Investigation of hip kinematics in adult sports participants during single leg drop landing with chronic groin pain

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“DECLARATION

In a previous feedback I have already changed this paragraph to the correct format.

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ABSTRACT

Introduction

Groin injuries are among the top six most cited injuries in soccer and account for 10-18 per cent of all injuries reported in contact sport. Groin pain can result from a variety of pathologies, but according to literature, 63 per cent of groin pain is due to adductor pathology.

Objective

The objective of this study was to explore if there are kinematic differences in the hip joint in sports participants with groin pain compared to matched healthy controls.

Study design

A cross sectional, descriptive study was conducted.

Study setting

The study was conducted at the FNB -3D motion analysis laboratory at the University of Stellenbosch, South Africa.

Outcome variables

The dependent variables included hip kinematics in the sagittal, frontal and transverse planes at foot strike, lowest vertical point of the pelvis and total range of hip motion during a single leg drop landing.

Methodology

The study sample comprised 20 male club level soccer-and, rugby players, running and cycling participants between the ages of 18-55 years of age**.** Ten of the subjects had chronic groin pain and the other ten were healthy matched controls.

An eight-camera Vicon system was used to analyse the kinematics of the hip joint during single leg drop landing. For the purpose of comparison, the data was analysed for participants with unilateral groin pain and matched controls (n=14) and participants with bilateral groin pain and controls (n=6). The full set of data was subdivided for analysis into three distinct sub-groups. Unilaterally injured groin cases (n=7) were matched with seven healthy controls for analysis. Bilaterally injured groin cases (n=3) were matched with three healthy controls.

Results

Cases with unilateral groin pain at initial contact had significantly more abduction of the hip joint when compared to controls ($p<0.05$). The effect size of this difference was large (0.94). Cases with unilateral groin pain also demonstrated greater hip internal rotation while the controls had external rotation ($p<0.05$) during a drop landing activity. Bilaterally injured groin cases landed with significantly (p=?) greater ranges of hip flexion as well as in significantly (p=?) more hip abduction during a drop landing activity. They also demonstrated greater total range of motion in the frontal plan when compared to controls. Groin pain cases overall demonstrated greater ranges of motion and tended to land in more abduction compared to controls.

Conclusion

This study found that during a single leg drop landing, sports participants with unilateral chronic groin pain landed with significantly greater hip abduction and exhibited larger total range of motion in the transverse plane, which may indicate impaired stability of the hip complex when compared to controls.

OPSOMMING:

Inleiding

Liesbeserings is een van die top ses mees prominente sokker beserings. Dit beloop 10-18 persent van alle beserings wat in kontaksport aangemeld word. Liespyn kan die gevolg wees van ‘n verskeidenheid patologië , maar volgens die literatuur is 63 persent van liespyn as gevolg adduktor patologie.

Doelwitte

Die doelwit van hierdie studie was om ondersoek in te stel of daar enige kinematiese veranderinge in die heupgewrig is in spelers met liespyn in vergelyking met dieselfde vergelykbare spelers sonder liespyn.

Studie Ontwerp

‘n Deursnit, beskrywende studie was onderneem.

Studie Omgewing

Die studie was uitgevoer by die FNB-3D bewegingsanalise laboratorium van die Stellenbosch Universiteit, Suid-Afrika.

Uitkomsveranderlikes

Die afhanklike veranderlikes het in gesluit die heup kinematika in die sagitale, frontale en transvers vlakke met voet kontak endie laagste vertikale punt van die pelvis sowel as die totale heup omvang van beweging gedurende een been landing.

Metodologie:

Die studie populasie het bestaan uit 20 manlike sokker- en, rugbyspelers, hardlopers en fietsryers tussen die ouderdomme van 18 en 55 jaar. Tien van die deelnemers het kroniese liespyn gehad en die ander tien in die gelyke gesonde groep was sonder liespyn.

Die agt kamera Vicon sisteem was gebruik om die kinematika van die heupgewrig te analseer tydens een been landing. Vir die doel om 'n vergelyking te kan maak, was die data geanaliseer van deelnemers met unilaterale liespyn en die vergelykende groep sonder liespyn (n=14) en deelnemers met bilaterale liespyn en hulle vergelykende groep sonder liespyn (n=6).. Die volledige stel data was onderverdeel in drie afsonderlike sub groepe. Vir die analiese was unilaterale liesbeserings (n=7) vergelyk met sewe deelnemers sonder liespyn in die kontrolegroep. Deelnemers met bilaterale liesbeserings (n=3) was vergelyk met drie in die kontrolegroep.

Resultate

Die deelnemers met unilaterale liespyn het met eerste kontak beduidend meer abduksie van die heupgewrig gehad in vergelyking met die kontrolegroep ($p<0.05$). Die effek van hierdie verskil was groot (0.94). Die deelnemers met unilaterale liespyn het ook 'n grooter interne rotasie getoon, terwyl die kontrole groep meer eksterne rotasie gedemonstreer het ($p<0.05$) met landing. Deelnemers met bilaterale liespyn het beduidend (p=?) meer heup fleksie en abduksie omvang van beweging tydens landing. Hulle het ook 'n groter totale heup omvang van beweging in die frontale vlak gehad in vergelyking met die kontrolegroep. Deelnemers met liespyn het oor die algemeen 'n grooter omvang van beweging getoon, en was geneig om met meer abduksie van die heup te land as die kontrolegroep.

Gevolgtrekking

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Die studie toon dat deelnemers met kroniese unilaterale liespyn, tydens een been landing, beduidende meerheup abduksie toon en dat die heup in die transverse vlak meer totale omvang van beweging gebruik wat kan dui op onstabiliteit in die heupkompleks in vergelyking met die kontrolegroep.

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TABLE OF CONTENTS

Stellenbosch University http://scholar.sun.ac.za

Stellenbosch University http://scholar.sun.ac.za

LIST OF TABLES

Stellenbosch University http://scholar.sun.ac.za

LIST OF FIGURES

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LIST OF APPENDICES

CHAPTER 1
INTRODUCTION

Groin injuries are among the top six most cited injuries in the sports of ice hockey and soccer (Maffery & Emery, 2007). Groin injuries account for 10-18 per cent of injuries in contact sports, and symptoms have the potential to lead to career-ending chronic pain (Morelli & Weaver, 2005). In Morelli & Weaver's systematic review (2005) it was found that 62 per cent of groin-related pain was in fact due to adductor muscle pathology, which in turn was a result of repeated strains. According to the latter, initial injury of the adductor muscles greatly increased the chance of re-injury. The high incidence of adductor muscle pathology in groin injuries requires further investigation.

According to Cross (2010), groin pain in the athlete refers to discomfort noted around the area of the lower abdomen anteriorly, the inguinal regions, the area of the adductors and perineum and the upper anterior thigh and hip. Chronic groin pain can be as result of a wide variety of pathologies, including *Osteitis Pubis*, Sports Hernia, Snapping Hip Syndrome, Osteoarthritis of the hip joint, Acetabula Labral tears, Femoral-Acetabula impingement, muscular injuries, stress fractures and avulsion injuries.

Groin pain can also be discogenic from the lumbar spine or because of pelvic nerve entrapment (Hackney, 2012; Cross, 2010). Each condition has overlapping and unique symptoms and objective findings.

Currently there is much controversy in defining groin pain due to the difficulty of diagnosis, but also because 27-90 per cent of patients presenting with groin pain have more than one coexisting groin pathology (Morelli & Weaver, 2005; Maffey & Emery, 2007; Holmich, 2004). The coexistence of multiple pathologies can complicate the subjective and objective presentation of patients. In Morelli & Weaver's study (2005) it was found that 62 per cent of groin injuries were identified as adductor strains, which highlighted the importance of the exclusion of other pathologies, such as those listed above.

Zuzana *et al* (2009) proposed that musculoskeletal groin pain could result from acute traumatic mechanisms or a more chronic condition aggravated by sporting activity, resulting in repetitive strain type injuries. Hackney (2012) stated that forced abduction of the hip was the most common cause of adductor strain, occurring most frequently at the musculo-tendinous junction. However the majority of chronic groin pain cases, according

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to Morelli & Weaver (2005), were progressive over time indicating a more atraumatic aetiology, which may indicate that biomechanical factors could play a role in the development of groin pain.

Fast changes in direction place large biomechanical demands on the adductors. This may explain why groin pain may be more prevalent in sports such as soccer, hockey and rugby, as these sports often require quick changes in direction and large ranges of motion at the hip. Groin injuries can also occur during landing actions. Hackney (2012) and Tyler (2010) discussed the mechanism of injury particularly in single leg weight-bearing changes in direction or plyometric type actions such as single leg drop landing actions.

A large ball and socket joint that allows movement in three planes, the hip joint serves as a central pivot for the body. Pathology that affects the strength, control or flexibility of the hip musculature can disrupt the fluidity and metabolic functioning of the hip joint in normal movement (Neumann *et al*., 2010). When a specific muscle, capsule or ligament is weak, painful or tight this may affect the alignment throughout the entire lower limb, which may lead to impaired functioning of a specific joint as highlighted above (Neumann *et al*., 2010).

There are 22 muscles acting on the hip joint that provide stability and movement (Byrne *et al*., 2012). Of these, six are adductors of the hip. According to Tyler *et al* (2010) and Quinn (2012), the primary function of the adductor muscle group is adduction of the hip in open-chain motions, such as swing phase during walking and running, as well as stabilisation of the pelvis and hip joints in closed-chain motion such as stance phase. These muscles also play an important role in stabilisation during the landing phase of a jump, when they function in synchrony with the hip abductors.

Morelli & Weaver (2005) and Maffey & Emery (2007) proposed that the biomechanics of the lower limb were particularly important, and may be causative factors of chronic groin pain. It is proposed that poor shock attenuation of the foot and knee joints such as those in cases of hyper-pronation of the foot, or internal or external rotation of the knee joint, may place strain on the groin muscles due to marked displacement of the body's centre of mass during activities with a small base of support, such as single leg landing.

According to Morelli & Weaver (2005), important factors to be considered were abnormalities such as leg length discrepancy or over-pronation of the feet, which would result in internal rotation at the knee joint, placing strain on the adductor muscles as well as muscular imbalances at the hip joint.

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Tyler *et al* (2001) showed that the hip adductor/abductor strength ratio was significantly lower in an injured group of ice hockey players compared to controls, which correlates with findings by Crowe *et al* (2010). In this investigative study Tyler found that pre-season dynamometric hip adductor power was 18 per cent lower in players who later subsequently sustained groin injuries, compared to those who did not.

Jinger & Kram (2005) in their analysis of running found that as the ground reaction force increased, further adduction (varus) occurred at the knee to absorb these forces and this placed large loads on the adductors. Therefore, lower limb biomechanics may play a role in the causal mechanisms of groin pain.

There is poor understanding of the association between chronic groin pain and the kinematics of the hip joint (including biomechanical risk factors). To date, no biomechanical studies have been conducted exploring the kinematics of the hip joint in subjects with groin pain. Research into the biomechanical factors of the groin will provide insight into the aetiology of groin pain and may yield meaningful information to be applied clinically.

Therefore, the purpose of this study was to explore the three-dimensional (3D) kinematics of the hip joint in three planes during a single leg drop landing activity in sports participants with chronic groin pain compared to healthy subjects. The specific objectives were:

1. To explore kinematics of the hip joint in male sports active subjects with unilateral chronic groin pain compared to healthy controls.
2. To explore kinematics of the hip joint in male sports' active bilateral chronic groin pain cases' most painful limb compared to healthy controls.
3. To explore kinematics of the hip joint in male active sports bilateral chronic groin pain cases' least painful limb compared to healthy controls.

The hypothesis of the study is that kinematic differences do exist between chronic groin pain cases and healthy controls.

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CHAPTER 2
LITERATURE REVIEW

2.1 AIM OF THE REVIEW

The search strategy used in this literature review was as follows: several search engines were used, namely Google Scholar, Ebscohost, Medline, Science Direct, Pedro, and Journal of Orthopaedic and Sports Physiotherapy. Key words “chronic” and “groin pain” were initially used. Only free access articles via the University of Stellenbosch database were used, and only articles published after 2000 were included, with the exception of two articles, which were of value despite their publication date. Articles were then gathered and read for feasibility and value for inclusion in this literature review.

Groin injuries are among the top six most cited injuries in the sports of ice hockey and soccer, and is more common in sports, which require fast changes in direction and strong eccentric contraction of the adductor muscles (Maffery & Emery 2007). Groin pain can be defined as subjectively reported discomfort in the area arising from the illiopsoas to the adductor muscle groups, or objectively as pain on palpation of the lower abdominal muscle wall or adductor muscle group, which most commonly results from adductor muscular pathology (Zuzana, 2009; Tyler, 2010). According to Cross (2010), groin pain in the athlete refers to discomfort noted around the area of the lower abdomen anteriorly, the inguinal regions, the area of the adductors and perineum and the upper anterior thigh and hip.

Groin pain may be local or diffuse and the source of symptoms that arise may be of nociceptive or neuropathic sources (Quinn, 2010). Athletes who compete in high plyometric demand sports, as well as sports that require rapid changes in direction, and repetitive landings are at higher risk of developing athletic groin pain (Tyler, 2010). This literature review will aim to define groin pain and the respective biomechanics and anatomy related to groin pain, explore possible current kinematic and biomechanical risk factors and strategies and identify possible areas in the literature, which require further investigation.

2.2 PREVALENCE AND INCIDENCE OF GROIN PAIN

Incidence of groin and hip injuries in sport is significant, with groin pain accounting for over 10 per cent of attendances to sports medicine centres in the United States (Quinn, 2010).

A 12 per cent prevalence of groin pain has been reported in football and soccer players (Quinn, 2010).

According to Tyler *et al* (2010), the yearly incidence of thigh and groin pain in sports participants ranges between 8-18 per cent and is particularly prevalent in sports that have repetitive impact movements, such as soccer as well as track and field.

2.3 ANATOMY & HIP KINESIOLOGY

According to Neumann (2010) in his clinical commentary using data from a dissection study compiled by Dostal *et al* (1986), the hip joint serves as a central pivot point in the human body. Pathology that affects the strength, control or flexibility of the surrounding hip musculature can significantly affect the efficient functioning of the hip joint. Furthermore altered performance of the musculature surrounding the hip joint may alter the distribution of forces around the joint predisposing the joint to degenerative change of the bone or surrounding connective tissue. There are three distinctive planes of motion in the hip joint namely, sagittal, horizontal and frontal planes. The line from the origin to the insertion of a particular muscle can strongly suggest the line of action of the muscle; and in addition according to Neumann, can indicate the relative moment arm length of leverage of the muscle. Also according to Neumann mechanics, which alter the length or direction of this imaginary arm, can affect both muscular and joint performance, as well as lead to pathology of the articular and surrounding connective tissues, such as the adductor muscles.

Increased internal rotation of the femur during stance phase of gait for example, would alter the line of action of the adductors and affect their leverage or arm length, thus (according to Neumann) lead to pathology.

The ranges of motion of the hip joint include flexion, extension, abduction, adduction, and rotation, with specific physiological limitation by the soft tissues of the joint. Flexion is limited by the hamstring muscle group. Extension is limited by the ligamentous thickening of the capsule; abduction, by the adductor group of muscles; adduction, by the tensor muscle and fascia of the abductor muscles; and rotation, by the fibrous capsular fibres.

The hip is a true ball-and-socket joint surrounded by a well-developed musculature, which enables range of motion in several physical planes while also providing sound stability. The hip joint serves as the connection between the lower extremities and the axial skeleton, and transmits forces from the axial skeleton distally. Due to its wide range of motion and inherit stability, the hip joint is crucial in athletic activities in which it is often exposed to greater than normal forces, such as those experiences in plyometric-type sports involving fast changes in direction.

There are 22 muscles acting on the hip joint that provide stability and movement (Byrne *et al*., 2012). Of these, six are adductors of the hip, namely, the adductors longus, magnus and brevis, and gracillis, obturator externus, and pectinius. According to Tyler *et al* (2010) and Quinn *et al* (2012) the primary function of the adductor muscle group is adduction of the hip in open-chain motions, such as swing phase during walking and running, as well as stabilisation of the pelvis and hip joint in closed-chain motion such as stance phase. They are exposed to injury through muscle imbalance, fatigue or overload. In a systematic review, Maffey & Emery (2007) suggested that a large percentage of groin pain may actually be due to inability to properly transfer load from the legs such as in the case of hyper-pronation of the foot or internal rotation of the knee, thereby placing strain on the muscles attached to the pelvis.

Morelli & Weaver (2005) and Maffey & Emery (2007) proposed that the biomechanics of the lower limb were particularly important and may be causative factors of recurrent groin injury. Tyler *et al* (2001) showed that the hip abductor/adductor strength ratio was significantly lower in an injured group of ice hockey players compared to controls, which correlates with findings by Crowe *et al* (2010). In their investigative pre-season blind study Tyler *et al* analysed pre-season hip abductor and adductor power using a dynamometer and found that pre-season hip adductor power was 18 per cent lower in NHL hockey players who subsequently developed groin injuries. In a subsequent investigative pre-season blind study in 2010 Tyler *et al* found that pre-season hip adductor vs. abductor strength ratios were statistically significantly higher in the uninjured leg compared to the injured leg. Tyler reported that pre-season readings showed that in controls the adductor power was a mean value of 86 per cent of the abductor power while in the injured leg it was only 70 per cent. In a pre-season investigative study in soccer players Ekstrand *et al* also found that decreased pre-season range of abduction was more prevalent in those who later sustained groin injuries compared to those who did not (1983).

Abnormalities of biomechanics at the ankle can also change the biomechanics at the knee (Nicola & Jewison, 2012). The hyper-pronation of the fixated foot on the running surface at the ankle leads to external tibial rotation at the knee joint and corresponding internal femoral rotation at the hip joint. Load transfer in mid-stance of gait (loading phase) is important during the gait cycle. In this moment a co-contraction of the abductors and adductors are critical for pelvis stabilisation (Quinn, 2012; Nicola & Jewison, 2012; Tyler *et al*., 2010; and Maffey & Emery, 2007) .However, the lower limb biomechanics have not been studied in individuals with chronic groin injuries.

2.4 ADDUCTOR MUSCLES

The adductor muscles of the hip joint are responsible for stabilisation of the hip on the pelvis in closed kinematic chain activities and adduction of the hip in open kinematic chain activities. This study focuses on adductor pathology as it accounts for up to 62 per cent of groin-related pain.

The most common cause of groin pain is adductor strains which can be easily diagnosed by pain on palpation of the adductor muscles, or pain with resisted adduction such as those used in the adductor squeeze test. Strains normally occur at the musculotendinous junction of the gracillis or adductor longus muscles. According to Tyler *et al* in a pre-season investigative study (2010), the adductor longus is the most commonly strained muscle in adductor injuries due to its mechanical disadvantage or leverage. The adductor squeeze test is used to determine adductor pathology in groin pain. The intra-class correlation coefficient for the Adductor Squeeze Test, which was established as 0.92 (Delahunt *et al*., 2011).

2.5 BIOMECHANICAL RISK FACTORS

Decreased adductor strength and flexibility have both been shown to have an increased incidence in groin strains (Morelli, 2005; Tyler, 2010; Zuzana, 2009; and Quinn, 2010). Decreased pre-season hip abduction range of motion in soccer players who sustained groin injuries was found in several studies (Eksrand *et al*., 2001; and Tyler *et al*., 2010). This decreased abduction range may indicate decreased flexibility of the adductors, thus when placed in plyometrically demanding circumstances such as those during fast changes in direction, lead to injury. According to Neumann *et al* in his clinical commentary (2010), muscle flexibility is a vital component for the efficient functioning of the hip joint, and decreased flexibility of any muscle surrounding the hip may lead to pathology. In a clinical commentary article (2010), Quinn stated that muscular imbalances, as well as core muscle weakness and delayed onset of specifically transversus abdominus, have been proposed as risk factors. As Neumann mentioned, muscle strength, control and flexibility are all vital components to ensure efficient functioning of the hip joint. Circumstances where the flexibility of the adductors is decreased may result in impaired force moments and decreased muscle leverage resulting in pathology. Hip flexor weakness and decreased eccentric illiopsoas control of the hip have also been proposed as risk factors. Optimal muscular power, flexibility and control are constant themes found in the literature, which are essential in ensuring optimal non-pathological biomechanical functioning of the hip joint.

Tyler *et al* (2010) found pre-season hip adduction strength was 18 per cent lower in hockey players who sustained groin injuries during that season; he showed that an abduction versus adduction pre-season strength ratio of less than 80 per cent increases the risk of groin injury. This finding may indicate that if the adductors are not conditioned to cope with the demands of plyometric sports, this may be a contributing factor to adductor pathology. Tyler *et al* (2007)), in a pre-season blind intervention study, also showed that strengthening of the adductor muscles was effective in decreasing the prevalence of groin injuries in professional hockey players from 8 per cent down to 2 per cent. Maffery & Emery (2007) in a systematic review demonstrated that players who trained regularly in off-season times were less likely to sustain groin injuries compared to those who did not. This off-season sport-specific training may contribute to maintaining joint range of motion, muscle flexibility and strength, which according to Tyler, are important factors in reducing the prevalence of groin injuries.

Ferber *et al* (2003) in an investigative study of lower extremity kinematics, found statistically significant differences between male and female participants when performing running at a set speed. Taking into consideration these kinematic differences in healthy individuals, participants of the same sex will be used to ensure more reputable results.

Other factors that may contribute to hip and groin-related injuries include sport-specific training including pre-season and off-season training, and previous injury to the groin, which also greatly increased chance of re-injury, especially in cases of incomplete rehabilitation according to Quinn *et al* (2010). Quinn in her clinical commentary, highlighted the importance of identifying biomechanical risk factors in order to develop prevention strategies through appropriate screening regimes, but the precise biomechanical risk factors should be explored in future research.

2.6 Pathopsychology

Zuzana *et al* (2009) proposed that musculoskeletal groin pain could result either from acute traumatic mechanisms or a more chronic condition aggravated by sporting activity, resulting in repetitive strain-type injuries in the adductor muscles, most commonly the adductor longus or gracillis muscles. The acute traumatic mechanism, according to Zuzana, was due to an unexpected forced abduction of the hip joint resulting in poor eccentric control of abduction by the adductors and a resultant muscular lesion or tear developed.

Hackney (2012) agreed and stated that forced abduction of the hip was the most common cause of adductor strain, occurring most frequently at the musculo-tendinous junction of the adductor longus. However the majority of chronic groin pain cases, according to a systematic review by Morelli & Weaver (2005), were progressive over time, indicating a more atraumatic aetiology, where no one specific traumatic incident was responsible for pain. According to Morelli & Weaver gradual progressive eccentric loading of the adductor muscles resulted in weakening of the adductor tendons at the insertion into the pelvis causing pain. This progressive atraumatic aetiology may be related to impaired alignment of the force moments and impaired leverage of the respective muscles as stated by Neumann *et al* (2010).

2.7 Management

Currently the best evidence exists in combination therapy in the management of groin pain; this includes pharmacotherapy, surgery, and active/passive physical therapy, however no standardised regime for therapy exists, and treatments are based on professional experience (Zuzana *et al*., 2009).

In 2008 two systematic reviews by Choi *et al* and Jansen *et al* were published. Jansen *et al* conducted a systematic review involving five randomised control trials on the management of longstanding groin pain. The review found that the initial presentation and complexity of the pathology does have a direct effect on treatment. Treatment consisted of conservative management, which most commonly involved a rest period of three to five weeks followed by physical therapy, including electrotherapy, strengthening of the adductors and rehabilitation of the hip and core stabilisers, or a more aggressive surgical approach, which was also most commonly followed, by physical therapy. Poor to moderate evidence was found for physical therapy modalities mentioned above, with the best level evidence found for eccentric control and strengthening of the adductors.

Most common physical therapy included local measures to decrease pain and then rehabilitation focussing on stability of the lumbopelvic complex and strengthening of the adductor muscles (Choi *et al*., 2008; and Jansen *et al*., 2008). No studies are available examining individual outcomes of specific exercise programmes in the treatment of the athlete presenting with groin pain. There is a clear need for systematic reviews to examine the effectiveness of specific exercises in this pathology. The current reviews available involved a multimodality approach, which does not allow one to determine which specific intervention is most effective in the management of chronic groin pain.

Zuzana *et al* (2009) in her systematic review which included five randomised control trials showed favourable outcomes with an exercise programme ranging from four to sixteen weeks in both the short and long terms in the management of the athlete presenting with groin pain, with positive outcomes of up to two years after intervention. Strengthening exercises, including strengthening of the hip flexors, adductors and abductors, were present in 95 per cent of the studies reviewed, and all studies used through-range (isokinetic) exercises in functional positions. The randomised control trials however, were of moderate design and according to Zuzana ey al (2009), future methodologically sound randomised control trials are required to examine the effect of exercise on chronic groin pain.

These findings further support the notion that mechanical factors may be implicated in the risk factor profile of individuals with groin pain as exercise interventions which aim to restore neuromuscular control appear to have a positive effect on groin pain. Future research according to several articles (Zuzana *et al*., *year*; Cross *et al*., *year*; Maffery *et al*., *year*; and Nicola *et al*., *year*) should focus on specific exercise interventions in the rehabilitation of athletes presenting with groin pain as well as biomechanical predisposing factors which may increase the risk of developing groin injuries.

2.8 Conclusion

Groin pain has an incidence of 12-18 percent and is particularly prevalent in plyometric-type sports involving quick changes in direction. To date and to the author's knowledge no studies have been conducted exploring the kinematics of the hip joint in groin pain cases during functional plyometric-type activities. Current literature does suggest that mechanical

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factors of the groin muscle itself as well as other structures may form part of the risk profile, and interventions addressing these mechanical factors, such as muscle strength and neuromuscular control, have been shown to reduce the incidence and impairment of groin pain in sports participants.

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CHAPTER 3
MANUSCRIPT

Investigation of hip kinematics in adult sports participants during single leg drop landing with chronic groin pain

Manuscript to be submitted to Journal of Physical Therapy and Sport. Journal submission guidelines included as Appendix D

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Mrs Lynette Crous
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Mrs Leone Williams

3.1 ABSTRACT

3.1.1 Objectives

To explore if kinematic differences at the hip joint do exist in groin pain individuals when matched with healthy controls.

3.1.2 Study design

The study is a cross-sectional descriptive study. This study formed part of a larger study in which the kinematics of several other joints was investigated simultaneously.

3.1.3 Study setting

The study was conducted at the FNB-3D motion analysis laboratory at the University of Stellenbosch, South Africa.

3.1.4 Outcome variables

The dependent variables included hip angles in the sagittal, frontal and transverse planes during a drop landing activity specifically at foot contact until the lowest vertical position of the pelvis.

3.1.5 Methodology

The study sample was comprised of 20 male club level soccer, rugby, running and cycling participants between the ages of 18 and 55 years of age**.** Anthropometric measurements of the hip in three planes were captured by the VICON 3D-motion analysis system during a structured drop landing. These measurements were tabulated and statistical analysis was conducted comparing the results of the cases and healthy controls.

3.1.6 Results

Unilaterally injured groin cases landed with a significantly higher range of hip abduction and showed greater total range of motion in the transverse plane when compared to controls. Bilaterally injured groin cases landed in significantly higher ranges of hip flexion and abduction and had significantly larger total range of motion in the transverse plane when compared to controls.

3.1.7 Conclusion

Unilaterally injured groin cases landed in hip abduction and had greater total range of motion in the transverse plane when compared to healthy controls, while bilaterally injured groin cases landed in greater amounts of hip abduction as well as flexion, and had greater

total range of motion in the transverse plane when compared to controls. These findings may suggest that the mechanics of the hip joint may form part of the risk profile of developing groin injuries.

Key words

Groin pain, Hip kinematics, biomechanics.

3.2 INTRODUCTION

Groin pain has a prevalence of 10-18 per cent in football and soccer, and is among the top six most cited injuries in contact sports globally (Morelli & Weaver, 2005). 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 somatic structures (Tyler, 2010). According to Zuzana *et al* (2009), the most common cause of groin pain is adductor muscle pathology including tears and strain.

Biomechanical abnormalities of the lower quadrant have been cited as predisposing factors to developing groin pain. Several important biomechanical factors are redundant in the current literature including hip flexibility, specifically abduction. Decreased pre-season abduction has been shown with higher incidences of groin injury. Adductor strength according to Tyler *et al* (2010) is also an important biomechanical factor in groin pain. Several studies have shown that sport-specific pre-season and off-season training decreases the incidence of groin injuries in a specific sport population.

According to Morelli & Weaver (2005), Tyler *et al* (2010), and Zuzana (2009), decreased active hip abduction range and adductor strength are important predisposing factors in the development of groin pain. Strengthening of the abductor and adductor muscle groups has also been shown to be effective in the prevention of developing groin injuries (Tyler *et al*., 2010). The adductor muscles, together with the abductors, are important in stabilisation of the pelvis and hip joints, particularly in closed kinetic chain activities such as single leg weight-bearing actions (Tyler *et al*., 2010). If adductor or abductor weakness was present in chronic groin pain individuals, kinematic abnormalities or differences with sport-specific activities could be expected. Currently no definite kinematic abnormalities have been objectively identified in chronic groin pain and no standard assessment or treatment regime for biomechanical abnormalities is available.

Currently the best evidence exists in combination therapy in the management of groin pain; this includes pharmacotherapy, surgery, and active/passive physical therapy, however, no standardised regime for therapy exists and treatment is based on professional experience (Zuzana *et al*., 2009). The most common physical therapy included local measures to decrease pain followed by rehabilitation focussing on stabilisation of the lumbopelvic complex and strengthening of the adductor muscles. Understanding the kinematics of the hip joint in chronic groin pain sportsmen may allow physical therapists to understand some of the underlying risk factors, which can facilitate the development of evidence-based exercise and rehabilitation programmes to manage individuals, allowing them to return to activity more effectively.

To date, and to the authors' knowledge, no studies exist which objectively explore the kinematics of the hip joint in chronic groin pain individuals compared to healthy controls.

Therefore the purpose of the study was to explore if kinematic differences of the hip joint do exist in groin pain individuals and matched, healthy controls during a drop landing functional task.

3.3 METHODOLOGY

3.3.1 Study location

This descriptive study was conducted at the FNB-3D motion analysis laboratory at Stellenbosch University.

3.3.2 Ethical considerations

Ethics approval was obtained from the Human Research Ethics Committee at Stellenbosch University and once the clubs were contacted, all participants provided written informed consent once identified as potential candidates before research commenced.

3.3.3 Study design

This study was a cross-sectional, descriptive study. This particular study formed part of a larger study in which the kinematics of several anatomical areas were examined during a drop landing activity. This study however only focussed on data obtained from the hip joint.

3.3.4 Study sample recruitment

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A convenient sample was recruited. Appropriate sports clubs in the Western Province were contacted by an informative letter (Appendix J) and interest in participation was determined in this way. Consecutive sampling was performed as potential participants responded. Participants who met the diagnostic criteria outlined below, were selected as cases. Matching controls were also recruited from the specific sport clubs.

3.3.4.1 Sample demographics

The study sample comprised 20 male club level soccer, rugby, running and cycling participants aged between18 and 55 years of age. Half of the samples were symptomatic groin pain cases and the other half healthy controls. Potential cases for inclusion were defined as symptomatic groin pain participants who had symptoms for at least three months and had a positive adductor squeeze test at 45° which has an interclass coefficiency (ICC) of 0.92 (Delahunt *et al*., 2011). Potential controls were defined as active sports participants with no lower limb injuries.

Potential participants (cases and controls) were excluded if they had undergone any orthopaedic procedures to the spine or lower quadrant in the past 12 months, had neurological disorders, or any systemic disease which may affect movement, such as rheumatoid arthritis.

Cases were then matched with controls according to age, sport, gender and club of affiliation.

3.3.5 Instrumentation

To assess the 3D-kinematics of the hip joint, an eight camera Vicon T-series motion analysis system was used. The system was calibrated according to the manufacturing settings prior to capture. The Vicon motion analysis (Ltd) (Oxford, UK) system is a 3D camera system which is used in a wide variety of ergonomics and human factor applications and is considered the gold standard for movement analysis due to its reliability and validity (Windolf *et al*, 2007).

3.3.6 Procedures

An appointment was scheduled to undergo analysis at the motion laboratory once written consent was obtained.

After tuition of the procedures, each participant’s anthropometrics were measured for use by the system. These included the weight, height, leg length, knee width and ankle width.

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A standardised assessment, including a brief subjective history (Appendix F) in which exclusion criteria was explored, and an objective examination (Appendix G) conducted blind by a physiotherapist. An adductor squeeze test and adductor muscle belly palpation was conducted prior to VICON motion analysis to confirm if the participants' pain was in fact related to the adductor muscles. A positive adductor squeeze test indicates adductor related pathology.

A standardised warm up (Appendix I) was completed by each subject prior to motion analysis. Participants were dressed appropriately to expose the anatomical landmarks where retro-reflective landmarks were placed according to the Plug-in-Gait model 2010. 33 markers were required and placed at various points on the body according to the standard lower limb marker placement protocol (Appendix H). To ensure intra-rater reliability, the same research assistant (laboratory physiotherapist) who had experience in reflective marker placement applied all markers. This physiotherapist has had extensive training in marker placement, understands the Plug-in-Gait model and has a high inter-session reliability (r=0.92) for all three planes.

The test movement was a single leg drop landing from a height of 20cm. The test movement was first demonstrated to the participants and then a practice drop was conducted before data collection. The participant was instructed to stand on the box with arms next to sides, then lift one leg up until the hip and knee were bent to 90°, then drop down from the box with the landing foot touching the white line (Appendix H). Random selection was done (tossing of a coin) to decide on which leg the participant will first land. Each drop on each respective leg was conducted six times (Appendix E).

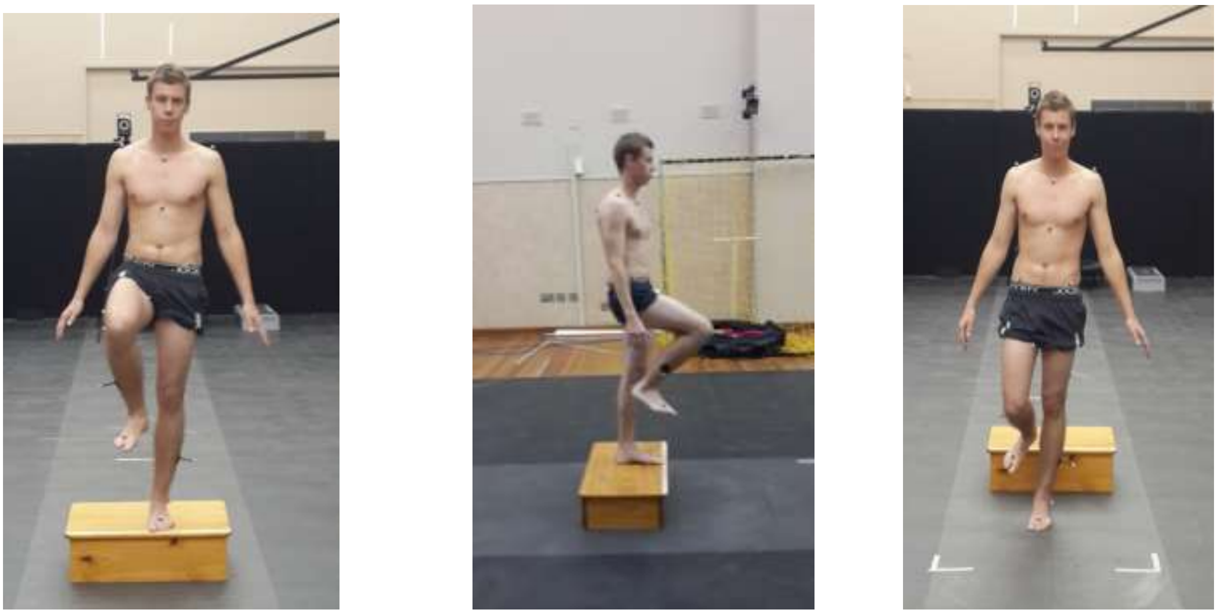

Figure 3.1: Visual representation of data collection

3.3.6 Data processing

Hip kinematics (angles) were measured as the position of the thigh relative to the pelvis in the three respective planes. 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.

3.3.7 Outcome variables

The dependent variables included 3D hip kinematics in the sagittal, frontal and transverse planes at foot strike, lowest vertical point of the pelvis and total range of motion during the single leg drop landing.

Initial contact was defined at the moment which any part of the foot came into contact with the force plate (force plate measured at least 30N), and the angle at the lowest point was defined as the lowest point of the pelvis (central point of the pelvis was calculated from the four pelvic markers) during the single leg drop landing.

In the sagittal plane, flexion was noted as positive value and extension negative. In the frontal plane abduction was a negative value and adduction a positive value. In the transverse plane external rotation was a negative value, while internal rotation had a positive value.

3.3.8 Sample size

A post hoc sample size calculation was calculated using the GPower Version 3.1 statistical power analysis program. Considering a medium size effect of at least 0.15 (alpha 0.05) and 14 participants (seven cases with unilateral groin pain and seven controls), the power was calculated to be 73 per cent. In order to detect a large effect size of at least 1 (alpha 0.05) and a huge effect size of at least 1.45 (alpha 0.05) the post hoc power was set to be 50 per cent and 80 per cent respectively for the subgroup of six participants with bilateral pain (three cases and three controls).

3.3.9 Data analysis

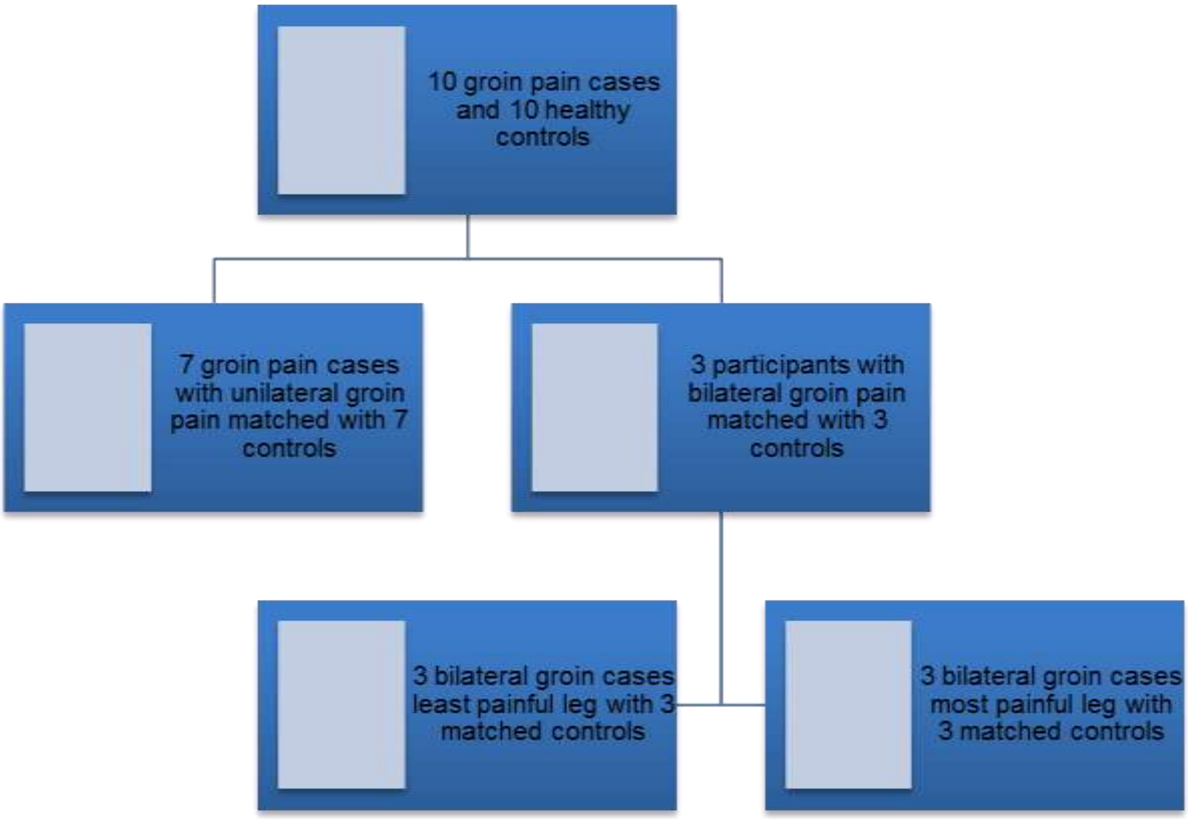

Figure 3.2: Illustration of subgroup analysis

**Bilateral groin cases matched with same side controls*

Descriptive statistics (mean and range to indicate variability) were used to describe the participants' demographics. The mean and standard deviations for pelvic kinematics were calculated. Significant differences in pelvic kinematics between subgroups (Figure 3.2) ($p<0.05$) were determined using two-tailed student t-tests. The Cohen's D effect size calculator was used to calculate the effect size of significant differences in pelvic kinematics between the case and control groups. The relative size of the Cohen's D is illustrated in Table 3.1.

Table 3.1: Relative size of Cohen's D

Effect	Size
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

3.4 RESULTS

3.4.1 Sample description

Twenty participants (10 cases and 10 controls) participated in this study. Ten participants played rugby, four were runners, two were cyclists and the remaining four were soccer players. All cases had a positive adductor squeeze test at 45 degrees of hip flexion. Three participants presented with bilateral groin pain. The demographics (n=20) are presented in Table 3.2. There were no statistically significant differences in age, weight or height. The mean visual analogue scale (VAS) score immediately post activity, and mean duration of groin pain is also presented in Table 3.2. The unilaterally injured groin participants reported a mean VAS post sport of 6.2, while the bilaterally injured groin injured groins reported a VAS of 6 directly post sport. The mean duration of symptoms in the unilaterally injured groins was 1.69 years while 3.34 in the bilaterally injured groins.

Table 3.2: Characteristics of participants

	Age (yrs)	Weight (kg)	Height (m)	VAS Post Activity (/10)	Duration of Symptoms (yrs)
Unilateral Pain Cases and 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 Pain Cases 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	-	-

(*bilateral symptomatic cases most painful limb)

± standard deviation

3.4.2 Kinematic differences between cases and controls

3.4.2.1 Kinematic differences between unilaterally injured and matching side of controls

Table 3.3 illustrates the differences between unilaterally injured groin pain subjects (n=7) and their matched controls.

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- Sagittal plane

  There were no kinematic statistically significant differences found in the sagittal plane.
- Frontal plane

  Significant (<0.001) differences were found in the frontal plane of unilateral symptomatic groin cases (figure 3.3). Cases at initial contact had more hip abduction compared to controls and this was statistically significant (Figure 3.2).

  Cases also had more total range of hip motion in the frontal plane, but this was not statistically significant ($p=0.84$).
- Transverse plane

  In the transverse plane at initial contact the cases landed in external rotation of the hip, while controls landed in internal rotation (Table 3.3). The mean total range of motion in the transverse plane of the cases was statistically significantly ($p<0.002$) more than the controls (Table 3.3).

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Table 3.3: Unilateral injured compared to matching side of controls (n=14)

	Angle at foot contact	ROM	Angle at lowest point
SAGITTAL PLANE			
Cases	26.61° SD 11.18	12.47° ± 5.65	38.51° ± 14.68
Controls	17.54° ± 14.72	10.08° ± 6.45	26.73° ± 19.18
P value	0.93	0.62	0.90
FRONTAL PLANE			
Cases	-11.89° ± 4.72	11.16° ± 5.04	-0.94° ± 5.47
Controls	-7.29° ± 5.76	7.55° ± 3.41	-1.23° ± 19.18
P value	*<0.001	0.84	0.83
Effect size	0.94 large effect		
TRANSVERSE PLANE			
Cases	-1.31° ± 6.66	17.12° ± 6.71	15.39° ± 7.76
Controls	8.33° ± 13.81	11.84° ± 8.21	19.73° ± 17.89
P value	*<0.002	*<0.002	0.18
Effect size	0.96 large effect	0.71 medium effect	

**P value of less than 0.005 considered statistically significant*

Positive values indicate internal rotation; negative values indicate external rotation

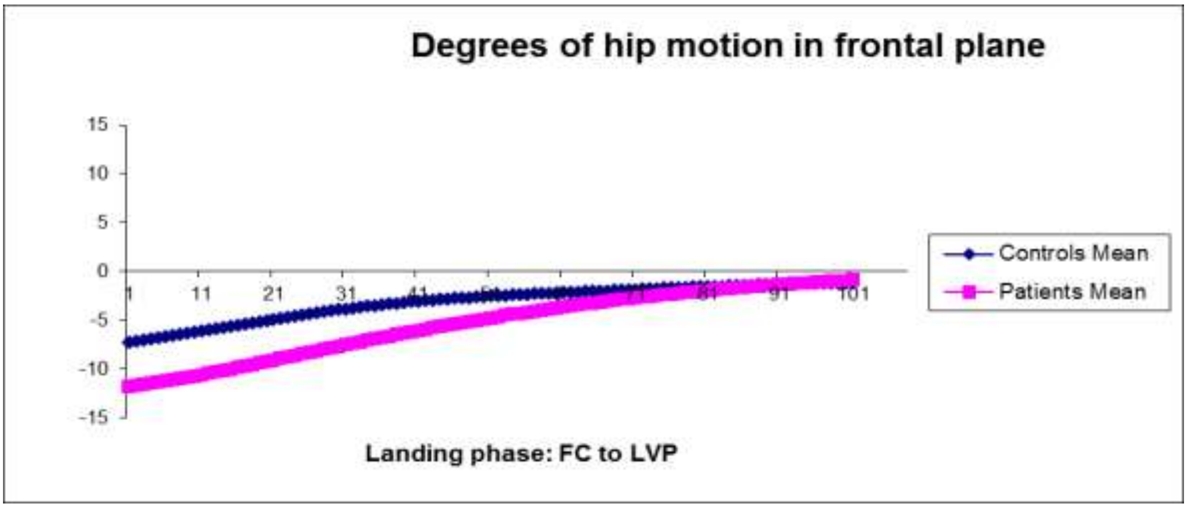

Figure 3.3: Frontal plane hip motion

3.4.2.2 Kinematic differences between cases with bilateral pain: most painful side compared to matching side of the controls

Table 3.4 illustrates the differences between bilaterally injured groin cases' (n=3) most painful leg compared with their matched control.

- Sagittal plane

  Cases landed with a higher mean hip flexion compared to controls, which was statistically significant (Table 3.4). There was also a greater mean total range of motion in cases compared to controls but with no statistical significance.
- Frontal plane

  Cases landed with increased ranges of hip abduction when compared to controls but with no statistical significance. The total range of movement in the hip joint was greater in the controls when compared to cases, which were statistically significant.
- Transverse plane

  In the hip joint there were no statistical differences in landing position. Cases showed a larger total range of motion with statistical significance when compared to controls.

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Table 3.4: Cases with bilateral groin pain: most painful side compared to matching side of controls (n=6)

	Angle at foot contact	ROM (Degrees)	Angle at lowest point (Degrees)
SAGITTAL PLANE			
Cases	32.70°SD 4.25	10.93° +-2.97	43.50° +-5.55
Controls	23.76° ± 6.49	9.60° ± 6.87	31.89° ± 12.04
P value	*0.003	0.51	0.04
Effect size	1.66 huge effect		
FRONTAL PLANE			
Bilat groin most painful	-11.76° ± 1.99	8.41° ± 2.75	-3.39° ± 2.20
Controls	-8.69° ± 3.64	10.04° ± 3.41	-0.22° ± 4.74
P value	0.006	*0.003	*0.003
Effect size		0.64 medium effect	0.68 medium effect
TRANSVERSE PLANE			
Bilat groins most painful	3.90° ± 8.72	5.49° ± 3.95	8.98° ± 6.69
controls	-4.12° ± 8.40	12.48° ± 11.61	8.0° ± 11.36
P value	0.24	*0.003	*0.004
Effect size		0.99 large effect	0.13 negligible

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**** statistically significant p values***

3.4.2.3 Kinematic differences between cases with bilateral pain: least painful side compared to matching side of the controls

Table 3.5 illustrates the differences between bilaterally injured cases' least painful leg compared with their matched controls.

- Sagittal plane

  No statistical differences were noted between the cases and controls.
- Frontal plane

  Cases landed in more hip abduction range of motion than the controls, which was statistically significant. Cases also reached a higher degree of abduction when compared to controls, which was statistically significant.
- Transverse plane

  No statistically significant differences were noted between the two groups.

In summary the results showed that all three symptomatic groups landed in more abduction compared to healthy controls. Some differences between groups were however found. In the bilateral symptomatic cases the most painful leg, results showed that cases landed with increased hip flexion and exhibited larger degrees of total range of motion in the frontal plane. In the bilateral symptomatic cases least painful leg the results showed that cases landed in higher degrees of hip abduction.

Table 3.5: Cases with bilateral groin pain: least painful side compared to matching side of controls (n=6)

	Angle at foot contact	ROM (for each plane) (Degrees)	Angle at lowest point (Degrees)
Sagittal Plane			
Cases	17.08° ± 21.20	9.31° ± 3.81	26.03° ± 19.16
Controls	21.70° ± 6.49	9.12° ± 6.87	29.82° ± 12.04
P value	0.18	0.22	0.20
Frontal Plane			
Bilat groins least painful	-14.06° ± 2.58	10.51° ± 2.97	-3.58° ± 4.14
Controls	-5.39° ± 3.64	10.12° ± 3.41	-0.32° ± 4.74
P value	*<0.002	0.51	*<0.002
Effect size	2.08 huge effect		0.92 large effect
Transverse plane			
Bilat groins least painful	5.73° ± 9.55	8.22° ± 6.22	13.34° ± 15.24
Controls	-3.10° ± 8.40	11.50° ± 11.61	7.0° ± 11.36
P value	0.31	0.14	0.94

3.5 DISCUSSION

Existing literature sources suggest that biomechanical and kinematic differences may exist in patients with chronic groin pain (Morelli, 2005; Tyler, 2010; Zuzana, 2009; and Quinn, 2010), but to date no previous studies using the VICON system have objectively evaluated if these differences are present when compared to healthy controls. This study therefore aimed to explore the kinematic differences of the hip joint in groin pain cases compared to healthy controls. Neumann *et al* (2010) discussed how pathology of the muscles surrounding the hip joint can effect efficiency of movement and disrupt the force moments of movement occurring at the hip joint. These factors may lead to degeneration of the hip articular surfaces and the pathology of connective tissues surrounding the hip, as well as affect the line of action and leverage of these muscles. Not only does the musculature surrounding the hip joint directly affect the kinematics of the joint, but all connective tissue including capsule and ligaments too.

It was reported in this study that during a single leg drop landing at initial contact, unilaterally symptomatic groin cases had statistically significant greater degrees of hip abduction in the frontal plane when compared to healthy controls; the effect size for this was large (0.94). Unilaterally symptomatic groin cases also exhibited greater decreases of total range of motion both in the frontal and transverse planes respectively. One may therefore conclude that when completing a one-leg drop landing type activity, unilaterally symptomatic groin cases exhibited greater range of motion in two planes, which would possibly indicate instability of the hip joint. Increased levels of abduction in sports which require multiple one-leg weight bearing and change in direction may place repetitive longitudinal loading on the adductor muscles, thus leading to recurrent groin injuries. However, this theory is not supported by any literature presented in this study. Tyler *et al* (2010) stated that decreased hip adductor strength and flexibility was a common finding in top level adult ice hockey players and found that eccentric and concentric strengthening of the adductors was effective in both injury prevention and rehabilitation. This type of eccentric and concentric strengthening of the adductors may biomechanically improve the stability of the hip joint by allowing for less abduction during one-leg weight-bearing activities such as a drop landing. Similar findings were found in a randomised control trial involving cases with patellofemoral pain syndrome, in which strengthening of the muscles surrounding the hip joint greatly decreased knee pain during functional activities (Dolak *et al*., 2011).

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In this descriptive, cross-sectional study it cannot be said whether the increased abduction and rotation motions in the symptomatic cases was the cause of the chronic groin pain or as a result of the pathology. However, according to the data found in this study kinematic differences do exist between unilaterally symptomatic chronic groin pain cases when compared to healthy controls.

Neumann *et al* (2010) stated that the adductors of the hip are capable of adduction, flexion and internal rotation of the hip and during one leg weight-bearing these muscles assist with stabilisation of the hip joint complex. Weak adductors therefore, according to Neumann's' description of function, may result in increased external rotation and abduction as found in this study in stabilisation-type scenarios such as a drop landing.

In the bilaterally symptomatic most painful chronic groin pain cases, statistically significantly greater hip flexion was shown at initial contact when compared to controls. This finding was not exhibited in the unilaterally symptomatic cases, possibly suggesting that the kinetics of bilaterally symptomatic groin cases is in fact different. According to the limited sample size of this study, three out of every 15 cases of groin pain are in fact bilateral. According to Tyler *et al* (2010) up to 25 per cent of sportsmen suffering from chronic groin pain will have bilateral symptoms at some stage in their career. The increased hip flexion exhibited may be due to higher levels of somatic pain with impact, or in fact compensation of the trunk from bilaterally hypermobile hip joints with landing. This theory can be supported by the fact that the most painful hip exhibited higher degrees of total range of motion in both the frontal and transverse planes, while the least painful hip exhibited a higher total range of motion in the frontal plane only.

At initial contact of the gait cycle, stability of the pelvis and hip complex are required for efficient load transfer. During unilateral/ weight shifting activities a co-contraction of the hip abductors and adductors are critical for pelvic stabilisation thus limiting the amount of abduction or adduction when performing a task such as the drop landing in this study.

In the bilaterally symptomatic cases least painful leg, no significant differences were seen in the sagittal plane. This result is in contrast to that found when comparing the most painful side. The increased levels of somatic pain according to the results lead to increased levels of hip flexion, possibly due to increased levels of pain with the initial contact during drop landing. The least painful symptomatic groin also landed in higher degrees of hip abduction, as mirrored in the most painful side and the unilaterally injured side. However, the least painful symptomatic groin seemed to show more stability, with no statistically significant increased ranges in the sagittal or transverse plane but when compared to controls exhibited higher total ranges of motion in the frontal plane. This result may indicate that higher levels of pain lead to higher levels of instability in functional tasks such as a drop landing. Literature sources have suggested that lumbopelvic stability may be impaired in active sports participants with chronic groin pain (Maffery & Emery, 2007; Tyler *et al*., 2010).

A stable base of the spine as well as the more distal joints are imperative in providing the hip with distal and proximal stability when performing various tasks Holmich *et al* (2000). Previously, literature has shown that impairments of joints along the kinetic chain both proximally and distally can affect entire limb biomechanics and kinetics (Tyler *et al*., 2010; and Zuzana *et al*., 2009). This study however, does not investigate the kinematics of the pelvis, knee, ankle or spine during a drop landing activity; larger ranges of motion in two planes were found at the hip joint in chronic groin cases which could be as a result of the impaired function of the adductor muscles or compensation, due to instability somewhere else along the kinetic chain.

Neumann *et al* (2010) in the article on the kinesiology of the hip joint dissected various muscles passing the joint. They stated that the action of the muscle was directly related to the imaginary line drawn from the origin to insertion. If this line passed anteriorly to the rotational axis of the joint then the muscle would be a flexor and if it passed posteriorly an extensor, and so forth. This imaginary line can give one an idea of the muscle's action as well as the muscle length and resultant leverage and ability to generate force Applying these principles clinically, then instability of the pelvis or other structures surrounding the hip that may affect this line of action would then affect both the muscle action plane and leverage of the muscle. The adductors are important in the eccentric control of abduction of the hip joint, and then eccentric control may be impaired if alignment is not anatomically correct. The ability of the adductors to control abduction relies on the biomechanical orientation of the pelvis on the hip. This allows for slow controlled lengthening of the adductors.

Neumann *et al* (2010) suggested that as the hip adductors contract to produce an adduction torque, an eccentric contraction of the gluteus medius/minimus muscles would be required to eccentrically control the adduction movement. The gluteus medius is also essential for pelvic stability in weight-bearing activities such as the drop landing activity performed in this study (Dolak *et al*., 2011). According to several studies cited in the literature review a common phenomenon found in pre-season athletes who later subsequently developed recurrent groin injuries, was weak hip adductors and an abductor/adductor power ratio of less than 80 per cent. Considering that the function of the adductors was stabilisation of the hip in closed kinematic chain activities and eccentric control of abduction, findings in this study of increased levels of abduction in all three samples would in fact correlate with weak adductor findings by Tyler *et al* and several other authors.

The population in this study compromised participants from various sporting codes and the standard deviation in the age was large. One would expect variable kinematics in different age groups because articular surfaces degenerate and neuromuscular function deteriorates as one ages. Other studies exploring biomechanics in chronic groin cases were largely compromised of top level ice hockey or football players with ages ranging from 20-35 years of age. The kinematic results found in this study may have been affected not only by the large differences in the age of the participants, but also by the various sports codes they were involved in, as one would expect different muscle conditioning and proprioceptive control in different sporting codes. Sport participants participating in codes which require repetitive one-leg weight-bearing activities, would be better conditioned for the functional task used in this study.

Future research should focus on the investigation of hip and pelvic kinematics in chronic groin pain cases with larger sample sizes, possibly including other plyometric activities such as two-leg drop landing and incorporating the entire lower limb kinetic chain data in order to find common patterns. Another possible research avenue could be strengthening and stability type interventions for the lumbopelvic-hip complex and measuring their effect on function in chronic groin pain cases.

3.6 CONCLUSION

Groin pain is a major problem due to its high rate of recurrence in sports which involve quick changes in direction and unilateral weight-bearing activities. This study highlighted that during a single leg drop landing, sports participants with unilateral/bilateral groin pain landed with statistically significantly greater hip abduction as compared to uninjured

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matched controls in all three experimental groups. This implies that during sporting activities which require one leg landing, groin pain subjects may perpetuate the injury by repetitive stretching of the adductors possibly due to poor adductor eccentric control, or weakness as suggested by several other authors (Tyler *et al*., 2010; Zuzana *et al*., 2009; Maffery & Emery, 2007).

CHAPTER 4
SUMMARY

Groin pain has a prevalence of up to 18 per cent in contact sports, particularly those in which fast changes in direction occur (Tyler *et al*., 2002). Multiple authors have suggested that mechanics of the lower limb, particularly those of the adductor muscle strength and flexibility themselves, may form part of the risk profile of the injury, and several randomised control trials have shown favourable results in injury prevention and a return to sport by addressing mechanical impairment such as muscle strength and length, and eccentric adductor control (Tyler *et al*., 2010; Hackney, 2012; Holmich, 2004; Ibrahim, 2007; and Maffery & Emery, 2007).

Groin pain may be local or diffuse and the source of symptoms that arise may be of nociceptive or neuropathic sources. Athletes that compete in high plyometric demand sports, as well as sports that require rapid changes in direction, are at higher risk of developing athletic groin pain. The adductor muscles are responsible for stabilisation of the hip on the pelvis in closed kinematic chain activities and adduction & internal rotation of the hip in open kinematic chain activities. Decreased adductor strength and flexibility have both been shown to have an increased incidence in groin strains. Decreased pre-season hip abduction range of motion in soccer players who sustained groin injuries was found in several studies conducted by Tyler (2002, 2007, 2010) suggesting that individual mechanics, such as hip range of motion and adductor flexibility, may form part of the risk profile.

Systematic reviews showed favourable outcomes of an exercise programme in both the short and long terms in the management of the athlete presenting with groin pain, with positive outcomes for up to two years after intervention (Quinn *et al*., 2010). Similar findings were found in exercise programmes involving strengthening of the muscles surrounding the hip joint in randomised control trials of cases with patellofemoral pain syndrome (Dolak *et al*., 2011).

This study explored hip kinematics in three planes of groin pain cases compared to healthy controls during a functional drop landing activity. Results showed that symptomatic cases with unilateral groin pain landed with a statistically significant greater degree of hip abduction and larger total range of motion in the transverse plane when compared to healthy controls. Cases with bilateral groin pain most painful leg landed in greater degrees of hip flexion as well as statistically significantly greater hip abduction, while bilaterally injured groin pain cases least painful leg mirrored results found in the two other respective groups landing in higher ranges of hip abduction.

Tyler *et al* (2010) stated that decreased hip adductor strength was a common finding in top level adult ice hockey players, and found in an intervention study that strengthening of the adductors was effective in both injury prevention and rehabilitation. Increased levels of hip abduction with one leg drop or weight-bearing activities may repetitively place tension or strain on the adductor muscles. In this descriptive, cross-sectional study, it cannot be said whether the increased abduction found in the symptomatic cases was the cause of the chronic groin pain or as a result of the pathology. Many authors have suggested that lumbopelvic stability may be impaired in active sports participants with chronic groin pain.

The results of this study show that chronic groin pain cases do exhibit higher degrees of hip abduction and in most cases larger total ranges of motion in the frontal and transverse plane, suggesting possible weakness or decreased stability. Clinically, one may use this information to facilitate or rehabilitate abductor and adductor strength, and hip and pelvic stability, particularly in the first few seconds of landing in one leg drop or weight-bearing type activities.

4.1 CLINICAL IMPLICATIONS

Clinically, one could use this information to facilitate or rehabilitate hip abductor and adductor strength and pelvic stability, particularly in the first few seconds of landing in one leg drop or weight-bearing type activities, to ensure that the line of action of the adductors is in fact anatomically correct and that the muscle has optimal length for leverage. Clinically one should also always examine the pelvic and lumbar stability during dynamic functional tasks in patients who present with groin pain.

4.2 LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The limitations of this study are however evident, as the study made use of a relatively small sample size which may not give a true reflection of the kinematics of chronic groin pain cases. The standard deviation in the age was also large which in itself may have a profound effect on kinematics as the range of movement in the hip joint has been shown to decrease with age, and young fit athletes may have better neuromuscular control than

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older athletes. The cases and controls were only matched according to age and sport participated in, and not according to leg dominance which may also in itself affect the kinematic results, as one would expect the dominant leg to be stronger and have improved proprioceptive control.

Future research should examine hip kinematics as well as kinetics during functional drop landing activities using larger sample sizes and possibly incorporating more sport-specific tasks. Future research should examine the effect of lumbopelvic stabilisation exercises on the clinical and biomechanical presentation of patients presenting with groin pain.

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APPENDICES:

APPENDIX A

Approval Notice

New Application

03-Dec-2012

MORRIS, Tracy Louise

Ethics Reference #: S12/10/265

Title: Exploration of Biomechanics during functional Activities in Adults 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

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Meintjes, WAJ Jack

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

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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 primary or secondary healthcare facilities 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

Stellenbosch University http://scholar.sun.ac.za

Protocol

Sincerely,

Franklin Weber

HREC Coordinator

Health Research Ethics Committee 1

Stellenbosch University http://scholar.sun.ac.za

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 University Health Research Ethics Committee Standard Operating Procedures www.sun025.sun.ac.za/portal/page/portal/Health_Sciences/English/Centres percent20and per cent 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 B: STUDY FLOW GRAPH

APPENDIX C: CONSENT FORMS

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:

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 standardised 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 participants' 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 a interpreter. (*If a 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:

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 D: JOURNAL FORMAT 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.
Masterclasses: Usually a commissioned piece by an expert in their field. If you would like to submit a non-commissioned article, please check with the editorial office beforehand.
Clinical Approaches: These include clinical approaches or opinions which may be novel or practiced with minimal evidence available in the literature.
Professional Issues: An occasional series which aims to highlight changes in guidelines or other professional issues.

These word counts include Keywords, Acknowledgements and the references contained within the article. The reference list at the end of the article, the Abstract, figures/tables, title and author information and Appendices are not included in the word count.

Authorship
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 analysis 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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Contributors and acknowledgements

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 analysis 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. In the covering letter to the editorial office, we ask you make a true statement that all authors meet the criteria for authorship, have approved the final article and that all those entitled to authorship are listed as authors.

Those who meet some but not all of the criteria for authors can be identified as "contributors" at the end of the manuscript with their contribution specified under the subheading "Acknowledgements". All those individuals who provided help during the research (e.g., collecting data, providing language help, writing assistance or proofreading the article, etc.) that do not meet criteria for authorship should be acknowledged in the paper.

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New guidance for Randomised controlled trials
Clinical Trials that commence after 1st June 2013 must be registered to be considered for publication in *Physical Therapy in Sport*. Authors will be asked to state the trial registration number during the submission system as well as at the end of the manuscript file. From January 2014 *Physical Therapy in Sport* will not be able to accept any unregistered Clinical Trial papers. By 2015 the journal will not be able to publish any Clinical Trials that are unregistered prior to recruitment of the first participant.

All randomised controlled trials submitted for publication in *Physical Therapy in Sport* should refer to the Consolidated Standards of Reporting Trials (CONSORT) flow chart. Please refer to the CONSORT statement website at http://www.consort-statement.org for more information. It may be helpful to authors to complete the CONSORT checklist.

Physical Therapy in Sport has adopted the proposal from the International Committee of Medical Journal Editors (ICMJE) (see a recent Editorial in *Manual Therapy* Editorial:

Clinical trial registration in physiotherapy journals: Recommendations from the International Society of Physiotherapy Journal Editors), which require, as a condition of consideration for publication of clinical trials, registration in a public trials registry. Trials must register at or before the onset of patient enrolment. The clinical trial registration number should be included at the end of the abstract of the article. For this purpose, a clinical trial is defined as any research project that prospectively assigns human subjects to intervention or comparison groups to study the cause and effect relationship between a medical intervention and a health outcome. Studies designed for other purposes, such as to study pharmacokinetics or major toxicity (e.g. phase I trials) would be exempt. Further information can be found at http://www.icmje.org.

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Text

Single author (Graham, 2001)

Two authors (Geyer & Braff, 1999)

Three to six authors (Lehman, Stohr, & Feldon, 2000)

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Reference to a journal publication:
Herrington, L., and Munro, A. (2010). Drop jump landing knee valgus angle; normative data in a physically active population. *Physical Therapy in Sport*, 11, 56-59. Reference to a book:

Magee, D.J. (1997). *Orthopaedic physical assessment*. (3rd ed.). Philadelphia: Saunders.

Reference to a chapter in an edited book:
Hudson, Z., & Brown, A. (2003). Athletes with disability. In: G. S. Kolt, & L. Snyder-Mackler (Eds.), *Physical therapies in sport and exercise* (pp. 521-304). Edinburgh: Churchill Livingstone.

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• Manuscript has been "spellchecked"
• References are in the correct format for this journal
• All references mentioned in the Reference list are cited in the text, and vice versa
• Permission has been obtained for use of copyrighted material from other sources (including the Web)

APPENDIX E: DROP LANDING PROTOCOL

DROP LANDING
• **Stand on box, arms next to your sides.**
• **Lift one leg until the hip and knee is bent to 90 degrees.**
• **Your foot must touch the line on the 20cm cm box.**
• **Jump down onto the ground with your landing foot touching the white line.**
• **Hold your landing positioned for 5 seconds.**

APPENDIX F: SUBJECTIVE EXAMINATION

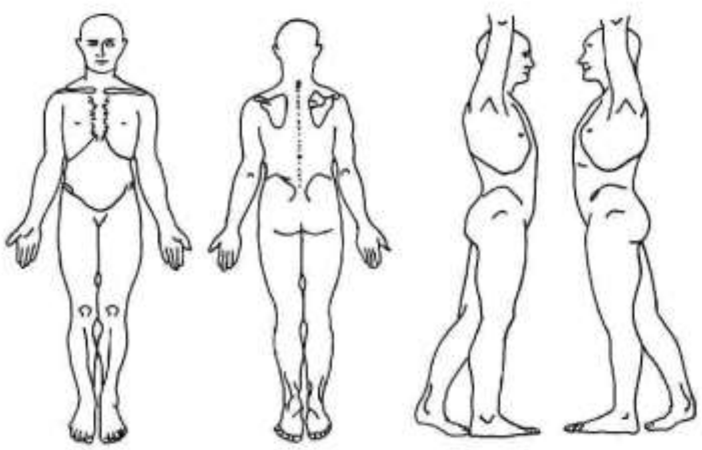
Name:

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 G: OBJECTIVE 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 H: VICON MARKER PLACEMENT

Placement of the head markers:

- LFHD/RFHD - front approximately over temples
- LBHD/RBHD - in horisontal 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:

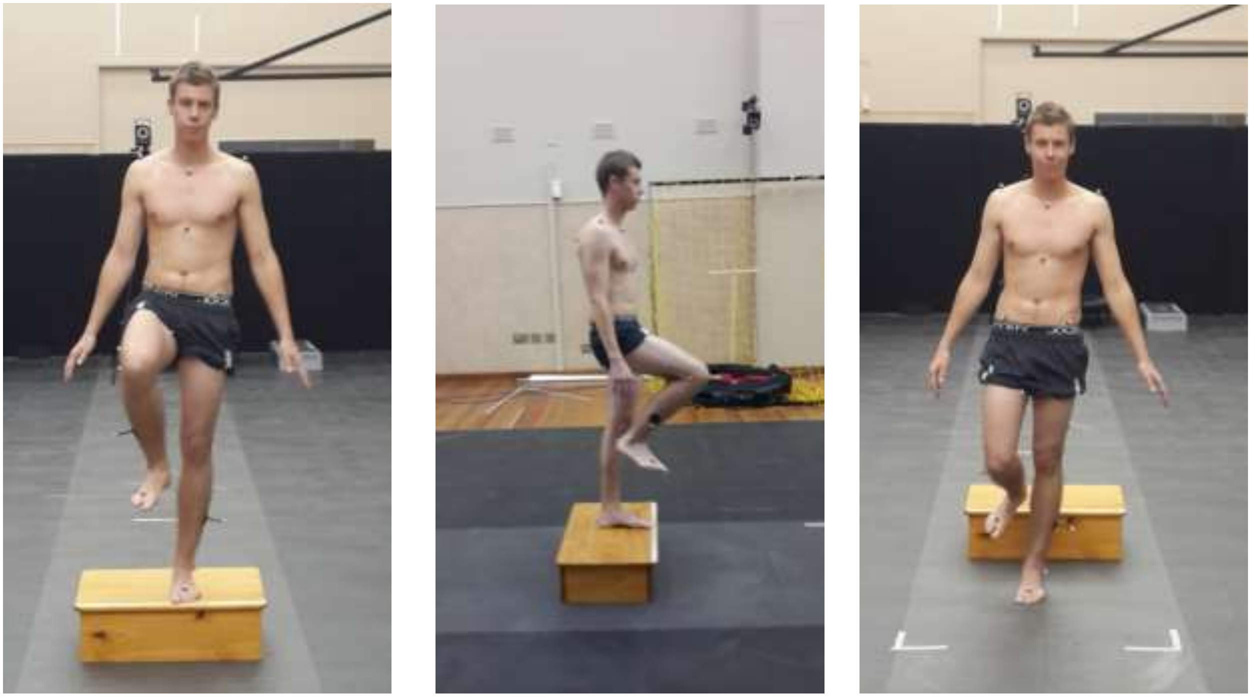
- Left tibia/Right tibia – lower lateral 1/3 of the tibia to determine the alignment of the ankle flexion axis. The marker is placed in a line joining the knee and the ankle markers
- A wand mounted marker may be used

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 I

All participants will be dressed appropriately in PT rugby shorts and barefoot.

The warm up will require each subject to walk on the treadmill for 5 minutes on a selected speed of 5.5 km per hour.

APPENDIX J: COACHES INFORMATION BOOKLET AT INITIAL CONTACT

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Coaches and managers information booklet

Dear coaches and managers we are second year Master of Science students at the University of Stellenbosch. We are conducting research into the biomechanics of sports participants with chronic groin problems.

Groin injuries have a high prevalence in contact sport accounting for 10-18 per cent of injuries and symptoms have the potential to lead to career ending chronic pain (Morelli and Weaver 2005). In our literature review many authors have cited a possible biomechanical relation to chronic groin pain and injuries.

The purpose of this study is to explore the kinetics/kinematics of the lower limb and trunk of active rugby, hockey and/or soccer players with chronic groin pain compared with healthy controls.

In our study we aim to explore certain biomechanical parameters in the trunk and lower limbs in fifteen sports participants who suffer from groin pain and compare these parameters to asymptomatic controls to ascertain if such biomechanical differences or abnormalities do exist.

We will be utilising state of the art motion analysis technology at the medical campus of the University Of Stellenbosch to measure the parameters mentioned above. Your players are exposed to no risks during the research and are free to withdraw from the study at any time by informing any one of the researchers.

We will gladly provide you with a copy of our study once completed and provide you with the biomechanical details found in the study with regards to each player.

We would appreciate your support in our research and would like to thank you for allowing us to make use of your players in our research.

Kind regards

Michael Dare, Lauren Harwin, Lienke Janse Van Rensburg, Karien Visser & Tracy Morris