

POSTURAL SWAY IN RUGBY PLAYERS WITH CHRONIC GROIN PAIN

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Declaration Page

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Abstract

Introduction

Center of pressure (COP) has been frequently used as a guide of postural stability in standing.

Objectives

The study aimed to describe postural sway (as determined by the center of pressure) during pelican stance and during foot contact of the landing phase of a double leg jump in rugby players with chronic adductor related groin pain compared to asymptomatic controls.

Methodology

Study Design: A descriptive observational cross-sectional study was conducted.

Setting: The study was performed at the 3D Human Biomechanics Central Analytical Facility at Stellenbosch University, South Africa.

Participants: A consecutive sample of eight participants, four cases and four controls with chronic adductor related groin pain were included. One of the cases had bilateral groin pain and three had unilateral groin pain.

Main Outcome Measures: Center of pressure (range of movement and velocity) were measured and analysed at foot contact during a double leg landing and during pelican stance by means of a force platform.

Results

There were no significant differences between affected and unaffected sides within cases, nor between the affected side and same side in matched controls for any of the measurements recorded. However, in most cases greater antero-posterior range of movement and velocity is seen while standing on the affected side when compared to standing on the unaffected leg. There were also no significant differences found for postural sway when referring to antero-posterior and medio-lateral mean range of movement and velocity

Conclusion

Postural Sway is not significantly affected in rugby players with chronic groin pain. There were no differences in center of pressure range of movement and velocity

amplitude between cases and controls during a pelican stance test and after a double leg landing. It is postulated that a player with groin pain have over time learned to compensate in adjusting their COP. The study however tested participants who at the time of testing presented with no pain and were not fatigued prior to testing which may have obscured the impact of the condition on balance as determined by postural sway. Further research examining the risk of injury by fatiguing participants prior to testing may shed more light on the effect chronic groin pain has on postural sway in this population.

Keywords: *Chronic groin pain, Center of Pressure, postural sway, double leg landing, pelican stance, rugby players*

OPSOMMING

Inleiding

Middel punt drukking is dikwels gebruik as n gids van posturale stabiliteit (Ruhe, Fejer and Walker, 2011).

Doel

Die doel van hierdie studie was om Posturale Swaai te beskryf bepaal deur middel punt drukking (~ *center of pressure*) tydens een-been-staan en voet kontak tydens dubbel-been-landing in rugbyspelers met adduktor-verwante liespyn en dit te vergelyk met 'n nie-symptomatiese kontrole groep.

Metodologie

Ontwerp: 'n Beskrywende waarnemende deursnitstudie is uitgevoer.

Omgewing: Die studie is by die 3D Menslike Biomeganika Sentrale Analiserings Fasiliteit by die Universiteit van Stellenbosch uitgevoer.

Deelnemers: 'n Groep van agt aktiewe rugbyspelers is stelselmatig gewerf, nl. vier deelnemers, drie met unilaterale en een met bilaterale adduktor-verwante liespyn, en vier met geen simptome wat as kontroles gedien het.

Uitkomstmetings: Middel punt drukking (omvang van beweging en spoed) is gemeet en geanaliseer op die punt van voetkontank tydens 'n dubbel-been-landing en een-been-staan aktiwiteit deur middel van force platform.

Resultate

Geen betekenisvolle verskille is gevind tussen die geaffekteerde en ongeaffekteerde kante in individue met kroniese adduktor lies pyn, en ook nie tussen die geaffekteerde kant en ooreenstemmende kant van die kontrole groep. Tog in meeste gevalle is 'n groter A-P omvang en spoed gemeet veral met staan op die geaffekteerde been in vergelyking met staan op die nie-geaffekteerde been. Daar was ook geen beduidende verskille in posturale swaai wanneer verwys word na antero-posterior en medio-lateral omvang van beweging en spoed nie.

Gevolgtrekking

Posturale Swaai word nie beduidend geaffekteer in rugbyspelers met kroniese adduktor verwante liespyn nie. Daar was geen verskille in Middel Punt Drukking omvang of spoed gevind nie. Daar word veronderstel dat spelers met lies pyn oor 'n tydperk aanleer om te kompenseer en sodoende hul middel punt drukking aanpas. Hierdie studie het wel deelnemers getoets wat tydens toetsing met geen pyn gepresenteer het nie en is ook nie tot uitputting geneem voor toetsing nie, wat dalk die impak van hierdie toestand op balans soos bepaal deur posturale swaai, onderskat het. Verdere navorsing om die risiko vir besering te ondersoek deur deelnemers uit te put voordat hulle getoets word, mag dalk meer lig werp op die effek van liespyn op posturale swaai in hierdie populasie.

Sleutelwoorde: *kroniese liespyn, middel punt drukking, posturale swaai, dubbel-been-landing, een-been-staan, rugbyspelers*

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List of abbreviations

A-P	Antero-Posterior
CAF	Centre analytical facilities
COP	Centre of pressure
COG	Centre of gravity
EMG	Electromyography
FP	Force plate
ICC	Interclass correlation coefficient
M-L	Medio-Lateral
MRI	Magnetic Resonance Imaging
OMT	Orthopaedic Manipulative Therapy
ROM	Range of Movement
SA	Sway Area
SD	Standard deviation
VAS	Visual Analogue scale
3D	Three-dimensional

List of definitions

Groin Pain: Chronic groin pain is a “discomfort noted around the front area of the lower abdomen, upper thigh and hip as well as areas such as the inguinal region, the adductor muscles and the perineum” (Cross, 2010).

Balance: “The Sensing of the position of the body’s center of mass and moving the body to adjust the position of the center of mass over the base of support provided by the feet” (Nashner et al., 1988).

Biomechanics: “The science concerned with the internal and external forces acting on the human body and the effects produced by these forces” (Pietro, 2006).

Centre of Pressure: Refers to the point at which the pressure of the body over the soles of the feet would be if it were concentrated in one spot (Ruhe et al. 2011)

Postural Sway: Refers to the natural migration of the centre of mass of the body and the point of application of the ground reaction force (centre of pressure; COP) when person stands quietly (Danna-Dos-Santos et al. 2008)

CHAPTER 1: Introduction

Cross (2010) defines chronic groin pain as “discomfort noted around the front area of the lower abdomen, upper thigh and hip as well as areas such as the inguinal region, the adductor muscles and the perineum” (Cross 2010). Groin pain is usually observed unilaterally, but can be bilateral as well with a progressive development over time (Morelli & Weaver, 2005; Rhea, Kiefer, Haran, Glass & Warren, 2014; McSweeney, Naraghi, Salonen, Theodoropoulos & White, 2012).

Groin pain is one of the most common complaints amongst athletes taking part in competitive sport (Sedaghati, Alizadeh, Shirzad & Ardjmand, 2013). It is predominantly observed in the field sports among hockey, soccer, football and rugby players (Weber, Rehnitz, Ott & Streich, 2013; Hölmich, Larson, Krogsgaard & Gluud, 2010; Morelli & Weaver, 2005). Rugby players have a greater than average risk of injury compared with players of other popular team sports (Brown, Verhagen, Knol, Van Mechelen & Lambert, 2016) and when looking at specific rugby injuries, the risk of sustaining a groin injury is 23% per season (O’Connor, 2004).

Common to all these high-risk field sports, placing athletes at risk for sustaining groin injuries, are frequent and abrupt rotational movements or twisting of the hip joint, rapid change in direction, kicking and sprinting tasks (Jansen, Mens, Backx, Kolfschoten & Stam, 2008; Patel, Wallace & Busconi, 2011). Athletes exposed to frequent jumping (Delahunt et al., 2012) and landing strategies (Morelli & Weaver, 2005; Lawrence, Kernozek, Miller, Torry & Reuteman, 2008) are also at risk for sustaining chronic groin injuries (Paajanen, Ristolainen, Turunen & Kujala, 2011). Sports including running, sudden changes in direction, repetitive kicking and physical contact increase biomechanical demands on the hip adductors (Zuzana, Kumar & Perraton, 2009; Morelli & Weaver, 2005) and are identified as major risks factors for injuries to the lower limb (Lawrence et al., 2008; Morelli & Weaver, 2005).

Due to the complex anatomy of the groin and pelvic region groin pain remains inadequately defined and lacks clear diagnostic measurements (Crow, Pearce, Veale, van der Westhuizen, Coburn & Pizzarie, 2010). A systematic review by Serner, van Eijck, Beumer, Hölmich, Weir & de Vos (2015) including 72 studies revealed 33 different diagnoses used to identify groin pain in athletes which complicates the management of these injuries (Serner et al., 2015). According to Lynch & Renstrom (1999) groin pain diagnosis is also often delayed for many months leading to devastating consequences for the athlete (Lynch & Renstrom 1999). Factors negatively affecting the outcome of these injuries include inappropriate management and re-injury which often arise due to inadequate diagnosis and confusion with regards to the different complex clinical presentations of groin pain (Drew, Osmotherly & Chiarelli, 2014).

Groin injuries are susceptible to recurrence (Hölmich, Thorborg, Dehlendorff, Krogsgaard & Gluud, 2014) and could become a chronic problem which may result in the end of an athlete's promising sports career (Morelli & Weaver, 2005). Athletes are often forced to take extended time off from sporting activities because of groin injuries (Werner, Hagglund, Walden, & Ekstrand, 2009; Hanna, Fulcher, Raina, & Moyes, 2010; Almeida, Silva, Andriolo, Atallah & Peccin, 2013). According to Hanna et al. (2010), 22% of groin related injuries require time away from the sport (Hanna et al., 2010). When groin pain lingers over time and becomes chronic the management thereof becomes more difficult (Weir, Jansen, van de Sande, van de Port, Tol & Backx, 2011) and 72% of athletes with long standing groin pain had to end their sport career (Holmich et al., 1999; Holmich & Renstrom, 2007).

Risk factors relating to groin injury have not been clearly identified for injury prevention strategies to be implemented (Van Beijsterveldt, van de Port, Krist, Schmikli, Stubbe, Frederiks & Backx 2012; Esteve, Rathleff, Bagur-Calafat, Urrútia & Thorborg, 2015). However, Esteve et al. (2015) reported that injury prevention strategies are being implemented with the emphasis on strengthening and coordination exercises of the adductor and abdominal muscles (Esteve et al., 2015). Biomechanical studies have indicated that the pelvic ring requires mechanisms with which to stabilize the pelvis and trunk against forces such as kicking and rapid change of direction (Cowan, Schache,

Brukner, Bennell, Hodges, Coburn & Crossley, 2004). Since Cowan et al. (2004) published their findings regarding the association between delayed transversus abdominus activation and chronic groin pain in Australian football players, no literature could be found on rehabilitation methods specifically involving or improving balance or motor control in athletes with groin pain. It would thus be beneficial to determine the effect that groin injuries may have on balance to help identify potential areas for evaluation or treatment methods for rehabilitation going forward. The study thus aimed at describing postural sway (as determined by the center of pressure) during pelican stance and during the landing phase of a double leg jump in rugby participants with chronic groin pain compared to asymptomatic controls.

CHAPTER 2: Literature Review

2.1 Introduction

The aim of this literature review is to provide an overview of chronic groin pain in sport participants with a specific focus on how it affects center of pressure (COP) as determined by 3D motion analysis. A narrative review was conducted and the following electronic databases at the Stellenbosch University Library and Information Services were searched: Pubmed, PEDro, Google scholar, Scopus, BioMedLib, Cinahl and Medline-Proquest. Keywords used in different combinations included 'groin pain', 'chronic groin pain', 'groin anatomy', 'sports injuries', 'muscle imbalance', 'adductor strain', 'COP', 'postural sway' and 'balance'. Literature search was conducted between February 2015 and October 2017. Studies deemed relevant to the topics covered in this literature review were retrieved and included.

2.2 Anatomy and Biomechanics of the Pelvis and Hip.

According to Morrenhof (1981) the pelvis contributes significantly within sports biomechanics (Morrenhof, 1981). Apart from a concentric function on the non-weight bearing leg the muscles of the pelvis also have a primary eccentric function as stabilizer of the pelvis, hip and trunk (Morrenhof 1981). Furthermore it provides a base of support and stability for other peripheral movements which depend on a well-balanced pelvis (Serner, van Eijck, Beumer, Hölmich, Weir & de Vos, 2015). Therefore, one could assume that if one of the pelvic structures is injured and not functioning optimally, the equilibrium of structures around the pelvis could be altered and could also place other pelvis-related structures at risk.

According to Serner et al. (2015) the groin region has a complex anatomy and consists of a great number of pain-generating structures (Serner et al., 2015). These structures include, but are not confined to, the sacroiliac joint, the hip joint, the obturator nerve, the iliopsoas muscle and the adductor longus muscle (LeBlanc & LeBlanc, 2003; Hölmich, 2007; Paajanen, Brinck & Hermunen, 2011; Drew et al., 2014). Groin pain resulting from a strain to the adductor longus muscle is the most common cause of groin pain (Hölmich

et al., 2014) and the most commonly injured muscle of the adductor group (Tyler, Silvers Gerhardt & Nicholas, 2010).

As adductor muscle strains are considered the major cause for groin injuries, this section focusses more on describing this muscle group and its role in movement and posture. The adductors contribute to guidance and control of the hip and provide the necessary stability to the hip joint (Delahunt, McEntee, Kennely, Green & Coughlan, 2011). The adductor muscle group which are exposed to injury through muscle imbalance, fatigue or overload plays an important role in stabilization of the pelvis and hip joint in closed chain motions such as the stance phase (Tyler, Nicholas & Campbell, 2001; Quinn, 2010).

In mid-stance, a co-contraction of the abductors and adductors for pelvis stabilisation to transfer weight from the one leg to the other is needed (Nicola & Jewison, 2012; Tyler et al., 2001). Therefore, load transfer in mid-stance is usually the moment in the gait cycle where the risk for injury is greatest (Quinn, 2010; Nicola & Jewison, 2012). In open chain motions like the swing phase when walking and running the muscle adducts the leg (Tyler et al., 2001 & Quinn, 2010). According to Delahunt et al. (2011) the muscle also acts as an accessory hip joint flexor when being concentrically contracted to facilitate hip joint flexion from 0-90° (Delahunt et al., 2011). However, when the hip is being flexed higher than 90°, the muscle also acts as an accessory hip joint extensor while decelerating hip flexion (Lawrence et al., 2008). Therefore, an increase load is placed on the hip adductors (Lawrence et al., 2008).

Reduced adductor muscle strength (Tyler et. al., 2001 & Maffrey & Emery, 2007) and muscle imbalances between the hip abductors and adductors can hamper efficient load transfer during gait and may lead to injuries (Quinn, 2010; Nicola & Jewison, 2012; Tyler et al., 2001; Maffey & Emery, 2007).

2.3 Aetiology

Groin pain could have a traumatic aetiology such as sustaining an injury during a sporting event. It can be observed unilaterally, meaning that only one side is affected, or it can be seen bilaterally with a progressive development over time (Morelli & Weaver, 2005;

McSweeney & Nagarhi, 2012). Risk factors may include running activities, particularly with rapid changes in direction, while activities like repetitive kicking and bodily contact have also been reported to increase risk of groin pain (Macintyre, Johnson & Schroeder, 2006). A previous groin injury also puts one at risk for re-injury (Hölmich et al., 2014).

In a high percentage of athletes, biomechanical risk factors of groin pain are multifactorial. These factors could include muscle weakness, muscle control (Sedaghati et al., 2013; Davidson, Madigan & Nussbaum, 2004), soft tissue stiffness, incorrect hip, knee and ankle biomechanics (Sedaghati et al., 2013), overload and fatigue (Zuzana et al., 2009; Davidson et al., 2004), muscle imbalance (Sedaghati et al., 2013; Davidson et al., 2004) decrease hip range of movement on the affected side (Tak, Engelaar, Gouttebarga, Barendrecht, Van den Heuvel, Kerkhoffs, et al., 2017; Ryan, DeBurca & McCreesh 2014) and Body Mass Index (BMI) (Ryan et al., 2014). Muscle imbalances reported are mostly strength ratios between the abductor and adductor muscles as well as delayed onset of transversus abdominal muscle recruitment which could also increase the risk for groin injuries (Maffey & Emery 2007).

Apart from inguinal, iliopsoas and pubic related groin pain, adductor-related dysfunction is found to be the primary cause of groin injuries. The most common risk factors for adductor muscle injuries include adductor stiffness (Ekstrand & Gillquist, 1983), adductor weakness (Tyler, Nicholas & Campbell, 2001), adductor overuse (Sedaghati et al., 2013), large eccentric contractions (Chaudhari et al., 2014), pre-season weakness in adductor tendon strength and an imbalance in adductor-to-abductor strength (Tyler et al., 2001). The presence of one these factors may lead to injury on the adductor muscles, and subsequently a groin injury which could influence a player's ability to maintain the centre of gravity within a base of support posing as a reason for the current investigation of the effect of balance on players with groin injuries.

2.4 Prevalence

Participation in most sporting activities could lead to a groin injury which is also found to be the most dominant lower limb injury (Sedaghati et al., 2013). It is estimated that 10-18% of injuries in contact sports are groin related (Maffery & Emery, 2007; Morelli &

Weaver, 2005) with hockey and rugby being more prevalent (Morelli & Weaver, 2005). According to Morelli & Weaver (2005), 62% of groin injuries are related to adductor muscle strains with the tendon of adductor longus being most frequently involved (Morelli & Weaver, 2005).

Hölmich et al. (2007) reported that adductor dysfunction was identified as the primary entity in 58% of runners and in 69% of the football players (Hölmich et al., 2007). Athletes participating in sport activities involving twisting, rapid change in direction, kicking and sprinting tasks are susceptible to injury of the groin area (Jansen et al., 2008; Patel et al., 2011). Landing (Lawrence et al., 2008; Morelli & Weaver, 2005) and frequent jumping (Delahunt & Prendiville, 2012) exposures are also known risk factors. Sports such as Australian football, soccer, rugby, and ice hockey consist of these types of functional tasks and are therefore high-risk sport codes for groin injuries (Emery et al., 2001; Cowan et al., 2004; Fricker et al., 1991). According to Brown et al. (2016) rugby players have a greater than average risk of groin injury compared with players of other popular team sports (Brown et al., 2016).

Sport codes involving twisting, landing and jumping not only increase demands on the hip adductors (Zuzana et al., 2009; Morelli & Weaver, 2005) but also increases the biomechanical demands on players which are identified as major risk factors for injuries to the lower limb (Lawrence et al., 2008; Morelli & Weaver, 2005). It has also been reported that the risk of developing a groin injury is twice as high for athletes with a previous groin injury and four times higher for athletes with decreased adductor muscle strength (Engebretsen, Myklebust, Holme, Engebretsen & Bahr, 2010).

2.5 Diagnosis of Groin Pain

Diagnosing groin pain is complex (Morelli & Weaver 2005, Maffey & Emery 2007 & Holmich 2007). Twenty-seven to 90% of patients presenting with groin pain do not have one straightforward groin pathology, but usually either have multiple pathologies or the pain is being widely spread with unclear referral patterns (Hackney, 2012). The complexity of the diagnosis and management of groin injuries are discussed in the

systematic review by Serner et al. (2015) (Serner et al., 2015). They revealed 33 different diagnoses used to identify groin pain in athletes such as sportsman's hernia, adductor tendinitis and osteitis pubis, just to mention a few (Serner et al., 2015).

As adductor muscle strains are the major cause for groin injuries, the assessment and management of these muscles are essential in the diagnosis and rehabilitation of groin pain (Lovell, Blanch & Barnes, 2012; Fulcher, Hanna & Elley, 2010; Wollin & Lovell, 2006). One step guiding the clinician in the right direction for appropriate evaluation is to make use of the adductor squeeze test which is reliable and is best tested in 45 degrees of hip flexion (Delahunt et al; 2011). In before mentioned position, the adductor muscles are at their largest mechanical advantage and the most force can be produced in this position (Lovell et al. 2012). According to Lovell et al. (2012) and Delahunt et al. (2011) this position is best for hip strengthening as well (Lovell et al., 2012; Delahunt et al., 2011). In contrast, Gill et al. (2014) reported that tenderness lengthways to the tendon with passive abduction and resisted hip adduction in extension is a positive finding for adductor longus tendinopathy and is the most reproducible finding (Gill et al., 2014). Groin strain-related biomechanical risk factors such as muscular imbalance and muscle fatigue lacks evidence of thorough identification or adequate investigation (Maffey & Emery 2007). Therefore, groin injuries could become a chronic problem which may result in the end of an athlete's promising sports career (Morelli & Weaver, 2005), because almost 22% of groin related injuries are often forced to take more time off from sporting activities (Hanna et al., 2010).

Differential diagnosis remains important to identify or exclude different structures possibly involved in groin pain. There are many clinical and diagnostic tests to differentiate between groin pathologies which include palpation, dynamic ultrasound, MRI, squeeze test, single leg adduction and bilateral leg adduction (Drew et al., 2014). Sensitivity and specificity for diagnostic tests such as MRI and dynamic ultrasound ranged between 68 - 100% and 33 - 100% respectively with negative likelihood ratios between 0 - 0.32 and positive likelihood ratios between 1.5 - 8.1. Sensitivity and specificity of clinical tests

ranged between 30 - 100% and 88 - 95% respectively with negative likelihood ratio of 0.15 - 0.78 and positive likelihood ratios of 1.0 - 11.0.

Apart from the challenges reported in the literature in diagnosing groin pain there is a lack of validated diagnostic clinical tests available for clinicians to use. Therefore, clinicians are advised to place more emphasis on specifically identifying the patho-anatomical disorder(s) and to do this a better understanding of the contributing factors is necessary (Drew et al., 2014). Groin disorders, because of its degree of symptoms overlapping, its complex design and difficulty in diagnosis, should be managed holistically by different health care providers (Hackney, 2012). Most importantly, a thorough history, clinical examination, special tests and good team work is needed in making a correct diagnosis (Lynch & Renstrom, 1999).

During groin injuries chronic damage to the sensory tissues may affect postural stability (Ruhe et al., 2011). Deterioration of this proprioceptive information from these areas may be the determining factor in reducing the accuracy in the sensory integration process. Ideally the body should be able to generate quick center of pressure transitions that just exceed the current position of the center of mass (COM) and accelerate it into the opposite direction in order to maintain balance (Ruhe et al. 2011). However, pain may cause an increased presynaptic inhibition of muscle afferents as well as affecting the central modulation of proprioceptive spindles of muscles, causing prolonged latencies by the decrease in muscle spindle feedback which may lead to decreased muscle control and result in increased postural sway (Ruhe et al. 2011).

Therefore, it can be hypothesized that the value of balance in people with groin pain is under investigated or underestimated. Due to the limited available diagnostic tools, this study aims at investigating how postural sway inferred as balance is affected in players with groin pain. It is assumed that balance could be used as an outcome measure or clinicians might target balance as part of an intervention package.

2.6 Balance

A body is in mechanical equilibrium when the sum of all the forces (F) and torques (M) that act on it is equal to zero ($\sum F=0$ and $\sum M=0$) (Duarte & Freitas, 2010). The forces acting on the body can be classified as external and internal forces (Duarte & Freitas, 2010). Because the human body is never in a condition of perfect equilibrium and sways all the time good postural control and balance are important factors to consider when trying to prevent a fall (Duarte & Freitas, 2010; Rogind, Lykkegaard, Bliddal & Danneskiold-Samsoe, 2003). This means that the body is constantly in motion, which is called postural sway (Rogind et al., 2003). Sway is the horizontal movement of the center of gravity (COG) even when a person is standing still (Duarte & Freitas, 2010). A certain amount of sway is essential and inevitable due to small physiological disturbances (Duarte & Freitas, 2010). Perturbations are also referred to as internal forces within the body e.g., a heartbeat, breathing, activation of the muscles necessary for the maintenance of posture and the performance of the body's own movements, shifting body weight from one foot to the other or from forefoot to rear foot (Duarte & Freitas, 2010). External disturbances include gravity, ground reaction forces, visual distortions & floor translations (Duarte & Freitas, 2010).

2.7 Role of balance in activity

Maintaining balance is necessary for almost every activity or sport to prevent a fall or injury (Rogind et al., 2003). Equilibrium, postural control and balance are descriptions used to define how we adjust our body position when necessary or how we keep our body in an upright position (Rogind et al., 2003). These differ somewhat from each other. Balance is known as the ability to sense the position of the body's center of mass and by moving the body to adjust the position of the center of mass over the base of the feet (Nashner et al., 1988). Shumway-Cook, Anson & Haller (1998) also reports balance as the ability to maintain the line of gravity (vertical line from center of mass) of a body within the base of support but adds that it is maintained with minimal postural sway (Shumway-Cook et al., 1998).

Body systems such as the visual system, the somatosensory system (such as proprioception and kinesthesia) and the vestibular organ interact and register inputs from surroundings, which are integrated and processed in the central nervous system (Moller, 1989). These systems also play an important role in maintaining the line of gravity and improving balance. Feedback is then normally provided as to how gravity affects the body through sensory receptors in the skin and via mechanoreceptors in the muscles (Magnusson, Enbom, Johansson & Wiklund, 1990; Stal, Fransson, Magnusson & Karlberg, 2003).

For the purpose of this study we investigated the role of balance in standing and foot contact during landing after a double leg jump and will refer to postural sway as balance. There are many other factors that could affect postural sway such as age, gender, vision, vestibular function, muscle strength, neuromuscular control and muscle fatigue (Era et al., 2006; Davidson, 2004).

2.8 General factors influencing postural sway

Factors such as performing head movement, holding the head in extended tilt position and a disturbance in cervical proprioception can increase postural sway (Paloski, Wood, Feiveson, Black, Hwang & Reschke, 2006; Patel, Fransson, Karlberg, Malmstrom & Magnusson, 2009). The position of the vestibular organ, especially rotation of the head, seems to have a smaller influence on postural sway, especially medio-laterally compared to vision and cervical proprioception (Hansson et al., 2010).

2.8.1 The role of age on balance

According to Era, Sainio, Koskinen, Haavisto, Vaara & Aromaa (2006) a decline in balance is noted at the age of 30 and a further acceleration in postural sway is seen in subjects older than 60 years (Era et al., 2006).

Age-related decline in the ability of the balance systems to receive and integrate sensory information contributes to poor balance in older adults (Schmitz, 2007). Ryan et al., (2014) reported that older athletes' tissues are less adaptable to respond to quick force changes

because the body's collagen tissue becomes less elastic and less able to absorb forces with age (Ryan et al., 2014). Thus, the elderly is at an increased risk of falls. In fact, one in three adults aged 65 and over will fall each year (Ryan et al., 2014). Typically, older adults have more body sway with all testing conditions (Hageman, Leibowitz & Blanke, 1995). Tests have shown that older adults demonstrate shorter functional reach and larger body sway path lengths (Hageman et al., 1995).

2.8.2 The effect of eyes open compared to eyes close on postural sway

It was found that vision (eyes closed) seemed to affect postural sway most, in terms of increased mediolateral and anteroposterior sway as well as sway area (Hansson et al., 2010). Postural sway has been shown to increase in older healthy subjects when eyes are closed (Era et al., 2006) and during visual stimulation in healthy participants aged 25-50 years of age (Tsutsumi, Murakami, Kawaishi, Chida, Fukuoka & Watanabe, 2010). Kinsella-Shaw, Colon-Semenza, Harrison & Turvey (2006) found that the average anterior and posterior center of pressure in older adults aged 65-82 years increased 24% more when they closed their eyes (Kinsella-Shaw et al., 2006). It may take an older person longer to compensate for the lack of vision due to declined cognitive and motor abilities (Kinsella-Shaw et al., 2006). Younger participants aged 22-24 swayed less with their eyes closed compared to eyes open (Kinsella-Shaw et al., 2006). This is due to the circumstance that as humans, we are presented with many visual stimuli daily, and we create deviations to maintain our stability when placed in certain situations. A younger participant will reduce their sway when their eyes are closed because they are not distracted by their visual surroundings (Kinsella-Shaw et al., 2006). Overall, Kinsella-Shaw et al., (2006) concluded that age does play a role affecting sway but that each individual's sensitivity level towards stimuli has a greater effect on sway (Kinsella-Shaw et al., 2006).

Despite what has been argued in the literature that more sway (Hansson et al., 2010) vs less sway (Kinsella-Shaw et al., 2006) can be expected in people while their eyes are closed this study will focus on eyes open as it can be concluded that all sports reported

in the literature are executed with open eyes. No studies were included on visually impaired individuals' sport.

2.8.3 Gender relating to groin injuries and postural sway

Males have a greater incidence of sustaining a groin injury compared to women even when playing the same sport such as ice hockey and football codes (Orchard 2015). Similarly, Era et al (2006) showed that in most cases males tend to have more pronounced sway as indicated by the speed and amplitude aspects of the movement of the center of pressure during the force platform registrations and these differences were also larger in the older age groups.

2.8.4 Environmental factors relating postural sway

The following environmental factors such as light conditions and floor surface changes can also affect postural sway (Schilling et al., 2009). Especially bright light or when moving from a hard floor surface to a soft surface can increase postural sway whereas people might be more fixed in darker conditions (Schilling et al. 2009). According to Patel et al. (2008) postural sway in younger participants with a mean age of 22.5 increases when a person is standing on foam due to the surface not being stable (Patel et al., 2008). Other factors that could influence balance negatively leading to an increase in sway include alcohol, drugs and ear infection (Schilling et al. 2009).

2.9 Measurement of balance

Due to recent technological advances, a growing trend in balance assessments has become the monitoring of centre of pressure (Schilling et al., 2009). In scientific studies, the definition COP is the preferred terminology used compared to center of gravity (COG), because COG is an entire body characteristic which are difficult to measure (Schilling et al., 2009). COP is the location of the vertical ground reaction force on the surface upon which the subject stands (Schilling et al., 2009). Laboratory-grade force plates are considered the "gold-standard" of measuring COP (Hof, Gazendam & Sinke, 2005). Force

plate measurement of the COP can occur in a mediolateral (ML) direction as well as in an anteroposterior (AP) direction (Rogind et al., 2003; Era et al., 2006). Force plates have been tested for test-retest and inter-session reliability as well as validity and was found to be a valid and reliable tool in the measurement of postural sway (Era et al., 2006; Bauer, Groger, Rupprecht, & Gassmann, 2008). For these tests, all the calculated intraclass correlation coefficients (ICCs) were over 90.

To detect differences in postural sway requires a set of measures that can sufficiently characterize the “random” oscillatory motions that constitute sway (Pavol, 2005). Many and varied sway measures exist, in both the time domain and the frequency domain. Yet few comprehensive investigations have explored the relationships between these different sway measures nor the number of independent characteristics that they measure (Kitabayashi et al., 2003; Prieto et al., 1996; Rocchi, Chiari & Cappello, 2004). The main point of agreement of these studies is that multiple measures are needed to characterize postural sway (Pavol, 2005).

Maurer & Peterka (2005) used a simple model of the human postural control system to investigate the relationship between different measures of postural sway and the sensitivity of these measures to changes in the properties of the postural control system by measures of sway amplitude and measures of sway velocity (Maurer & Peterka, 2005). The practical implication is that measures of sway amplitude and velocity are both needed, and may in fact be sufficient, to characterize antero-posterior postural sway (Pavol, 2005).

For the purpose of this study antero-Posterior and medio-lateral postural sway will be used to investigate balance as a valid outcome measure to investigate the integrity of the equilibrium system as indicated in the literature according to Rogind et al., 2003 and Era et al., 2006.

2.14 Statement of the problem

There is poor understanding of the association between groin pain and balance. To date no studies have been conducted exploring how balance is affected by groin injuries. According to Lynch & Renstrom (1999); Drew, Osmotherly & Chiarelli (2014) groin pain diagnosis is also often delayed for many months leading to devastating consequences for the athlete including inappropriate management and re-injury (Lynch & Renstrom, 1999); (Drew et al., 2014). It is therefore postulated that balance should be included in the assessment of groin pain. The purpose of this study therefor was to explore the effect of chronic groin pain on postural sway in rugby players.

CHAPTER 3: Methodology

3.1 Aim

The aim of this study was to determine the effect of chronic groin pain on balance in a group of club-level rugby players.

3.2 Objectives

The specific objectives of this study were to determine and compare the effect of groin pain on balance between affected and control cases as inferred by the following COP sway measurements:

- 3.2.1 Antero-posterior (A-P) sway in pelican stance (stork test)
- 3.2.2 A-P sway during the landing phase of a double leg landing
- 3.2.3 Medio-lateral (M-L) sway in pelican stance
- 3.2.4 M-L sway during the landing phase of a double leg landing

Additional objectives:

The study furthermore aimed:

- To explore relationships between anthropometric variables (age, height, weight and ROM) and balance as inferred by the above COP sway measurements
- And within subjects to compare the effect of chronic groin pain on balance when standing and landing on the affected leg with standing and foot contact after landing on the unaffected leg

3.3 Study Design

A cross-sectional, descriptive study design was conducted in that postural sway during stance and landing was measured and compared between cases and unaffected controls and between standing and landing on the affected and unaffected sides.

Relationships between age, gender, body mass index (BMI), leg dominance and balance measures were also investigated.

3.4 Setting

The study took place at the 3D Human Biomechanics Central Analytical Facilities (CAF), at Stellenbosch University, South Africa. Rugby players from various clubs within the Western Cape were invited to participate in this study. This is a sub-study, which forms part of a larger study that aimed to determine whether there are differences in the lower quadrant and trunk biomechanics among rugby and soccer playing athletes who present with chronic adductor related unilateral and/ or bilateral groin pain. This study is limited to the analysis of the effect of groin pain on balance as inferred from postural sway measurements.

3.5 Sampling-size

Convenience sampling was performed to recruit participants both with and without a history of groin pain from rugby clubs situated in the Cape Peninsula area, Western Cape, South Africa. The study participants had to comply with the following inclusion criteria and were matched with controls according to age and gender. The intention was to recruit at least 40 participants.

3.6 Participant criteria

Inclusion criteria

To be included in the study, participants had to comply with the following:

- Rugby players playing at a club level
- Males between the ages of 18-55 years

- Chronic unilateral or bilateral groin pain located at the proximal insertion of the adductor muscles on the pubic bone, of a duration of more than 3 months
- Groin pain during or after sporting activity
- Positive Adductor squeeze test with a sphygmomanometer (Delahunt et al., 2011).
- Participating in sport or physical training despite the groin injury
- Good general health on day of testing.

Inclusion Criteria for Controls

- Rugby players at a club level.
- Males between the ages of 18-55 years of age.
- No history of groin pain.
- Negative Adductor squeeze test with a sphygmomanometer (Delahunt et al., 2011).
- Good general health.

Exclusion Criteria for cases and control

To be included in the study, participants had to exclude the following:

- Any orthopaedic surgical procedure of the lower quadrant and lumbar spine within the last 12 months.
- Positive findings on previous imaging for bony lesions in the hip joint.
- Any disease or condition that has an influence on functional ability/movement e.g. Ankylosing, Spondylosis, Scheuerman's disease
- Any other co-morbidities that could affect balance such as diabetes

- History of spinal, lower limb or pelvis pathology other than groin injury.
- Clinical suspicion of nerve entrapment syndrome.
- Palpable inguinal or femoral hernia.
- Positive findings for ankle instability

3.7 Procedure

The different clubs' physiotherapist and/or coach were contacted to identify potential participants. The eligible case and controls were provided with information pertaining to the study (Appendix B) and were asked to provide written informed consent to participate in the study. Eligible participants were screened by the same two experienced musculoskeletal physiotherapists, of whom the researcher was one of them (refer to Appendix C). This followed by physical tests such as squats, hip special tests and diagnostic tests (refer to Appendix D and E) and were also completed by the same two physiotherapists, the researcher and a colleague. Players that tested positive on the adductor squeeze test (Delahunt, Kennely, McEntee, Coughlan & Green 2011) were invited to participate and those that provided written informed consent were invited to a testing session at the Motion Analysis Laboratory at SU. If controls had no history of groin pain and the adductor squeeze test was negative, they were included in the study. Cases' and controls' body mass index (BMI) and self-reported leg dominance was recorded. On the day of testing the following procedures were followed:

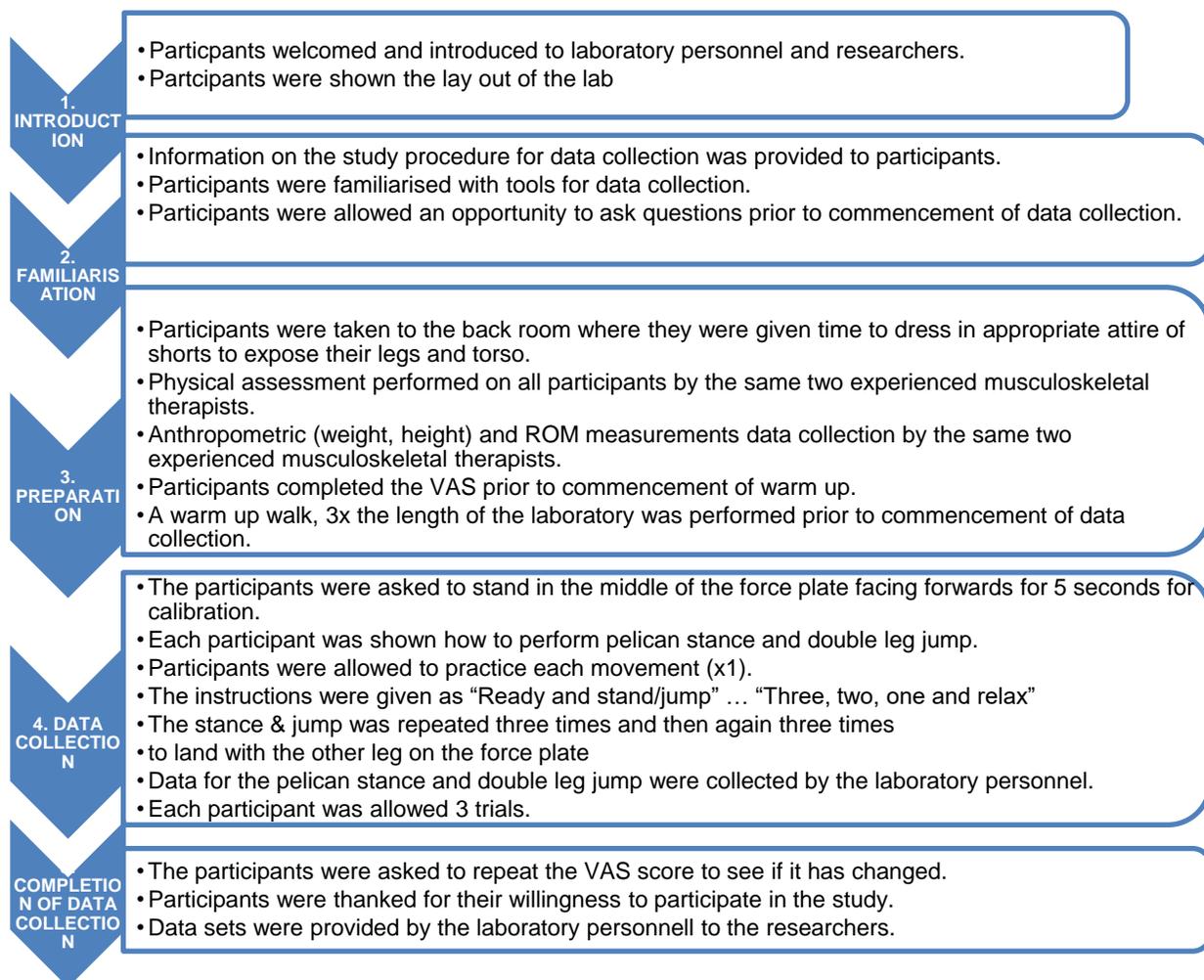


Figure 1: Procedure

3.7 Instrumentation

The following instruments were used by the researcher to assess pain, strength, ROM at the hip, knee and ankle joints, and force plate data to measure postural sway balance (motion referred to as postural sway).

3.7.1 Visual Analogue Scale

A visual analogue scale (VAS) was used to measure perceived levels of pain (Bijur et al., 2001). The visual analogue scale (VAS) is a self-report instrument consisting of a

horizontal or vertical line on a page used to measure perceived levels of pain (Bijur et al., 2001). The one extremity is marked 'no pain', and the other 'pain as bad as it can be' (Bergh et al., 2010). The participant makes a mark on the line indicating his/her pain intensity.

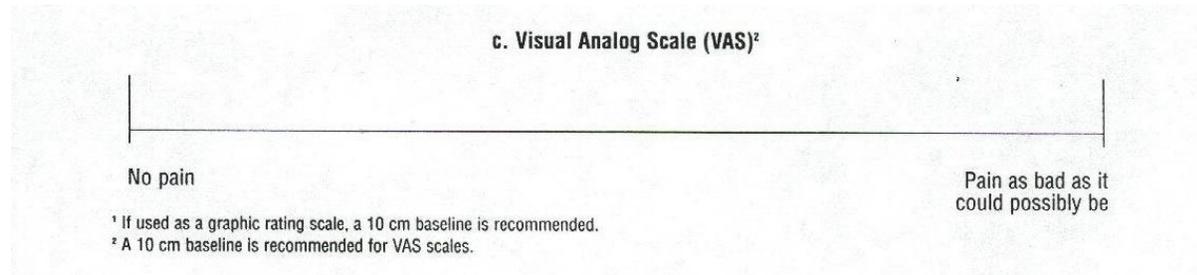


Figure 1: A schematic demonstration of the Visual Analogue Scale

According to Bijur et al., (2001) and Price et al. (1983) VAS is a valid measure of chronic pain (Bijur et al., 2001); (Price et al., 1983). In their study Price et al. (1983) showed that sensory intensity responses to different levels of chronic pain, and direct temperature (experimental pain) matched to 3 levels of chronic pain and were all internally consistent, thereby demonstrating the valid use of VAS (Price et al., 1983) Whether participants presented with acute or chronic pain or anything in between repeated measures produced consistent results. The test re-test reliability is good. According to Ferraz et al. (1990) Interclass Correlation Coefficient scores ranged between 0.71 - 0.99 (Ferraz et al., 1990).

In this study the examiner measured the distance from the 'no pain' extremity to the point marked by the participant in millimetres (mm), with below 40mm interpreted as mild pain; between 41mm - 74mm interpreted as moderate pain and above 75mm as severe pain (Sommer et al., 2008).

3.7.2 Adductor squeeze test

The adductor squeeze test is a pain provocation test that has shown to be a positive predictive value of chronic groin pain (Crow et al., 2010) that was used in the current

study to identify groin pain. Participants are positioned in a crook-lying position with a single pillow under the head and arms folded cross their chest. The participant's hips are positioned in 45° of flexion with both knees flexed to 90° (verified with a universal goniometer) and hips in neutral rotation. A sphygmomanometer was pre-inflated to 10mmHg and placed between the participant's knees such that the middle third of the cuff will be located at the most prominent point of the medial femoral condyles (as seen in Figure 2). The same device was used for all participants. The participant was instructed to squeeze the cuff as hard as possible and maintain the squeeze for 10 seconds before returning to relaxed position. A 2min rest period was allowed between each of the three trials (Nevin et al., 2014). The highest-pressure value displayed on the sphygmomanometer dial was recorded during each maximal adductor squeeze test.



Figure 2: Sphygmomanometer An image illustrating the adductor squeeze test (Nevin & Delaunt, 2014)

Verrall et al. (2005) showed that this test is 95% predictive of chronic groin pain when compared with bone marrow oedema seen on Magnetic Resonance Imaging (MRI) Verrall et al. (2005). Similarly, a cross-sectional analysis by Mens et al. (2002) concluded that the adductor squeeze test was capable of correlating hip adduction strength with disease severity in patients with Posterior Pelvic Pain since Pregnancy (PPPP) (Mens et al., 2002). The adductor squeeze test's intra- and inter-tester reliability was established as acceptable to good, with Pearson's correlation coefficient and the intra-class correlation coefficients (ICC) both = 0.79, (Mens et al., 2002).

3.7.3 Goniometer

A universal goniometer was used to measure range of motion of the hip, knee and ankle (Roach et al., 2013). Range of movement such as flexion, extension, abduction, adduction, internal rotation, external rotation, dorsi- and plantarflexion respectively were measured by the researcher while the others (the others formed part of another individual studies which investigated hip kinetics, EMG activity and ground reaction forces) noted the measurements. According to Tak et al., (2017) in order for an examiner to be able to detect ROM changes over time it is best to use a single observer for range of movement assessment (Tak et al., 2017). The universal goniometer is also easy to use, low cost and portable means of measuring range of motion (Roach et al., 2013).

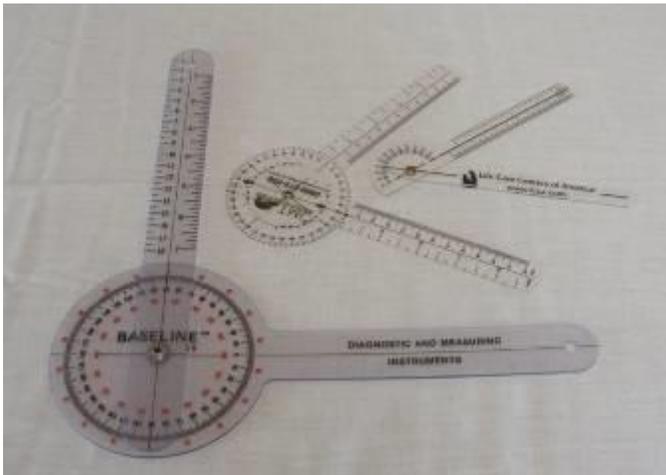


Figure 3. Example of a goniometer

The universal goniometer is a valid tool commonly used by clinicians for measuring range of motion (Roach et al., 2013). Range of motion measurement with a universal goniometer during passive hip flexion; extension; internal rotation and external rotation noted an intra- class correlation coefficient (ICC) of 0.80, producing good reliability of the universal goniometer (Roach et al., 2013). These changes may only be true if they exceed 7° for either IR or ER (hip and knee flexed as reported by Tak et al. (2017) (Tak et al., 2017).

Force Plate

In general, the force plate consists of a board in which some (often four) force sensors of load cell type or piezoelectric are distributed to measure the three force components, F_x , F_y and F_z (x , y , and z are the anterior-posterior, medial-lateral, and vertical directions, respectively), and the three components of the moment of force (or torque), M_x , M_y , and M_z , acting on the plate (Duarte and Freitas 2010).

The FP9060-15 force platform method for measurement of postural sway is based on the simultaneous measurement of vertical ground reaction force at points in the corners of a rigid platform on which the subject is placed. Compared with other techniques, the force platform method has advantages, particularly pertaining to ease of use and availability of standardized equipment (Rogind et al., 2003). As certain force plates measure six physical variables, these force plates are generally known as force plates of six components. The center of pressure data is related to a measure of position given by two coordinates on the plate surface dependent on the orientation of the individual assessed. Based on the signals measured by the force plate, the center of pressure position in the antero-posterior and mediolateral directions are calculated as $CP_{ap} = (-h \cdot F_x - M_y) / F_z$ and $CP_{ml} = (-h \cdot F_y + M_x) / F_z$ (Duarte and Freitas 2010).

For the purpose of the current study only the following measures pertaining to force plate data were analysed. Measures of medio-lateral (ML) speed (mm/s), antero-posterior (AP) speed (mm/s), and sway area (SA) (mm^2/s) were captured during pelican standing and foot contact following landing after a double leg jump.

Pelican: The participant was asked to stand barefoot on the provided area with arms placed on the hips. The test was demonstrated by a researcher and the participant practiced it once on each leg. The participant was asked to raise the heel of one leg and position the unsupported leg's hip and knee in 90° of flexion, the ankle and foot was kept in a neutral position. Participants were instructed to maintain the position for 10s, with their eyes open and to focus on one point in the room in front of them, before the foot is lowered to the floor. Respective studies by Era et al. (2006) and Tsutsum et al. (2010) have demonstrated that postural sway increases when eyes are closed and during visual

stimulation (Era et al., 2006; Tsutsum et al., 2010). The test was repeated three times on both legs, alternating from one leg to the other. A two-minute rest period was granted in between each trial.

Double leg landing: This test was also performed bare feet. A researcher demonstrated the test and the participant practiced it once. The participants were asked to perform a maximum effort jump repeating it 3 times from a neutral standing position individually marked for each participant and to land flat and together on both feet. The distance was calculated by measuring each individual's full leg length (using a tape measure) from the anterior superior iliac spine to the medial malleolus. Both feet landed on the force plate per trial and the landing position had to be kept for three seconds in order to measure the postural sway, before returning to the neutral standing position.

3.8 Data processing and analysis

For the purpose of this study the researcher acted as the reviewer and analyzed the data independently. The events for foot contact and lowest vertical position of the pelvis were calculated automatically using Matlab Version R2012b during the double leg landing and foot off for Pelican stance. Data was exported to Matlab to extract data. The subjects were divided into two subgroups: unilateral pain and bilateral pain. The subject with bilateral groin pain could indicate which side of the groin was most affected. Descriptive statistical data of demographics (mean, range and SD) were used to indicate variability between case vs control. A two-tailed Student's t-test was performed to calculate significant differences between the affected leg in cases and same legs in controls. Within cases the affected side was also compared with the unaffected side and in controls right and left sides were compared. Pearson's correlation was done to explore relationships between demographic variables (age, height, weight, ROM, causality) and sway measurements. Statistical significance was set at $p > 0.05$

3.9 Ethical considerations

The Health Research Ethics Committee of the Stellenbosch University granted institutional ethical approval (ethics number S12/10/265) (Appendix A). All participants provided written informed consent (Appendix B) following the recruitment procedure. Participants could voluntary participate in the study and withdraw without consequences.

No injuries occurred during testing and screening. Participants were not paid for participating in the study. However, they were reimbursed for their time and inconvenience. Confidentiality was ensured, as data was kept locked and handled with care. The study results will be published in a thesis format.

CHAPTER 4: RESULTS

For the study the affected legs of cases were compared to the same legs of matching controls, the affected legs compared to the unaffected legs within cases and the left legs compared to the right legs in controls. In this section, the results are reported following a description of the sample.

4.1 Description of the sample:

Although the original intent was to recruit 40 participants some challenges occurred at the time of recruitment. Players were screened at club level by the researcher and were informed that the actual data collection would take place at the 3D Human Biomechanics Central Analytical Facility at Stellenbosch University, South Africa. Even after transport was provided many participants reported transport as the main reason for not being able to attend the data collection appointments. After the data from the umbrella study was processed only four cases and four matched controls between the ages of 18 – 40 were deemed suitable for analysis for this part of the study. One of the cases had bilateral groin pain and three had unilateral groin pain. No participants had pain at the time of arrival for testing as indicated in Table 1, however presented with pain during the adductor squeeze test.

As a group, there were no significant differences between the cases and controls for any of the variables measured. Data is reported as mean and ranges. The raw data is displayed individually for all the cases.

Table 1: Demographic Data for participants as a group

Unilateral Groin Pain Group (n=3)			
	Age (yrs.)	Weight (kg)	Height (m)
	Mean	Mean	Mean
	Range	Range	Range
CASE (n=3)	21.3	83.7	172.5
	19 - 23	73.3-86.5	166-179
CONTROLS (n=3)	21.7	83.3	170.6
	20 - 24	79.3 -88.7	164-177
SD CASE	2.1	9.3	9.2
SD CONTROLS	2.1	4.9	6.5
Bilateral Groin Pain Group (n=1)			
	Age (yrs.)	Weight (kg)	Height (m)
CASE (n=1)	19.0	79.0	166.0
CONTROLS (n=1)	19.0	72.2	174.0

Table 2: Demographic data in patients with chronic groin pain vs. matched controls

Participant	Aff. Side	Height	Weight	Age	Pain	Aetiology	Hip ext	Hip flex	Hip abd	Hip add	Hip int	Hip ext
P1	R	166	86,5	23	No	T	20°	105°	22°	11°	33°	20°
C5	R	171	81,8	24	No	T	14°	105°	56°	21°	27°	25°
P2	L	179	73,3	22	No	T	14°	111.3°	31,6°	20.6°	60°	15.3°
C6	L	164	79,3	20	No	T	28°	105°	31.6°	20°	30°	28°
P3	R	189	91,4	19	No	T	10°	106°	26.3°	15°	20°	36°
C7	R	177	88,7	21	No	T	14°	120.3°	35.3°	20°	37.3°	26°
P4	L	166	79	19	No	T	16.6°	121.6°	26.6°	10.6°	20°	29.6°
C8	L	174	72,2	19	No	T	18.6°	111.5°	25°	14.3°	36°	28.3°

P. -Participant, Aff. -Affected C. -Control, R. -Right, L. - Left, T. -Traumatic, ext. -Extension, flex. -Flexion, abd. -Abduction, add. -Adduction, int. -Internal rotation, ext. -External rotation, °-degrees,

4.2 Effect of groin pain on postural sway measurements

The results are described below as the effect of groin pain on balance in the following order:

- Antero-posterior (A-P) sway in pelican stance (stork test)
- A-P sway during the landing phase of a double leg landing
- Medio-lateral (M-L) sway in pelican stance
- M-L sway during the landing phase of a double leg landing

The Tables 3, 4, 5 and 6 below summarises the measurements between the following for each category mentioned above:

- Affected legs in cases vs same legs in controls
- Affected legs vs unaffected legs within cases
- Left legs vs right legs in controls

4.2.1 Effect of groin pain on balance as measured by antero-posterior (A-P) sway (ROM and velocity) in pelican stance

When grouped together no significant differences for A-P ROM and velocity measurements were found when standing on the affected leg compared to the measures recorded in controls while standing on the same side ($p= 0.75$ for A-P ROM and 0.11 for A-P Velocity) (Table 3). Similarly, there were no differences seen when cases performed the activity on the unaffected side ($p= 0.36$ for A-P ROM and $p= 0.86$ for A-P Velocity) (Table 3) and when controls performed the activity on the opposite side ($p= 0.54$ for A-P ROM and $p= 0.33$ for A-P Velocity) (Table 3).

Table 3: Measurements for Antero-posterior (A-P) sway (ROM and velocity) in pelican stance (Stork)

Affected legs vs same legs in controls				Affected legs vs unaffected legs of cases				Left legs vs right legs in controls			
Participant	Side	Stork		Participant	Side	Stork		Participant	Side	Stork	
		A-P ROM	A-P Vel			A-P ROM	A-P Vel			A-P ROM	A-P Vel
		mm ²	mm/s			mm ²	mm/s			mm ²	mm/s
P1	R	4,1	5,8	P1	R	4,1	5,8	C5	L	3,6	6,9
C5	R	3,9	3,9	P1	L	4,2	6,3	C5	R	3,9	3,9
P2	L	3,3	7,0	P2	L	3,3	7,0	C6	R	3,1	7,0
C6	L	2,5	6,7	P2	R	3,3	6,4	C6	L	2,5	6,7
P3	R	4,6	5,8	P3	R	4,6	5,8	C7	L	3,8	6,7
C7	R	7,1	7,3	P3	L	2,8	5,5	C7	R	7,1	7,3
P4	L	4,3	7,2	P4	L	4,3	7,2	C8	R	4,4	0,3
C8	L	4,5	7,8	P4	R	3,7	7,1	C8	L	4,5	7,8

ROM. - Range of movement, mm². - Square millimetre, Vel. - Velocity, mm/s. - millimetre per second, A-P. - Anterior Posterior, M-L. - Medial Lateral

When referring to individual cases P2, P3 and P4 had greater A-P velocity measurements when standing on the affected leg compared to the unaffected leg (Table 3). A-P ROM were greater for controls C5, C7 and C8 when compared to opposite legs during pelican stance (Table 3).

4.2.2 Effect of groin pain on balance as measured by A-P sway during the landing phase of a double leg jump

When grouped together no significant differences for A-P ROM and velocity measurements were found when landing on the affected leg compared to the measures recorded in controls while landing on the same side ($p=0.73$ for A-P ROM and $p=0.10$ for A-P Velocity) (Table 4). Similarly, there were no differences seen when cases performed the activity on the unaffected side ($p=0.77$ for A-P ROM and $p=0.07$ for A-P Velocity) (Table 4) and when controls performed the activity on the opposite side ($p=0.95$ for A-P ROM and $p=0.69$ for A-P Velocity) (Table 4).

Table 4: Measurements for Antero-posterior (A-P) sway (ROM and velocity) in double leg landing.

Affected legs vs same legs in controls				Affected legs vs unaffected legs of cases				Left legs vs right legs in controls			
Participant	Side	Double leg		Participant	Side	Double leg		Participant	Side	Double leg	
		A-P ROM	A-P Vel			A-P ROM	A-P Vel			A-P ROM	A-P Vel
		mm ²	mm/s			mm ²	mm/s			mm ²	mm/s
P1	R	46,6	361,9	P1	R	46,6	361,9	C5	L	57,1	587,2
C5	R	51,7	391,1	P1	L	29,9	165,4	C5	R	3,9	391,1
P2	L	66,9	297,6	P2	L	66,9	297,6	C6	R	68,8	774,1
C6	L	42,9	501,9	P2	R	61,7	292,4	C6	L	42,9	501,9
P3	R	51,3	349,3	P3	R	51,3	349,3	C7	L	27,8	313,1
C7	R	61,3	592,8	P3	L	47,2	333,1	C7	R	61,3	592,8
P4	L	51,7	650,7	P4	L	51,7	650,7	C8	R	38,3	606
C8	L	59,9	1006,9	P4	R	52,9	545,6	C8	L	59,9	1006,9

ROM. -Range of movement, mm². - Square millimetre, Vel. - Velocity, mm/s. - millimetre per second, A-P. - Anterior Posterior, M-L. - Medial Lateral

When referring to individual cases the affected legs of P1, P2, P3 and P4 had less A-P velocity measurements compared to their match controls during double leg landing (Table 4). The affected legs of P1, P3 and P4 had less A-P ROM measurements compared to their match controls during double leg landing. The affected legs of P1, P2, and P3 had greater A-P ROM measurements compared to unaffected legs during double leg landing. All four affected legs had greater A-P velocity measurements compared to the unaffected legs.

4.2.3 Effect of groin pain on balance as measured by medio-lateral (M-L) sway (ROM and velocity) in pelican stance

When grouped together no significant differences for M-L ROM and velocity measurements were found when standing on the affected leg compared to the measures recorded in controls while standing on the same side (p= 0.97 for M-L ROM and p= 0.40 for M-L Velocity) (Table 5). Similarly, there were no differences seen when cases performed the activity on the unaffected side (p= 0.74 for M-L ROM and p= 0.98 for M-L

Velocity) (Table 5) and when controls performed the activity on the opposite side ($p= 0.77$ for M-L ROM and $p= 0.49$ for M-L Velocity) (Table 5).

Table 5: Measurements for medio-lateral (M-L) sway (ROM and velocity) in pelican stance (Stork)

Affected legs vs same legs in controls				Affected legs vs unaffected legs of cases				Left legs vs right legs in controls			
Participant	Side	Stork		Participant	Side	Stork		Participant	Side	Stork	
		M-L ROM	M-L Vel			M-L ROM	M-L Vel			M-L ROM	M-L Vel
		mm ²	mm/s			mm ²	mm/s			mm ²	mm/s
P1	R	0,2	5,5	P1	R	0,2	5,5	C5	L	0,2	6,3
C5	R	0,2	6,5	P1	L	0,2	6,1	C5	R	0,2	6,5
P2	L	3,6	6,5	P2	L	3,6	6,5	C6	R	2,4	5,8
C6	L	2,7	5,7	P2	R	3,1	5,0	C6	L	2,7	5,7
P3	R	3,2	4,6	P3	R	3,2	4,6	C7	L	3,2	5,6
C7	R	4,3	6,2	P3	L	2,8	4,6	C7	R	4,3	6,2
P4	L	0,2	7,3	P4	L	0,2	7,3	C8	R	8,3	8,7
C8	L	0,3	8,4	P4	R	0,3	7,6	C8	L	0,3	8,4

ROM. -Range of movement, mm². - Square millimeter, Vel. - Velocity, mm/s. - Millimeter per second, A-P. - Anterior Posterior, M-L. - Medial Lateral

When referring to individual cases the affected legs of P1, P3 and P4 had less M-L velocity measurements compared to their match controls during standing (Table 5).

4.2.4 Effect of groin pain on balance as measured by M-L sway during the landing phase of a double leg landing

When grouped together no significant differences for M-L ROM and velocity measurements were found when landing on the affected leg compared to the measures recorded in controls while landing on the same side ($p= 0.63$ for M-L ROM and $p= 0.53$ for M-L Velocity) (Table 6). Similarly, there were no differences seen when cases performed the activity on the unaffected side ($p= 0.65$ for M-L ROM and $p= 0.45$ for M-L Velocity) (Table 6) and when controls performed the activity on the opposite side ($p= 0.95$ for M-L ROM and $p= 0.99$ for M-L Velocity) (Table 6).

Table 6: Measurements for Medio-lateral (M-L) sway (ROM and velocity) in double leg landing.

Affected legs vs same legs in controls				Affected legs vs unaffected legs of cases				Left legs vs right legs in controls			
Participant	Side	Double leg		Participant	Side	Double leg		Participant	Side	Double leg	
		M-L ROM	M-L Vel			M-L ROM	M-L Vel			M-L ROM	M-L Vel
		mm ²	mm/s			mm ²	mm/s			mm ²	mm/s
P1	R	29,9	165,4	P1	R	29,9	165,4	C5	L	29,9	177,2
C5	R	29,9	187,2	P1	L	29,9	164,7	C5	R	29,9	187,2
P2	L	61,7	292,4	P2	L	61,7	292,4	C6	R	37,8	360,7
C6	L	39,5	346,5	P2	R	65,4	753,5	C6	L	39,5	346,5
P3	R	47,2	333,1	P3	R	47,2	333,1	C7	L	55,1	444,7
C7	R	51,6	447,8	P3	L	65,6	357,9	C7	R	51,6	447,8
P4	L	30,1	239,6	P4	L	30,1	239,6	C8	R	20,6	201,8
C8	L	25,1	255,6	P4	R	30,1	222,0	C8	L	25,1	255,6

ROM. - Range of movement, mm². - Square millimeter, Vel. - Velocity, mm/s. - Millimeter per second, A-P. - Anterior Posterior, M-L. - Medial Lateral

When referring to individual cases the affected legs of P1, P2, P3 and P4 had less M-L velocity measurements than their match controls during double leg landing (Table 6). Controls C5, C7 and C8 had greater M-L velocity measurements compared to opposite legs during landing (Table 6).

4.2.5 Association between anthropometric variables vs other outcomes

One case, P1 (Table 2) with the smallest measurement for hip abduction (0 - 22°) also presented with the smallest measurements for A-P ROM for the affected and unaffected leg in landing, in A-P velocity in the unaffected leg for landing as well as in M-L ROM and velocity in the affected and unaffected leg in landing. This is in contrast to the control C8 (Table 2) with the smallest measurement for hip abduction of (0 - 25°) who presented with the largest measurement for A-P velocity in standing and landing and in M-L velocity in standing.

One case, P2 with the largest measurement for hip abduction of 31.6° (Table 2) presented with the smallest measurement for A-P ROM in standing and with the largest measurement for M-L ROM during standing and landing

The largest sway in A-P ROM and M-L velocity measurements was seen in the tallest participant P3 (Table 2) during standing and landing respectively.

CHAPTER 5: DISCUSSION

This novel study aimed to determine whether balance as measured by postural sway measurements is affected in rugby players who have chronic groin pain. Two activities namely, pelican stance and double leg jump were selected and measurements were taken while standing on one leg and during the landing phase of the double leg jump. Due to the small sample size, no conclusive evidence can be drawn from this study. No significant differences were found for any of the measurements between affected and unaffected legs of cases, between affected legs and controls and between right and left legs of controls.

When referring to individual cases this study found mixed results in terms of increase versus decrease in sway measurements. Although not significant when referring to individual cases P2, P3 and P4 had greater A-P velocity measurements when standing on the affected leg, compared to standing on the unaffected leg (refer to table 3). Similarly, P1, P2 and P3 had greater A-P ROM measurements when landing on the affected leg compared to landing on the unaffected side (refer to table 4). Ekvall-Hansson et al. (2010) reported that ROM and velocity in an A-P direction in healthy subjects standing erected on a firm surface is 50% higher than the sway seen in a M-L direction when standing whether eyes are open or not (Ekvall-Hansson et al., 2010). Our study found greater A-P velocity measurements in sway when standing on the affected side compared to the unaffected side (table 3). COP may therefore be affected in participants with chronic groin pain but not to the extent that it could lead to loss of balance.

Although the majority of measurements recorded in standing on the affected side produced greater ROM and velocity measurements, there were cases who presented similar to findings described in the literature suggesting that less sway is found on the affected side due to excessive co-contraction when protecting the injured leg. When referring to individual cases the affected legs of P1, P2, P3 and P4 had less A-P velocity measurements compared to their match controls during double leg landing (refer to Table 4). The affected legs of P1, P3 and P4 had less A-P ROM

measurements compared to their match controls during double leg landing (refer to Table 4). Similarly, for M-L velocity measurements the affected legs of P1, P2, P3 and P4 had lower measurements than their matched controls during double leg landing (refer to Table 6). Even in standing the affected legs of P1, P3 and P4 had less M-L velocity measurements compared to their match controls (refer to Table 5). A possible explanation could be that during mid-stance, gait demands a co-contraction of the abductors and adductors muscles for pelvis stabilisation to transfer weight from the one leg to the weight bearing leg during closed chain motions such as the stance phase (Nicola & Jewison, 2012; Tyler et al., 2001 & Quinn 2010) and that lesser sway was perhaps found as a result of the adductor muscles also referred to as one of the coronal plane muscles not effectively co-contracting due to the presence of pain/ dysfunction when attempting to provide pelvic stability. (Morissey, Graham, Screen, Sinha, Small & Twycross-Lewis, et al., 2013).

Another explanation could be that muscle fatigue can influence postural stability or sway (Kuni et al. 2014). Fatigue around the hips (gluteal and lumbar extensors) and knees was also shown by Davidson (2004) to increase postural sway (Davidson 2004). Because the purpose of the larger study aimed to determine whether there are differences in the lower quadrant and trunk biomechanics among rugby and soccer playing athletes with chronic groin pain, participants were not fatigued as it was assumed that fatiguing would affect their gross motor function. Kuni et al., (2014) demonstrated that dynamic postural control in landing after a jump is impaired after a 30-minute run requiring more neuromuscular control and the risk for injury under such fatigue conditions could be greater (Kuni et al., 2014). When hip and pelvis muscles are therefore pushed to fatigue the effects of pain on balance however could be more apparent (Kuni et al., 2014). We hypothesized that in the presence of groin pain players may fixate and therefore reduce the measurement of sway. Because these participants were not pushed to fatigue the influence of groin pain on balance is less obvious when participants are in a rested state.

It is reported that left and right (M-L) sway is greater than front and back (A-P) sway during an upright posture (Kitabayashi et al., 2002). During body sway front and back sway can easily be controlled (Kitabayashi et al., 2003). Knee and ankle joints can easily move into

forward and backward directions therefor executing better muscle control during pelican stance (Kitabayashi et al., 2003). Our study found the same in that greater M-L velocity measurements were found even in a healthy population seen in C5, C7 and C8 when comparing left with right legs during foot contact after a double leg landing.

According to Duncan (1990), height can influence body however does not specify whether height increases or decreases sway. In our study we found that participant (P3) presented with a height of 189cm, showed greater A-P and M-L velocity after the double leg landing for both injured and uninjured sides (Duncan 1990).

When referring to controls, it is evident that even in controls the measurement differences when standing on one leg compared to the other is from negligible to significant. This is especially seen in case C8 (Table 4) for AP ROM and velocity which suggest that even in a healthy population differences are expected and most likely due to dominance.

As Rogind et al. (2003) stated that although there are many factors affecting COP such as decreased proprioception, strength, flexibility and muscle imbalance, humans have the ability to adjust their equilibrium to maintain COP (Rogind et al., 2003). One possible explanation as to why no significant difference was found, could be due to cases with long standing groin pain having learnt to adapt their postural control or equilibrium over time therefore compensating during functional tasks and are able to maintain their COP.

In a rested state, groin pain does not seem to significantly affect balance in rugby players however in more than 50% of cases measurements were affected when standing on the affected leg. Whether balance might be affected in this population after players are pushed to fatigue warrants further investigation.

Limitations of the study

A preliminary sample size calculation at the onset of the umbrella study suggested that this study would need a sample size of 40 participants to identify significant findings in the kinematic variables. Due to recruitment limitations, the results of this study are based

on only three cases with unilateral groin pain and one with bilateral groin pain and their matched controls.

The study was limited to all those who developed groin pain following a traumatic incident as such it cannot be generalized to other causalities of groin pain. Similarly, an accurate / confirmed diagnosis regarding which structure or the actual origin of the groin pain was not conducted in any of these cases.

Another limitation is that the adductor muscle group's strength was not tested in this study although the literature does indicate that weakness of this muscle is a risk factor for adductor-related groin pain (Maffey & Emery 2007; Tyler, Silvers, Gerhardt & Nicholas 2010). However, if the pelvis and the lower limb is being stabilised by this muscle group in a closed kinematic chain, the results of this study might suggest that no difference exist between the adductor muscle strength of subjects and controls.

Not all variables reported in the literature contributing to poor biomechanics such as adductor muscle strains, overload, body mass index, age and muscle imbalance were investigated and should also be factored into a study of this nature.

RECOMMENDATIONS FOR FURTHER RESEARCH

It is recommended that further research use random sampling and include a bigger sample size to validate results and add significance to study measurements and outcomes. By including male and female participants could provide insight as to why males have more pronounced sway than woman. A broader age range should be included to better validate the demographics of adductor-related groin pain.

To include subgrouping of participants according to range of motion (ROM) and visual analogue scale (VAS) findings were beyond the scope of this study and the small sample size does not allow for this, however including these outcomes in future studies is necessary as it has the potential to better validate findings of future studies.

Reliability of the testing was not done which could lead to less accurate results. In future studies the researcher should at least demonstrate reliability of self when using outcome measures.

Associated factors such as strength and stiffness should also be investigated in future research. Further investigation is needed to determine how COP is affected by acute groin pain.

According to Kuni et al., (2014) fatigue has an adverse effect on kinetics (Kuni et al., 2014). Fatiguing of participants in this study did not take place, we thus recommend that future research includes fatiguing of participants to measure the effect that fatiguing would have on postural control and to consider the outcome when planning a rehabilitation program. Real-life activity is not reflected in this study since all the testing was laboratory based. During real-life sporting activities, landing might be bilateral or unilateral. In this study participants were instructed to perform a double leg landing which is a bilateral activity where COP and the better or unaffected side may compensate sufficiently for the affected side. Landing on one leg should be included in future investigations.

Participants were not given specific instructions such as increasing the flexion at their hips, knees or ankles when landing to increase the landing time (Ortega et al., 2010), instead they were asked to jump and land on both feet. Therefore, it was not possible to measure if all participants had the same style of jump and landing technique.

The current study is not able to contribute to intervention approaches/strategies as the findings suggest that balance is not affected by the presence of chronic groin pain. Not having fatigued participants before measurement, may however have underestimated the impact of chronic groin pain on balance in this population.

CONCLUSION

The aim of this study was to determine whether there were any differences in COP ROM and velocity amplitude measurements in rugby players with chronic groin pain between cases and controls during a pelican stance test and after a double leg landing. No significant differences were found for A-P and M-L mean ROM and velocity. It is postulated that a player with groin pain have over time learned to compensate in adjusting their COP or current the methodology used in this research masked the effect of fatigue on these variables associated with balance.

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Appendix A: Ethics Approval

JOB KNOWLEDGE • YOUR KNOWLEDGE • BETTER

Ethics Letter

015

Reference #: S12/10/265

Trial Reference #:

Measurement of Biomechanics during functional Activities in Adults Sports participants with Chronic

Tracy MORRIS,

I have approved your application for a Protocol Amendment dated 2 October 2014.

I was also granted for the new research team for the extended study namely:

Principal Investigator:

LOUW

Members:

INE BRUINDERS

-LYNN MOODIEN

DOETSEE

WHITEBOOI

NE DU PLESSIS

Observers:

✓ MARI VAN NIEKERK

ANDI BRINK

KEEMAH INGLIS JASSIEM

IN COCKCROFT

RIANNE UNGER

ARLETTE BURGER

Appendix B: Participant Information Leaflet

You are herewith invited participate in a research project. The study is aimed at analyzing the trunk and lower limb movements of soccer and rugby players that have chronic groin injuries and comparing them to players that are uninjured. This will allow for a greater understanding as to the possible causing/ contributing factors of a groin injury.

Please take some time to read the information presented here, which will explain the details of this project. Please feel free to contact the **Principal Investigator** should any questions about any part of this project, should you not fully understand. It is very important that you clearly understand what this research entails and how you would be involved.

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.

PRINCIPAL INVESTIGATOR

Prof Quinette Louw

CONTACT NUMBER

021 938 9667

CO-INVESTIGATORS

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Catherine Du Plessis

074 176 8747

Title**COP DURING PELICAN STANCE AND DOUBLE LEG LANDING IN RUGBY PARTICIPANTS WITH CHRONIC GROIN PAIN.****Introduction**

Groin pain is a common complaint amongst athletes and with a higher prevalence in athletes partaking in sports that involve sprinting, twisting, kicking and rapid change in direction (Jansen et al. 2008, Patel et al. 2011). Adductor strain-related injuries account for 58% of sport related groin injuries with the tendon of adductor longus being involved most frequently (Hölmich et al. 2007, Sedaghati et al. 2013, Gill et al. 2014). Adductor strains can either be due to a traumatic mechanism such as forced abduction of the hip or as a result of repetitive strain of the adductor muscle (Machotka 2009, Hackney 2012). An athlete with a previous adductor strain injury is twice as likely to experience recurring injuries in the groin (Engebretsen et al. 2010). Groin injury is susceptible to chronicity and recurrence, however remains inadequately defined and lacks clear diagnostic measures (Crow et al. 2010).

There is poor understanding of the mechanism of chronic groin pain and the association thereof with biomechanical risk factors of the pelvis and lower limb (Morrissey et al 2012). A study by Morrissey et al. (2012) found a significant reduction in the ratio of gluteus medius and adductor longus activation during standing hip flexion (pelican stance) due to injured subjects having a marked reduction in gluteus medius activation pattern. Furthermore, they made a finding which noted the injury-associated muscle imbalance to be present when testing the uninjured leg of injured subjects which could have been a reflection of predisposition to injury or the bilateral effect of groin injury (Morrissey et al. 2012).

The purpose of this study is to explore differences in the COP in active rugby and soccer players with chronic groin pain compared with asymptomatic controls.

Research Question

What are the differences in COP in athletes with chronic adductor-related groin pain during pelican stance and double leg landing compared to healthy controls?

Aims

The aim of the study is to determine how COP is affected among rugby and soccer players with chronic adductor related unilateral and/ or bilateral groin pain during pelican stance and double leg landing, compared to healthy controls.

Objectives

1. To describe postural sway (as determined by the center of pressure) during pelican stance.
2. To describe postural sway (as determined by the center of pressure) during the landing phase of a double leg jump.

Methodology

Population: Males ranging from 18–55 years of age who actively participate in soccer and rugby.

Study setting: The Physiotherapy and FNB-3D Movement Analysis Laboratory, Stellenbosch University, Tygerberg Campus, Cape Town, South Africa.

Sample size: 8 participants, 4 cases and four asymptomatic matched controls, based on the inclusion and exclusion criteria for cases and control in table 1 and 2, respectively, as seen in Appendix A.

Sampling method: Convenience sampling will be performed to recruit participants from soccer and rugby clubs situated in the Cape Peninsula area, Western Cape, South Africa.

Diagnostic criteria: Subjective examination revealing unilateral or bilateral inguinal pain and a positive adductor squeeze test indicating adductor muscle related pain.

Measurement Tools

Visual analogue scale (VAS): A self-reporting instrument on pain intensity.

Force plate: This will be used to measure postural sway in the landing phase of the double leg jump and during pelican stance.

Anticipated Risks

There are no anticipated risks for the participants that will take part in this study.

Anticipated Benefits

The study will provide insight into whether there are biomechanical differences in the lower quadrant and trunk among rugby and soccer playing athletes with chronic groin pain. This will facilitate the understanding of the possible aetiology of groin pain.

Ethical Considerations

Approval for conducting the study will be obtained from the Committee of Human Research at Stellenbosch University. The study will be conducted according to the internationally accepted ethical standards and guidelines as stipulated in the Declaration of Helsinki (2013) and South African Guideline for Good Clinical Practice. Informed voluntary written consent will be obtained from each participant. All the procedures will be explained to each participant and the results will be shared with them. A number will be allocated to each participant ensuring their anonymity. Separate consent will be obtained for the use of photographs taken during the study.

There are no foreseeable risks involved in this study. It is hoped that the information gained in this study will provide a better understanding of adductor related groin pain which may lead to better future prevention and management strategies. Participants will not receive any remuneration for participating in the study, however they will be reimbursed for transportation and meal costs.

Appendix C: Participant Screening Form

Name:

Age:

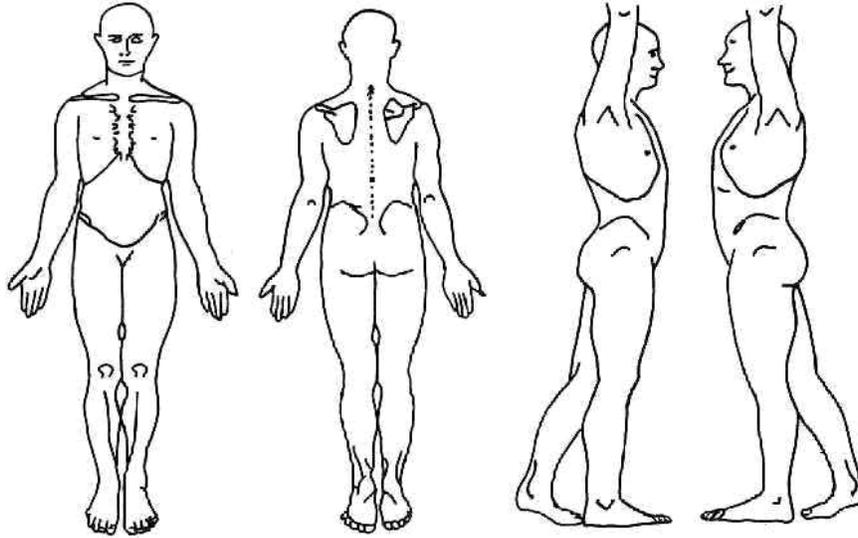
What sport do you play	Rugby	Soccer
How many hours do you spend training and participating in your sport per week		
Have you ever had any pain over your groin area?	YES	NO
Has the groin pain been there for longer than three months?	YES	NO
Is the groin pain currently stopping you from participating in sport?	YES	NO
Which side is your pain? (It can be on both sides)	LEFT	RIGHT
Do you feel generally healthy?	YES	NO
Do you have a history of neck, back, pelvis or limb	YES	NO

injuries? If YES, please state	Types of injuries: _____	
Have you suffered from any of the symptoms related to prostatitis or urinary tract infection, as listed adjacently? YES/ NO	Pain and tenderness in upper back and sides.	Rectal pain.
	Pain in the pelvis, genitals, lower back and buttocks.	Discomfort in the perineal area (area between the scrotum and the anus)
Have you had symptoms associated with nerve entrapment syndrome in your legs (tingling, pins and needles, numbness or burning pain)?	YES	NO
Have you undergone any orthopaedic surgery, as listed adjacently in the last 12 months? YES/ NO	Lumbar spine	Pelvis
	Hip Joint	Knee joint
	Ankle joint	Foot
Have you been diagnosed with any of the following illnesses? YES/ NO	Ankylosing Spondylosis;	Scheuerman's disease
	Rheumatoid Arthritis;	Muscular Dystrophy
	Paget's disease	

Thank you for your time. We will contact you in regard to forming part of the study.

Appendix D: Physical Examination

Body chart:



Observation:

Functional demonstration/activity:

Squats

Lunges

Active physiological movements:

Passive physiological movements:

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

Special tests:

- Leg Length
- Lumbar (Active physiological movements, Combined movements, if indicated)
- Knee (Active physiological movements, Combined movements, if indicated)
- Ankle (Active physiological movements, Combined movements, if indicated)
- SIJ (battery of 4 tests):
 - Fabers Test, Gaenslen's Test
 - P4 Test, Palpation of the Long dorsal ligament (LDL)
- Hip Quadrant (if indicated)
- Femoral nerve (mid lumbar slump)
- Pain on coughing

Appendix E: Diagnostic Physical Examination

1. Battery of 4 tests for SIJ clearance

Three out of these four tests need to be positive for diagnoses of SIJ dysfunction.

1.1 Faber's Test

1.1.1 Description

The patient lies supine, one leg is flexed, abducted and externally rotated so that the heel rests on the opposite knee. The examiner presses gently on the superior aspect of the tested knee joint.

1.1.2 Interpretation

If pain is felt in the sacroiliac joint or in the symphysis, the test is considered positive (Vleeming et al. 2008).

1.2 Gaenslen's Test

1.2.1 Description

The patient lying supine flexes the hip/knee and draws it towards the chest by clasping the flexed knee with both hands. The opposite leg extends over the edge while the other leg remains flexed. The examiner uses this maneuver to gently stress both sacroiliac joints simultaneously.

1.2.2 Interpretation

This test is positive if the patient experiences pain (either local or referred) on the provoked side (Vleeming et al. 2008).

1.3 P4 Test

1.3.1 Description

The test is performed supine and the patient's hip flexed to an angle of 90 degrees on the side to be examined. Light manual pressure is applied to the patient's flexed knee

along the longitudinal axis of the femur while the pelvis is stabilized by the examiners other hand resting on the patient's contralateral superior anterior iliac spine.

1.3.2 Interpretation

The test is positive when the patient feels a familiar well localized pain deep in the gluteal area (Vleeming et al. 2008).

1.4 Palpation of the LDL

1.4.1 Description

Patient is in supine lying, the long dorsal ligament is palpated by the examiner.

1.4.2 Interpretation

Tenderness over the ligament is interpreted as a positive test (Vleeming et al. 2008).

2. Femoral nerve test (Mid lumbar slump)

2.1.1 Description

Patient is in side lying on the edge of the bed. The testing side is on the bottom. The patient holds the upper hip and knee in more than 90degrees of flexion. The cervical spine is supported in neutral on his arm and is in flexion. The tester stands behind the patient, the cephalad hand reaches over to hold the bed side and stabilize the patient's trunk, the other hand supports the patients lower leg under the knee and moves the hip back into extension.

2.1.2 Interpretation

Pain in area can be structurally differentiated by doing active cervical extension into neutral; if the pain dissipates the test is negative (Shacklock, 2005).