

# **INVESTIGATION OF THORACIC SPINE KINEMATICS IN ADULT SPORTS PARTICIPANTS WITH CHRONIC GROIN PAIN DURING A SINGLE LEG DROP LANDING TASK**

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**Tracy Louise Morris**

Supervisors:

**Dr. Ina Diener**

**Prof. Quinette Louw**

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## **ABSTRACT:**

Chronic groin pain is widespread across many sporting disciplines. The aim of our research was to determine if there are kinematic differences of the thoracic spine in active sports people with chronic groin pain, compared with healthy controls. A cross-sectional descriptive design was followed. Participants were required to complete six single leg drop landings with each leg from a 20cm height.

The study was done in the 3D Movement Analysis Laboratory at the University of Stellenbosch. Ten male participants with unilateral or bilateral chronic groin pain of more than 3 months duration and 10 asymptomatic males, matched for age and sports participation, were recruited.

The main outcome measures were: thoracic spine angle at initial foot contact, maximum thoracic spine angle, range of movement (ROM) (difference between the minimum and maximum values) and thoracic spine angle at lowest vertical point of the pelvis. This was assessed in all 3 movement planes: the sagittal plane (X plane), the coronal plane (Y plane) and the transverse plane (Z plane).

The results of our study showed that for the unilaterally affected groin pain group, the cases landed in significantly more thoracic flexion ( $P < 0.001$  with large effect size) and were in significantly more thoracic flexion still at the lowest point. Peak thoracic flexion was significantly more in the cases than the controls. ( $P < 0.001$  with medium effect size) The same was true for the bilaterally affected group when landing on the most painful side, although this was not statistically significant. There were no significant differences in the frontal or transverse planes. In the bilaterally painful group, axial rotation ROM was significantly reduced when landing on either leg (worst affected side:  $P = 0.040$  with medium effect size and least affected side:

$p=0.006$  with large effect size). The same occurred in the unilaterally affected group, although this was not statistically significant.

Our study suggests that, in participants with chronic groin pain, there is greater thoracic forward flexion away from neutral during landing and that total axial rotation ROM during landing is diminished.

**Keywords:** Thorax, chronic groin pain, kinematics.

## ABSTRAK:

Kroniese liespyn kom dikwels en in verskeie sportsoorte voor. Die doel van ons studie was om te bepaal of daar kinematiese verskille van die torakale werwelkolom is in aktiewe sportmense met chroniese liespyn, in vergelyking met gesonde kontroles. 'n Dwars-deursnit beskrywende studiemetode is gevolg, en uitgevoer in die 3D Beweging Analise Laboratorium, Universiteit van Stellenbosch. Deelnemers moes ses landings op een been doen, met elke been, vanaf 'n 20cm hoogte. Tien mans met eensydige of bilaterale chroniese liespyn vir langer as 3 maande, en 10 asimptomatiese mans (ooreenstemmende ouderdom en sport deelname) het deelgeneem. Die hoof uitkomst wat gemeet is, was torakale werwelkolom krommingshoek by aanvanklike voet-kontak, maksimum torakale werwelkolom krommingshoek, omvang van beweging (OVb) (verskil tussen die minimum en maksimum waardes) en torakale werwelkolom krommingshoek by die laagste punt van die bekken. Dit is beoordeel in al 3 beweging vlakke: die sagittale (X) vlak, die koronale/frontale (Y) vlak en die transversale (Z) vlak.

Die resultate van die studie het getoon dat, in die eensydig-geaffekteerde liespyn groep, die deelnemers in beduidend meer torakale fleksie geland het ( $P < 0.001$ , met 'n groot effekgrootte), asook met aansienlik meer torakale fleksie by die laagste punt na landing. Piek torakale fleksie was aansienlik meer in die liespyn-gevalle as in die kontroles. ( $P < 0.001$ , met middelmatige effekgrootte) Dieselfde het vir die bilateraal-geaffekteerde groep gegeld wanneer hulle op hul mees pynlike kant geland het, hoewel dit nie statisties beduidend was nie. Daar was geen betekenisvolle verskille in die frontale of transversale vlakke van beweging nie. In die bilateraal pynlike groep, was aksiale rotasie OVb aansienlik verminder wanneer die gevalle op hul pynlikste been óf op hul minder pynlike been geland het ( mees pynlike been :  $P =$

0,040, met 'n middelmatige effekgrootte en minder pynlike been :  $p = 0,006$ , met 'n groot effekgrootte ). Dieselfde het in die eensydig-geaffekteerde groep gebeur, hoewel dit nie statisties beduidend was nie.

Ons studie dui daarop dat, in deelnemers met chroniese liespyn, daar meer torokale fleksie weg van neutraal tydens landing is en dat die totale aksiale rotasie OVB tydens die landing verminder is, in vergelyking met die kontrolegroep.

**Sleutelwoorde:** torakale werwelkolom, chroniese liespyn, kinematika.

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## LIST OF TABLES

Table 1: Summary of differential diagnosis for groin pain.....	10
Table 2: Inclusion and exclusion criteria for participants .....	23
Table 3:Relative size of Cohen's d .....	29
Table 4: Sample demographics.....	31
Table 5: The UNILATERALLY painful cases (n=7) compared to the same side of their matched controls (n=7).....	32
Table 6: The BILATERALLY painful cases (n=3) worst-affected side compared to the same side of their matched controls.....	34
Table 7: The BILATERALLY painful least-affected side (n=3) compared to the same side of their matched controls .....	36



## LIST OF FIGURES

Figure 1: Flow chart of subject recruitment .....	25
Figure 2: Start position for drop landing .....	27
Figure 3: Mean sagittal plane kinematics of unilateral groin-pain cases (n=7) versus controls (n=7) .....	33
Figure 4: Mean transverse plane kinematics of bilateral groin-pain cases (n=3) versus controls (n=3) on worst-affected side .....	35
Figure 5: Mean frontal plane kinematics of bilateral groin-pain cases (n=3) versus controls (n=3) on least-affected side .....	37
Figure 6: Frontal plane kinematics of bilateral groin-pain cases (n=3) versus controls (n=3) on least-affected side.....	37

## TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION .....	3
CHAPTER 2: LITERATURE REVIEW .....	6
2.1    Prevalence .....	6
2.2    Risk factors for groin injury .....	6
2.3    Differential diagnosis .....	9
2.4    The thorax and lower-extremity injuries .....	10
2.5    Drop landings .....	13
2.6    Anatomical considerations.....	14
2.7    Interventions.....	15
CHAPTER 3: MANUSCRIPT.....	19
3.1    ABSTRACT .....	19
3.2    INTRODUCTION .....	20
3.3    METHODOLOGY .....	21
3.3.1    Study Design .....	21
3.3.2    Ethical considerations .....	22
3.3.2    Sample Recruitment.....	22
3.3.5    Instrumentation .....	25
3.3.6    Motion analysis .....	26
3.3.7    Data Processing.....	28
3.3.8    Sample size calculation .....	29
3.3.9    Statistical analysis .....	29
3.4    RESULTS.....	30
3.4.1    Sample description.....	30
3.4.2    Sample kinematics: Differences between cases and controls .....	32
3.5    DISCUSSION.....	38
3.6    CONCLUSION.....	40
3.7    REFERENCES .....	41

CHAPTER 4: SUMMARY AND CONCLUSION .....	44
APPENDICES .....	48
APPENDIX A – Letter to the editor: <i>SA Journal of Physiotherapy</i> .....	48
APPENDIX B – Manuscript title page .....	49
APPENDIX C – Ethics approval letter .....	50
APPENDIX D – Ethics consent form .....	51
APPENDIX E – <i>South African Journal of Physiotherapy</i> Guidelines for Authors .....	55
APPENDIX F – Consent forms .....	59
APPENDIX G – Subjective assessment .....	70
APPENDIX H – Physical assessment .....	71
APPENDIX I – Vicon marker placement .....	73
APPENDIX J – Investigator’s declaration .....	75
APPENDIX K – Coaches’ and managers’ information booklet .....	77
REFERENCES .....	79

## CHAPTER 1: INTRODUCTION

Groin injuries account for 10–18% of all injuries in contact sports and symptoms have the potential to lead to career-ending chronic pain (Morelli and Weaver, 2005). In a systematic review of the effectiveness of exercise therapy for groin pain (Machotka, Kumar and Perraton, 2009), it is suggested that between four and sixteen weeks of exercise intervention may be required to effectively treat groin injuries, and on average eighteen-and-a-half weeks for chronic groin injuries (Holmich et al., 1999). There is often great pressure on all concerned to return an athlete to their sport as treatment of these injuries is costly for the player, the team and the health-care system. An improved understanding of the biomechanical factors that may be involved in chronic groin injuries would therefore be beneficial for all concerned.

Currently there is much controversy in defining groin pain, not only because of the difficulty of definitive diagnosis, but also because 27% to 90% of patients presenting with groin pain have more than one coexisting groin pathology (Morelli and Weaver, 2005; Maffey and Emery, 2007). According to Cross (2010), groin pain in the athlete refers to pain felt in 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 the result of a wide variety of diagnoses, including osteitis pubis, sports hernia, snapping hip syndrome, osteoarthritis of the hip joint, acetabular labral tears of the hip, femoral-acetabular impingement syndrome, muscular injuries, stress fractures (os pubis, sacroiliac and femoral) and avulsion injuries. Groin pain can also be a result of referred pain from compression of the

nerves of the upper lumbar spine (Koulouris, 2008) or pelvic nerve entrapments (obturator nerve entrapment, ilioinguinal neuralgia or iliohypogastric nerve entrapment) (Cross, 2010; Hackney, 2012).

In Morelli and Weaver's (2005) systematic review, 62% of groin injuries were identified as adductor strains. According to Tyler et al. (2001) and Quinn (2010), the primary function of the adductor muscle group is adduction of the hip in open-chain motion, as well as stabilisation of the pelvis and hip joint in closed-chain motion. The adductors are exposed to injury if stabilisation is disturbed through muscle imbalance, muscular fatigue or overload and can act more efficiently when the trunk-stabilising muscles are working effectively (Quinn, 2010). Machotka 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 a repetitive strain-type injury. Rapid changes in direction (Hrysomallis, 2009; Holmich et al., 2010) as well as repetitive kicking, twisting and turning (Quinn, 2010) place large biomechanical demands on the adductors and may explain why groin pain is more prevalent in sports such as soccer, ice-hockey, tennis, basketball and rugby. According to Morelli and Weaver (2005), the majority of chronic groin pain cases are progressive over time, indicating a more atraumatic aetiology.

In the systematic review by Maffey and Emery (2007) it is suggested that a large percentage of groin pain may be due to an inability to properly transfer load from the legs and torso to the pelvis. French et al (2008) state that spinal instability, as well as injuries to lower-extremity muscles or joints sustained during movements, are associated with insufficient strength and endurance as well as inappropriate recruitment of the trunk-stabilising muscles. A lack of core strength and endurance

in the trunk and hip has been linked with increased incidence of lower extremity injuries in collegiate soccer players (Wilkerson et al. 2012) as well as collegiate track and basketball players (Leetun et al., 2004). This trunk instability reportedly results in an inefficient technique with uncontrolled joint motions which may predispose the athlete to injury. (Wilkerson et al. 2012)

The importance of trunk movement in human gait has been established (Chockalingham et al., 2002) and increasingly scientists are expanding their research to include joint biomechanics proximal and distal to the injury site because of the closed chain nature of athletic activity (Leetun et al., 2004). Control of the trunk is important for posture and balance, because approximately two-thirds of the human body's mass lies above the waist (Konz et al., 2006). In a study on trunk kinematics during locomotor activities, it was suggested that upper-torso kinematics relative to both pelvis and gravity are important for locomotor control (Krebs et al., 1992). There is also evidence that altering the sagittal plane body position during landing clearly influences trunk and lower-extremity kinetics, kinematics and muscle activation (Kulas et al., 2008; Shimokochi et al., 2012), but this has not been studied with regard to groin pain.

While there are many studies linking reduced core function with lower extremity injuries, including groin injuries, no biomechanical studies exploring the biomechanics of the trunk in individuals with chronic groin pain could be found in the literature. Therefore, the purpose of this study was to explore the kinematics of the thorax in active sports people with chronic groin pain and compare this with healthy controls.

## **CHAPTER 2: LITERATURE REVIEW**

### **2.1 Prevalence**

Groin injuries are among the top six most commonly cited injuries in the sports of ice hockey, soccer, Australian Rules football, calisthenics and cricket (Maffey and Emery, 2007). Groin injuries are also known in other sports such as running, tennis, rugby, American football, basketball and others (Holmich, 2007; Quinn 2010) and account for up to 18% of all injuries in contact sports (Morelli and Weaver, 2005). In a study of long-standing adductor-related groin pain in soccer players, 72% of the athletes with groin pain had ceased to participate in sport because of the groin pain (Holmich et al., 1999; 2010).

Sport-specific groin-strain injury rates vary from 0.2 to 5.17 injuries per 1000 participation hours (Maffey and Emery, 2007). The annual frequency of groin injuries is 8–18% in football players (Holmich, 2007) and 20% in ice hockey players (Emery, 2003). The incidence of groin injuries among adult male soccer players at the elite level has been estimated to range between 25 and 35 per 1,000 game hours (Engebretsen et al., 2008); however, many authors have noted that few studies actually define the groin injury. Adductor strains in sport can vary from Grade I to Grade III depending on the level of injury. While any part of the adductor group can be injured (including pectineus, adductor brevis, adductor magnus, gracilis and obturator externus), adductor longus is the muscle most frequently affected (Quinn, 2010).

### **2.2 Risk factors for groin injury**

Machotka et al. (2009) proposed that musculoskeletal groin pain could be a result of an acute traumatic incident or a more chronic condition aggravated by sporting

activity. It has been suggested that groin strains occur in sports that involve repetitive kicking, twisting and turning, rapid acceleration and sudden changes in direction, as well as powerful overstretching of the leg and thigh in abduction and external rotation (Hrysomallis, 2009; Morelli and Weaver, 2005; Quinn, 2010; Tyler, 2001). This places large biomechanical demands on the adductors and may explain why groin pain is more prevalent in sports such as soccer, ice-hockey, tennis, cricket and rugby. In addition, sports that involve running with repetitive impact such as track and field events are also implicated (Holmich et al., 2010; Quinn 2010). One-third of athletes recall a specific traumatic event as the cause of symptom onset, but the majority of chronic groin pain cases are progressive over time, indicating a more atraumatic aetiology (Morelli and Weaver, 2005; Morelli and Espinosa, 2005).

In their systematic review of risk factors for groin-strain injury in sport, Maffey and Emery (2007) identified certain non-modifiable risk factors, including:

- previous injury (two studies on soccer and ice-hockey players);
- age/sport experience (veterans and players <18 years were at increased risk);
- sport-specific training (increased risk in breaststroke swimmers); and
- body mass index and decreased dominant femur diameter, which showed increased risk in the study involving rugby players by O'Connor (2004).

Modifiable risk factors for groin-strain injury that were identified included:

- decreased hip abduction range of motion (ROM) in one study on soccer players only. This finding was refuted in other studies done on soccer players, as well as ice-hockey, rugby and Australian Rules football players. In another systematic review, Hrysomallis (2009) found that low hip adductor flexibility was associated



with an increased risk of injury in three out of the four studies on soccer players, but not in ice-hockey (three studies) or Rugby League (one study) players;

- decreased levels of pre-season sport-specific training (<18 sessions in the pre-season increases risk in elite ice-hockey players); and
- delay in transversus abdominus muscle recruitment (Australian Rules football players), but no delay in other abdominal muscles.

Other predisposing factors have been studied and while there is inconsistent evidence regarding muscle strength as a risk factor for groin injury, muscular imbalance appears to play a role. Hip flexor and lower abdominal weakness (with increased relative adductor strength) has been reported as part of posterior wall inguinal insufficiency in patients who presented with sports hernia or groin disruption (Morelli and Weaver, 2005) and hip flexor and abductor weakness with increased adductor strength on the injured side have been found in recreational runners with overuse injuries (Quinn, 2010). In contrast, Tyler (2001) concluded that groin strain injuries in ice-hockey players were 17 times more likely to occur if the hip adductor strength was less than 80% of the hip abductor strength and in a study on elite under-age Australian footballers by Crow (2010), results showed that hip adductor muscle strength is decreased before and during the onset of groin injury.

In their study on the prevention of groin injuries in soccer players, Holmich et al. (2010) showed that having had a previous groin injury almost doubles the risk of developing a new groin injury, while playing at a higher level of sport almost triples the risk of developing a groin injury. On the other hand, Schick and Meeuwisse (2003) showed that gender was not a risk factor for groin-strain injury in ice-hockey players, while leg dominance did not influence the site of the adductor strain in the

study on one hundred Rugby League players (O'Connor, 2004). O'Connor (2004) concluded that groin injuries were most likely to be as a result of many risk factors being present at the same time, as opposed to one single factor.

Vezina and Hubley-Kozey (2000) stated that spinal instability and injuries to the lower extremity sustained during activities are associated with insufficient strength and endurance of the trunk-stabilising muscles and inappropriate recruitment of the trunk and abdominal muscles. Roetert (2001) reported that this lack of core strength and stability is thought to result in an inefficient technique, which predisposes the athlete to injury. This is supported by Maffey and Emery (2007), who suggested that a large percentage of groin pain may be due to an inability to properly load transfer from the legs and torso to the pelvis.

### **2.3 Differential diagnosis**

Accurate diagnosis of groin pain remains difficult, not only because of the complex regional anatomy, but also because groin pain can result from a wide variety of causes and 27% to 90% of patients presenting with groin pain have more than one coexisting groin pathology, often with overlapping symptoms (Morelli and Weaver, 2005; Maffey and Emery, 2007; Quinn 2010). For example, Holmich (2007) highlights the similarity of the symptoms found in patients with iliopsoas pain, rectus abdominis pain and sports hernia. In his study on 207 athletes with long-standing groin pain, mainly football players and runners, 34% of patients had two origins of groin pain and 8% had three. He found that adductor-related pain was the primary cause in 58% of the athletes and iliopsoas-related pain in 35% of the athletes. Among football players specifically, adductor-related pain increased to 69%, with iliopsoas-related pain the secondary clinical entity. In Morelli and Weaver's (2005) systematic review, 62% of groin injuries were identified as adductor strains.

According to Cross (2010), groin pain in the athlete refers to discomfort around the anterior lower abdomen, 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, many of which are listed in Table 1, below.

**Table 1: Summary of differential diagnosis for groin pain**

	Groin injuries: Differential diagnosis
Bone injuries	Stress fractures (os pubis, sacroiliac and femoral) Avulsion and apophyseal injuries Hip dislocations, subluxations or bone bruising
Joint injuries	Osteo-arthritis of the hip joint Femoral-acetabular impingement syndrome Labral tears Loose bodies in the hip joint Osteitis pubis/osteomyelitis pubis Joint contusions
Soft-tissue injuries	Inguinal hernia Sports hernia/athletic pubalgia/Gilmore's groin Groin Disruption Snapping hip, e.g. iliotibial band or iliopsoas tendinitis Iliopsoas bursitis Capsuloligamentous injuries of the hip or sacro-iliac joint Muscular contusions, e.g. hip pointer Muscular strains/tendinopathies, e.g. quadriceps, hamstrings, abdominals, adductors, iliopsoas Pelvic floor myalgia
Neural injuries	Compression of the nerves of the upper lumbar spine Pelvic nerve entrapments (obturator nerve entrapment, ilioinguinal neuralgia or iliohypogastric nerve entrapment)
Other	Legg-Calve-Perthes disease Myositis ossificans Slipped capital epiphysis Other rheumatic diseases, e.g. rheumatoid arthritis, gout/pseudo-gout, ankylosing spondylitis Tumours Infectious diseases, e.g. septic arthritis Intra-abdominal pathology, e.g. aneurysm, appendicitis, diverticulosis, inflammatory bowel disease, urinary tract infection, lymphadenitis, prostatitis, scrotal and testicular abnormalities, gynaecologic abnormalities, nephrolithiasis

Source: Cross (2010); Jansen et al. (2008); Morelli and Weaver (2005); Quinn (2010).

## 2.4 The thorax and lower-extremity injuries

There have been many studies on core instability and the resulting predisposition to spinal and lower extremity injuries in athletes. In a prospective cohort study by

Leetun et al (2004), involving 123 collegiate track athletes and basketball players, it was concluded that core stability has an important role in injury prevention. Athletes who experienced an injury over the course of the season demonstrated lower core stability measures than those who did not. This was true for core stability measures of the hip and trunk, suggesting that this weakness affected the ability of the athlete to stabilise these regions. No specific mention was made of groin injuries, but injuries to the thigh were noted. Even though only static tests were used to assess this, Leetun et al., (2004) state that core stability is the product of motor control and muscular capacity of the trunk-hip complex.

In addition, poor core stability and endurance have been shown to increase injury vulnerability throughout the kinetic chain in a cohort study done by Wilkerson et al. (2012) on 83 collegiate football players. Injuries to the groin were included and players with reduced core function had twice the injury risk overall. This increased to three times the risk with a high level of exposure to game conditions. The tests used to assess core function were the maximum amount of time the player could hold the following four positions: horizontal back extension hold, sitting sixty degrees trunk flexion hold, side-bridge hold and bilateral wall-sit hold. Core stability is defined in this study as “the ability to control the position and motion of the trunk over the pelvis and leg to allow optimum production, transfer and control of force and motion to the terminal segment in integrated kinetic chain activities”. It is stated that neuromuscular control of the core musculature should not be neglected in rehabilitation.

The trunk segment alone comprises 35.5% of body mass, contributing majorly to the ground-reaction forces during landing (Konz et al., 2006). Kulas et al. (2008) state

that, according to the kinetic chain concept, the biomechanical demands on the hip, knee and ankle in landing can be affected by changes in trunk position and trunk mass. They showed that an added trunk load will increase hip biomechanical demands (during drop landings), depending on the trunk landing position. The group using trunk extension landing strategies decreased hip joint moments by 11%, while those using trunk flexion landing strategies increased hip joint moments by 19% (following the additional 10% body weight applied to the trunk). Kulas et al. (2008) state that these findings are in line with previous studies that also showed that as trunk flexion in landing increases, hip extensor muscle activation and moment demands increase. This supports the hypothesis that both added trunk load and trunk position adaptations to the load affect hip joint function.

In addition, increased trunk flexion during landing is associated with increases in knee and hip flexion angles. This finding was supported in a study by Blackburn and Padua (2008), who demonstrated that a more flexed/less erect trunk posture during landing is associated with a reduced anterior cruciate ligament (ACL) injury risk, because flexing the trunk increased the maximum hip and knee flexion angles. This reduces quadriceps muscle activation during the entire descending phase of the landing and produces a smaller peak vertical ground-reaction force compared with that of the more erect trunk position. They advise incorporating greater trunk flexion during landing to prevent ACL injury. In a further study on sagittal plane body position and non-contact ACL injury by Shimokochi et al. (2012), the findings of the Blackburn and Padua (2008) were supported, as it was shown that altering the sagittal plane body position during landing clearly influences the trunk and lower-extremity biomechanics and lower-extremity muscle activation. It was reported that leaning the whole body forward could simultaneously reduce the knee extensor

moment and increase the ankle and hip extensor moments during single-leg landings.

What is extremely relevant with respect to the current study is that the hip extensor moments at the time of peak knee extensor moment were greater for those who landed in the leaning-forward position compared with those in the upright-landing group. According to Tyler et al. (2001) and Quinn (2010) the adductor muscle group helps stabilise the hip joint and pelvis in closed-chain motion. It may be then that this leaning-forward position strategy that appears to protect the ACL may indeed place higher biomechanical demands on the adductors, as well as other hip joint and trunk-stabilising muscles.

## **2.5 Drop landings**

Drop landings have been widely used in recent biomechanical studies, together with three-dimensional (3D) movement analysis, to assess kinetics and kinematics of the lower extremity and trunk in an effort to understand the reasons for common lower-extremity injuries and work out the best ways to deal with such injuries. Examples of studies using variations of drop landings include Kulas et al. (2008), Blackburn and Padua (2008) and Shimokochi et al. (2012).

Leetun et al. (2004) state that, because core stability is the product of motor control and muscular capacity of the hip and trunk, dynamic tests of lower extremity alignment during closed chain activities are preferable to conventional strength tests to assess this. They advise the “single leg step down test” for future studies. A single leg drop test, such as the one used in the current study, could be used when

participants are functioning at a reasonably high level, needing and a more difficult variation of this task.

In a study by Ford, Myer and Hewitt (2007) to determine the reliability of 3D lower-extremity kinematic and kinetic variables during drop landing in young athletes, the reliability of within-session measurements and those made between two relatively extended sessions (approximately seven weeks) were analysed using rigorous statistical methods. It was found that there were no differences in within-session reliability for peak angular rotations between planes with all discrete variables combined.

## **2.6 Anatomical considerations**

In their literature review, Barker et al. (2009) state that there are a number of recent updates to the descriptions of pubic-region anatomy, three of which are of interest in the pathogenesis and treatment of athletes with chronic groin pain. These are as follows:

*Composition and arrangement of the pubic attachments of the adductor longus (AL) muscle:*

- Sixty-two per cent of the pubic attachment of AL is composed of muscle fibres, which is in contrast with textbook descriptions of an entirely tendinous origin.
- This predominantly muscular attachment of AL into the pubic bone implies that an adductor-related groin pain will more likely be an enthesopathy rather than tendinopathy and that treatment should be geared to this.

*Arrangement of the lower fibres of the internal oblique (IO) muscle and the lower part of the transversus abdominis (TrA) aponeurosis:*

- The lower fibres of IO and TrA attach separately into the rectus sheath and not as a 'conjoint tendon' onto the pubic bone.

*Relations of the soft tissue structures anterior to the pubic symphysis:*

- AL and rectus abdominus (RA) are attached to the pubic symphysis capsular tissues, the interpubic disc and adjacent articular cartilage.
- The anterior relations of the pubic symphysis imply that the AL, RA, IO and TrA muscles have the potential to anatomically provide a mechanism for pelvic ring stability and force transmission. Also, these close anatomical connections provide an explanation for overlapping pathologies and strengthen the hypothesis that chronic groin pain may involve multiple structures, a common reaction pattern to repetitive pubic region loading.

## **2.7 Interventions**

Cusi et al. (2001) showed that Rugby Union players had fewer groin-strain injuries at one year follow-up when adding three Swiss ball stability exercises to a standardised stretching and fitness programme, although these findings were not statistically significant. Up to 16 weeks was required to complete the exercise programme.

In an earlier randomised controlled trial (RCT), Holmich et al. (1999) demonstrated that a rehabilitation programme including strength training of the adductors, abdominal and low-back muscles, combined with coordination and balance exercises, was significantly better in treating long-standing adductor-related groin injuries in athletes than traditional physiotherapy without these activities added. These athletes had been injured for an average of nine months prior to the study and 72% had halted sporting activity. The treatment was carried out in groups, three times a week for 8–12 weeks and after the trial 80% of the players returned to their previous level of sport without any groin pain. The time from entering the study to



return to sport was between 13 and 26 weeks, again highlighting the long rehabilitation times needed for chronic groin injuries.

In a recent systematic review on the effectiveness of exercise therapy for groin pain (Machotka, Kumar and Perraton, 2009), it was concluded that exercise therapy is a key factor in rehabilitation and that strengthening of the hip and abdominal muscles was likely to be effective. Their suggestions include that exercises should start in static positions and progress to through-range and then to functional positions. There is less evidence to support passive treatments and medication, but cardio-vascular exercise is also useful and exercise interventions for groin pain are most effective when delivered in small groups of up to four people, supervised by a physiotherapist. Anywhere from 4 to 16 weeks may be required for exercise intervention to be effective for groin injuries which is not routine practice considering the great pressure on all concerned to return the athlete to their sport. Managing the player's expectations is important.

In a study on injuries in male soccer players, Ekstrand et al. (2007) showed a lower re-injury rate following a ten-step rehabilitation programme that included various turning and cutting manoeuvres, progressing to kicking and skills training with the ball, including shooting, jumping and sprinting in various directions. This allowed the coaches to assess symptoms through functional rehabilitation, thereby avoiding premature return to play and decreasing the risk of re-injury as a result of incomplete tissue healing or because functional skill and endurance had not been restored.

Pre-rehabilitation to prevent groin injuries has also been studied. The results of an intervention study indicate that pre-season hip strengthening in professional ice hockey players whose adductor-to-abductor muscle strength ratio was less than 80% can lower the incidence of adductor muscle strains (Tyler, 2002). This study followed

on an earlier study (Tyler, 2001) in which it was found that the adductor/abductor strength ratio in elite ice hockey players was 18% less in injured players. Tyler (2002) states that his study provides some evidence that detecting and correcting strength weakness may reduce injury risk. He suggests that eccentric training may also be worthwhile in prevention, and eccentric exercises have been emphasised as being of major value in the treatment of tendon-related overuse injuries in other studies (Holmich, 2010). Holmich et al. (2010) completed a cluster-randomised trial with the aim of preventing groin pain in soccer players. A programme of six exercises that included strength (concentric and eccentric), balance, and core-stability exercises was used. The risk of sustaining a groin injury was decreased by 31%, although this reduction was not statistically significant. In a study using the FIFA 11+ program, which includes core and leg strengthening and stretching as well as balance, agility, plyometrics, running and cutting manoeuvres (focusing on correct technique and lower extremity alignment), injuries in elite male basketball players were significantly reduced (Longo et al., 2012). When this program was used as a warm-up for 1982 female club level soccer players in Norway, there was a significant reduction in injuries overall, especially overuse and serious injuries, including groin injuries (Soligard et al., 2008).

The findings of this literature review indicate that most groin pain is progressive over time, indicating a non-traumatic aetiology. The majority of groin injuries involve the adductor muscles, predominantly adductor longus, but it is common for more than one origin of groin pain to exist. Chronic groin injuries take a long time to heal and can lead to career-ending chronic pain, but exercise therapy is an effective cornerstone of rehabilitation. Neuromuscular control of the trunk and lower-extremity-stabilising muscles is important for torso stability and load transfer during landing, so

exercises should start in static positions, but needs to progress to through-range and then to functional positions. Exercise programs that include core and leg strengthening, as well as motor control activities that address the entire kinetic chain from the foot to the trunk have been shown to reduce lower extremity injuries in sports. Sport-specific skills training is also useful to prevent re-injury and monitor injury progress.

The purpose of our study, therefore, is to examine the kinematics of the thorax in individuals with chronic groin pain and compare this with healthy controls as a means to further understand how trunk stability or trunk movement adaptations may be involved with chronic groin pain.

## **CHAPTER 3: MANUSCRIPT**

### **Manuscript to be submitted to the South African Journal of Physiotherapy as per submission guidelines (Appendix E)**

#### **3.1 ABSTRACT**

Chronic groin pain is widespread across many sporting disciplines. The aim of our study was to determine whether there are kinematic differences of the thorax in active sports people with chronic groin pain versus healthy controls. This descriptive study took place at the FNB-3D Motion Analysis Laboratory at Stellenbosch University. Twenty subjects (ten healthy controls and ten cases with chronic groin pain) were included. Three of the cases had bilateral groin pain and seven had unilateral groin pain. Three-dimensional thoracic kinematics were analysed from foot contact to the lowest vertical position of the pelvis, during single-leg drop landings.

For the unilaterally affected groin pain group, the cases landed in significantly more thoracic forward flexion ( $p < 0.001$ ) and peak thoracic flexion was significantly more ( $p < 0.001$ ). In the bilaterally painful group the same trend was observed, plus axial rotation range of movement (ROM) was significantly reduced when landing on either leg. This also occurred in the unilaterally affected group, although this was not statistically significant. Our study demonstrated that, in participants with chronic groin pain, there is greater thoracic forward flexion away from neutral during landing and that total axial rotation ROM during landing is diminished, therefore suggesting that rehabilitation after groin injury should not only involve the adductors and the hip joint, but the entire kinetic chain.

**Keywords:** Thorax, chronic groin pain, kinematics

### 3.2 INTRODUCTION

Groin injuries account for 10–18% of all injuries in contact sports and have the potential to lead to career ending chronic pain (Morelli and Weaver, 2005). The anatomical and biomechanical causes of groin pain are complex and controversial (McSweeney et al.; 2012), not only due to the difficulty of diagnosis, but also because groin pain can arise from a multitude of sources and many patients presenting with groin pain have more than one coexisting groin pathology (Morelli and Weaver, 2005; Maffey and Emery, 2007; Holmich, 2007).

In Morelli and Weaver's (2005) systematic review, 62% of groin injuries were identified as adductor strains. According to Tyler (2002) and Quinn (2010) the primary function of the adductor muscle group is adduction of the hip in open-chain motion, as well as stabilisation of the pelvis and hip joint in closed-chain motion. The adductors are exposed to injury if stabilisation is disturbed through muscle imbalance or overload and can act more efficiently when the trunk-stabilising muscles are effective (Quinn, 2010). Machotka et al. (2009) proposed that while musculoskeletal groin pain could result from acute traumatic mechanisms, the majority were progressive, aggravated by sporting activity, resulting in repetitive strain-type injuries. Groin pain is more prevalent in sports such as soccer, hockey/ice-hockey, tennis, cricket and rugby, because these sports require repetitive kicking or twisting and turning, rapid changes in direction and large ranges of motion at the hip (Holmich et al., 2007; Quinn 2010).

Maffey and Emery (2007) suggested that a large percentage of groin pain may be due to an inability to properly transfer load from the legs and torso to the pelvis. French et al. (2000) stated that injuries to lower extremity muscles and joints

sustained during movements are associated with insufficient strength and endurance as well as inappropriate recruitment of the trunk-stabilising muscles, including the abdominal muscles. A lack of core strength and endurance in the trunk and hip has been shown to predispose athletes to lower extremity and spinal injury, including groin injuries (Leetun et al., 2004; Wilkerson et al., 2012).

Control of the trunk is important for posture and balance, partially because approximately two-thirds of body mass lies above the waist (Chockalingham et al., 2002). In a study on trunk kinematics during locomotor activities by Krebs et al. (1992) it was suggested that upper-torso kinematics relative to both pelvis and gravity is important for locomotor control.

No biomechanical studies exploring the biomechanics of the trunk in individuals with chronic groin pain could be found in the literature even though core stability is known to impact lower extremity function. Therefore, the purpose of this study was to explore the kinematics of the thorax in active sports participants with chronic groin pain, compared with healthy controls.

### **3.3 METHODOLOGY**

#### **3.3.1 Study Design**

A cross-sectional descriptive study design was chosen as a means to observe and simultaneously compare the two different populations. It is appropriate, cost effective and since no information is available on this topic, a longitudinal study could not be performed at this stage.

### **3.3.2 Ethical considerations**

Ethical approval was obtained from the Human Research Ethics Committee of the University of Stellenbosch (Reference number S12/10/208). The project was conducted according to the internationally accepted standards and guidelines of the Declaration of Helsinki, the South African Guidelines of the South African National Health Act No. 61 of 2003 and the South African Medical Research Council Ethical Guidelines for Research. All subjects gave written informed consent to participate in the study.

### **3.3.2 Sample Recruitment**

Appropriate sports clubs in the Western Province were contacted by an informative letter to determine interest in participation. Consecutive sampling was performed as potential participants responded. Participants who met the diagnostic criteria, outlined in Table 2 below, were selected as cases. Matching controls were recruited from the specific sport clubs and through local Physiotherapy practices.

### **3.3.3 Sample demographics:**

Twenty male participants between the ages of 19 and 55 were recruited from various sports clubs in the Western Province, ten with chronic groin pain and ten without. These included four runners, two cyclists, four soccer players and ten rugby players. Potential cases for inclusion were defined as symptomatic groin pain participants with symptoms of at least 3 months duration and who also had a positive adductor squeeze test (at 45° hip flexion) which has a interclass coefficient (ICC) of 0.92 (Delahunt et al, 2011). The matching controls were defined as individuals who met all the inclusion criteria as defined in Table 2, but had not experienced any lower quadrant pain/lower back pain (LBP) in the last three months.

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 any neurological disorders or had any had any systemic disease which may affect movement of the spine or extremities.

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

**Table 2: Inclusion and exclusion criteria for participants**

	Inclusion criteria	Exclusion criteria
Cases	<ul style="list-style-type: none"> <li>• Adult sports participants (aged 18–55)</li> <li>• Currently participating in club level sport or any form of physical exercise</li> <li>• In good general health</li> <li>• Chronic groin pain of any intensity for at least the last three months.</li> <li>• Positive adductor squeeze test<sup>1</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Any orthopaedic surgical procedure of the lower quadrant (LQ) or lumbar spine (LX) within the last 12 months.</li> <li>• Positive findings on previous imaging for bony lesions in the LQ or LX</li> <li>• Any disease that has an influence on functional ability/movement, e.g. ankylosing spondylitis, Scheuermann's disease, rheumatoid arthritis, muscular dystrophy, Paget's disease</li> </ul>
Controls	<ul style="list-style-type: none"> <li>• Soccer, hockey or rugby players at club level (aged 18–55)</li> <li>• In good general health</li> <li>• Participating in sport or any form of physical training</li> </ul>	<ul style="list-style-type: none"> <li>• Any orthopaedic surgical procedure of the LQ or LX within the last 12 months</li> <li>• Positive findings on previous imaging for bony lesions in the LQ or LX</li> <li>• Any disease that has an influence on functional ability/movement, e.g. ankylosing spondylitis, Scheuermann's disease, rheumatoid arthritis, muscular dystrophy, Paget's disease</li> </ul>

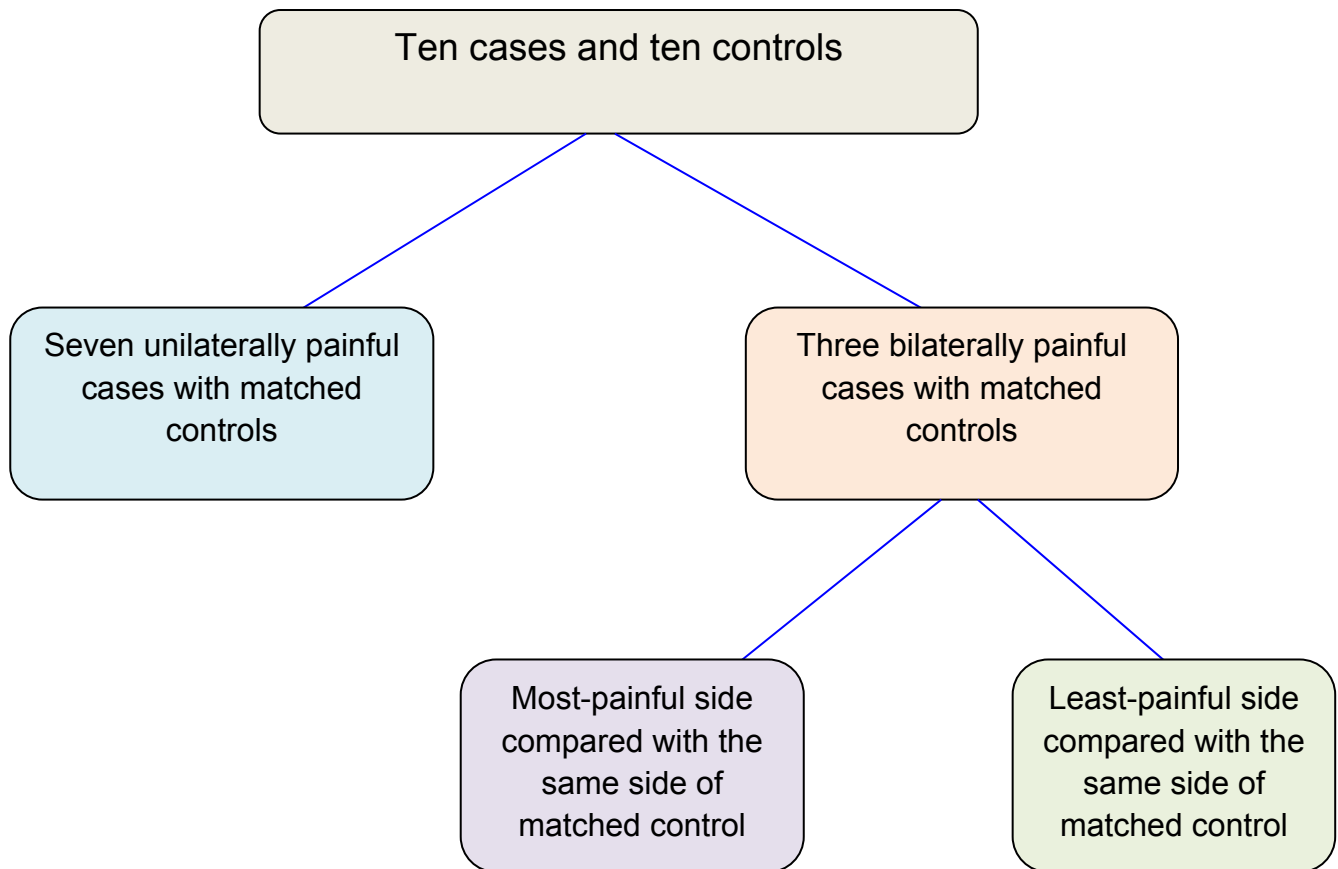
<sup>1</sup> Positive adductor squeeze test: measured with a sphygmomanometer (Delahunt et al., 2011). This includes palpation over the adductor muscle belly and insertion as a pain provocative test. This was the main objective measurement for identifying participants (Delahunt et al., 2011; Holmich, 2007). This was done at the first contact session between the researcher and the participants which took place at the sports club or physiotherapy practice.



### 3.3.4 Procedure

After the first contact session an appointment was scheduled with the potential participants, telephonically or by email, to undergo analysis at the motion analysis laboratory.

Once there, all participants were assigned a number that indicated whether they were a patient/case or a control, and if they were a case, the affected side was determined. Leg dominance was recorded and was defined as the kicking leg (Schneiders et al, 2010). For bilaterally affected cases, the most painful side was identified. Participants then underwent a standard subjective and objective physical assessment conducted by a non-blinded physiotherapist according to the Maitland principles (Appendix G and H). Even though the cases had a positive adductor squeeze test indicating adductor pathology, the sacro-iliac joint (SIJ) was excluded as a source of groin pain with the following battery of tests: Patrick's FABER test, Gaalen's test, the P4 test and the anterior pelvic gapping test (Vleeming et al., 2008) and the hip joint was excluded as a source of groin pain with the hip quadrant test (Maitland, 1991). An assessment of the spinal curvature of the participants was performed using the scoligauge with the participants in standing, full forward flexion of the trunk and knees extended. Measurements were taken at the level of the PSIS, T12, T8 and T2. The scoligauge is an application on the Apple iPhone. This has been validated previously in a study comparing it to the scoliometer (Franko et al., 2012). The procedure is the same as for the scoliometer but the examiners's thumbs are placed along the lower border of the device with the ends of the thumb tips in line with the markers. The thumbs are then placed on either side of the spinous process at the level to be measured. The cases were asked to cough as a crude eliminator of Sportsman's Hernia. (Messaoudi et al., 2012; Morelli and Weaver, 2005)



**Figure 1: Flow chart of subject recruitment**

### **3.3.5 Instrumentation**

For this study an eight-camera T-10 Vicon (Ltd) (Oxford, UK) system with Nexus 1.4 116 software was used to capture trials. The Vicon Motion Analysis (Ltd) (Oxford, UK) system is a three-dimensional (3D) system that is used in a wide variety of ergonomic and human factor applications (Windolf et al., 2008).

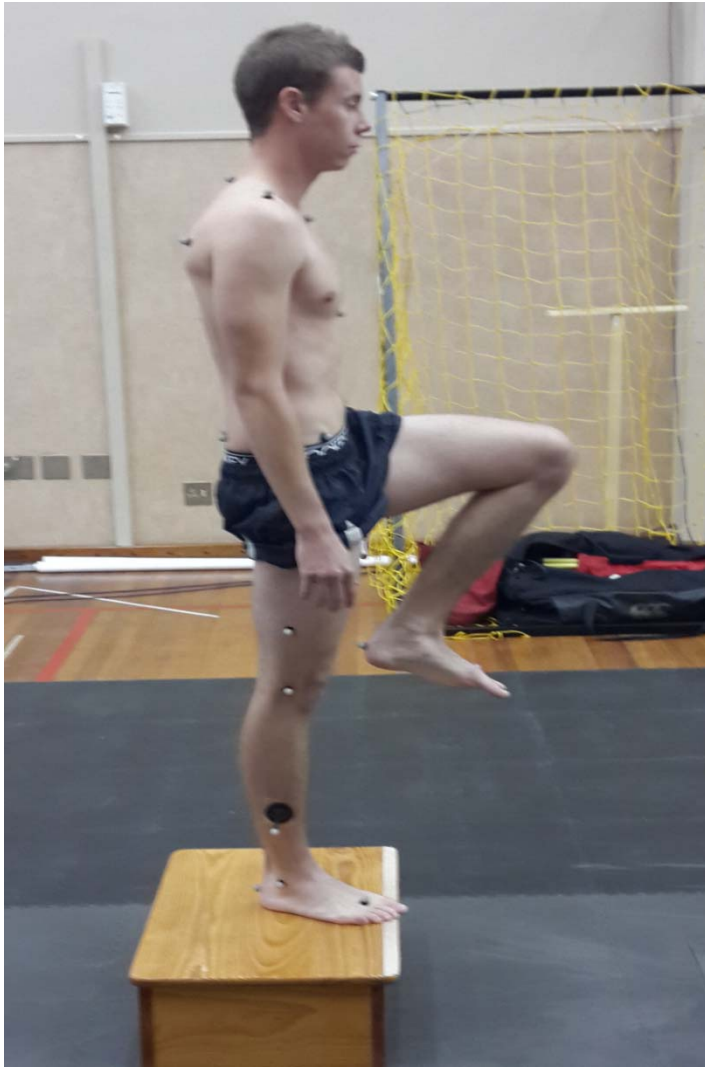
### 3.3.6 Motion analysis

Anthropometric measurements required for Vicon motion analysis were taken by the same research assistant who applied the markers to insure intra-rater reliability. These included leg length, weight, height, knee width and ankle width. These measurements were taken according to the prescribed manor for the Plug-in Gait (PIG) model of Vicon (Ltd) (Oxford, UK) (Vicon Plug-in Gait Product Guide-Foundation Notes Version 2.0 2010: 67-68 at [www.vicon.com](http://www.vicon.com)). This research assistant has extensive experience in this as well as extensive training in marker placement, understands the PIG model and has a high inter-session reliability ( $r=0.92$ ) for all three planes. Thirty-three retro-reflective markers (14 mm diameter) were placed on bony landmarks according to the Plug-in Gait (PIG) full-body model (see Appendix I).

Participants were dressed in shorts. All other clothing, including shoes, and all reflective articles such as jewellery and watches, were removed.

Calibration was performed with each participant performing a T-pose (standing with feet hip distance apart and both arms at 90 degrees of flexion and abduction with elbows extended and hands facing downwards) in the capture volume to determine if all markers were detected by the system. The markers applied to the anatomical body positions were labelled to construct a graphic simulation of the subject.

A standardised warm-up of six walking trials (approximately 20 m each) was completed by each subject prior to motion analysis testing. All system calibration and preparation was done by the laboratory engineers prior to data capture, who were also not blinded. Participants were required to complete six single-leg drop landings with each leg from a 20 cm height platform (Figure 2).



**Figure 2: Start position for drop landing**

The start leg was randomised with a coin toss and thereafter alternated. The platform was placed at a distance of exactly 60% of a particular participant's leg length (iliac crest to the inferior lateral malleolus) away from the force plate. Participants were asked to stand in the middle of the platform with their toes behind the painted line and their weight evenly distributed on both feet. They were instructed to bend the hip and knee of the non-testing leg up to 90 degrees, keeping their arms comfortably at their sides. They were then requested to jump with the stance leg onto the force plate. The instructions given were: 'ready ... lift ... jump'. They were

asked to land comfortably and maintain their position, balancing on the landing foot, for five seconds. If the participant fell upon landing then the drop landing was repeated. A fall was defined as a touch onto the force plate by any body part other than the required foot. The procedure was demonstrated by the researcher and the participants were given one practice jump on each leg. One practice jump only on each leg was allowed so that the risk of fatigue and symptom provocation was diminished, especially in the cases. Six trials of 101 seconds duration on each leg were captured for thoracic spine kinematics.

### **3.3.7 Data Processing**

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

The key outcomes measured were:

- thoracic spine angle at initial foot contact;
- maximum thoracic spine angle;
- ROM (difference between the minimum and maximum values); and
- thoracic spine angle at lowest vertical point of the pelvis.

This was captured in all three movement planes: the sagittal plane (X plane), the coronal plane (Y plane) and the transverse plane (Z plane).

### 3.3.8 Sample size calculation

Gpower Version 3.1 statistical power analysis was used for the calculation.

*Unilaterally painful (n=14)*: For a large effect size of one (alpha 0.05) and a sample size of 14 the post hoc power calculation is 93%. For a medium effect size (alpha 0.05) and a sample size of 14, the post hoc power calculation is 73%.

*Bilaterally painful (n=6)*: For a large effect size of one (alpha 0.05) and a sample size of 6, the post hoc power calculation is 50%. For a huge effect size (alpha 0.05) and a sample size of 6, the post hoc power calculation is 80%.

**Table 3: Relative size of Cohen's d:**

Effect	Size
Small effect	$\geq 0.15$ and $< 0.40$
Medium effect	$\geq 0.40$ and $< 0.75$
Large effect	$\geq 0.75$ and $< 1.10$
Very large effect	$\geq 1.10$ and $< 1.45$
Huge effect	$> 1.45$

### 3.3.9 Statistical analysis

All data was analysed by the laboratory technicians and researchers (using graphs) to identify outliers. The corrected data was substituted where necessary. Descriptive statistical analysis was conducted to assess for differences in demographic data between the two groups and the t-test was used to obtain the p value:  $p \leq 0.05$  was

used to represent statistical significance. Thereafter the cases were separated into two sub-groups: unilaterally painful and bilaterally painful. The t-test was again used to determine statistically significant differences between these two sub-groups. Descriptive statistical analysis was then applied to the kinematic data of the chosen parameters and the effect size was calculated using the Cohen's d equation (Table 3). For the bilaterally painful group, the most affected leg was compared with the same leg of the matched control and the same done for the least painful leg. Standard Deviation (SD) is given given in brackets throughout in Table 4 to Table 7.

### **3.4 RESULTS**

#### **3.4.1 Sample description**

The ten cases (mean age:  $27.31 \pm 9.75$ ) and ten controls (mean age:  $28 \pm 10.06$ ) were matched with regard to age and sport participation. Three cases had bilateral groin pain with one side worse than the other and seven cases had unilateral groin pain. No clinically significant spinal curvature was recorded in any of the participants (Grindstaff et al., 2012). None of the participants had positive findings for the SIJ or the hip joint as primary or secondary causes of their groin pain. None of the participants had a positive cough test.

Table 4 describes the basic sample demographics, VAS scores and symptom duration. There were no significant differences in age, weight, height, VAS (worst VAS post-activity) or duration of symptoms between the groups; however, the mean weight of the bilaterally painful group was 10 kg more than their matched controls.

**Table 4: Sample demographics**

	Mean age (yrs)	Mean weight (kg)	Mean height (m)	Mean worst VAS post- activity ( /10)	Mean duration of symptoms (yrs)
<b>Unilateral pain participants (seven participants)</b>					
<b>Cases</b>	29 (10.26)	86.8 (21.67)	1.80 (0.07)	6.29 (1.11)	1.64 (1.99)
<b>Control</b>	28.71 (11.79)	85.71 (17.02)	1.77 (0.09)	-	-
<b>p value<sup>1</sup></b>	0.958	0.873	0.187		
<b>Bilateral pain participants (three participants)</b>					
<b>Case</b>	28.67 (9.61)	91.83 (15.26)	1.81 (0.09)	6 (3)	3.34 (2.52)
<b>Control</b>	26.34 (5.69)	81.57 (6.38)	1.77 (0.08)		
<b>p value<sup>1</sup></b>	0.696	0.4866	0.441		

<sup>1</sup>  $P \leq 0.05$  was used to represent statistical significance for all comparisons.



### 3.4.2 Sample kinematics: Differences between cases and controls

#### 3.4.2.1 *Unilaterally painful group*

From Table 5 one can see that the cases land in significantly more thoracic forward flexion (large effect) and are in significantly more thoracic flexion still at the lowest point. Peak thoracic flexion is significantly more in the cases than the controls. There were no significant differences in the frontal or transverse planes.

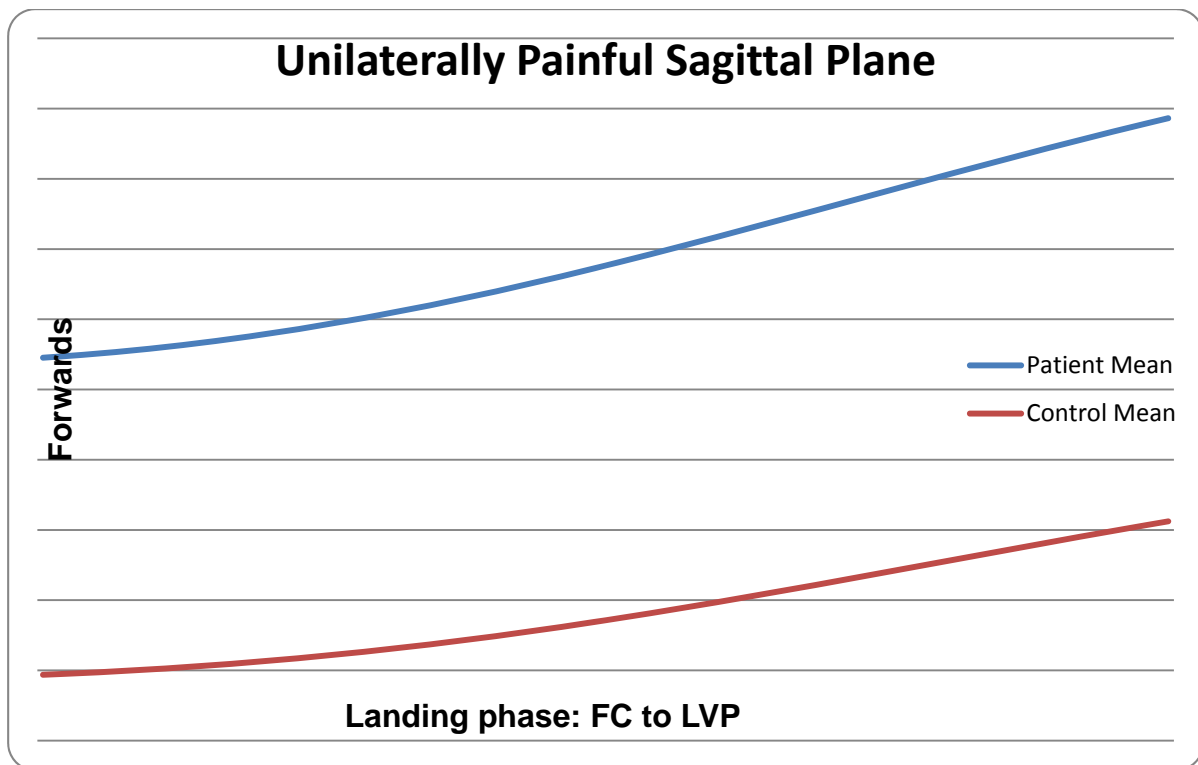
**Table 5: The UNILATERALLY painful cases (n=7) compared to the same side of their matched controls (n=7)**

	Angle at foot contact mean (SD)	Max. mean (SD)	Range mean (SD)	Angle at lowest point mean (SD)
<b>Sagittal plane (X)<sup>1</sup></b>				
<b>Case</b>	5.452 (4.26)	9.39 (8.6)	4.58 (5.03)	8.86 (8.64)
<b>Control</b>	0.94 (6.94)	3.69 (9.23)	3.38 (2.55)	3.12 (9.83)
<b>p value</b>	p<0.001	p<0.001	p=0.060	p<0.001
<b>Effect size</b>	0.85 large	0.69 medium	0.33 small	0.67 medium
<b>Frontal plane (Y)<sup>2</sup></b>				
<b>Case</b>	-5.75 (4.00)	-4.39 (5.16)	2.47 (1.64)	-5.45 (5.92)
<b>Control</b>	-5.59 (4.23)	-4.84 (4.55)	2.39 (1.81)	-6.53 (5.21)
<b>p value</b>	p=0.068	p=0.658	p=0.844	p=0.324
<b>Transverse plane (Z)<sup>3</sup></b>				
<b>Case</b>	3.57 (2.98)	4.68 (3.80)	2.04 (1.61)	3.73 (4.28)
<b>Control</b>	2.29 (3.85)	5.19 (6.55)	3.45 (5.30)	4.66 (6.97)
<b>p value</b>	p=0.161	p=0.917	p=0.128	p=0.661

<sup>1</sup> **Sagittal plane:** positive value indicates flexion (F) and negative value indicates extension (E).

<sup>2</sup> **Frontal plane:** positive value indicates lateral flexion (LF) towards the centre and a negative value indicates LF downwards away from the centre/towards landing leg.

<sup>3</sup> **Transverse plane:** positive value indicates thoracic spine (TX) rotation towards the landing side and a negative value indicates TX rotation away from the landing side.



**Figure 3: Mean sagittal plane kinematics of unilateral groin-pain cases (n=7) versus controls (n=7) from foot contact (FC) to the lowest vertical point of the pelvis (LVP)**

### 3.4.2.2 *Bilaterally painful group: Worst-affected side*

Table 6 demonstrates that the cases land in significantly more axial rotation and are in significantly more rotation still at the lowest point. Peak thoracic rotation is significantly greater, and yet the total ROM of the cases in the transverse plane (axial rotation) was significantly less than the controls.

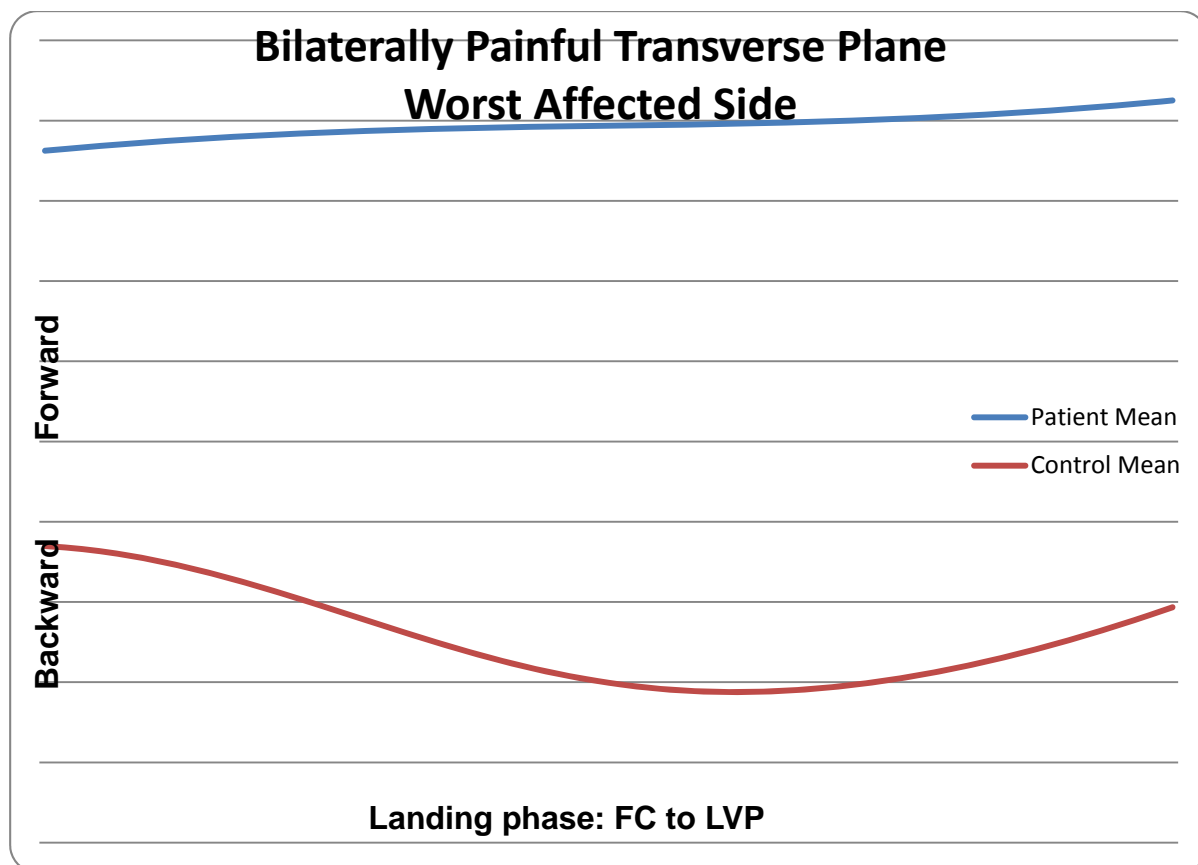
**Table 6: The BILATERALLY painful cases (n=3) worst-affected side compared to the same side of their matched controls**

	Angle at initial foot contact mean (SD)	Max. mean (SD)	Range mean (SD)	Angle at lowest point
<b>Sagittal plane (X)<sup>1</sup></b>				
<b>Case</b>	0.72 (2.09)	4.49 (3.36)	4.52 (2.39)	3.78 (4.35)
<b>Control</b>	0.18 (4.27)	3.18 (6.69)	3.21 (2.78)	2.85 (6.70)
<b>p value</b>	p=0.608	p=0.536	p=0.260	p=0.692
<b>Frontal plane (Y)<sup>2</sup></b>				
<b>Case</b>	-5.62 (3.35)	-4.24 (2.67)	2.53 (1.69)	5.31 (3.38)
<b>Control</b>	-4.27 (1.96)	-2.86 (2.82)	3.94 (3.18)	-4.96 (5.04)
<b>p value</b>	p=0.117	p=0.117	p=0.123	p=0.802
<b>Transverse plane (Z)<sup>3</sup></b>				
<b>Case</b>	1.81 (3.08)	2.13 (3.48)	0.31 (0.40)	2.13 (3.48)
<b>Control</b>	-0.65 (5.58)	-0.66 (5.59)	1.46 (0.58)	-1.03 (4.75)
<b>p value</b>	p=0.042	p=0.042	p=0.040	p=0.002
<b>Effect size</b>	0.67 medium	1.37 very large	0.42 medium	0.79 large

<sup>1</sup> **Sagittal plane:** positive value indicates flexion (F) and negative value indicates extension (E).

<sup>2</sup> **Frontal plane:** positive value indicates lateral flexion (LF) towards the centre and a negative value indicates LF away from the centre/towards landing leg.

<sup>3</sup> **Transverse plane:** positive value indicates thoracic spine (TX) rotation towards the landing side and a negative value indicates TX rotation away from the landing side.



**Figure 4: Mean transverse plane kinematics of bilateral groin-pain cases (n=3) versus controls (n=3) on worst-affected side**

### 3.4.2.3 *Bilaterally painful group: Least-affected side:*

The cases displayed significantly greater axial rotation on landing and lowest vertical point. Peak axial rotation was greater, yet the total ROM for the cases in the transverse plane was again significantly less than for the controls. No significant differences were noted for the sagittal plane. In the frontal plane, the cases landed in significantly more lateral flexion towards the landing leg.

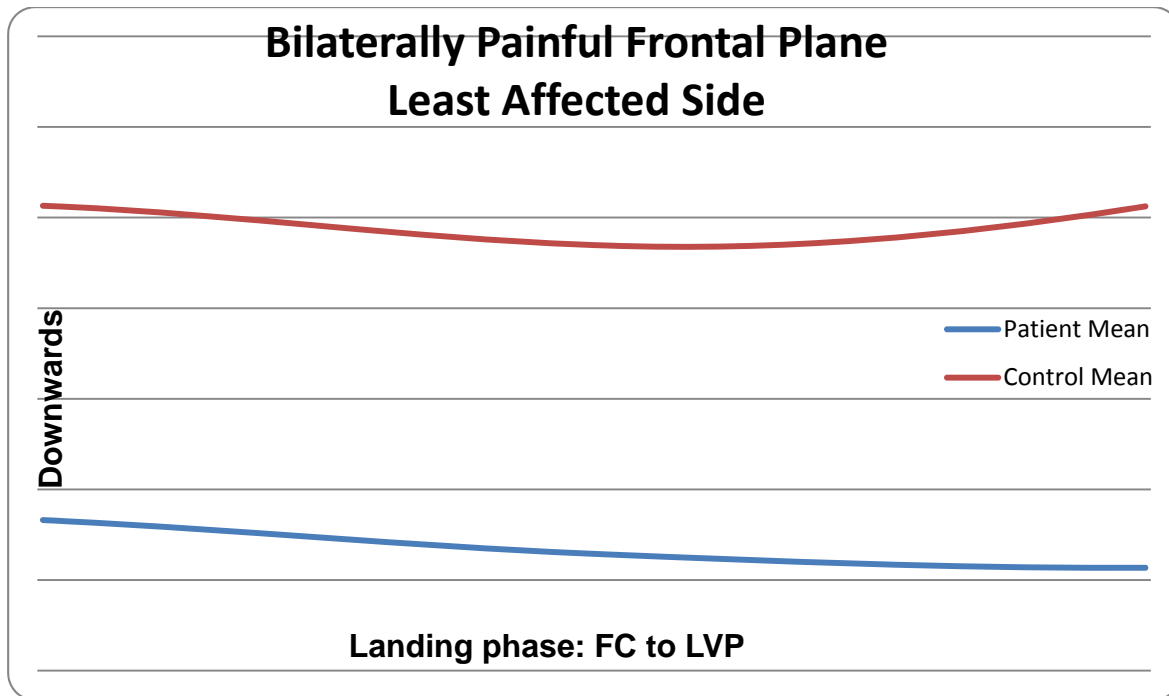
**Table 7: The BILATERALLY painful least-affected side (n=3) compared to the same side of their matched controls**

	Angle at initial foot contact mean (SD)	Max. mean (SD)	Range mean (SD)	Angle at lowest point of pelvis
<b>Sagittal plane (X)<sup>1</sup></b>				
<b>Case</b>	-0.17 (3.67)	1.10 (0.55)	2.26 (4.57)	2.06 (5.75)
<b>Control</b>	1.54 (4.07)	4.03 (5.80)	2.85 (2.13)	3.82 (5.97)
<b>p value</b>	p=0.214	p=0.051	p=0.609	p=0.469
<b>Frontal plane (Y)<sup>2</sup></b>				
<b>Case</b>	-10.67 (7.87)	-9.60 (8.49)	3.40 (2.43)	-11.73 (9.96)
<b>Control</b>	-3.73 (3.05)	-2.23 (4.39)	3.40 (2.26)	-3.75 (5.38)
<b>p value</b>	p=0.007	p=0.012	p=0.992	p=0.014
<b>Effect size</b>	1.42 very large	1.34 very large		1.22 very large
<b>Transverse plane (Z)<sup>3</sup></b>				
<b>Case</b>	-6.03 (5.94)	-5.00 (6.08)	2.05 (1.39)	-6.03 (6.02)
<b>Control</b>	1.53 (3.29)	3.05 (4.56)	3.40 (1.67)	1.29 (5.50)
<b>p value</b>	p<0.001	p<0.001	p=0.006	p<0.001
<b>Effect size</b>	1.93 huge	1.83 huge	1.08 large	1.55 huge

<sup>1</sup> **Sagittal plane:** positive value indicates flexion (F) and negative value extension (E).

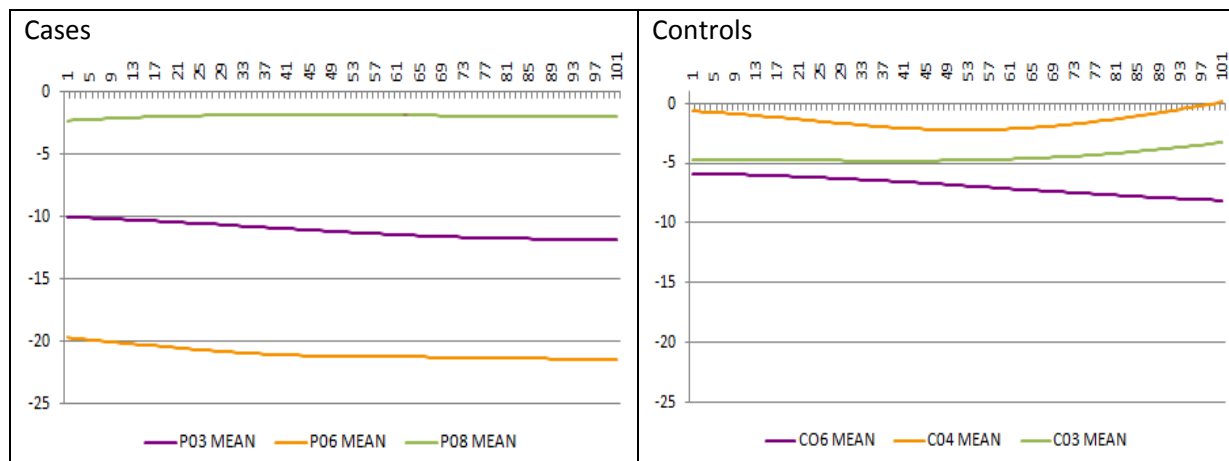
<sup>2</sup> **Frontal plane:** positive value indicates lateral flexion (LF) towards the centre and a negative value indicates LF away from the centre/towards landing leg.

<sup>3</sup> **Transverse plane:** positive value indicates thoracic spine (TX) rotation towards the landing side and a negative value indicates TX rotation away from the landing side.



**Figure 5: Mean frontal plane kinematics of bilateral groin-pain cases (n=3) versus controls (n=3) on least-affected side**

However, for the bilaterally affected group of three men there were large differences between the cases and also between the cases and the controls. Figure 6 demonstrates this for movement in the frontal plane on the least painful side.



P06 (102.8 kg) matched C04 (74.7 kg) and landing on left (non-dominant) side.

P03 (98.3 kg) matched C06 (87.3 kg) and landing on right (dominant) side.

P08 (74.4 kg) matched C03 (82.7 kg) and landing on left (non-dominant) side.

**Figure 6: Frontal plane kinematics of bilateral groin-pain cases (n=3) versus controls (n=3) on least-affected side**

### 3.5 DISCUSSION

From the results there is a strong indication that there are kinematic differences in the thoracic spine between those sports participants with long-standing groin pain and those without. The cases with unilateral groin pain landed in significantly more thoracic forward flexion and remained in significantly more flexion throughout the landing phase, with peak thoracic flexion also significantly greater than controls. The same tendency existed in the bilaterally painful group, but this was not statistically significant.

Blackburn and Padua (2008) reported that flexing the trunk during a drop landing produces a smaller peak vertical ground-reaction force. Shimokochi et al. (2012) supported these findings and showed that modifying upper-body position at initial foot contact during landing considerably influences lower extremity neuromuscular control during the subsequent descending phase. They suggested that leaning forward may be ACL protective. Certainly, protecting joints requires increased muscular strength and control. In addition, a greater trunk perturbation would require increased muscular effort in the extremities to maintain balance. This exaggerated trunk flexion may therefore also be a result of core instability. Reduced hip and trunk strength has been associated with an increased risk of knee injury (Cowan, Crossley and Bennell, 2011) as well as spinal and lower extremity injury (Leetun et al., 2004) and including groin injuries (Wilkerson et al., 2012). Cowan et al. (2004) showed that there was a delayed transversus abdominus contraction in the long-standing groin-injury group compared with controls. Transversus abdominus has been shown to stiffen the spine in anticipation of movement in the extremities and is believed to be important for core stability (Cowan et al., 2004).

In the bilaterally painful group, axial rotation ROM was significantly reduced when landing on either leg. The same occurred in the unilaterally affected group, although this was not statistically significant. Seay, Van Emmerik and Hamill (2011) suggested that runners with LBP incorporated a 'guarded gait' that reduced the amount of rotation between the trunk and pelvis during running. Considering that the adductors are stabilisers of the leg in closed-chain activities, this reduction in axial rotation may then also be protective or 'guarding' in nature.

In the bilaterally affected group the significant difference noted in the frontal plane was thought to be skewed because the two heavier cases landed in significantly more lateral flexion away from neutral than the other case or the three controls.

Applying these findings clinically, our research results suggest that rehabilitation after groin injury should not only involve the adductors and the hip joint, but the entire kinetic chain. Care should be taken to include functional rehabilitation like cutting manoeuvres and landing strategies. Ekstrand et al. (2007) showed a lower re-injury rate in male soccer players following such a ten-step programme, which also offered a structured way of assessing symptoms through functional rehabilitation, thereby avoiding premature return to play. The FIFA 11+ program, which includes core and leg strengthening and stretching as well as balance, agility, plyometrics, running and cutting manoeuvres, has also been shown to significantly reduce injuries in elite male basketball players (Longo et al., 2012) when used as pre-rehabilitation and in female soccer players (Soligard et al., 2008) when used as a warm-up program. Evidence suggests that between 4 and 16 weeks are required for exercise intervention to be effective for groin injuries (Machotka, Kumar and Perraton, 2009) and on average 18-and-a-half weeks for chronic groin injuries (Holmich et al., 1999)



The limitations of our study include, firstly, that kinetics were not looked at and secondly, that we were not able to find standard measurements on how many degrees of trunk perturbation during landing is actually normal or harmful to the lower-extremity stabilising muscles so that we could compare our results. Thirdly, because our study is cross-sectional, cause and effect cannot be determined. No blinding of assessors was done, but owing to the objective nature of Vicon motion analysis and the fact that it is difficult to manipulate the data, it is uncertain what effect blinding would have achieved. Further research is needed to establish these norms and to confirm our findings in larger sample sizes.

### **3.6 CONCLUSION**

Chronic groin pain is a problem for active sports participants because of the high prevalence rate, complex pathology and prolonged time away from activity. The aim of this study was to determine if there are thoracic kinematic differences in chronic groin-pain patients versus controls during a single-leg drop-landing task. Our study suggests that, in participants with chronic groin pain, there is greater thoracic forward flexion away from neutral during landing and that total axial rotation ROM during landing is diminished, therefore suggesting that rehabilitation after groin injury should not only involve the adductors and the hip joint, but the entire kinetic chain. Further research is needed to investigate these parameters with a larger sample of athletes.

### 3.7 REFERENCES

- Blackburn JT, Padua DA 2008 Influence of trunk flexion on hip and knee joint kinematics during a controlled drop landing. *Clinical Biomechanics* 23(3): 313–319.
- Chockalingam N, Dangerfield PH, Giakas G, Dorgan J, Cochrane T 2002 Examination of relative movement between the back and lower limb. *Studies in Health Technology and Informatics* 88: 95–99.
- Cowan SM, Crossley KM, Bennell KL 2009 Altered hip and trunk muscle function in individuals with patellofemoral pain. *British Journal of Sports Medicine* 43: 584–588.
- Cowan SM, Schache AG, Brukner P 2004 Delayed onset of transversus abdominus in long-standing groin pain. *Medicine and Science in Sports and Exercise* 36(12): 2040–2045.
- French D, Hibbs AE, Spears I, Thompson KG, Wrigley A 2008 Optimizing performance by improving core stability and core strength. *Sports Medicine* 38(12): 995.
- Hackney R 2012 Groin pain. *Journal of Orthopaedics and Trauma* 26(1): 25–32.
- Holmich P 2007 Long-standing groin pain in sports people falls into three primary patterns, a ‘clinical entity’ approach: a prospective study of 207 patients. *British Journal of Sports Medicine* 41: 247–252.
- Koulouris G 2008 Imaging review of groin pain in elite athletes: an anatomic approach to imaging findings. *American Journal of Rehabilitation* 191: 962–972.

- Kulas A, Zalewski P, Hortobagyi T, DeVita P 2008 Effects of added trunk load and corresponding trunk position adaptations on lower extremity biomechanics during drop-landings. *Journal of Biomechanics* 41(1): 180–185.
- Maffey L, Emery C 2007 What are the risk factors for groin strain injury in sport? *Sports Medicine* 37(10): 881–894.
- McSweeney SE, Naraghi A, Salonen D, Theodoropoulos J, White LM 2012 Hip and groin pain in the professional athlete. *Canadian Association of Radiologists Journal* 63(2): 87–99.
- Morelli V, Weaver V 2005 Groin injuries and groin pain in athletes: part 1. *Primary Care* 32(1): 163–183.
- Machotka Z, Kumar S, Perraton L 2009 A systematic review on the effectiveness of exercise therapy for groin pain. *Sports Medicine, Arthroscopy, Rehabilitation, Therapy and Technology* 1(5): 1–10.
- Quinn, A 2010 Hip and groin pain: physiotherapy and rehabilitation issues. *Open Sports Medicine Journal* 4: 93–107.
- Seay JF, Van Emmerik REA, Hamill J 2011 Influence of low back pain status on pelvis-trunk coordination during walking and running. *Spine* 36(16): E1070–E1079.
- Windolf AW, Götzen N, Morlock M 2008 Systematic accuracy and precision analysis of video motion capturing systems—exemplified on the Vicon-460 system. *Journal of Biomechanics* 41: 2776–2780.



## CHAPTER 4: SUMMARY AND CONCLUSION

While groin injuries are common in sport, the diagnosis, treatment, and rehabilitation of these injuries is a complex and challenging area for all clinicians (Quinn, 2010). Often there is more than one cause for the groin pain and symptoms overlap. In a study of long-standing groin pain in athletes, Holmich et al. (1999) found that 72% of athletes had ceased to participate in sports because of their groin pain and the protracted rehabilitation times needed for full recovery and return to activity was highlighted. Many authors agree that a better understanding of the biomechanical factors that may be involved in chronic groin pain would be beneficial to everyone concerned.

Maffey and Emery (2007) suggested in their systematic review that a large percentage of groin pain may be due to an inability to properly load transfer from the legs and torso to the pelvis, and concluded by stating that future research should target risk factors beyond the groin alone, including torso stabilising muscles. There has been increasing interest in the role of the trunk and thorax with lower extremity injuries recently and a great deal of emphasis has been placed on core strength in the rehabilitation of these injuries. Shimokochi et al. (2012) stated that although there have been some limited reports, few comprehensive examinations of the actual effects of different (sagittal plane) body positions on lower-extremity biomechanics during landing exist. Therefore, the objective of our study was to explore the kinematics of the thorax in active sports participants with chronic groin pain, compared with healthy controls.

Our study was a cross-sectional descriptive study that took place at the University of Stellenbosch 3D Movement Analysis Laboratory. Twenty male participants between

the ages of 19 and 55 were recruited from various sports clubs in the Western Province, ten with chronic groin pain (unilateral or bilateral of more than three months duration) and ten without, matched for age and sports participation. These included four runners, two cyclists, four soccer players and ten rugby players. The inclusion criteria for all participants were that they were generally in good health and still participating in sport or exercise of some nature. In Morelli and Weaver's (2005) systematic review, 62% of groin injuries were identified as adductor strains. In order to confirm an adductor musculo-tendinous origin for our groin-pain cases, the adductor squeeze test was done and only those with a positive test were recruited. The matching controls were required not to have experienced any lower quadrant pain/lower back pain in the last three months. For bilaterally affected cases, the most painful side was identified. The participants all underwent a standardised subjective and objective physical assessment to ensure that they had full functional range of motion and did not have any other lower-extremity or spinal injuries. The hip joint and the SIJ were eliminated as sources of the groin pain and the 'cough test' was performed as a crude eliminator of sportsman's hernia. An assessment of the spinal curvature of the participants was performed using the scoligauge. No secondary clinical entities and no clinically significant spinal curvature presented in any of the participants.

For motion analysis data capture, 33 retro-reflective markers (14 mm diameter) were placed on bony landmarks of all participants according to the PIG full-body model. After a standardised warm-up and system calibration, participants were required to complete six single-leg drop landings with each leg from a 20 cm height. The start leg was randomised and subsequently alternated. The platform was placed at a distance of exactly 60% of a participant's leg length (iliac crest to the inferior lateral

malleolus) away from the force plate. The outcome measures recorded were thoracic spine angle at initial foot contact, maximum thoracic spine angle, ROM (difference between minimum and maximum values) and thoracic spine angle at the lowest vertical point of the pelvis. This was assessed in all three movement planes: the sagittal plane (X plane), the coronal plane (Y plane) and the transverse plane (Z plane).

The results of our study indicate that for the unilaterally affected groin-pain group the cases landed in significantly more thoracic forward large flexion ( $p < 0.001$  with large effect size) and were in significantly more thoracic flexion still at the lowest point. Peak thoracic flexion was significantly more in the cases than the controls ( $p < 0.001$  with medium effect size). The same was true for the bilaterally affected group when landing on the most painful side, although this was not statistically significant. There were no significant differences in the frontal or transverse planes. In the bilaterally painful group, axial rotation ROM was significantly reduced when landing on either leg (worst-affected side:  $p = 0.040$  with medium effect size and least-affected side:  $p = 0.006$  with large effect size). The same occurred in the unilaterally affected group, although this was not statistically significant.

Our study suggests that in participants with chronic groin pain there is greater thoracic forward flexion away from neutral during landing and that total axial rotation ROM during landing is diminished.

Applying these findings clinically, our research suggests that rehabilitation after groin injury should not only involve the adductors and the hip joint, but the entire kinetic

chain. Care should be taken to include functional rehabilitation like cutting manoeuvres, skills training and landing strategies.

The limitations of our study include, firstly, that kinetics were not looked at and secondly that we were not able to find standard measurements on how many degrees of trunk perturbation during landing is actually normal or harmful to the lower extremity stabilising muscles. That would have allowed us to compare our results. Thirdly, because our study is cross-sectional, cause and effect cannot be determined.

The fact that three of our cases presented with bilateral groin pain compromised our sample size as separate groups had to be established, which reduced the number of cases in each group. Further research is needed to establish these norms and to confirm our findings in larger sample sizes.



## APPENDICES

### APPENDIX A – Letter to the editor: *SA Journal of Physiotherapy*

**Tracy Louise Morris: Registered Physiotherapist**

**Pr. no. 7224877**

*Unit 5, 1<sup>st</sup> Floor*

*Hout Bay Medical Centre*

*30 Victoria Avenue, Hout Bay, 7806*

*Tel: (021) 7901115 (h) (021) 7904094 (w)*

To: Prof. J. Franz  
P/Bag X17  
Bellville  
7535  
PH: (021) 959 2542  
Fax: (021) 959 1217  
Email: [sajp@wwc.ac.za](mailto:sajp@wwc.ac.za)

Dear Editor

I would like to submit my manuscript entitled “Thoracic spine kinematics during single leg drop landing in sports participants with chronic groin pain”.

This manuscript will be of interest to your readers because it focuses on trunk kinematics in patients with chronic groin strains and contributes to the growing body of knowledge about how landing strategies during sporting activities affect lower limb injuries.

To date there has been no research into kinematics of the trunk with regards to chronic groin pain and so I hope my article will address this gap in present knowledge.

Kind regards,

Tracy Louise Morris

## **APPENDIX B – Manuscript title page**

### **THORACIC SPINE KINEMATICS DURING SINGLE LEG DROP LANDING IN SPORTS PARTICIPANTS WITH CHRONIC GROIN PAIN**

#### **Authors:**

**Morris TL (BSc Physiotherapy) <sup>1</sup>**

Unit 5, 1st Floor

Hout Bay Medical Centre

30 Victoria Avenue, Hout Bay, 7806

Tel: +27 21 790 4094 (w) +27 21 790 1115(h)

**Diener I (PhD)<sup>1</sup>**

16 Formosa Street, Stellenbosch, Western Cape, 7600

Tel: +27 21 887 1804 (w) Fax: +27 21 616 1208

**Louw Q (PhD)<sup>1</sup>**

Stellenbosch University Physiotherapy Department, Francie van Zijlrylaan, Parow,  
Western Cape, 7500

Tel: +27 21 938 9111 (w)

#### **Correspondence author:**

**Morris TL (BSc Physiotherapy)<sup>2</sup>**

Unit 5, 1st Floor

Hout Bay Medical Centre

30 Victoria Avenue, Hout Bay, 7806

Tel: +27 21 790 4094 (w) +27 21 790 1115(h)

**This thesis fulfils a requirement for a M.Sc in Physiotherapy (OMT) at the  
University of Stellenbosch.**

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<sup>1</sup> University of Stellenbosch, Western Cape, South Africa.

<sup>2</sup> University of Stellenbosch, Western Cape, South Africa.

## **APPENDIX C – Ethics approval letter**

### **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

## APPENDIX D – Ethics consent form

	<b>STELLENBOSCH UNIVERSITY</b> <b>FACULTY OF MEDICINE AND HEALTH SCIENCES</b>	
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### HEALTH RESEARCH ETHICS COMMITTEE 1 AND 2 APPLICATION FORM

*(INFORMATION SHOULD BE TYPED)*

SECTION 1: DETAILS OF APPLICANT/PRINCIPAL INVESTIGATOR		
Name: Tracy	Surname: Morris	Professional Status: Physiotherapist
University Division and Department:		MSc OMT, Physiotherapy, Faculty of Health Sciences
Complete Postal Address: PO Box 1203, Bokkemannskloof, Hout Bay, 7806		
Telephone No: 021 790 1115	Fax No: 086 529 4212	Cell No: 083 682 0644
E-mail address:		tracyloumorris@gmail.com
SECTION 2: TITLE OF STUDY		
Title of Research Project:		
Exploration of Biomechanics During Functional Activities in Adult Sports Participants with Chronic		
Groin Pain		
Sponsor's Protocol No. (if applicable)		
Sponsor's Details (if applicable)		
SECTION 3: STUDY FOR DEGREE PURPOSES		Not applicable
Name of Degree: MSc OMT		Supervisor: Professor Quinette Louw
Division/Department: Physiotherapy		E-mail: qalouw@sun.ac.za
Contact No:		

**OFFICE USE ONLY**

Approved by HREC 1		Approved by HREC 2		Project ID
Conditional				
Provisional				
Direct				
Final				
<b>SECTION 4: DETAILS OF SUB-INVESTIGATORS</b>				
Name and Title		Position	Division/Department	
1. Michael Dare		Physiotherapist	Private Sector	
2. Lauren Harwin		Physiotherapist	Department of Defence	
3. Lienke Janse van Rensburg		Physiotherapist	Private Sector	
4. Karien Visser		Physiotherapist	Private Sector	
5.				
<b>SECTION 5: DETAILS OF COLLABORATING INVESTIGATORS</b>				
Name and Title		Position	Division/Department	
1.				
2.				
3.				
4.				
<b>SECTION 6: WHERE WILL THE STUDY BE CONDUCTED?</b>				
1. Tygerberg Hospital				
2. Stikland Hospital				
3. Karl Bremer Hospital				
4. Faculty of Medicine and Health Sciences				
5. Other: please list		Physiotherapy and Motion Analysis Clinic, Tygerberg Campus		

SECTION 7: HUMAN SUBJECTS RESEARCH PROTECTION			
1. Does the Research involve Human Subjects who are Alive? Dead (includes identifiable tissues specimens)? Medical records only?			Yes No No
2. Will any medicine be tested during the investigation?			No
2.1 If Yes to question 2, is the medicine approved by the Medicines Control Council?			N/A
2.2 If yes to question 2.1, is the medicine registered for the dose which will be used in this specific project?			N/A
2.3 If Yes to question 2.1, is the medicine registered for the indication(s) which will be used in this specific project?			N/A
2.4 If No to question 2.1, is the medicine approved by the Medicines Control Council for your use in this specific project?			N/A
2.5 If No to question 2.2 and/or 2.3, is the medicine approved by the Medicines Control Council for your use in this specific project?			N/A
1. Will any radioactive material be administered to the patient during the investigation?			No
2. Is any biohazardous material (*) involved in the project?			No
3. Have you acquainted yourself with the code of conduct regarding the Ethics of research and this Institution and do you undertake to fully comply with it at all times?			Yes
(*) "Biohazardous material" refers to recombinant DNA molecules, viruses, fungi, parasites, bacteria and all other potentially biohazardous material or products that are dangerous to both the experimental patient and the researcher, and which is patient to ct stricontainment specifications and safety measures.			
SECTION 8: STUDY TYPE			
1. Industry Sponsored Clinical Trial		2. Self Initiated Clinical Trial	
3. Retrospective Record Review		4. Laboratory-Based Research	
5. Qualitative Research		6. Prospective Descriptive Study	x
7. Other		8. Please state type if 'Other':	
SECTION 9: HOW IS THIS RESEARCH FUNDED? STATE APROXIMATE TOTAL BUDGET			
1. Industry	R	2. NIH	R
3. Internal/Self	R	4. Other/ US Fed Agency	R

5.		6.	
7. External SA Grant	R	8. Internat. Grant	R
<b>SECTION 10: SIGNING OF APPLICATION</b>			
<p><b>Applicant:</b> .....</p> <p><b>Supervisor:</b> .....</p> <p><b>*Departmental Head:</b> .....</p> <p><b>*The Departmental Head may delegate this authority to a Divisional Head if he/she deems this appropriate.</b></p>			

The following obligatory documentation must be attached to this application form:

<b>PROTOCOL SUMMARY (Obligatory)</b>	
<p>Please provide a protocol synopsis or summary of the proposed research, <b>in addition to the full Protocol</b>, that is between <b>800 and 1500 words</b> long / no longer than 2 pages. The Protocol Synopsis or summary should contain the following:</p> <ul style="list-style-type: none"> <li>▪ Title</li> <li>▪ A short introduction, motivation and literature overview (1 paragraph only)</li> <li>▪ Research question or hypothesis</li> <li>▪ Aims and Objectives</li> <li>▪ A concise summary of the methodology</li> <li>▪ Description of subject population including characteristics, age range and number of subjects</li> <li>▪ If the Research will require blood draws, bone marrow biopsy samples, other biopsies or the collection of tissues, etc., performed solely because of participation in the Research, please indicate the exact amounts and frequency with which the samples will be taken</li> <li>▪ Anticipated risks as well as the precautions taken to minimize risk</li> <li>▪ Anticipated benefits</li> <li>▪ Ethical Considerations</li> </ul>	
<b>Checklist (Obligatory):</b>	
<b>General OR</b>	<b>x</b>
<b>Clinical Trial</b>	
<b>Investigator Declaration for principal, co- and sub investigators (Obligatory)</b>	<b>x</b>
<b>Investigator CVs</b>	<b>x</b>
<b>Protocol</b>	<b>x</b>

## **APPENDIX E – *South African Journal of Physiotherapy* Guidelines for Authors**

### **GUIDELINES FOR AUTHORS:**

Contributions to the *South African Journal of Physiotherapy* are invited on any topic related to Physiotherapy or rehabilitation. All articles that are submitted to the journal for publication must be accompanied by two questions with the correct answers.

#### **Types of Manuscripts**

1. Research
2. Case report
3. Clinical report
4. Technical report
5. Literature review
6. Short report

All manuscripts should be accompanied by a reference list.

#### **Legal Considerations**

Contributions will be considered for publication in the *South African Journal of Physiotherapy* on condition that

- they have not been published previously.
- they have not been submitted for publication elsewhere.
- the Publications Division of the SASP reserves the copyright of all material published.

#### **Acceptance of manuscripts**

All manuscripts will be reviewed by two appointed referees. Identities of both authors and reviewers will be kept confidential in order to eliminate bias. Most articles require revision, in which case the reviewers' comments will be returned to the authors for consideration and alteration.

#### **Preparation and Presentation of Manuscripts**

##### ***Articles***

1. Articles should be restricted to between 2 500 and 3 000 words.
2. The article should be typewritten with double spacing and wide margins.
3. A title page should be supplied as a separate sheet and include the name(s), qualifications and affiliation(s) of the author(s), together with addresses and telephone numbers (at home and at work).



4. Each article must be accompanied by an abstract of not more than 200 words. This should be on a separate sheet and should be intelligible without reference to the main text. Up to five key words should be included.
5. All abbreviations should be spelt out when first used.
6. The metric system is to be used throughout.
7. Headings must be presented in upper and lower case. Avoid using capitals only.
8. Authors must provide contact details; telephone numbers and email as well as postal address and institutional affiliation (hospital, University).

### ***Letters to the editor***

- if a letter is intended for the correspondence column it should be marked “for publication”.
- it should be no longer than 400 words.

### ***References***

The accuracy and the completeness of references are of the utmost importance, and a maximum of 15 references per paper is required.

#### **1. References in the Text of the Article**

When referring to more than one paper, place the names of the principal authors in alphabetical order, eg Armstrong (1990), Jones (1988) and Smith and Jones (1990) refer to similar findings.

When there are two authors of a paper, mention both, eg Smith and Jones (1990), but when there are three or more, mention only the principal author and follow with et al, eg Thomas et al (1980).

When citing an author's work within a sentence in the main text of your article, follow these examples:

- \_Smith (1982) refers to the length of time taken for the subject to respond to a stimulus.
- \_Smith and Jones (1990) refer to similar findings.
- -Smith (1982) and Thomas et al (1980) refer to problems in the method.

If quoting directly from another author, place the words in inverted commas and include the page number on which the quotation appears. For example: The clinical significance of increased tension or interruption of free movement in neural tissues is well recognised ...” (Yaxley and Jull 1990, p.143)

(Reference: Allison G (editor) 1997 Australian Journal of Physiotherapy Guidelines for Authors. In: Scientific Writers' Handbook. Australian Journal of Physiotherapy (publisher): 117)

## **2. Reference list**

This should appear at the end of the paper in alphabetical order. The author's name should be followed by the initials (unpunctuated) and separated from the next author by a comma. The names of all the authors should be cited and et al should not be used in the reference list. Next should follow the date of publication and then the details of the publication.

a) Journal articles. Having stated the authors and the year of publication, the title of the article should be given in full. There should be a full stop after the title. This should be followed by the full title of the journal (abbreviations should not be used), then the volume number (not the part number) followed by a colon and then the first and last pages of the publication. The required format is illustrated in the following example: Erickson M, Upshur C 1989

Caretaking burden and social support: Comparison of mothers of infants with and without disabilities. *American Journal of Mental Retardation* 94:250-258

b) Books. The format as illustrated in the example should be followed. (Note the use of punctuation and capital letters<sup>1</sup>).

1) Payton OD 1994 Research: The validation of clinical practice, 3<sup>rd</sup> edn. ppl51-156. F.A. Davis Company, Philadelphia

2) Shephard KF 1993 Questionnaire design and use. In: Bork CE (ed) *Research in Physical Therapy*, ppl76-204. J.B. Lippincott Company, Philadelphia

## **Illustrations**

- Tables and figures should be kept to a minimum and be on separate sheets.
- Each table should be numbered and have a clear title. Tables should not repeat material stated in the text. All tables and figures must be referenced in the text in sequential order.
- Don't send photographs as an integral part of a Word document. Send them separately as a Jpeg file.
- All illustrations should be clearly marked on the reverse side with arabic numerals, author's name and article, and an indication of the top side.
- All legends must be typed on a separate sheet.

- If a figure has been published before, the author must submit written permission from the copyright holder to reproduce the material.

### **Manuscript submission**

- A covering letter, which must include the signature of each co-author, should accompany each manuscript.
- Permission to reprint figures, extracts or abstracts from other publications should be included with the manuscript on submission.

### **Tick List: Yes No**

Covering Letter

Abstract 200 words

Article content 2500 – 3000

Short Report 1500

References as indicated in guidelines

3 CPD questions have been attached at the end of the article

All articles to be submitted electronically to [sajp@uwc.ac.za](mailto:sajp@uwc.ac.za)

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

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

A total of 33 markers will be required and placed on various points on the participants body. The participant will then be required to walk down a straight path while the markers record data on your movement. The participant will also be required to jump onto one leg from a set height while the markers once again record data on 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 has been completed you will be required to perform self-selected walking in the Vicon lab and a single-leg drop landing where various measurements will be taken and recorded with regard to the way in which you move.

**Will you benefit from taking part in this research?**

You will not immediately benefit from taking part in the research. But by participating 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:** Onderzoek 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 individuele met geen lies pyn. Data van dié 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 gestandaardiseerde 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 laboratorium 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, VK) system is 'n kamera georiënteerd, 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 laboratorium 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 laboratorium, asook een been val/spring aksie uit te voer terwyl die Vicon sisteem sodoende u bewegings 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 beskikking 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 laboratorium.

**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 getui**

## APPENDIX G – Subjective assessment

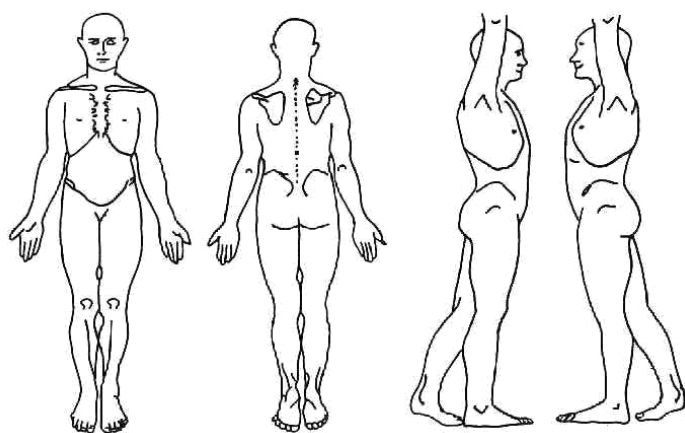
Name:

Age:

Dominance:

Main problem:

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



Behaviour of symptoms: Agg/easing/24 hours

History: present/past

Special questions

## APPENDIX H – Physical assessment

Name:

Age:

Case/control number:

Affected adductor:

Any other physical complaints/conditions:

Shoe size:

Observation: Alignment, swellings,

Feet-

Knees-

Pelvis/Lx-

Tx-

Functional demonstration/activity: Alignment and control

Squats (holding on with both hands on plinth-flat foot squat)

Lunges (forward-stepping lunge, back to start position X 3 each leg)

Passive physiological movements:

Hip		Left1	Left2	Left3	Mean	Right1	Right2	Right3	Mean
Extension									
Flexion (PRN)									
Abduction									
Adduction (PRN)									
Internal rotation									
External rotation									
Knee	Left 1	Left 2	Left 3	Mean	Right 1	Right 2	Right 3	Mean	



Flexion (PRN)								
Extension								
Ankle	Left 1	Left 2	Left 3	Mean	Right 1	Right 2	Right 3	Mean
Plantar flexion								
Dorsi flexion								

Special tests:

Leg length: (ASIS to MM)

SIJ (4 battery of tests):

Faber's test

Gaelen's test

P4 test

Anterior gapping

Hip quadrant (if indicated)

Pain on coughing

Navicular drop test: Left-

Right-

Scoligauge: T2

T8

T12

PSI

## **APPENDIX I – Vicon marker placement**

Placement of the head markers:

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

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

Placement of the torso markers:

- Clavicle – superno-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/right 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

In some patients, especially those who are obese, the markers either cannot be placed exactly anterior to the ASIS or are invisible in this position to cameras. In these cases, move each marker laterally by an equal amount, along the ASIS-ASIS axis. Inter-ASIS distance must then be recorded (using anthropometer) and entered on the subject parameters form. Wand mounted markers may also be used.

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

*University of Stellenbosch Motion Analysis Lab*

**APPENDIX J – Investigator's declaration**

	<b>STELLENBOSCH UNIVERSITY</b> <b>FACULTY OF MEDICINE AND HEALTH SCIENCES</b>	
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**HEALTH RESEARCH ETHICS COMMITTEE 1 & 2****INVESTIGATOR'S DECLARATION**

The principal investigator, as well as all sub- & co-investigators must each sign a separate declaration.

**A. RESEARCHER**

<b>Surname</b>	Morris			<b>Initials</b>	T	<b>Title</b>	Mrs
<b>Capacity</b>	<b>Principal investigator</b>	x	<b>Sub-investigator</b>		<b>Co-investigator</b>		
<b>Department</b>	Private sector						
<b>Present position</b>	Physiotherapist			<b>E-mail</b>	tracyloumorris@gmail.com		
<b>Telephone no.</b>	<b>(w)</b>	021 790 4094	<b>Cell</b>	083 682 0644		<b>Fax</b>	086 529 4212

**B. PROJECT TITLE (MAXIMUM OF 250 CHARACTERS FOR DATABASE PURPOSES)**

Exploration of Biomechanics During Functional Activities in Adult Sports Participants with Chronic Groin Pain
---

I, (Title, Full name) .....Mrs Tracy Louise Morris.....declare that

- I have read through the submitted version of the research protocol and all supporting documents and am satisfied with their contents
- I am **suitably qualified and experienced** to perform and/or supervise the above research study.
- I agree to conduct or supervise the described study **personally** in accordance with the relevant, current protocol and will only change the protocol after approval by the **HREC**, except when urgently necessary to protect the safety, rights, or welfare of subjects. In such a case, I am aware that I should notify the HREC without delay.
- I agree to timeously report to the HREC **serious adverse events** that may occur in the course of the investigation.
- I agree to maintain **adequate and accurate records** and to make those records available for inspection by the appropriate authorised agents when and if necessary.
- I agree to comply with all other requirements regarding the obligations of clinical investigators and all other pertinent requirements in the Declaration of Helsinki, as well as South African and ICH GCP Guidelines and the Ethical Guidelines of the Department of Health as well as applicable regulations pertaining to health research.
- I agree to comply with all regulatory and monitoring requirements of the HREC.

- I agree that I am conversant with the above **guidelines**.
- I will ensure that every patient (or other involved persons, such as relatives), shall at all times be **treated in a dignified manner and with respect**.
- I will submit all required reports within the stipulated **time frames**.

**Principal / Sub- / Co-investigator /Supervisor:**.....

(print name)

**Signature** : .....

**Date** : .....

**CONFLICT OF INTEREST DECLARATION (OBLIGATORY)**

I.....declare that I have no **financial or non-financial interests**, which may inappropriately influence me in the conduct of this research study.

**OR**

☐ I do have the following financial or other competing interests with respect to this project, which may present a potential conflict of interest: (Please attach a separate detailed statement)

**Signature:**

**Date**

## **APPENDIX K – Coaches' and managers' information booklet**



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jou kennisvenoot • your knowledge partner

---

### **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% 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 15 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 regard 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

**Appendix A:** This picture shows the placement of the motion analysis markers in the Vicon Motion Analysis Laboratory.



## REFERENCES

- Barker PJ, Fahrer M, Robertson BA, Schache AG 2009 The anatomy of the pubic region revisited: implications for the pathogenesis and clinical management of chronic groin pain in athletes. *Sports Medicine* 139(3): 225.
- Blackburn JT, Padua DA 2008 Influence of trunk flexion on hip and knee joint kinematics during a controlled drop landing. *Clinical Biomechanics* 23(3): 313–319.
- Chockalingam N, Dangerfield PH, Giakas G, Dorgan J, Cochrane T 2002 Examination of relative movement between the back and lower limb. *Studies in Health Technology and Informatics* 88: 95–99.
- Cowan SM, Crossley KM, Bennell KL 2009 Altered hip and trunk muscle function in individuals with patellofemoral pain. *British Journal of Sports Medicine* 43: 584–588.
- Cowan SM, Schache AG, Brukner P 2004 Delayed onset of transversus abdominus in long-standing groin pain. *Medicine and Science in Sports and Exercise* 36(12): 2040–2045.
- Cross T 2010 Groin pain in athletes: assessment and management. <http://www.sportsmedicinesydney.com.au>.
- Crow JF, Pearce AJ, Veale JP, Vanderwesthuizen D, Coburn PT, Pizzari T 2010 Hip adductor muscle strength is reduced preceding and during the onset of groin pain in elite junior Australian football players. (Report) *Journal of Science and Medicine in Sport* 13(2): 202
- Cusi MF, Juska-Butel CJ, Garlick D 2001 Lumbopelvic stability and injury profile in rugby union players. *New Zealand Journal of Sports Medicine* 29(1):14-18



- Delahunt E, Kennelly C, McEntee BL, Coughlan GF, Green BS 2011 The thigh adductor squeeze test: 45° of hip flexion as the optimal test position for eliciting adductor muscle activity and maximum pressure values. *Manual Therapy* 16(5): 476–480.
- Delahunt E, McEntee BL, Kennelly C, Green BS, Coughlan GF 2011 Intrarater reliability of the Adductor Squeeze Test in Gaelic games athletes. *Journal of Athletic Training* 46(3): 241–245.
- Ekstrand J, Hagglund M, Walden M 2007 Lower reinjury rate with a coach-controlled rehabilitation program in amateur male soccer: a randomized controlled trial. *American Journal of Sports Medicine* 35(9): 1433.
- Emery CA 2003 Risk factors for injury in child and adolescent sport: a systematic review of the literature. *Clinical Journal of Sport Medicine* 13: 256–268.
- Emery CA, Meeuwisse WH 2001 Risk factors for groin injuries in hockey. *Medicine and Science in Sports and Exercise* 33(9): 1423–1433.
- Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R 2008 Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. *American Journal of Sports Medicine* 36(6).
- Ford KR, Myer GD, Hewett TE 2007 Reliability of landing 3D motion analysis: implications for longitudinal analyses. *Medicine and Science in Sports and Exercise* 39(11): 2012–2028.
- French D, Hibbs AE, Spears I, Thompson KG, Wrigley A 2008 Optimizing performance by improving core stability and core strength. *Sports Medicine* 38(12): 995.

- Franko OI, Bray C, Newton PO 2012 Validation of a scoliometer smartphone app to assess scoliosis. *Journal of Pediatric Orthopaedics* 32(8): 72–75.
- Grindstaff TL, Johnson KD, Kim K-M, Saliba SA, Yu B-K 2012 Reliability of thoracic spine rotation range-of-motion measurements in healthy adults. *Journal of Athletic Training* 47(1): 52.
- Hackney R 2012 Groin pain. *Journal of Orthopaedics and Trauma*. 26(1): 25–32..
- Holmich P, Uhrskou P, Ulnits L, Kanstrup I-L, Bachmann Nielsen M, Bjerg AM, Krogsgaard K 1999 Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomised trial. *Lancet* 6(353): 439–443.
- Holmich P 2007 Long-standing groin pain in sports people falls into three primary patterns, a 'clinical entity' approach: a prospective study of 207 patients. *British Journal of Sports Medicine* 41: 247–252.
- Holmich P, Larsen K, Krogsgaard K, Gluud C 2010 Exercise program for prevention of groin pain in football players: a cluster-randomized trial. *Scandinavian Journal of Medicine and Science in Sports* 20: 814–821.
- Hrysomallis C 2009 Hip adductors' strength, flexibility, and injury risk. *Journal of Strength and Conditioning Research* 23(5) : 1514–1517
- Jansen J, Mens J, Backx F, Stam H 2008 Diagnostics in athletes with long-standing groin pain. *Scandinavian Journal of Medicine and Science in Sports* 18: 679–690.
- Konz RJ, Fatone S, Stine RL, Ganju A, Gard SA, Ondra SL 2006 A kinematic model to assess spinal motion during walking. *Spine* 31(24): E898–E906.

- Koulouris G 2008 Imaging review of groin pain in elite athletes: an anatomic approach to imaging findings. *American Journal of Rehabilitation* 191: 962–972.
- Krebs DE, Wong D, Jevsevar D 1992 Trunk kinematics during locomotor activities. *Physical Therapy* 72: 505–514.
- Kulas A, Zalewski P, Hortobagyi T, DeVita P 2008 Effects of added trunk load and corresponding trunk position adaptations on lower extremity biomechanics during drop-landings. *Journal of Biomechanics* 41(1): 180–185.
- Leetun DT, Ireland ML, Wilson JD, Ballantyne BT, Davis IM 2004 Core Stability Measures as Risk Factors for Lower Extremity Injury in Athletes. *Medicine and Science in Sports and Exercise* 36(6):926-934.
- Longo UG, Loppini M, Berton A, Marinozzi A, Maffulli N 2012 The FIFA 11+ Program Is Effective in Preventing Injuries in Elite Male Basketball Players. *American Journal of Sports Medicine* 20(5):996-1005
- Maffey L, Emery C 2007. What are the risk factors for groin strain injury in sport? *Sports Medicine* 37(10): 881–894.
- Maitland GD 1991 *Peripheral Manipulation* 3<sup>rd</sup> edition. Oxford: Butterworth-Heinemann.
- McGinley J, Baker R, Wolfe R, Morris M 2009 The reliability of three dimensional kinematic gait measurements: a systematic review. *Journal of Gait Posture* 29: 360–369..
- Messaoudi N, Jans C, Pauli S, Van Riet R, Declercq G, Van Cleemput M 2012 Surgical Management of the Sportsman's Hernia in Professional Soccer Players. *Orthopedics* 35(9):1371-1375.

- Morelli V, Weaver V 2005 Groin injuries and groin pain in athletes: part 1. *Primary Care* 32(1): 163–183.
- Morelli V, Espinoza L 2005 Groin injuries and groin pain in athletes: part 2. *Primary Care* 3 (1): 185–200.
- Machotka Z, Kumar S, Perraton L 2009 A systematic review on the effectiveness of exercise therapy for groin pain. *Sports Medicine, Arthroscopy, Rehabilitation, Therapy and Technology* 1(5): 1–10.
- O'Connor D 2004 Groin injuries in professional rugby league players: a prospective study (of 100 Rugby League players over a 2 year period). *Journal of Sports Science* 22: 629–636.
- Quinn, A 2010. Hip and groin pain: physiotherapy and rehabilitation issues. *Open Sports Medicine Journal* 4: 93–107.
- Roetert PE 2001 3D balance and core stability. In: Foran B, editor. High-performance sports conditioning: modern training for ultimate athletic development. Champaign (IL): Human Kinetics.
- Seay JF, Van Emmerik REA, Hamill J 2011 Influence of low back pain status on pelvis-trunk coordination during walking and running. *Spine* 36(16): E1070–E1079.
- Schneiders AG, Sullivan SJ, O'Malley KJ, Clarke SJ, Knappstein SA, Taylor LJ 2010 A Valid and Reliable Clinical Determination of Footedness. *Physical Medicine and Rehabilitation* 2(9):835-841
- Schick D, Meeuwisse W 2003 Injury rates and profiles in female ice hockey players. *American Journal of Sports Medicine* 31(1):47-52
- Shimokochi Y, Ambegaonkar JP, Meyer EG, Lee SY, Shultz SJ 2012 Changing sagittal plane body position during single-leg landings influences the risk of

non-contact anterior cruciate ligament injury. *Knee Surgery, Sports Traumatology, Arthroscopy*. [Epub ahead of print]

Soligard T, Myklebust G, Steffen K, Holme I, Silvers H, Bizzini M, Junge A, Dvorak J, Bahr R, Andersen TE 2008 Comprehensive warm-up to prevent injuries in young female footballers: cluster randomised controlled trial. *British Medical Journal* 337; a2469.

Tyler TF, Nicholas SJ, Campbell RJ, McHugh MP 2001 The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. *American Journal of Sports Medicine* 29(2): 124–128.

Tyler TF, Nicholas SJ, Campbell RJ, McHugh MP 2002 The effectiveness of a pre-season exercise program to prevent adductor muscle strains in professional ice hockey players. *American Journal of Sports Medicine* 30(5): 680–683.

Vezina MJ, Hubley-Kozey CL 2000 Muscle activation in therapeutic exercise to improve trunk stability. *Archives of Physical Medicine and Rehabilitation* 81(10): 1370-1379.

Vleeming A, Albert H, Stuge B 2008 European guidelines for the diagnosis and treatment of pelvic girdle pain. *European Spine Journal* 17(6):794-819.

Wilkerson GB, Giles JL, Seibel DK 2012 Prediction of core and lower extremity strains and sprains in collegiate football players: a preliminary study. *Journal of Athletic Training* 47(3):264-272.

Windolf AW, Götzen N, Morlock M. 2008 Systematic accuracy and precision analysis of video motion capturing systems—exemplified on the Vicon-460 system. *Journal of Biomechanics* 41: 2776–2780.