Masters Degree

ANKLE KINEMATICS AND GROUND REACTION FORCE DURING SINGLE LEG DROP LANDING IN SPORTS PARTICIPANTS WITH CHRONIC GROIN PAIN

Thesis presentation, in the format of a journal article (pre-peer reviewing material), in a partial fulfilment of the requirements for the degree of Master of Science in Physiotherapy (Structured) OMT in the Faculty of Medicine and Health Sciences at Stellenbosch University

Lauren Sandra Harwin

Supervisors:

Mr Dominic Fisher

Prof Quinette Louw

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Declaration

I, the undersigned, hereby declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Abstract

Aims: This study aims to ascertain if there are differences in ankle kinematics and ground reaction force in sports participants with chronic groin pain compared to healthy controls.

Methods: A cross sectional descriptive study design was used. Twenty participants - 10 cases with chronic groin pain and 10 healthy controls participated. The 10 cases included participants with unilateral pain (n=7) and bilateral pain (n=3). For analysis, the bilateral pain group was divided into the most and less painful side. The study was conducted at the FNB 3D Motion Analysis Laboratory, Stellenbosch University. Sagittal plane kinematics and VGRF was analysed during a single leg drop landing.

Results: The group with unilateral groin pain had a higher peak force compared to the matched side of the controls. The bilateral pain groups had less plantarflexion at foot contact (most affected p=<0.001; least affected p=<0.001) and total range of motion (p=<0.05) compared to the control group. The bilaterally injured groin pain groups demonstrated less peak force when compared to controls.

Conclusion: This is the first study to indicate alterations in ankle kinematics and VGRF and that these changes are more apparent in sports participants with bilateral pain. Less range of motion during the landing task illustrated by the bilateral pain group suggests less effective force absorption of the distal segments. In the bilateral groups it suggests that force attenuation may have occurred high up the kinetic chain which may place more strain on the groin. Clinically rehabilitation of the athlete with chronic groin pain should include the distal segments of the lower limb. Further research should be conducted in larger groups.

Opsomming

Doelstellings: Hierdie studie poog om vas te stel of daar verskille in enkelbeweging en grondvloer-reaksiekrag is in deelnemers van sport met chroniese liespyn in vergelyking met gesonde kontrole deelnemers.

Metode: 'n Deursnee beskrywende studieontwerp is gebruik. Twintig deelnemers, 10 gevalle met chroniese liespyn en 10 gesonde kontrole het deelgeneem. Die 10 gevalle het ingesluit deelnemers met eensydige pyn (n=7) en bilaterale pyn (n=3). Vir die analise, is die bilaterale pyngroep verdeel in die mees en mins geaffekteerde kant. Die studie is gedoen by die FNB3D Beweginsanalise-laboratorium, Universiteit van Stellenbosch. Sagitaal-platvlak kinematiek en vertikale reaksiekrag is geanaliseer gedurende 'n enkele beenlanding.

Resultate: Die groep met eensydige liespyn het 'n hoër piekkrag gehad in vergelyking met dieselfde kant van die kontrolegroep. Die bilaterale pyngroep het minder plantaarfleksie met voetkontak getoon (mees geaffekteer p=<0.001; minste geaffekteer p=<0.001) en totale beweginsomvang (p=<0.05) in vergelyking met die kontrolegroep. Die bilateraal-liesbeseringsgroep het minder piekkrag getoon in vergelyking met die kontrolegroep.

Gevolgtrekking: Hierdie is die eerste studie om veranderings in enkelbeweging en grondreaksiekrag aan te toon, asook dat hierdie veranderinge meer opvallend is in persone wat aan sport deelneem wat bilaterale pyn ondervind. Verminderde beweginsomvang gedurende die landingstaak deur die bilaterale pyngroep suggereer minder effektiewe kragabsorpsie van die distale segmente. In die bilaterale groep suggereer dit dat kragvermindering waarskynlik hoog op die kinematiese ketting

voorgekom het wat weer meer stremming op die lies plaas. Kliniese rehabilitasie van die atleet met chroniese pyn behoort die distale segmente van die onderste ledemaat in te sluit. Verdere navorsing behoort in groter groepe uitgevoer te word.

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List of Abbreviations

CAI - Chronic Ankle Instability

MAI - Mechanical Ankle Instability

FAI - Functional Ankle Instability

FNB - First National Bank

3D - Three Dimensional

ICC - Intra – Class Coefficient

Hz - Hertz

ROM - Range of Motion

N - Newtons

VAS - Visual Analogue Scale

Yrs - Years

Kg - Kilograms

m - Meters

SD - Standard Deviation

FC - Foot Contact

LVP - Lowest Vertical Point

VGRF - Vertical Ground Reaction Force

CHAPTER 1

1. Introduction

Groin injuries account for 10 - 18% of injuries in contact sports with symptoms having the potential to lead to career-ending chronic pain (Ekstrand and Gillquist, 1983; Nielsen and Yde, 1989; Renstrom and Peterson, 1980). According to Tyler, Nicholas and Campbell (2001), groin pain can be defined as subjectively reported discomfort in the area arising from the illiopsoas to the mid adductor region. Groin pain is common in athletes who engage in sports which involve kicking, rapid accelerations and decelerations and sudden directional changes (Macintyre, Johnson and Schroeder, 2006). This may explain why groin pain may be more prevalent in sports such as soccer, hockey and rugby.

Groin pain is often multifactorial with the involvement of several anatomic structures (Macintyre et al, 2006). The most common site of strain is the musculo-tendinous junction of the adductor longus or gracillis (Morelli and Smith, 2001). Morelli and Weaver (2005) stated that 62% of groin injuries were identified as adductor strains, but also highlighted the importance of the exclusion of other pathologies, as symptoms may arise from a number of structures in and around the area. The primary function of the adductors is stabilisation of the lower extremity and pelvis in the closed kinetic chain, adduction of the thigh in the open kinetic chain and assisting in femoral flexion and rotation (Nicholas and Tyler, 2002). The adductors are active throughout the running gait cycle (Nicola and Jewison, 2012) and are therefore vulnerable to fatigue. This can result in injury due to poor muscle endurance. Holmich (2007) stated that muscle fatigue had been postulated to increase the risk of adductor strain. Abnormalities or mal-alignment of the foot or lower leg, muscular imbalances, leg length discrepancy, gait or sport-specific motion abnormalities can all theoretically place abnormal loads on the adductors due to poor attenuation of force by the muscles below the groin (Holmich, 2007). The entire kinetic lower limb chain can therefore be associated with chronic groin pain.

Morelli and Weaver (2005) and Maffey and Emery (2007) proposed that the biomechanics of the lower limb were particularly important and may be causative factors of chronic groin pain. During the landing phase of activities such as running the foot can absorb up to three times body weight (Dicharry, 2010; Mann, 1982). The foot must therefore act as a shock absorber during landing activities (Nicola and Jewison, 2012). The higher the rate of impact-force application on the lower limb muscles, the more strain is placed on the lower limb muscles and joints. High stress application during a short period, such as the landing phase of a jump, produces a high rate of loading. This can place considerable strain on hip muscles such as the adductors (Abbasi, Tabrizi, Sarvestani and Bagheri, 2011). The ability to eccentrically control and adequately absorb high impact forces during dynamic, functional activity by slowing the rate of loading is key to the prevention of injury. Maffey and Emery (2007) suggest that a large percentage of groin pain may actually be due to an inability to properly transfer force from the initial point of impact at the ankle, through the knees, torso and to the pelvis. The distal segments of the leg (foot and ankle) are therefore important in reducing risk of groin injuries.

To our knowledge, no biomechanical studies have been conducted exploring the kinematics of the lower limb in individuals with chronic groin pain. As such, there is a poor understanding of the association between groin pain and lower limb kinematics. Increased knowledge could optimise clinical examination and treatment which is why the need for research in this field is highlighted. The specific objectives of this study are to explore the kinematics of the ankle with regards to the angle at foot contact, total range of motion from foot contact to lowest vertical position, time to lowest vertical position, as well as vertical ground reaction force (VGRF) during a single leg drop landing in active sports participants with chronic groin pain compared with healthy controls.

This thesis is presented according to the faculty's guidelines for the publication format. *Chapter 2* presents the most relevant information found in the literature, *Chapter 3* presents the manuscript and *Chapter 4* summarises the findings of this study.

CHAPTER 2

2. Literature Review

The aim of the literature review is to explore the available information most relevant to the topic objectives. The following databases were accessed: Google Scholar, PubMed, Biomed Central, British Medical Journal, Cinhal, Gale, Ovid and ProQuest. Keywords used contained combinations of the following: Chronic Groin Pain, Ankle, Kinematics, Biomechanics, Drop Landing and Ground Reaction Force.

2.1 Prevalence

Groin pain has the potential to prematurely end a career in professional sports (Morelli and Weaver, 2005) and is among the six most cited sports injuries in soccer and ice hockey (Maffery and Emery, 2007). The prevalence of groin pain varies in scientific literature from 5 - 18% (Syme, Wilson, Mackenzie and Macleod 1999; Gilmore, 1988; Delahunt, Kennelly, McEntee, Coughlan and Green, 2011).

2.2 Injury Mechanisms

Groin injuries may either be the result of an acute traumatic event or due to a progressive repetitive strain. The most common mechanism of acute onset of groin pain is as a result of forced hip abduction which most often causes a soft tissue strain of the musculo-tendinous junction of the adductor longus or gracillis muscle (Morelle and Smith, 2001). The adductor brevis and magnus as well as the pectineus and obtorator externus are also commonly acutely injured during sporting activities (Macintyre et al, 2006). However, it is more common that athletes present with chronic groin pain.

The insidious development of groin pain is attributed to relative inability to absorb impact forces (Hargrave, Carcia, Gansneder and Shultz, 2003). Maffey and Emery (2007) concur with the idea of load transfer through the pelvis from the lower limbs as a mechanism of groin injury. Hargrave et al (2003) reports that landing can produce impact forces of between two and twelve times body weight. The ability to control and absorb high impact forces during landing is important in the prevention of groin injury. Sporting codes that involve repetitive landing places increased strain on groin structures that can lead to groin pain in the long term. Understanding the factors that influence the body's ability to absorb impact loads, particularly in the lower limbs, may help identify conditioning strategies to prevent groin injury.

2.3 Aetiology

The difficulty in defining groin pain is due to the coexistence of other injuries in the athlete with chronic groin pain. It is reported that between 27 - 90% of individuals who present with groin pain have more than one injury in the area of the groin (Lovell, 1995; Westlin, 1997; Holmich, 2007). According to Cross (2010), groin pain is restricted to pain in the area of the lower abdomen anteriorly, the inguinal region, the area of the adductor muscles and perineum and the upper thigh and hip. Groin pain may be the result of bony pathologies as in the case of Osteitis Pubis, pubic stress fractures and avulsion injuries; hyaline cartilage in the case of osteoarthritis of the hip joint and femoral acetabular impingement; fibro-cartilage in the case of acetabular labral tears; muscle injuries in the case of adductor muscle strains; and connective tissue in the case of sports hernia. Pain may also be referred to the groin as a result of a lumbar disc injury (Hackney, 2012; Cross, 2010).

2.4 Risk Factors Associated with Groin Pain

A number of extrinsic risk factors have been associated with the onset of groin pain. According to Macintyre et al (2006), these include exposure to athletic activities that require rapid change of direction, rapid acceleration and deceleration as well as kicking. Running surfaces such as track running is also a reported risk for groin injuries due to the repetitive impact (Caudill, Nyland, Smith, Yerasimides and Lach, 2008). Paluska (2005) and Maffey and Emery (2007) report other extrinsic risks such as incomplete rehabilitation, following poor technique and footwear.

The intrinsic risk factors associated with groin injury include leg length discrepancy and excessive foot pronation (Holmich, 2007). There are a number of muscle imbalances identified that have been associated with groin injury such as greater hip abductor to adductor strength ratio, core muscle weakness, hip flexor weakness, hip flexor and abductor weakness and increased adductor strength on the injured side (Morelli and Weaver, 2005; Maffey and Emery, 2007; Niemuth, Johnson, Myers and Thieman, 2005; Caudill et al, 2008). Fatigue of the hip musculature has also been reported as a risk for groin injury (Holmich, 2007). Additionally, prior groin injury is a significant risk for further injury; Tyler et al (2006) reported that between 32 - 44% of groin injuries are recurrent injuries.

2.5 The Ankle: Normal Anatomy and Biomechanics

The ankle joint is a mortise joint that allows movement mainly in the sagittal plane. Proximally, the joint is concave and is formed by the distal ends of the tibia and fibula. The convex surface of the talus forms the distal end of this synovial hinge joint. During the closed chain, the forward movement of the shank over the planted foot is controlled by eccentric muscle contraction of the plantarflexors. It is the ankle plantarflexors that are mainly responsible for force attenuation during landing tasks (Devita and Skelly, 1992).

The ankle joint is a joint with high demands. During locomotion it is required for the transmission of loads, maintenance of balance and the adaptation of the foot to the contours of the ground. During the running gait cycle, Dicharry (2010) and Mann (1982) suggest that the foot will absorb up to three times body weight when striking the ground. Hengeveld and Banks (2005) stated that forces on the foot and ankle joint may exceed five times body weight during locomotion and up to thirteen times body weight during running. The foot must therefore act as a shock absorber and a lever to propel the lower extremity forward while adjusting to uneven surfaces (Nicola and Jewison, 2012). It is therefore evident that considerable forces act on the foot and ankle. The inability to optimally absorb these forces may therefore be a predisposing factor for groin injury.

Ankle sprains are the most frequent injuries sustained by athletes and may account for approximately 20 - 40% of all athletic injuries (Dubin, Comeau, McClelland, Dubin and Ferrel, 2011). Up to 74% of individuals who suffer an acute lateral ankle sprain develop residual symptoms defined as chronic ankle instability (CAI) (Anandacoomarasamy and Barnsley, 2005). Athletes with disturbed neuromuscular control of the ankle may place greater demands on the rest of the kinetic chain. During a soft landing task the muscular system absorbs 19% more of the body's kinetic energy (Devita and Skelly, 1992). The ankle plantarflexors provide the major energy absorption, averaging 44% of the total muscular work done, followed by the knee at 34% and the hip extensors at 22% (Devita and Skelly, 1992). This highlights the importance of the contribution, and optimal functioning, of the ankle during landing tasks.

Foot and ankle biomechanics have been shown to affect the more proximally located knee joint. Dugan and Bhat (2005) determined that hyper supination/pronation of the fixated foot leads to rotation of the tibia at the knee joint during the stance phase of running. This tibial rotation continues to rotate the femur which in turn causes rotation at the hip joint. In a study investigating the effect of ankle injury on hip kinematics during a landing task, Brown, Padua, Marshall and Guskiewics (2011) reported that subjects with mechanical ankle instability (MAI) displayed different hip kinematics than the group with functional ankle instability (FAI). There is evidence that foot and ankle kinematics may influence the proximal groin segment.

2.6 The Hip/Groin: Normal Anatomy and Biomechanics

The hip is a ball and socket joint thereby making it a multidirectional joint. Due to the geometry of the hip joint, it permits rotational motion in all directions; therefore it is necessary for a large number of controlling muscles to provide adequate stability (Byrne, Mulhall and Baker, 2010). There are 22 muscles acting on the hip joint that provide stability and movement (Byrne et al, 2010). Of these, 6 are adductors of the hip, namely the adductor longus, adductor magnus and adductor brevis, gracillis, obturator externus and pectinius. The abductors and adductors of the hip provide co-contraction stability of the stance leg during single leg support (Nicola and Jewison, 2012), such as in a landing activity. According to Nicholas and Tyler (2002) and Tyler et al (2001), the primary function of the adductor muscle group is adduction of the hip in open chain motions and stabilisation of the pelvis and hip joint in closed chain motions, as well as assistance in femoral flexion and rotation.

The co-contraction of hip abductors and adductors during landing activities is critical for the stabilisation of the hip and pelvis. Optimal load transfer from the lower limbs through the pelvis is therefore dependant on good muscle balance in the musculature around the hip joint (Quinn, 2012; Nicola & Jewison, 2012; Tyler et al, 2010 and Maffey & Emery, 2007).

2.7 Summary

Groin injuries are common in athletes who participate in sports that require rapid changes in direction and acceleration, as well as kicking (Macintyre et al, 2006). A primary mechanism of atraumatic groin injury is repetitive loading during these kinds of activities. It is postulated that the groin plays an important role in transferring load from the lower limbs through the pelvis during sporting activities that require force attenuation following landing and running. The ankle plays an important role in the absorption of force during landing tasks. It has been established that reduced ankle function after an injury results in increased dependence on the hip for lower limb stability (Brown et al, 2011). In order to determine if there is altered ankle function, one would need to establish the normal variation of ankle biomechanics during a landing task. There is no known exploration of normal ankle biomechanics during a landing task in participants with groin injuries; hence the importance of this study is established. Due to force being a common trend through the literature, the importance of its addition to this study is shown.

CHAPTER 3

This manuscript will be submitted to The Journal of Physiotherapy in Sports. Author guidelines have been included as an Appendix.

ANKLE KINEMATICS AND GROUND REACTION FORCE DURING SINGLE LEG DROP LANDING IN SPORTS PARTICIPANTS WITH CHRONIC GROIN PAIN

Authors and Affiliations

Ms Lauren Sandra Harwin - Division of Physiotherapy, University of Stellenbosch, Cape Town, South Africa

Mr Dominic Fisher - Division of Physiotherapy, University of Stellenbosch, Cape Town, South Africa

Prof Quinette Louw - Division of Physiotherapy, University of Stellenbosch, Cape Town, South Africa

Corresponding Author Contact Details

Ms Lauren Harwin

lharwin88@gmail.com

072 2184 102 (Cellphone); 022 772 2969 (Fax)

14 Zeeland Street, Langebaan, 7357

Abstract

Objectives: To analyse kinematics of the ankle in sagittal plane as well as vertical ground reaction force during a single leg drop landing in sports participants with chronic groin pain compared to healthy controls.

Design: Cross sectional descriptive study.

Setting: The study was conducted at the FNB 3D Motion Analysis Laboratory, Stellenbosch University.

Participants: Twenty participants - 10 cases with chronic groin pain and 10 healthy controls. The 10 cases included participants with unilateral pain (n=7) and bilateral pain (n=3). The bilateral pain group was further divided into the most and less affected side for analysis.

Main Outcome Measures: Ankle angle in the sagittal plane at foot contact; total range of motion in the sagittal plane used throughout the single leg landing phase; ankle angle at lowest vertical position, defined as the moment in time at which the centre point of the pelvis reaches its lowest point; time to lowest vertical position and; VGRF during the single leg drop landing.

Results: The group with unilateral groin pain participants had a higher peak force compared to same side of the controls. The bilaterally injured groin pain groups demonstrated less peak force when compared to controls. The bilateral pain groups had less plantarflexion at foot contact (most affected $p=<0.001$; least affected $p=<0.001$) and total range of motion ($p=<0.05$) compared to the control group.

Conclusion: This is the first study to indicate alterations in ankle kinematics and ground reaction force and that these changes are more apparent in sports participants with bilateral groin pain. Less range of motion during the landing task, illustrated by the bilateral pain group, suggests less effective force absorption of the distal segments. This is supported by the decreased peak force during single leg drop landing in the bilateral groups. These findings suggest that force attenuation may have occurred high up the kinetic chain which may place more strain on the groin. Clinically rehabilitation of the athlete with chronic groin pain should include the distal segments of the lower limb. Further research should be conducted in larger groups.

Key Words Ankle, Kinematics, Ground Reaction Force, Groin Pain, Drop landing

3.1 Introduction

Groin injuries account for 10 - 18% of injuries in contact sports and symptoms have the potential to lead to career-ending chronic pain (Ekstrand and Gillquist, 1983; Nielsen and Yde, 1989; Renstrom and Peterson, 1980). According to Tyler (2001), groin pain can be defined as subjectively reported discomfort in the area arising from the illiopsoas to the mid adductor region and symptoms may arise from a number of structures in and around the area. These structures include the lumbar spine, sacroiliac joint, hip joint, neural structures and muscles. Groin pain is often multifactorial with the involvement of several anatomic structures (Macintyre et al, 2006).

Groin injuries typically occur in sports which require rapid changes in direction, acceleration and deceleration (Macintyre et al, 2006), as well as repetitive landing. These actions occur in sports such as soccer, hockey and rugby. The onset can be traumatic or atraumatic in nature. The most common site of strain is the musculo-tendinous junction of the adductor longus or gracillis (Morelli and Smith, 2001). Groin injury can therefore compromise the stabilising role of the adductors during closed kinetic chain movements such as landing from a jump (Nicholas and Tyler, 2002).

Morelli and Weaver (2005) and Maffey and Emery (2007) proposed that the biomechanics of the lower limb were particularly important and may be causative factors of chronic groin pain. Abnormalities or mal-alignment of the foot or lower leg, muscular imbalances, leg length discrepancy, gait or sport specific motion abnormalities can all theoretically place abnormal loads on the adductors due to poor attenuation of force by the muscles below the groin (Holmich, 2007). Landing is a common athletic activity that can produce impact forces of two to twelve times body weight and is often associated with lower extremity injury (Hargrave et al, 2003). Maffey and Emery (2007) suggest that a large percentage of groin pain may actually be due to an inability to properly transfer force from the initial point of impact at the ankle, through the knees and torso to the pelvis. When landing, force is transmitted from the distal segments (ankle and foot) in an upward direction to the knee, hip and pelvis (Morelli and Weaver, 2005). The ankle plantarflexors play a substantial role in the absorption of landing forces, providing the major energy absorption and averaging 44% of the total muscular work done (Devita and Skelly, 1992). Impairments of the distal segments will therefore accentuate the strain on the proximal segments to absorb force, contributing to injury or chronicity.

To our knowledge the above-mentioned factors have not been studied in individuals with chronic groin injuries, nor have there been any biomechanical studies conducted exploring the kinematics of the lower limb in individuals with chronic groin pain. Better understanding of the association between groin pain, lower limb kinematics and ground reaction force, could optimise clinical examination and treatment. Further research is therefore warranted.

The purpose of this study is to ascertain if there are differences in ankle kinematics and ground reaction force in sports participants with chronic groin pain compared to healthy controls.

3.2 Methodology

3.2.1 Ethical considerations

Ethics approval was obtained from the University of Stellenbosch Human Research Ethics Committee prior to the commencement of this study (reference number S12/10/208). This study was conducted according to accepted international standards and guidelines of The Declaration of Helsinki, the Guidelines of the South African National Health act No.61 2003, as well as the South African Medical Research Council Ethical Guidelines.

Informed consent was obtained in writing from the respective participants prior to examination and testing. Precautions were taken to minimise anticipated risks and participants were selected according to a strict inclusion and exclusion criteria. If subjects experienced any exacerbation of symptoms during data collection, first aid was provided and they were excluded from further participation. Additionally, if during the interview and physical examination, any red flags were identified, the participants were referred appropriately.

Participation in this study was voluntary and the participants were able to withdraw at any time.

3.2.2 Study design

This study is a cross-sectional, descriptive study.

3.2.3 Sample recruitment and eligibility criteria

Appropriate sports clubs with personal affiliation to the researchers in the Western Province were contacted by an informative letter to determine interest. Participants, who met the diagnostic criteria, as well as the inclusion and exclusion criteria, were educated about the aims and objectives of the research. Participants who were interested, and provided consent, were selected as cases. Matching controls that met the inclusion and exclusion criteria and gave consent were also recruited from these specific sports clubs.

The study population was chosen as a sample of convenience and included only male active sports participants residing in the Western Cape between the ages of 18 and 55 years of age.

The study sample consisted of 10 cases with longstanding (greater than three months) groin pain situated between symphysis pubis and medial knee and 10 healthy controls.

One of the main objective measurements used for identifying participants was the Adductor Squeeze Test. The Adductor Squeeze Test has an intra-class coefficient (ICC) of 0.92 for intra-rater reliability measured with a sphygmomanometer (Delahunt, Kennelly, McEntee, Coughlan and Green, 2011). The test includes a combination of palpation over the Adductor muscle belly and insertion as a pain provocative test (Holmich, 2007; Delahunt et al 2011). The test was performed at the first contact session as it has shown to elicit the greatest amount of adductor muscle activity in 45° of hip flexion and was recommended as the optimal test position for injury screening by Delahunt et al (2011).

Eligible cases were all at a sports participating level, between the ages of 18 and 55 and who complained of chronic groin pain of any intensity for at least the last 3 months. All cases were still physically participating in sport or a form of physical training. On testing, all cases had a positive Adductor Squeeze Test and reported a general good health.

Eligible controls were individuals who have not had longstanding groin pain in the last three months and are pain free in the lower quadrant at the time of the study. They were matched to the cases for age, gender and sport.

Participants (cases and controls) were excluded if they had any orthopaedic surgical procedure of the lower quadrant and lumbar spine within the last 12 months, positive findings on previous imaging for bony lesions, or suffered from any disease that has an influence on functional ability/movement, e.g. Ankylosing Spondylosis, Scheuermann's disease, Rheumatoid Arthritis, Muscular Dystrophy, Paget's disease. In addition, participants were asked to disclose any previous injury, but this was only explored subjectively (eg. Previous ankle sprains).

3.2.5 Instrumentation

This study was conducted at the FNB 3D motion analysis laboratory, University of Stellenbosch, Tygerberg Campus, Cape Town, South Africa.

According to Windolf, Gotzen and Morlock (2008), the Vicon Motion Analysis (Ltd) (Oxford, UK) system is a three-dimensional (3D) system which is used in a wide variety of ergonomics and human factor applications. For this study an eight camera T-10 Vicon (Ltd) (Oxford, UK) system with Nexus 1.8 software was used to capture trials. The T-10 is a motion capturing system with a unique combination of high speed accuracy and resolution. Three dimensional (3D) motion analysis technology has been widely used in gait studies and is regarded as the gold standard for the analysis of movement (McGinley, Baker, Wolfe and Morris, 2009).

The Vicon motion analysis system was used to analyse specific parameters identified in the objectives of this study.

3.2.6 Procedures

On entering the lab each participant was familiarised with the procedures of the lab prior to commencing any evaluations. The required anthropometric measurements were then taken and a physical examination performed to exclude other sources of pain. A standardised warm up consisting of six walking trials of approximately 20m each was completed by each participant prior to motion analysis. A total of 33 markers were required to be placed on each participant according to the Plug-in Gait model by an experienced laboratory physiotherapist with good marker placement reliability. All system calibration and preparation was done by the laboratory engineer prior to data capturing.

Each participant was then asked to complete a single leg drop landing action from a 20cm step. A single leg drop landing is most widely used when assessing the lower limb as demonstrated in studies by Brown et al (2007) and Marshall, McKee and Murphy (2008). The selection of a 20cm drop was based on a study conducted by Peng (2011) who demonstrated that a drop landing exceeding 40cm offered no mechanical advantage, as well as a study by Wang and Peng (2013) which demonstrated that the best biomechanical benefit could be found in a single leg drop landing off a height of 30cm and most comparable intensity to a double legged drop at 20-30cm. A height of 20cm was therefore chosen due to the most benefit identified through these studies. The starting leg was randomly determined using coin tossing; thereafter jumps were performed with alternate legs. To capture the data, all participants performed six single leg drop landing tasks onto a force plate (to determine foot contact). The platform was placed the distance of 60% of the participant's leg length away from the force plate.

Standard instructions were given to perform the single leg drop landing. The participants were asked to stand in the middle of the platform with their toes behind the painted line and their weight evenly distributed on both feet. Thereafter they were instructed to bend the hip and knee of the non testing leg up to 90 degrees, keeping their arms comfortably at their sides. They were then requested to jump with the stance leg onto the force plate. The jump command given was: “ready... lift... jump”. They were asked to land comfortably and maintain the position and balance on the landing foot for 5 seconds. If the participant fell upon landing then the drop landing was repeated. A fall was defined as: a touch to the force plate by any other body part other than the required foot.

This procedure was demonstrated by the researcher and the participants were given one practice jump on each leg. This was repeated 6 times on each leg. If at any time the participant experienced an increase in pain, the activity was discontinued and recorded appropriately.

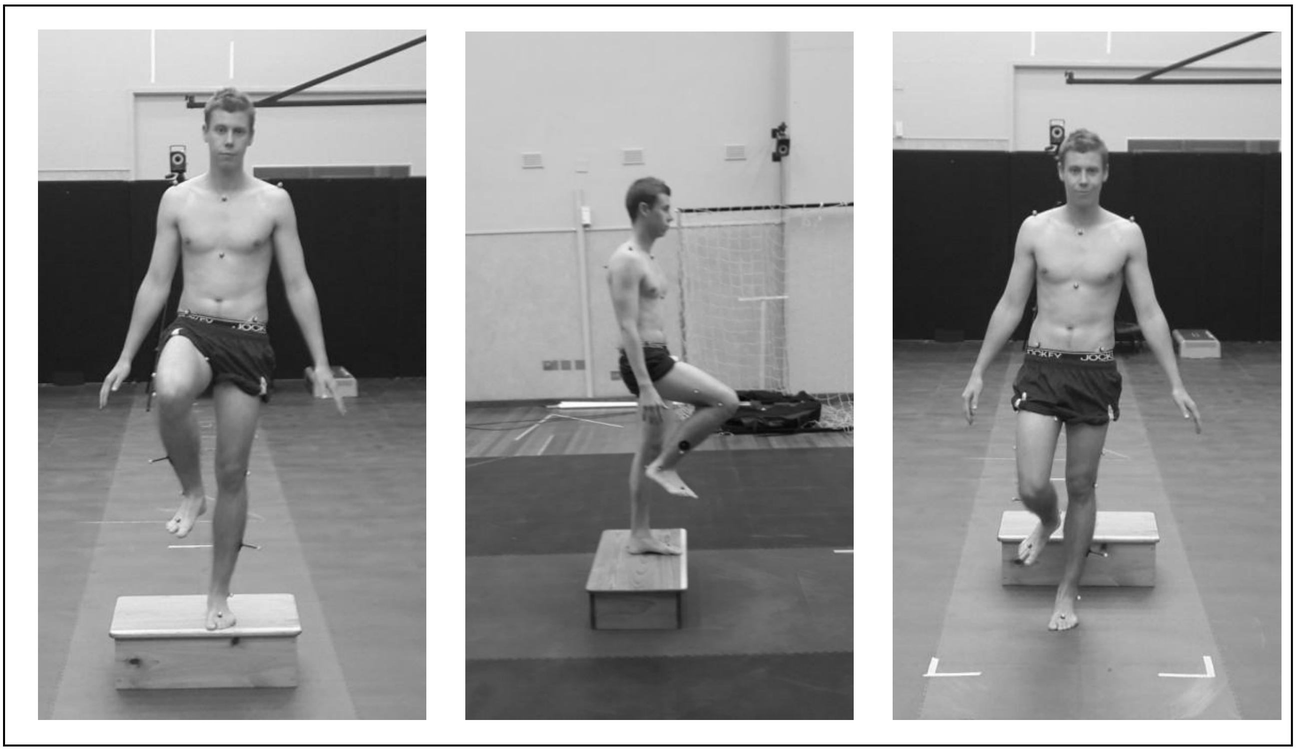

Figure 1: Vicon Marker Placement and Single Leg Drop Landing Demonstration

3.2.7 Data processing

Gap filling was performed using the standard Woltring filter supplied by Vicon. The events for foot contact and lowest vertical position of the pelvis were calculated automatically using Matlab. Segment and joint kinematics were calculated using the Plug-in-Gait model and filtered with a 4^{th} order Butterworth filter at a 10Hz cut-off frequency. Data was exported to Matlab to extract the parameters of interest.

3.2.8 Outcome variables

The parameters included in this study are ankle angles (talo crural) in the sagittal plane at foot contact, total ankle (talo crural) range of motion (ROM) in the sagittal plane from foot contact to point of lowest vertical position, ankle angles in the sagittal plane at point of lowest vertical position, time to point of lowest vertical position and VGRF (normalised to body mass).

For the purpose of this study, in the sagittal plane, all negative values pertain to plantarflexion and all positive values to dorsiflexion. Foot contact is defined as the moment in time of registration of 30 Newtons (N) of a force on the force plate. In terms of time to lowest vertical position, this is defined as the moment in time at which the centre point of the pelvis reaches its lowest point. The centre point was determined using the midpoint of the four pelvic markers.

3.2.4 Sample size

A post hoc sample size calculation was calculated using the G. Power (version 3.1) statistical power analysis program. Considering a large effect size of at least 1 (alpha 0.05) and sample size of 14 in the unilateral subgroup, the post hoc power was calculated to be 93%. For a medium effect size of at least 0.75 (alpha 0.05) and sample size of 14 in the unilateral subgroup, the post hoc power was calculated to be 73%.

Considering a large effect size of at least 1 (alpha 0.05) and sample size of 6 subjects in the bilateral subgroup, the post hoc power was calculated to be 50%. For a huge effect size of at least 1.45 (alpha 0.05) and sample size of 6 subjects in the bilateral subgroup, the post hoc power was calculated to be 80%.

3.2.9 Data analysis

The full data set was matched and divided into groups depending on whether they had unilateral or bilateral pain (Figure 2).

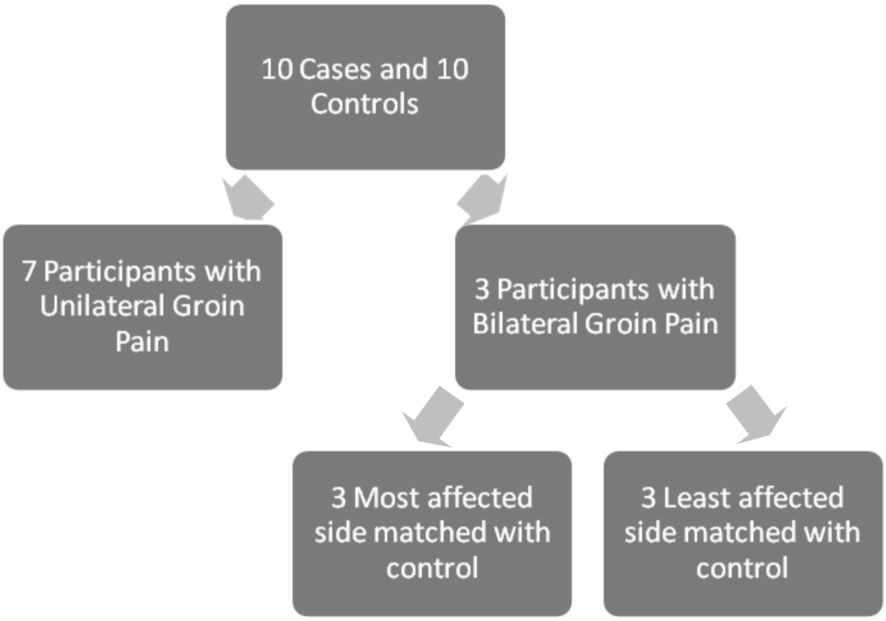

Figure 2: Organogram of sub-groups for analysis

Descriptive statistical data of demographics (mean and range) to indicate variability and kinematics (mean and standard deviations) were calculated to describe differences between cases and controls. To determine if there were significant differences, two tailed t-tests were conducted. The level for significance was set at p=<0.05. Cohens D effect sizes were calculated for all significant differences to determine the size of the effect. The interpretation of the effect sizes are indicated below in Table 1.

Table 1: Relative size of Cohen's D

Size of the Effect	Criterion values
Small effect	> = 0.15 and < 0.40
Medium effect	> = 0.40 and < 0.75
Large effect	> = 0.75 and < 1.10
Very large effect	> = 1.10 and < 1.45
Huge effect	> 1.45

3.3 Results

3.3.1 Sample description

Twenty participants (10 cases and 10 controls) participated in this study. Seven of the participants presented unilateral pain, while three participants presented bilateral pain. Ten participants played rugby, 4 were runners, 4 were soccer players and 2 were cyclists. All cases had a positive adductor squeeze test at 45 degrees of hip flexion. All cases and controls were matched for age, gender and sport. The basic sample demographics in terms of unilateral and bilateral pain groups are presented in Table 2.

In the unilateral pain group (n=7) there were no significant differences in age (p=0.96), weight (p=0.87) and height (p=0.19) when compared to matched controls. In the bilateral pain group (n=3) there were no significant differences in age (p=0.70), weight (p=0.49) and height (p=0.44) when compared to matched controls. The Visual Analogue Scale (VAS) score immediately post game/activity when comparing the unilateral and bilateral pain groups was not significant. In terms of duration of injury, it is evident that those individuals suffering from bilateral groin pain have a much longer duration than that of the unilateral pain group. Both the VAS and the duration are also presented in Table 2.

Table 2: Demographics of the Study Sample

	Age (yrs) Mean (SD)	Weight (kg) Mean (SD)	Height (m) Mean (SD)	VAS (/10) Mean (SD)	Duration (yrs) Mean (SD)
Unilateral Groin Pain Participants and Matching Controls (n=14)					
Cases	29 ± 10.26	86.8 ± 21.67	1.80 ± 0.07	6.29 ± 1.11	1.64 ± 1.99
Controls	28.71 ± 11.79	85.71 ± 17.02	1.77 ± 0.09	-	-
Bilateral Groin Pain Participants and Matching Controls (n=6)					
Cases	28.67 ± 9.61	91.83 ± 15.26	1.81 ± 0.09	6* ± 3	3.34 ± 2.52
Controls	26.34 ± 5.69	81.57 ± 6.38	1.77 ± 0.08	-	-

(*most affected side)

3.3.2 Kinematic differences between cases and controls

3.3.2.1 Kinematic differences of unilateral groin pain participants compared to matching side of controls

There were no statistically significant differences in the sagittal plane between unilateral groin pain cases compared to controls (Table 3). This finding is supported by the mean curve graph illustrated below (Figure 3).

Table 3: Unilateral Groin Pain Participants Compared to Matching Controls (n=14)

	Angle at FC Mean (SD)	Total ROM From FC to LVP Mean (SD)	Angle at LVP Mean (SD)
Sagittal Plane			
Cases	-13.6° ± 8.15°	35.46° ± 12.49°	21.71° ± 8.96°
Controls	-10.93° ± 9.98°	36.6° ± 10.58°	21.61° ± 10.7°
p-Value	0.49	0.89	0.56

Positive values = Dorsiflexion, Negative values = Plantarflexion; FC - Foot Contact; LVP - Lowest Vertical Point; SD - Standard Deviation

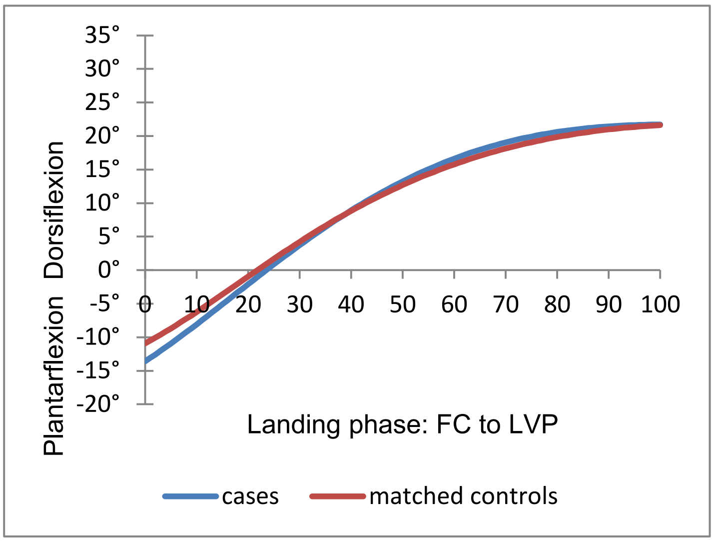

Figure 3: Landing phase of unilateral groin pain participants compared to matching side of controls

3.3.2.2 Kinematic differences of bilateral pain participants: Most affected side compared to matching side of controls

There were statistically significant differences noted between the control group and the most painful side of the bilaterally injured group in the sagittal plane for two of the parameters.

It was noted that the cases landed with less plantarflexion than the matched controls and when comparing the total range of motion in the sagittal plane, cases total ROM was less overall when compared to controls (Table 4).

These findings are supported by the mean curve graph illustrated below (Figure 4).

Table 4: Bilateral Groin Pain Participants – Most Affected Side Compared to Matching Control (n=6)

	Angle at FC Mean (SD)	Total ROM From FC to LVP Mean (SD)	Angle at LVP Mean (SD)
Sagittal Plane			
Cases	-2.89° ± 10.88°	28.74 ± 12.72	25.66° ± 3.81°
Controls	-6.28° ± 12.25°	32.99 ± 12.51	26.61° ± 3.01°
p-Value	<0.001*	<0.001*	0.36
Effect sizes	0.36	0.41	N/A

Positive values = Dorsiflexion, Negative values = Plantarflexion; * Indicates P<0.05 (significant difference); FC - Foot Contact;

LVP - Lowest Vertical Point; SD - Standard Deviation

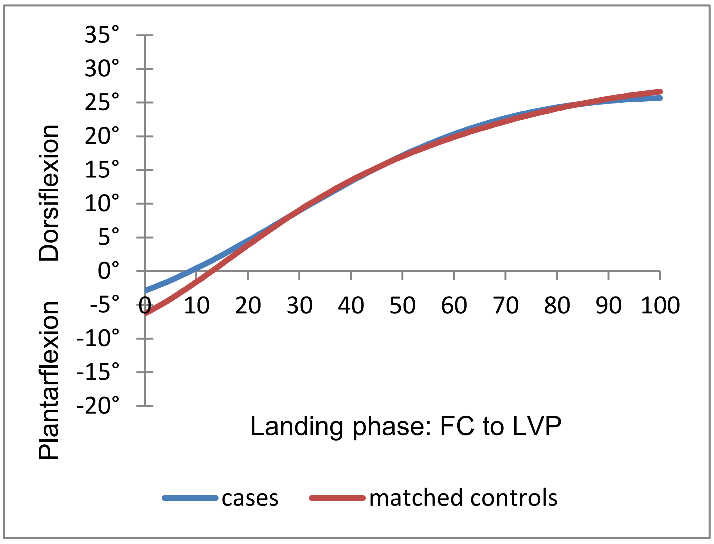

Figure 4: Landing phase of bilateral groin pain participants most affected side compared to matching side of controls

3.3.2.3 Kinematic differences of bilateral pain participants: Less affected side compared to matching side of controls

There were statistically significant differences noted between the control group and the less painful side of the bilaterally injured group in the sagittal plane for all parameters. At foot contact the painful group landed with less plantarflexion than controls and less total ROM in the sagittal plane was seen in cases when compared to controls (Table 5). When comparing the angle at lowest vertical position in the sagittal plane, the cases' lowest point was calculated to be at a lower angle than that of the controls (Table 5).

These findings are supported by the mean curve graph illustrated below (Figure 5).

Table 5: Bilateral Groin Pain Participants – Less Affected Side Compared to Matching Control (n=6)

	Angle at FC Mean (SD)	Total ROM From FC to LVP Mean (SD)	Angle at LVP Mean (SD)
Sagittal Plane			
Cases	-6.64° ± 6.82°	34.64° ± 8.53°	27.89° ± 4.11°
Controls	-14.59° ± 4.21°	39.60° ± 3.56°	24.95° ± 3.58°
p-Value	< 0.001*	0.02*	0.03*
Effect sizes	1.72	0.93	0.93

Positive values = Dorsiflexion, Negative values = Plantarflexion; * Indicates p<0.05 (significant difference); FC - Foot Contact;

LVP - Lowest Vertical Point; SD - Standard Deviation

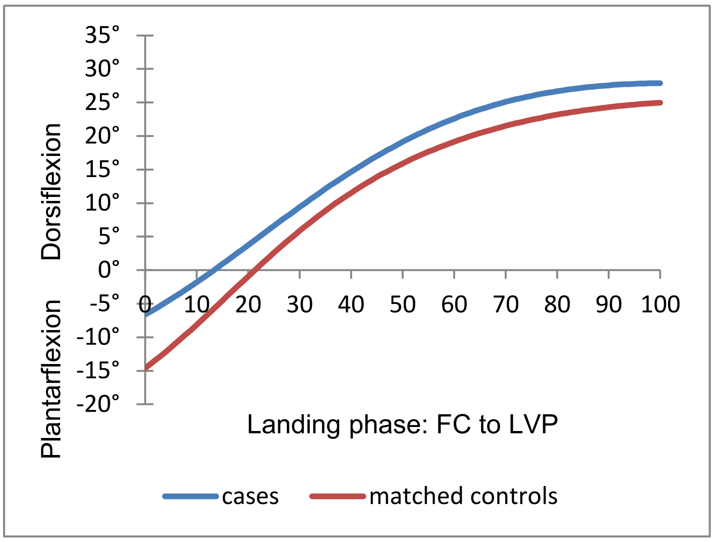

Figure 5: Landing phase of bilateral groin pain participants less affected side compared to matching side of controls

3.3.3 Time to lowest vertical position

When assessing time to lowest vertical position in unilateral as well as bilaterally injured participants (most and less painful side), no statistical significances were found (Table 6). Although it is important to note that in the bilaterally affected participants, a shorter time was used to reach lowest vertical position when compared to controls.

Table 6: Time to Lowest Vertical Position

	Unilateral	Bilateral Most Affected	Bilateral Less Affected
Time (s)			
Cases	0.17 ± 0.06	0.16 ± 0.02	0.16 ± 0.03
Controls	0.15 ± 0.03	0.19 ± 0.06	0.19 ± 0.06
p-Value	0.08	0.12	0.13

3.3.4 Vertical ground reaction force (VGRF) differences between cases and controls

3.3.4.1 VGRF differences of unilateral pain participants compared to matching side of controls

The unilateral groin pain participants demonstrated a higher peak force ($p=0.04$) compared to the matching side of their controls (see Figure 6).

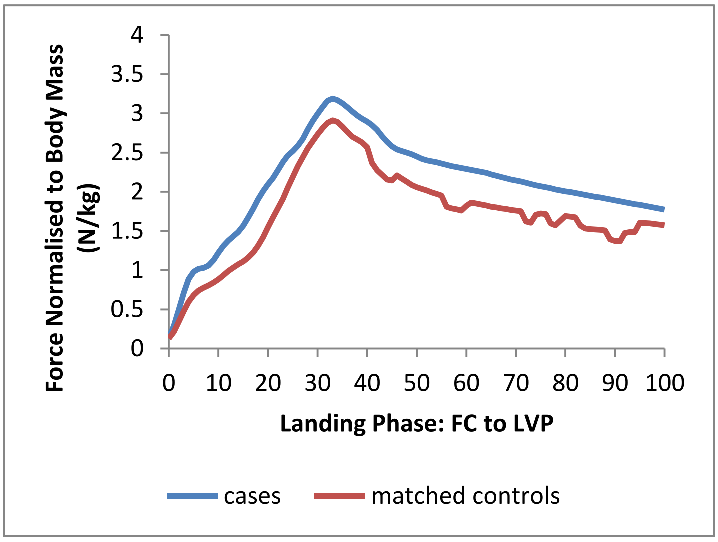

Figure 6: VGRF differences of unilateral pain participants compared to matching side of controls

3.3.4.2 VGRF differences of bilateral pain participants: Most affected side compared to matching side of controls

When comparing the peak force of the bilateral groin pain participants most affected side to the matching side of their controls ($p<0.001$), the groin pain subjects had a lower peak force (see Figure 7).

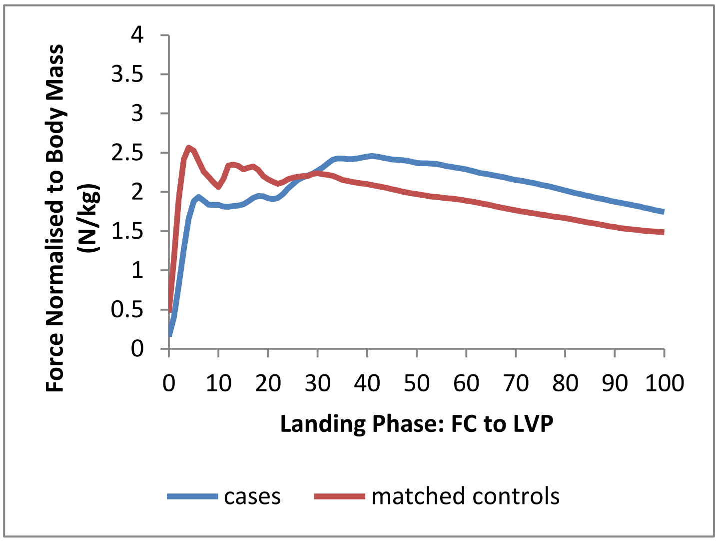

Figure 7: VGRF differences of bilateral pain participants most affected side compared to matching side of controls

3.3.4.3 VGRF differences of bilateral pain participants: Less affected side compared to matching side of controls

When comparing the peak force of the bilateral groin pain participants least affected side to the matching side of their controls there was a significant difference identified with a p-value of 0.03 (see Figure 8). The groin pain subjects had a lower peak force.

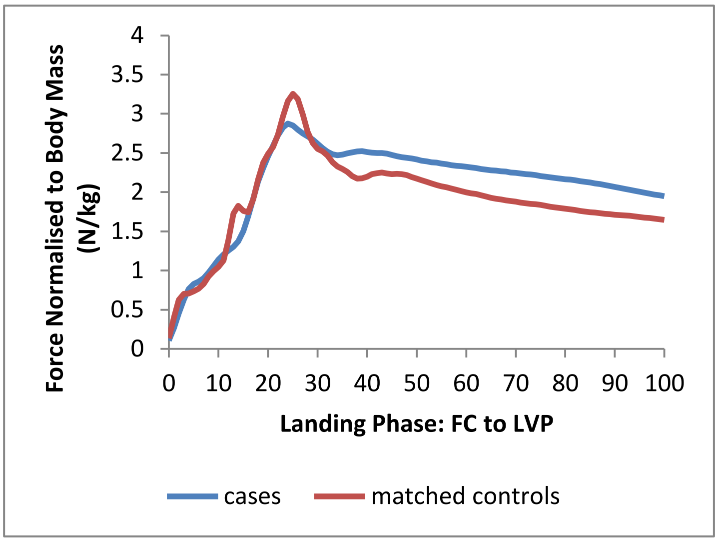

Figure 8: VGRF differences of bilateral pain participants less affected side compared to matching side of controls

3.4 Discussion

The purpose of this study was to examine the kinematics of the ankle in the sagittal plane, as well as VGRF during a single leg drop landing in chronic groin pain participants compared to controls.

The most significant findings of this study were seen in the bilateral pain groups. These findings were more significant than those found in the unilateral groin pain group compared to the matching side of their controls. This may be due to the fact that there are more predisposing or compensatory movement patterns in the bilateral groups and as a result both lower limbs are affected.

The findings illustrate decreased total range of motion during the landing action in the bilateral group. It is possible to say that the ankle is already far down the kinetic chain and therefore compensatory mechanisms for groin pain may have already occurred further up the chain, hence no significance is seen in the results shown for ankle kinematics in the unilateral pain group. This may imply that there may be reduced shock attenuation by the distal segments. As indicated by Hargrave et al (2003), the insidious development of groin pain is attributed to the relative inability to absorb impact forces. Maffey and Emery (2007) concur with the idea of load transfer through the pelvis from the lower limbs as a mechanism of groin injury. Therefore more strain is placed on the proximal segments which may play a role in reoccurrence or the chronicity of groin pain. The clinical implication is that the biomechanical analyses of the distal segments are important to identify biomechanical factors to be addressed in rehabilitation.

A decreased range of plantarflexion at foot contact was also found in the bilateral groups. During the closed chain, the forward movement of the shank over the planted foot, during an activity such as landing, is controlled by eccentric muscle contraction of the plantarflexors. It is the ankle plantarflexors that are mainly responsible for force attenuation during landing tasks, contributing 44% of the total muscular work done during a landing task (Devita and Skelly, 1992). Less range used means lowered force attenuation by the first line structures involved in a landing task, as well as adopting a more dorsiflexed position and thereby maintaining a closed pack position creating more stability and less movement (Pope, Chinn, Mullineaux, McKoen, Drewes and Hertel, 2011). It is a common high risk landing strategy in knee injuries and therefore retraining landing technique may also be required. It is suggested that increased plantarflexion at FC (increased ROM) is recommended to enhance force attenuation by the ankle and foot. This is due to the fact that landing styles play a large role in impact absorption during landing, yet landing style is an aspect of skilled performance that is unconstrained and not often taught as a motor skill (Hargrave et al, 2003). Due to large standard deviations in this study it is evident that participants may have used a variety of landing strategies. In addition, Brown et al (2011) reported that subjects with MAI displayed different hip kinematics than the group with FAI while investigating the effects of ankle injury on hip kinematics during a landing task, hence providing evidence that foot and ankle kinematics may influence the proximal groin segment. In another study by Marshall et al (2008) it was found that proximal system adaptations are associated with FAI. Also found to be associated is a decreased latency and altered recruitment pattern of hip muscle activation after ankle inversion as an adaptive strategy to reduce the load on the ankle as found by Beckman and Buchanan (1995). This premature muscle activation can lead to many consequences such as degeneration, altered joint reaction and muscle imbalances.

In terms of effect size of all of the above information, no significance in the unilateral group meant effect size could not be calculated. In the bilateral most affected group effect sizes were small to medium and therefore do not hold as much clinical significance as the bilateral less affected group with effect sizes of large to huge. Therefore a greater clinical significance is seen in the bilateral less affected group when compared to the bilateral most affected group results.

Differences were found in VGRF measured between the unilateral and bilateral groin pain groups. The unilateral groin pain group displayed a larger peak force than their matched controls, whereas the bilateral groin pain groups (most and less affected) displayed less peak force than their matched controls. This indicates different strategies between unilateral and bilateral groin pain groups. In the unilateral pain group, the ankle kinematics was the same as the controls. This may imply that the unilateral pain group are at risk of further deterioration as they have also not developed compensatory strategies to improve force attenuation by the proximal segments (evident by the high peak forces compared to controls). The bilateral group may also be at risk of chronic problems at the hip or knee - they had reduced force absorption of the distal segments (evident by reduced ankle range) but managed to land softly (reduced peak force compared to controls). This may imply that increased strain was placed on the hip and knee to absorb the forces during the landing phase and according to Nicholas and Tyler (2002) and Tyler et al (2001), the primary function of the adductor muscle group is adduction of the hip in open chain motions and stabilisation of the pelvis and hip joint in closed chain motions, such as when landing, thereby increasing strain on these areas.

Clinically this implies that rehabilitation after chronic groin pain should never just focus on the area of pain alone, but rather involve the full lower quadrant, with more focus on load transfer, emphasis on eccentric plantarflexor strength for absorption of impact forces, and stability throughout. Clinicians should be weary of compensatory/contributing mechanisms through the whole kinetic chain.

No further statistically significance was found in any of the other data (unilateral kinematics, time to lowest vertical position), although there are a few points worth mentioning. In the demographics it is evident that those participants suffering with bilateral pain have a longer average duration (3.34 years) when compared to unilateral pain participants (1.64 years) and a shorter time to lowest vertical position. A shorter time to lowest vertical position of the pelvis would indicate a faster landing phase and thereby affect load transfer/shock absorption. This calls for faster engagement of the appropriate musculature for stability - more specifically the groin musculature, which is used to stabilise the lower limb and pelvis during activity - and could result in an injury.

The study population was a good overall representation for age, gender and sporting codes. Groin injuries most commonly occur in sports such as soccer, rugby and hockey due to the fast changes in direction, rapid accelerations, decelerations and kicking these sporting codes require (Macintyre et al, 2006). These sports were represented in the majority of participants. It has also been demonstrated that more males suffer from groin injuries than females. This may be due to bias, as the high risk sports for groin injuries are practised by more males than females.

The limitations of this study were the small sample size, the inability to assess more than the sagittal plane movement effectively as well as being a cross sectional study, therefore cause and effect could not be determined. Due to the use of the plug in gait model pronation and supination was not analysed. Future research should make use of larger sample sizes to further support the findings in this study, as well as focus on a more detailed 3D foot analysis to attain information for pronation and supination for analysis. In addition functional ankle instability could be assessed prior to drop landing by making use of the Foot and Ankle Ability Measure (FAAM) Questionnaire or functional tests; EMG muscle activity could be assessed during drop landing, as well as further research on the effects of dominance during a single leg drop landing. Prospective study designs which will provide more insight into predictors or causation, is also warranted to improve understanding of this complex problem.

3.5 Conclusion

This is the first study to indicate alterations in ankle kinematics and ground reaction force and that these changes are more apparent in sports participants with bilateral pain. Less range of motion during the landing task illustrated by the bilateral pain group, suggests less effective force absorption of the distal segments. Furthermore this is supported by the decreased peak force in the bilateral groups when compared to controls. These findings suggest that force attenuation may have occurred high up the kinetic chain. This landing strategy requires increased force absorption in the more proximal segments of the kinetic chain. The increased burden of force absorption in the knee, hip and pelvis could potentially put these structures at increased risk of injury.

Clinically rehabilitation of the athlete with chronic groin pain should include the distal segments of the lower limb. Further research in this field is warranted using larger sample sizes to make more reliable conclusions about the role of the ankle in landing strategies of participants with chronic groin pain.

Ethical approval

Ethics approval was obtained from the University of Stellenbosch Human Research Ethics Committee prior to the commencement of this study (reference number S12/10/208).

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Conflict of interest

No conflict of interest exists in this study.

3.6 References

Abbasi, A., Tabrizi, H.B., Sarvestani, H.J., Bagheri, K. (2011). Ground Reaction Forces Attenuation in Supinated and Pronated Foot During Single Leg Drop-Landing. *Annals of Biological Research*. Vol 2 (6), 102 – 108.

Anandacoomarasamy, A., Barnsley, L. (2005). Long Term Outcomes of Inversion Ankle Injureis. *British Journal of Sports Medicine*. Vol 39: e14.

Beckman, S.M., Buchanan, T.S. (1995). Ankle Inversion Injury and Hypermobility: Effect on Hip and Ankle Muscle Electromyography Onset Latency. *Archives of Physical Medicine and Rehabilitation*. Vol 76 (12). 1138 – 1143.

Brown, C.N., Padua, D.A., Marshall, S.W., Guskiewics, K.M. (2011). Hip Kinematics During a Stop-Jump Task in Patients with Chronic Ankle Instability. *Journal of Athletic Training*. Vol 46 (5), 461 – 470.

Brukner, P.; Kahn, K. (2006). *Clinical Sports Medicine.* Third Edition. McGraw Hill Australia.

Bullock-Saxton, J.E. (1994). Local Sensation Changes and Altered Hip Muscle Function Following Severe Ankle Sprain. *Physical Therapy*. Vol 74 (1), 17 – 31.

Bullock-Saxton, J.E., Janda, V., Bullock, M.I. (1994). The Influence of Ankle Sprain Injury on Muscle Activation During Hip Extension. *International Journal of Sports Medicine*. Vol 15 (6), 330 – 334.

Byrne, D.P., Mulhall, K.J., Baker, J.F. (2010). Anatomy and biomechanics of the hip. *The open sports medicine journal*. Vol 4, 51 – 57.

Caudill, P., Nyland, J., Smith, C., Yerasimides, J., Lach, J. (2008). Sports Hernias: A Systematic Literature Review. *British Journal of Sports Medicine*. Vol 42, 954 – 64.

Delahunt, E., Kennelly, C., McEntee, B. L., Coughlan, G. F., & Green, B. S. (2011). The thigh adductor squeeze test: 45° of hip flexion as the optimal test position for eliciting adductor muscle activity and maximum pressure values. *Manual Therapy*. *16*(5), 476-480.

Devita, P., Skelly, W.A. (1992). Effect of Landing Stiffness on Joint Kinetics and Energetics in the Lower Extremity. *Medicine and Science in Sports and Exercise*. Vol 24 (1), 108 – 115.

Dicharry, J. (2010). Kinematics and Kinetics of Gait: From Lab to Clinic. *Clinical Sports Medicine.* Vol 29 (3), 347 – 64.

Dubin, J.C.; Comeau, D.; McClelland, R.I.; Dubin, R.A.; Ferrel, E. (2011). Lateral and Syndesmotic Ankle Sprain Injuries: A Narrative Literature Review. *Journal of Chiropractic Medicine*.
Vol. 10, 204 – 219.

Dugan, S., Bhat, K. (2005). Biomechanics and Analysis of Running Gait. *Physical Medicine Rehabilitation Clinical North America*. Vol 16 (3), 603 – 21.

Ekstrand, J., Gillquist, J. (1983). Soccer Injuries and their Mechanisims: A Prospective Study. *Medical Science Sports Exercise.* Vol 15 (3), 267 – 70.

Gilmore, J. (1998). Groin Pain in the Soccer Athlete: Fact, Fiction, and Treatment. *Clinical Sports Medicine*. Vol 17, 787 – 793.

Hackney, R. (2012). Groin pain. *Journal of Ortho and Trauma. 26(1), 25-32.*

Hargrave, M.D., Carcia, C.R., Gansneder, B.M., Shultz, S.J. (2003). Subtalar Pronation Does Not Influence Impact Forces or Rate of Landing During a Single-Leg Landing. *Journal of Athletic Training*. Vol 38 (1), 18 – 23.

Hass, C.J., Doidge, D., Wikstrom, E.A. (2010). Chronic Ankle Instability Alters Central Organization of Movement. *The American Journal of Sports Medicine*. Vol 38 (4), 828 – 834.

Hengeveld, E.; Banks, K. (2005). *Maitland's Peripheral Manipulation*. Fourth Edition. Elsevier Ltd.

Holmich, P. (2007). Long-standing groin pain in sports people falls into three primary patterns, a ‘‘clinical entity’’ approach: a prospective study of 207 patients. *Br J Sports Med.* Vol 41, 247–252.

Lovell, G. (1995). The Diagnosis of Chronic Groin Pain in Athletes: A Review of 189 Cases. *Australian Journal of Science and Medicine Sport*. Vol 27 (3), 76 – 9.

Macintyre, J., Johnson, C., Schroeder, M. (2006). Groin Pain in Athletes. *Current Sports Medicine Reports*. Vol 5, 293–299.

Maffey, L., Emery, C. (2007). What are the Risk Factors for Groin Injury in Sport? A Systematic Review of the Literature. Sports Medicine. Vol 37 (10). 881 – 894.

Mann, R.A. (1982). Biomechanics of Running. *American Academy of Orthopaedic Surgeons Symposium on the Foot and Leg in Running Sports.* St Louis. 1 -29.

Marshall, P.W.M., McKee, A.D., Murphy, B.A. (2008). Impaired Trunk and Ankle Stability in Subjects with Functional Ankle Instability. *Medicine and Science in Sports and Exercise*. 1549.

McGinley, J., Baker, R., Wolfe, R., Morris, M. (2009). The reliability of three dimensional kinematic gait measurements: a systematic review. *Journal of Gait Posture*. Vol 29, 360–9.

Morelli, V., Smith,V. (2001). Groin Injuries in Athletes. *American Family Physician*. Vol 64, 1405-14.

Morelli,V. & Weaver, V. (2005). Groin injuries and groin pain in athletes: Part 1. *Primary Care Clinics In Office Practice, Vol* 32, 163–183.

Nicholas, S.J., Tyelr, T.F. (2002). Adductor Muscle Strains in Sport. *Sports Medicine*. Vol 32, 339 – 344.

Nicola, T.L., & Jewison, D.J. (2012). The anatomy and biomechanics of running. *Clinical Sports Medicine.* Vol 31, 187 – 201.

Nielsen, A.B., Yde, J. (1989). Epidemiology and Traumatology of Injuries in Soccer. *American Journal of Sports Medicine.* Vol 17 (6), 803 – 7.

Niemuth, T.J., Johnson, P.E., Myers, R.J., Thieman, M.J. (2005). Hip Muscle Weakness and Overuse Injuries in Recreational Runners. *Clinical Journal of Sports Medicine*. Vol 15 (1), 14 – 21.

Paluska, S.A. (2005). An Overview of Hip Injuries in Running. *Sports medicine*. Vol 35 (11), 991 – 1014.

Peng, H.T. (2011). Changes in Biomechanical Properties During Drop Jumps of Incremental Height. Journal of Strength and Conditioning Research. Vol 25 (9), 2510 – 2518.

Pope, M., Chinn, L., Mullineaux, D., McKoen, P.O., Drewes, L., Hertel, J. (2011). Spatial Postural Control Alterations with Chronic Ankle Instability. *Gait and Posture*. Vol 34. 154 – 158.

Quinn, A. (2010). Hip and groin pain: physiotherapy and rehabilitation issues. *The open sports medicine journal*. Vol 4, 93 – 107.

Renstrom, P., Peterson, L. (1980). Groin Injuries in Athletes. *British Journal of Sports Medicine*.
Vol 14 (1), 30 – 6.

Syme, G., Wilson, J., Mackenzie, K., Macleod, D. (1999). Groin Pain in Athletes. *Lancet*. Vol 353, 1444.

Tyler T.F., Nicholas S.J., Campbell R.J. (2001). The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. *American Journal of Sports Medicine. Vol* 29(2), 124–8.

Wang, L.I., Peng, H.T. (2013). Biomechanical Comparisons of Single- and Double-Legged Drop Jumps with Changes in Drop Height. *International Journal of Sports Medicine*.

Westlin, N. (1997). Groin Pain in Athletes from Southern Sweden. *Sports Medicine and Arthroscopy Review*. Vol 5, 280 – 4.

Wikstrom, E.A., Naik, S., Lodha, N., Couraugh, J.H. (2010). Bilateral Balance Impairments After Lateral Ankle Trauma: A Systematic Review and Meta–analysis. *Gait and Posture*. Vol 31, 407 – 414.

Wikstrom, E.A., Tillman, M.D., Chmielewski, T.L., Cauraugh, J.H., Naugle, K.E. Borsa, P.A. (2010). Dynamic Postural Control but not Mechanical Stability Differs Among Those With and Without Chronic Ankle Instability. *Scandinavian Journal of Medical Science in Sports*. Vol 20 (1), 137 – 144.

Windolf a, W., Gotzen, N., Morlock, M. (2008). Systematic accuracy and precision analysis of video motion capturing systems—exemplified on the Vicon-460 system. *Journal of Biomechanics.*
Vol 41, 2776– 2780.

CHAPTER 4

4. Summary and Conclusion

4.1 Summary and Conclusion

The aim of this study was to ascertain if there are differences in ankle kinematics and ground reaction force in sports participants with chronic groin pain compared to healthy controls.

The findings of this study showed that the most significant findings were observed in the bilateral groin pain groups. These findings were more significant than those found in the unilateral groin pain group compared to the matching side of their controls. This may be due to the fact that there are more predisposing or compensatory movement patterns in the bilateral groups and as a result both lower limbs are affected.

The findings illustrated that decreased total range of motion of the ankle joint during the landing action was observed in the bilateral groups. It is possible to say that the ankle is already far down the kinetic chain and therefore compensatory mechanisms for groin pain may have already occurred further up the chain, hence no significance is seen in the results shown for ankle kinematics in the unilateral pain group. This may imply reduced shock attenuation by the distal segment and consequent strain on the more proximal segments in the bilateral groups as during a soft landing task (using more ROM) the muscular system absorbs 19% more of the body's kinetic energy (Devita and Skelly, 1992), thereby improving force attenuation with increased ROM.

A decreased range of plantarflexion at foot contact was also found in the bilateral groups. Less range used means lowered force attenuation by the first line structures involved in a landing task. The ankle plantarflexors provide the major energy absorption, averaging 44% of the total muscular work done (Devita and Skelly, 1992). This highlights the importance of the contribution, and optimal functioning, of the ankle during landing tasks. High risk landing strategy is common in knee injuries and therefore retraining landing technique may also be required. It is suggested that increased plantarflexion at FC (increased ROM) is recommended to enhance force attenuation by the ankle and foot.

In this study, subjects with bilateral groin pain (n=3) used less ankle movement in the sagittal plane during single leg landing and took a shorter time to lowest vertical position after landing. Furthermore, this group had less ankle plantarflexion at foot contact after landing than their matched controls. These movement strategies suggest that they were less effective at absorbing their body weight during the task. Interestingly less peak force was registered during the landing phase indicating a difference in landing strategy in the bilateral pain groups. Landing styles play a large role in impact absorption during landing, yet landing style is an aspect of skilled performance that is unconstrained and not often taught as a motor skill (Hargrave et al, 2003). Due to large standard deviations in this study it is evident that participants may have used a variety of landing strategies.

VGRF differed between the unilateral and bilateral groin pain groups. The unilateral groin pain group displayed a larger peak force than their matched controls, whereas the bilateral groin pain groups (most and less affected) displayed a lower peak force then their matched controls. This indicates different strategies between unilateral and bilateral groin pain groups. This may imply that the unilateral pain group are at risk of further deterioration as they have also not developed compensatory strategies to improve force attenuation by the proximal segments (evident by the high peak forces compared to controls). The bilateral group may also be at risk of chronic problems at the hip or knee, because they had reduced force absorption of the distal segments (evident by reduced ankle range), yet managed to land softly (reduced peak force compared to controls). This may imply that increased strain was placed on the hip and knee to absorb the forces during the landing phase. The co-contraction of hip abductors and adductors during landing activities is critical for the stabilisation of the hip and pelvis. Optimal load transfer from the lower limbs through the pelvis is therefore dependant on good muscle balance in the musculature around the hip joint (Quinn, 2012; Nicola & Jewison, 2012; Tyler et al, 2010 and Maffey & Emery, 2007). If this area is therefore compromised by injury, further strain may be placed on the specific areas responsible for force attenuation during a landing activity.

No further statistical significance was found in any of the other data (unilateral kinematics, time to lowest vertical position), although there are a few points worth mentioning. In the demographics it is evident that those participants suffering with bilateral pain have a longer average duration (3.34 years) when compared to unilateral pain participants (1.64 years) and a shorter time to lowest vertical position. A shorter time to lowest vertical position of the pelvis would indicate a faster landing phase and thereby affect load transfer/shock absorption. This calls for faster engagement of the appropriate musculature for stability - more specifically the groin musculature, which is used to stabilise the lower limb and pelvis during activity - and could result in an injury.

4.2 Limitations

The limitations of this study were as follows; Firstly the small sample size did not allow for larger subgroups in terms of unilateral and bilateral pain. Secondly, the inability to assess more than the sagittal plan movement due to the use of the plug in gait model resulted in pronation and supination not being analysed. Thirdly, dominance was not matched and functional ankle instability was not assessed in the methodology of this study and could therefore possibly affect the outcome of this study. And lastly, the study was a cross-sectional study; therefore the size of the cause and effect cannot be determined.

4.3 Recommendations

The clinical implication is therefore that biomechanical analysis of the distal segments is important to indentify biomechanical factors to be addressed in rehabilitation. Rehabilitation of the athlete with chronic groin pain should therefore include the entire lower quadrant and not only the area of injury. The rehabilitation program should include improving the athlete's ability to absorb forces during landing with a focus on eccentric plantarflexor strengthening for improved force attenuation.

Future research should make use of a larger sample size to further support the findings in this study. Furthermore, a multi-segment 3D foot model may provide greater insight into the triplanar mid-foot movement during landing tasks. In addition EMG muscle activity could be assessed, as well as further research on the effects of dominance during a single leg drop landing. Prospective study designs, which will provide more insight into predictors or causation, are also warranted to improve understanding of this complex problem.

References

Abbasi, A., Tabrizi, H.B., Sarvestani, H.J., Bagheri, K. (2011). Ground Reaction Forces Attenuation in Supinated and Pronated Foot During Single Leg Drop-Landing. *Annals of Biological Research*.
Vol 2 (6), 102 – 108.

Anandacoomarasamy, A., Barnsley, L. (2005). Long Term Outcomes of Inversion Ankle Injureis. *British Journal of Sports Medicine*. Vol 39: e14.

Brown, C.N., Padua, D.A., Marshall, S.W., Guskiewics, K.M. (2011). Hip Kinematics During a Stop-Jump Task in Patients with Chronic Ankle Instability. *Journal of Athletic Training*.
Vol 46 (5), 461 – 470.

Brukner, P.; Kahn, K. (2006). *Clinical Sports Medicine.* Third Edition. McGraw Hill Australia.

Bullock-Saxton, J.E. (1994). Local Sensation Changes and Altered Hip Muscle Function Following Severe Ankle Sprain. *Physical Therapy*. Vol 74 (1), 17 – 31.

Bullock-Saxton, J.E., Janda, V., Bullock, M.I. (1994). The Influence of Ankle Sprain Injury on Muscle Activation During Hip Extension. *International Journal of Sports Medicine*. Vol 15 (6), 330 – 334.

Byrne, D.P., Mulhall, K.J., Baker, J.F. (2010). Anatomy and biomechanics of the hip. *The open sports medicine journal*. Vol 4, 51 – 57.

Caudill, P., Nyland, J., Smith, C., Yerasimides, J., Lach, J. (2008). Sports Hernias: A Systematic Literature Review. *British Journal of Sports Medicine*. Vol 42, 954 – 64.

Delahunt, E., Kennelly, C., McEntee, B. L., Coughlan, G. F., & Green, B. S. (2011). The thigh adductor squeeze test: 45° of hip flexion as the optimal test position for eliciting adductor muscle activity and maximum pressure values. *Manual Therapy*. *16*(5), 476-480.

Devita, P., Skelly, W.A. (1992). Effect of Landing Stiffness on Joint Kinetics and Energetics in the Lower Extremity. *Medicine and Science in Sports and Exercise*. Vol 24 (1), 108 – 115.

Dicharry, J. (2010). Kinematics and Kinetics of Gait: From Lab to Clinic. *Clinical Sports Medicine.* Vol 29 (3), 347 – 64.

Dubin, J.C.; Comeau, D.; McClelland, R.I.; Dubin, R.A.; Ferrel, E. (2011). Lateral and Syndesmotic Ankle Sprain Injuries: A Narrative Literature Review. *Journal of Chiropractic Medicine*.
Vol. 10, 204 – 219.

Dugan, S., Bhat, K. (2005). Biomechanics and Analysis of Running Gait. *Physical Medicine Rehabilitation Clinical North America*. Vol 16 (3), 603 – 21.

Ekstrand, J., Gillquist, J. (1983). Soccer Injuries and their Mechanisims: A Prospective Study. *Medical Science Sports Exercise.* Vol 15 (3), 267 – 70.

Gilmore, J. (1998). Groin Pain in the Soccer Athlete: Fact, Fiction, and Treatment. *Clinical Sports Medicine*. Vol 17, 787 – 793.

Hackney, R. (2012). Groin pain. *Journal of Ortho and Trauma. 26(1), 25-32.*

Hargrave, M.D., Carcia, C.R., Gansneder, B.M., Shultz, S.J. (2003). Subtalar Pronation Does Not Influence Impact Forces or Rate of Landing During a Single-Leg Landing. *Journal of Athletic Training*. Vol 38 (1), 18 – 23.

Hass, C.J., Doidge, D., Wikstrom, E.A. (2010). Chronic Ankle Instability Alters Central Organization of Movement. *The American Journal of Sports Medicine*. Vol 38 (4), 828 – 834.

Hengeveld, E.; Banks, K. (2005). *Maitland's Peripheral Manipulation*. Fourth Edition. Elsevier Ltd.

Holmich, P. (2007). Long-standing groin pain in sports people falls into three primary patterns, a ''clinical entity'' approach: a prospective study of 207 patients. *Br J Sports Med.* Vol 41, 247–252.

Lovell, G. (1995). The Diagnosis of Chronic Groin Pain in Athletes: A Review of 189 Cases. *Australian Journal of Science and Medicine Sport*. Vol 27 (3), 76 – 9.

Macintyre, J., Johnson, C., Schoerder, M. (2006). Groin Pain in Athletes. *Current Sports Medicine Reports*. Vol 5, 293–299.

Mann, R.A. (1982). Biomechanics of Running. *American Academy of Orthopaedic Surgeons Symposium on the Foot and Leg in Running Sports.* St Louis. 1 -29.

McGinley, J., Baker, R., Wolfe, R., Morris, M. (2009). The reliability of three dimensional kinematic gait measurements: a systematic review. *Journal of Gait Posture*. Vol 29, 360–9.

Morelli, V., Smith,V. (2001). Groin Injuries in Athletes. *American Family Physician*. 64, 1405-14.

Morelli,V. & Weaver, V. (2005). Groin injuries and groin pain in athletes: Part 1. *Primary Care Clinics In Office Practice, Vol* 32, 163–183.

Nicholas, S.J., Tyelr, T.F. (2002). Adductor Muscle Strains in Sport. *Sports Medicine*. Vol 32, 339 – 344.

Nicola, T.L., & Jewison, D.J. (2012). The anatomy and biomechanics of running. *Clinical Sports Medicine.* Vol 31, 187 – 201.

Nielsen, A.B., Yde, J. (1989). Epidemiology and Traumatology of Injuries in Soccer. *American Journal of Sports Medicine.* Vol 17 (6), 803 – 7.

Niemuth, T.J., Johnson, P.E., Myers, R.J., Thieman, M.J. (2005). Hip Muscle Weakness and Overuse Injuries in Recreational Runners. *Clinical Journal of Sports Medicine*. Vol 15 (1), 14 – 21.

Paluska, S.A. (2005). An Overview of Hip Injuries in Running. *Sports medicine*. Vol 35 (11), 991 – 1014.

Quinn, A. (2010). Hip and groin pain: physiotherapy and rehabilitation issues. *The open sports medicine journal*. Vol 4, 93 – 107.

Renstrom, P., Peterson, L. (1980). Groin Injuries in Athletes. *British Journal of Sports Medicine*. Vol 14 (1), 30 – 6.

Syme, G., Wilson, J., Mackenzie, K., Macleod, D. (1999). Groin Pain in Athletes. *Lancet*. Vol 353, 1444.

Tyler T.F., Nicholas S.J., Campbell R.J. (2001). The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. *American Journal of Sports Medicine. Vol* 29(2), 124–8.

Westlin, N. (1997). Groin Pain in Athletes from Southern Sweden. *Sports Medicine and Arthroscopy Review*. Vol 5, 280 – 4.

Wikstrom, E.A., Naik, S., Lodha, N., Couraugh, J.H. (2010). Bilateral Balance Impairments After Lateral Ankle Trauma: A Systematic Review and Meta – Analysis. *Gait and Posture*. Vol 31, 407 – 414.

Wikstrom, E.A., Tillman, M.D., Chmielewski, T.L., Cauraugh, J.H., Naugle, K.E. Borsa, P.A. (2010). Dynamic Postural Control but not Mechanical Stability Differs Among Those With and Without Chronic Ankle Instability. *Scandinavian Journal of Medical Science in Sports*. Vol 20 (1), 137 – 144.

Windolf a, W., Gotzen, N., Morlock, M. (2008). Systematic accuracy and precision analysis of video motion capturing systems — exemplified on the Vicon-460 system. *Journal of Biomechanics.* Vol 41, 2776– 2780.

Appendices

Appendix 1 - Proposal Approval Letter

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

Approval Notice

New Application

03-Dec-2012

MORRIS, Tracy Louise

Ethics Reference #: S12/10/265

Title: Exploration of Biomechanics during functional Activities in Adult Sports participants with Chronic Groin Pain

Dear Ms Tracy MORRIS,

The **New Application** received on **22-Oct-2012**, was reviewed by Health Research Ethics Committee 1 via Committee Review procedures on **28-Nov-2012** and has been approved.

Please note the following information about your approved research protocol:

Protocol Approval Period: **28-Nov-2012 - 28-Nov-2013**

Present Committee Members:

Kinnear, Craig CJ

Seedat, Soraya S

Mukosi, M

Theunissen, Marie ME

Kearns, E

Meintjes, Jack WAJ

Mohammed, Nazli

Weber, Franklin CFS

Nel, Etienne EDLR

Sprenkels, Marie-Louise MHE

Rohland, Elvira EL

Theron, Gerhardus GB

Els, Petrus PJJS

Hendricks, Melany ML

Welzel, Tyson B

Barsdorf, Nicola

Please remember to use your **protocol number** (**S12/10/265**) on any documents or correspondence with the HREC concerning your research protocol.

Please note that the HREC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

After Ethical Review:

Please note a template of the progress report is obtainable on www.sun.ac.za/rds and should be submitted to the Committee before the year has expired.

The Committee will then consider the continuation of the project for a further year (if necessary). Annually a number of projects may be selected randomly for an external audit.

Translation of the consent document to the language applicable to the study participants should be submitted.

Federal Wide Assurance Number: 00001372

Institutional Review Board (IRB) Number: IRB0005239

The Health Research Ethics Committee complies with the SA National Health Act No.61 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 Part 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

Provincial and City of Cape Town Approval

Please note that for research at a primary or secondary healthcare facility permission must still be obtained from the relevant authorities (Western Cape Department of Health and/or City Health) to conduct the research as stated in the protocol. Contact persons are Ms Claudette Abrahams at Western Cape Department of Health (healthres@pgwc.gov.za Tel: +27 21 483 9907) and Dr Helene Visser at City Health (Helene.Visser@capetown.gov.za Tel: +27 21 400 3981). Research that will be conducted at any tertiary academic institution requires approval from the relevant hospital manager. Ethics approval is required BEFORE approval can be obtained from these health authorities.

We wish you the best as you conduct your research.

For standard HREC forms and documents please visit: www.sun.ac.za/rds

If you have any questions or need further assistance, please contact the HREC office at 0219389657.

Included Documents:

CV

Checklist

Application Form

Investigators' declaration

Protocol

Sincerely,

Franklin Weber

HREC Coordinator

Health Research Ethics Committee 1

Investigator Responsibilities

Protection of Human Research Participants

Some of the responsibilities investigators have when conducting research involving human participants are listed below:

1. Conducting the Research. You are responsible for making sure that the research is conducted according to the HREC approved research protocol. You are also responsible for the actions of all your co-investigators and research staff involved with this research.

2. Participant Enrolment. You may not recruit or enrol participants prior to the HREC approval date or after the expiration date of HREC approval. All recruitment materials for any form of media must be approved by the HREC prior to their use. If you need to recruit more participants than was noted in your HREC approval letter, you must submit an amendment requesting an increase in the number of participants.

3. Informed Consent. You are responsible for obtaining and documenting effective informed consent using **only** the HREC-approved consent documents, and for ensuring that no human participants are involved in research prior to obtaining their informed consent. Please give all participants copies of the signed informed consent documents. Keep the originals in your secured research files for at least fifteen (15) years.

4. Continuing Review. The HREC must review and approve all HREC-approved research protocols at intervals appropriate to the degree of risk but not less than once per year. There is **no grace period.** Prior to the date on which the HREC approval of the research expires, **it is your responsibility to submit the continuing review report in a timely fashion to ensure a lapse in HREC approval does not occur.** If HREC approval of your research lapses, you must stop new participant enrolment, and contact the HREC office immediately.

5. Amendments and Changes. If you wish to amend or change any aspect of your research (such as research design, interventions or procedures, number of participants, participant population, informed consent document, instruments, surveys or recruiting material), you must submit the amendment to the HREC for review using the current Amendment Form. You **may not initiate** any amendments or changes to your research without first obtaining written HREC review and approval. The **only exception** is when it is necessary to eliminate apparent immediate hazards to participants and the HREC should be immediately informed of this necessity.

6. Adverse or Unanticipated Events. Any serious adverse events, participant complaints, and all unanticipated problems that involve risks to participants or others, as well as any research related injuries, occurring at this institution or at other performance sites must be reported to the HREC within **five (5) days** of discovery of the incident. You must also report any instances of serious or continuing problems, or non-compliance

with the HRECs requirements for protecting human research participants. The only exception to this policy is that the death of a research participant must be reported in accordance with the Stellenbosch Universtiy Health Research Ethics Committee Standard Operating Procedures www.sun025.sun.ac.za/portal/page/portal/Health_Sciences/English/Centres%20and%20Institutions/Research_Development_Support/Ethics/Application_package All reportable events should be submitted to the HREC using the Serious Adverse Event Report Form.

7. Research Record Keeping. You must keep the following research related records, at a minimum, in a secure location for a minimum of fifteen years: the HREC approved research protocol and all amendments; all informed consent documents; recruiting materials; continuing review reports; adverse or unanticipated events; and all correspondence from the HREC

8. Reports to the MCC and Sponsor. When you submit the required annual report to the MCC or you submit required reports to your sponsor, you must provide a copy of that report to the HREC. You may submit the report at the time of continuing HREC review.

9. Provision of Emergency Medical Care. When a physician provides emergency medical care to a participant without prior HREC review and approval, to the extent permitted by law, such activities will not be recognised as research nor will the data obtained by

any such activities should it be used in support of research.

10. Final reports. When you have completed (no further participant enrolment, interactions, interventions or data analysis) or stopped work on your research, you must submit a Final Report to the HREC.

11. On-Site Evaluations, MCC Inspections, or Audits. If you are notified that your research will be reviewed or audited by the MCC, the sponsor, any other external agency or any internal group, you must inform the HREC immediately of the impending audit/evaluation.

Appendix 2 - Participant Information Leaflet and Consent Form

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM

TITLE OF THE RESEARCH PROJECT: Exploration of biomechanics during functional activities in adult sport participants with chronic groin pain

REFERENCE NUMBER: S12/10/265

PRINCIPAL INVESTIGATOR: Tracy Morris

ADDRESS: PO Box 12031 Hout Bay, 7806

CONTACT NUMBER: +27 83 682-0644

You are being invited to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the study staff any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how you could be involved. Also, your participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the Health Research Ethics Committee at Stellenbosch University **and will be conducted according to the ethical guidelines and principles of the**

international Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

What is this research study all about?

We are conducting this research to ascertain if movement differences exist between players who experience groin problems compared to those who do not. Data of this kind has not been collected before with regards to groin pain, thus it will increase our understanding of how the body moves when someone experiences groin pain. Collecting this data will provide a framework for future research to investigate possible causative factors of groin pain and possibly in the future aid in putting in place preventative measures.

The researchers will conduct a standardized assessment on each participant once informed consent is given. This will include an interview and basic hip examination at your club. A physical examination will be conducted during the second contact at Stellenbosch University's FNB 3D Movement Analysis Laboratory. Once the examination is completed we will analyze your movements using the Vicon system.

The Vicon motion analysis (Ltd) (Oxford, UK) system is a camera based, three-dimensional (3D) system which is used in a wide variety of ergonomics and human factor applications. The Vicon motion analysis system will be used to analyze specific parameters identified in the objectives of the study.

A total of 33 markers will be required and placed on various points on the participant's body. The participant will then be required to walk down a straight path while the markers record data of your movement. The participant will also be required to jump onto one leg from a set height while the markers once again record data of how you move.

Why have you been invited to participate?

You have been invited to participate in this research because you are an active sports participant who either suffers from groin pain currently or does not suffer from groin pain at all.

What will your responsibilities be?

Your responsibilities during this research will be to attend and allow the researchers to question you and conduct an examination on you which will involve measuring movement at various joints at the University of Stellenbosch motion analysis laboratory.

Once this is complete you will be required to perform self selected walking in the Vicon lab as well as a single leg drop landing where various measurements will be taken and recorded with regards to the way you move.

Will you benefit from taking part in this research?

You will not immediately benefit from taking part in the research. But by partaking in this research you will allow the researchers to objectively analyse movements in sports participants who suffer from groin pain and compare it to those who don't. By doing this we will be able to better understand groin pain and allow future research to investigate possible causative factors of the problem and put prevention measures in place.

Are there any risks involved in your taking part in this research?

There is minimal risk that you may experience your groin pain during the movement tasks, but this will be temporary. The university's indemnity insurance will apply if you should fall or injure yourself while visiting the movement laboratory.

If you do not agree to take part, what alternatives do you have?

You can consult your usual physiotherapist or medical practitioner.

Who will have access to your medical records?

The information gathered during the research will only be available to the researchers and the research supervisor.

What will happen in the unlikely event of some form of injury occurring as a direct result of your taking part in this research study?

The university's indemnity insurance will apply if you should fall or injure yourself while visiting the movement laboratory.

Will you be paid to take part in this study and are there any costs involved?

No, you will not be paid to take part in the study, but your transport and meal costs will be covered for each study visit. There will be no costs involved for you, if you do take part.

Is there anything else that you should know or do?

- **You can contact Tracy Morris at 0836820644 if you have any further queries or encounter any problems.**
- **You can contact the Health Research Ethics Committee at 021-938 9207 if you have any concerns or complaints that have not been adequately addressed by your study representative.**
- **You will receive a copy of this information and consent form for your own records.**

Declaration by participant

By signing below, I ……………………………..………… agree to take part in a research study entitled: *Exploration of biomechanics during functional activities in adult sport participants with chronic groin pain.*

I declare that:

- I have read or had read to me this information and consent form and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the study doctor or researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*) ....…........…………….. on (*date*) …………....………...

..	**...**
Signature of participant	Signature of witness

Declaration by investigator

I *(name)* ……………………………………………..……… declare that:

- I explained the information in this document to …………………………………..
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did/did not use an interpreter. (*If an interpreter is used then the interpreter must sign the declaration below.*

Signed at (*place*) ....…........……………….. on (*date*) …………....………..

....	....
Signature of investigator	Signature of witness

Declaration by interpreter

I *(name)* ………………………………………………..……… declare that:

- I assisted the investigator (*name*) ………………………………………. to explain the information in this document to (*name of participant*) ……………..……………………………….. using the language medium of Afrikaans/Xhosa.
- We encouraged him/her to ask questions and took adequate time to answer them.
- I conveyed a factually correct version of what was related to me.
- I am satisfied that the participant fully understands the content of this informed consent document and has had all his/her question satisfactorily answered.

Signed at (*place*)......................…........……………on (*date*)…………....………………..

....

Signature of interpreter Signature of witness

DEELNEMERINLIGTINGSBLAD EN -TOESTEMMINGSVORM

TITEL VAN DIE NAVORSINGSPROJEK: Ondersoek van die Biomeganika in volwasse sports persone met kroniese lies pyn tydens funksionele aktiwiteite.

VERWYSINGSNOMMER: S12/10/265

HOOFNAVORSER: Tracy Morris

ADRES: Privaat Posbus 12031 Houtbaai, 7806

KONTAKNOMMER: +27 83 682-0644

U word genooi om deel te neem aan 'n navorsingsprojek. Lees asseblief hierdie inligtingsblad op u tyd deur aangesien die detail van die navorsingsprojek daarin verduidelik word. Indien daar enige deel van die navorsingsprojek is wat u nie ten volle verstaan nie, is u welkom om die navorsingspersoneel daaroor uit te vra. Dit is baie belangrik dat u ten volle moet verstaan wat die navorsingsprojek behels en hoe u daarby betrokke kan wees. U deelname is ook **volkome vrywillig** en dit staan u vry om deelname te weier. U sal op geen wyse hoegenaamd negatief beïnvloed word indien u sou weier om deel te neem nie. U mag ook te enige tyd aan die navorsingsprojek onttrek, selfs al het u ingestem om deel te neem.

Hierdie navorsingsprojek is deur die **Gesondheidsnavorsingsetiekkomitee (GNEK) van die Universiteit Stellenbosch** goedgekeur en sal uitgevoer word volgens die etiese riglyne en beginsels van die Internasionale Verklaring van Helsinki en die Etiese Riglyne vir Navorsing van die Mediese Navorsingsraad (MNR).

Wat behels hierdie navorsingsprojek?

Hierdie studie word uitgevoer om in diepte ondersoek in te stel of daar wel biomeganiese verskille bestaan tussen sportspersone met lies pyn teenoor indivduele met geen lies pyn. Data van diè aard, spesifiek tot lies pyn was nog nie voorheen versamel nie, dus sal ons ons kennis verbreed in terme van liggaamlike beweging in reaksie tot lies pyn. Versameling van hierdie data sal 'n raamwerk bied vir toekomstige navorsing in moontlike faktore watkan bydrae tot lies pyn, met die hoop dat dit ook in die toekoms moontlike voorkomende faktore sal identifiseer

Die navorsers sal 'n gestandardiseerde evaluering uitvoer sodra toestemming vanaf die deelnemers bekom word. Dit sluit in 'n subjektiewe onderhoud asook 'n algemene ondersoek van die heup gewrig, wat by die verskeie klubs uitgevoer sal word. 'n Fisiese ondersoek sal by 'n tweede ontmoeting, by die FNB 3D-Bewegings Analiserings labatorium van Stellenbosch Universiteit, uitgevoer word. Sodra die fisiese ondersoek voltooi is sal u bewegings analise gedoen word, deur gebruik te maak van die Vicon sisteem.

Die *Vicon motion analysis (Ltd) (Oxford, UK) system* is 'n kamera georienteerd, drie-dimensionele (3D) sisteem wat toegepas word in 'n groot verskeidenheid ergonomika en menslike bewegingspatrone. The Vicon bewegings analise sisteem sal gebruik word om spesifieke parameters, wat in hierdie studie geïdentifiseer is, te meet.

Drie-en-dertig merkers sal gebruik word om op die verskeie punte op die individu se liggaam te plaas. Elke individu wat in die studie deelneem sal dan vereis word om op 'n reguit lyn te loop terwyl die merkers die data van u beweging vaslê. U sal ook vereis word om met een been van ‘n vooraf bepaalde hoogte aft e spring, terwyl die merkers weereens u beweging analiseer.

Waarom is u genooi om deel te neem?

U word uitgenooi om deel te neem in hierdie studie, aangesien u ‘n aktiewe sportspersoon is wat huidiglik lies pyn ervaar of glad nie lies pyn ervaar nie; en in die studie se insluitings en uitsluitings voldoen.

Wat sal u verantwoordelikhede wees?

U verantwoordelikhede tydens hierdie studie vereis bywoning van kontak sessies, asook toelating van evaluasie deur die navorser. Dit sluit die subjektiewe onderhoud in en ook fisiese meting van verskeie gewrigsbewegings, wat by die Bewegings analise labatorium van Stellenbosch Universiteit sal plaasvind.

Sodra dit voltooi is sal daar van u vereis word om te loop teen ‘n self geselekteerde spoed in die Vicon labatorium, asook een been val/spring aksie uit te voer terwyl die Vicon sisteem sodoende u bewegeings analiseer en dit op rekord te stel.

Sal u voordeel trek deur deel te neem aan hierdie navorsingsprojek?

U sal nie noodwendig onmiddelik self van hierdie studie baat nie, maar deur aan hierdie studie deel te neem laat u die navorsers toe om objektief die funksionele bewegings te aniliseer. En sodoende ‘n vergelyking te tref tussen die bewegingspatrone van sportspersone met lies pyn en die sonder lies pyn. Deur hierdie vergelyking laat dit toe vir toekomstige navorsing in faktore wat bydrae tot lies pyn en moontlike voorkomende riglyne in plek te stel.

Is daar enige risiko's verbonde aan u deelname aan hierdie navorsingsprojek?

Daar is wel 'n risiko dat u u lies pyn simptome tydens deelname aan hierdie aktiwiteite sal ervaar, maar dit is slegs tydelik. Die universiteit se vrywarings versekering sal wel in tree in die geval waar u sou val of u self beseer.

Watter alternatiewe is daar indien u nie instem om deel te neem nie?

U kan u huidige fisioterapeut of medies dokter raadpleeg.

Wie sal toegang hê tot u mediese rekords?

Die inligting bekom tydens die studie sal slegs tot die beskiking van die navorsers en hul toesighouer wees.

Wat sal gebeur in die onwaarskynlike geval van 'n besering wat mag voorkom as gevolg van u deelname aan hierdie navorsingsprojek?

Die universiteit se vrywarings versekering sal in tree in die geval waar u sou val of u self beseer met 'n besoek aan die bewegings labatorium.

Sal u betaal word vir deelname aan die navorsingsprojek en is daar enige koste verbonde aan deelname?

U sal nie betaal word vir deelname aan die navorsingsprojek nie, maar u vervoer en etes ten opsigte van elke besoek vir die navorsingsprojek sal betaal word. Deelname aan die navorsingsprojek sal u niks kos nie.

Is daar enigiets anders wat u moet weet of doen?

- **Vir verdere navrae of enige probleme kan u vir Tracy Morris kontak by 083 682 0644**
- **U kan die** Gesondheidsnavorsingsetiek administrasie **kontak by 021-938 9207 indien u enige bekommernis of klagte het wat nie bevredigend deur u studiedokter hanteer is nie.**
- **U sal 'n afskrif van hierdie inligtings- en toestemmingsvorm ontvang vir u eie rekords.**

Verklaring deur deelnemer

Met die ondertekening van hierdie dokument onderneem ek, ……..................…………...……...………., om deel te neem aan 'n navorsingsprojek getiteld: *Ondersoek van die Biomeganika in volwasse sports persone met kroniese lies pyn tydens funksionele aktiwiteite.*

Ek verklaar dat:

- Ek hierdie inligtings- en toestemmingsvorm gelees het of aan my laat voorlees het en dat dit in 'n taal geskryf is waarin ek vaardig en gemaklik mee is.
- Ek geleentheid gehad het om vrae te stel en dat al my vrae bevredigend beantwoord is.
- Ek verstaan dat deelname aan hierdie navorsingsprojek **vrywillig** is en dat daar geen druk op my geplaas is om deel te neem nie.
- Ek te eniger tyd aan die navorsingsprojek mag onttrek en dat ek nie op enige wyse daardeur benadeel sal word nie.
- Ek gevra mag word om van die navorsingsprojek te onttrek voordat dit afgehandel is indien die studiedokter of navorser van oordeel is dat dit in my beste belang is, of indien ek nie die ooreengekome navorsingsplan volg nie.

Geteken te *(plek*) ....…………….. op *(datum*) …………...………..

.. **..**

Handtekening van deelnemer Handtekening van getuie

Verklaring deur navorser

Ek *(naam)* …………………………………..………………… verklaar dat:

- Ek die inligting in hierdie dokument verduidelik het aan ……………………..………..
- Ek hom/haar aangemoedig het om vrae te vra en voldoende tyd gebruik het om dit te beantwoord.
- Ek tevrede is dat hy/sy al die aspekte van die navorsingsprojek soos hierbo bespreek, voldoende verstaan.
- Ek ’n tolk gebruik het/nie ’n tolk gebruik het nie. (*Indien ’n tolk gebruik is, moet die tolk die onderstaande verklaring teken.)*

Geteken te *(plek*) ....……………….. op *(datum*) …………...………...

....	....
Handtekening van navorder	Handtekening van getuie

Verklaring deur tolk

Ek *(naam)* ………………………………..………………. verklaar dat:

- Ek die navorser *(naam)* ……….............................…………………. bygestaan het om die inligting in hierdie dokument in Afrikaans/Xhosa aan *(naam van deelnemer)* ……………………………........................ te verduidelik.
- Ons hom/haar aangemoedig het om vrae te vra en voldoende tyd gebruik het om dit te beantwoord.
- Ek 'n feitelik korrekte weergawe oorgedra het van wat aan my vertel is.
- Ek tevrede is dat die deelnemer die inhoud van hierdie dokument ten volle verstaan en dat al sy/haar vrae bevredigend beantwoord is.

Geteken te *(plek)* ....……………….. op *(datum)* …………...………..

....	....
Handtekening van tolk	Handtekening van getuie

Appendix 3 - Subjective Assessment

Name:

Age:

Dominance:

Main problem:

Area of symptoms: Quality, intensity, depth, associated symptoms

Behaviour of symptoms: Agg/Easing/ 24 hours

History: present/past

Special questions

Appendix 4 - Physical Examination

Observation:

Functional demonstration/activity:

Squats

Lunges

Active physiological movements:

Passive physiological movements:

Hip	Left1	Left2	Left3	Mean	Right1	Right2	Right3	Mean
Extension								
Flexion								
Abduction								
Adduction								
Internal Rotation								
External Rotation								

Knee	Left 1	Left 2	Left 3	Mean	Right 1	Right 2	Right 3	Mean
Flexion								
Extension								
Ankle	Left 1	Left 2	Left 3	Mean	Right 1	Right 2	Right 3	Mean
Plantar flexion								
Dorsi flexion								
Eversion								
Inversion								

Special tests:

Leg Length

Lumbar (Active physiological movements, combined movements, if indicated)

Knee (Active physiological movements, combined movements, if indicated)

Ankle (Active physiological movements, combined movements, if indicated)

SIJ (4 battery of tests):

Fabers Test

Gaelen's Test

P4 Test

Posterior gapping

Hip Quadrant (if indicated)

Pain on coughing

Maitland's peripheral manipulation 4th Edition (2005)

Appendix 5 - VICON Marker Placement

Placement of the head markers:

- LFHD/RFHD - front approximately over temples
- LBHD/RBHD - in horizontal plane of front head markers

The markers over the temples define the origin and the scale of the head. The rear markers define the head's orientation.

Placement of the torso markers:

- Clavicle – supero-sternal notch
- Sternum – xiphoid process of sternum
- RBACK - place in the of the right scapula
- C7 – spinous process
- T10 – spinous process
- Placements of the arm markers:
- Left shoulder/Right shoulder – acromioclavicular joint
- Left elbow/R elbow– lateral epicondyle approximating elbow joint axis
- LWRA/RWRA – wrist bar, thumb side
- LWRB/RWRB – wrist bar, pinkie side

- Left finger/Right finger – dorsum of the hand just below the head of the second metacarpal

Placement of the pelvis markers:

- Left ASIS/Right ASIS – directly over the anterior superior iliac spines
- Left PSIS/Right PSIS – directly over the posterior superior iliac spines

Placement of knee markers:

- Left knee/Right knee– lateral epicondyle of the femur
- Left thigh/Right thigh - lower lateral 1/3 surface of the thigh, just below the swing of the hand
- Place the marker in a line from the greater trochanter and knee marker

Placements of the tibia markers:

- Left tibia/Right tibia – lower lateral 1/3 of the tibia to determine the alignment of the ankle flexion axis. The marker is placed in a line joining the knee and the ankle markers
- A wand mounted marker may be used

Placement of the ankle markers:

- Left ankle/Right ankle - lateral malleolus along an imaginary line that passes through the transmalleolar axis
- LMMAL/RMMAL – medial malleolus of the ankle (only used during the Oxford correction static subject calibration)
- The tibial marker should lie in the plane that contains the knee and ankle joint centres and the ankle flexion/extension axis.

Placement of the foot markers:

- LTOE/RTOE - second metatarsal head, on the mid-foot side of the equinus break between fore-foot and mid-foot
- LHEE/RHEE - Place on the calcaneus at the same height above the plantar surface of the foot as the toe marker

Appendix 6 – Journal Guidelines

PHYSIOTHERAPY IN SPORTS – JOURNAL GUIDELINES

TYPES OF PAPERS

Original Research: Provide a full length account of original research and will not normally exceed 4000 words.

Review Papers: Provide an in-depth and up to date critical review of a related topic and will not normally exceed 4000 words.

Case Studies: A case report providing clinical findings, management and outcome with reference to related literature.

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All authors should have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or anaylsis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

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