***Numerical Pain Rating Scale (Patient)*** ***Intern Rating*** ***A:***
Least 0 1 2 3 4 5 6 7 8 9 10 Worst

O: ***P:***

E:

Special attention to: ***Next appointment:***

Date: ***Visit:*** ***Intern:***
Attending Clinician: ***Signature***

S: ***Numerical Pain Rating Scale (Patient)*** ***Intern Rating*** ***A:***
Least 0 1 2 3 4 5 6 7 8 9 10 Worst

O: ***P:***

E:

Special attention to: ***Next appointment:***

APPENDIX L

Data Sheet number :	Gender	Male	Female
	Age		
Patient (file no):	Affected side	Right	Left

Visit one									
Tib fib angle		LL		Q angle		Feiss		KSQ	
Heel leg		Algo	a	b	av				
0 or best / no pain									100 or worst pain

Visit three									
Tib fib angle		LL		Q angle		Feiss		KSQ	
Heel leg		Algo	a	b	av				
0 or best / no pain									100 or worst pain

Visit five									
Tib fib angle		LL		Q angle		Feiss		KSQ	
Heel leg		Algo	a	b	av				
0 or best / no pain									100 or worst pain

Visit seven (post reading)									
Tib fib angle		LL		Q angle		Feiss		KSQ	
Heel leg		Algo	a	b	av				
0 or best / no pain									100 or worst pain

Appendix M

FORM C-22. SUBJECTIVE KNEE SCORE QUESTIONNAIRE

NAME____________________ SCORE________ DATE________ DOB________ AGE____

PLEASE CHECK THE STATEMENT THAT BEST DESCRIBES THE CONDITION OF YOUR KNEE

PAIN

20____ I experience no pain in my knee

16____ I have occasional pain with strenuous sports or heavy work. I don't think that my knee is entirely normal. Limitations are mild and tolerable.

12____ There is occasional pain in my knee with light recreational sports or moderate work.

8____ I have pain brought on by sports, light recreational activities, or moderate work. Occasional pain is brought on by daily activities such as standing or kneeling

4____ The pain I have in my knee is a significant problem with activities as simple as walking. The pain is relieved by rest. I can't participate in sports.

0____ I have pain in my knee at all times, even during walking, standing, or light work.

Intensity:	A[ ] Mild	B[ ] Moderate	C[ ] Severe	
Frequency:	A[ ] Constant	B[ ] Intermittent		
Location:	A[ ] Medial (inner side)	B[ ] Lateral (outer side)	C[ ] Anterior (front)	
	D[ ] Posterior (back)	E[ ] Diffuse (all over)		
Occurs:	A[ ] Kneel	B[ ] Stand	C[ ] Sit	D[ ] Stairs
Type:	A[ ] Sharp	B[ ] Aching	C[ ] Throbbing	D[ ] Burning

SWELLING

10____ I experience no swelling in my knees.

8____ I have occasional swelling in my knee with strenuous sports or heavy work.

6____ There is occasional swelling with light recreational activities or moderate work.

4____ Swelling limits my participation in sports and moderate work. Occurs infrequently with simple walking or light work. Occasionally with simple walking or light work—about 3 times a year.

2____ My knee swells after simple walking activities and light work. Rest relieves the swelling.

0____ I have severe swelling with simple walking activities. Rest does not relieve the swelling.

STABILITY

20____ My knee does not give out

16____ My knee gives out only with strenuous sports or heavy work.

12____ My knee gives out occasionally with light recreational activities or moderate work; it limits my vigorous activities, sports, or heavy labor

8____ Because my knee gives out, it limits all sports and moderate work. It occasionally gives out with walking or light work.

4____ My knee gives out frequently with simple activities such as walking. I must guard my knee at all times.

0____ I have severe problems with my knee giving out. I can't turn or twist without my knee giving out.

Stiffness:	A[ ] None	B[ ] Occasional	C[ ] Frequent	D[ ] Constant
Grinding:	A[ ] None	B[ ] Mild	C[ ] Moderate	D[ ] Severe
Locking:	A[ ] None	B[ ] Occasional	C[ ] Frequent	D[ ] Constant

OVERALL ACTIVITY LEVEL

20____ No limitations. I have a normal knee, and I am able to do everything including strenuous sports and/or heavy labor.

16____ I can partake in sports including strenuous ones but at a lower level. I must guard my knee and limit the amount of heavy labor or sports.

12____ Light recreational activities are possible with RARE symptoms. I am limited to light work.

8____ No sports or recreational activities are possible. Walking activities are possible with RARE symptoms. I am limited to light work.

4____ Walking activities and daily living cause moderate problems and persistent symptoms.

0____ Walking and other daily activities cause severe problems.

WALKING

10____ Normal, unlimited.

8____ Slight, mild problems.

6____ Moderate problem, flat surface up to half a mile.

4____ Severe problems, only 2–3 blocks.

2____ Severe problems, need cane or crutches.

STAIRS

5____ Normal, unlimited.

4____ Slight, mild problems.

3____ Moderate problems, only 10–15 steps possible.

2____ Severe problems, require banister for support.

1____ Severe problems, only 1–5 steps without support.

RUNNING

10____ Normal, unlimited, fully competitive.

8____ Slight, mild problems, run at half speed.

6____ Moderate problems, only 1–2 miles possible.

4____ Severe problems, only 1–3 blocks possible.

2____ Severe problems, only a few steps.

JUMPING AND TWISTING

5____ Normal, unlimited, fully competitive

4____ Slight, mild problems, some guarding.

3____ Moderate problems, gave up strenuous sports.

2____ Severe problems, affects all sports, always guarding.

1____ Severe problems, only light activity possible (pool/swim).

COMMENTS:____

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