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THE LOWER LIMB MUSCLE ACTIVITY AND LUMBO-PELVIC MOVEMENT CONTROL IN SOCCER PLAYERS: A MATCHED CASE CONTROL STUDY

Riali Roos
Student number 352991

A Research Report submitted to the Faculty of Health Sciences, University of the Witwatersrand

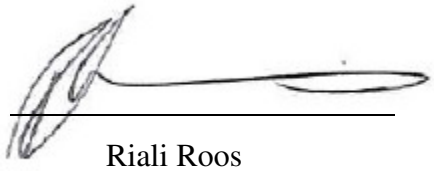
Gauteng, 2017

DECLARATION

I, Riali Roos, declare that the work contained in this research report is my own, except where otherwise indicated in the acknowledgement section.

This research report is being submitted to the University of the Witwatersrand, Johannesburg, South Africa for a degree of Masters in Sports Physiotherapy.

This work has not been submitted for any other degree or examination at this or any other university.



Riali Roos

28-02-2017

Date

ABSTRACT

Background

Soccer is a sport that is gaining in popularity in the elite and non-elite populations worldwide. As a result, the number of injuries in soccer is increasing. Hamstring injuries in particular, with a reported incidence rate as high as 63%, are of significant concern. Most hamstring injuries tend to occur during the swing phase of sprinting when hamstring activity is at its highest. As the speed of sprinting increases, greater mobility in the lumbo-pelvic area is required to maximise sprinting efficiency. Any abnormal or dysfunctional lumbo-pelvic movement during this phase could induce pain and hamstring injury. Lumbo-pelvic movement control dysfunction may therefore indirectly link abnormal lumbar spine movement to lumbo-pelvic pain and hamstring injury.

The first aim of this study was to compare the performance of the erector spinae, gluteus maximus, hamstrings (biceps femoris) and quadriceps (rectus femoris) muscles in soccer players, with and without recent hamstring injuries, while performing isometric contractions, a functional squat and sprinting. The study's second aim was to compare lumbo-pelvic movement control in soccer players with and without recent hamstring injuries.

Method

Thirty soccer players were selected to participate in this study. Fifteen were assigned to the injured group and 15 to an uninjured group. The injured group comprised players who had sustained a hamstring injury six months prior to the research and who had partially returned to training, and the uninjured group comprised players with no recent hamstring injuries and who were actively involved in full training. Players were matched in respect of age, height, weight and playing position.

All players gave informed written consent, completed the physical activity, training and injury questionnaire, and the Oslo hamstring injury questionnaire. Physical tests, which included isometric contraction of the erector spinae, gluteus maximus, hamstrings (biceps femoris) and quadriceps (rectus femoris) muscles, a functional squat and a thirty-metre sprint were done. Muscle activity during these tests was recorded via electromyography (EMG). To determine the lumbo-pelvic movement control of the players, the dorsal pelvic tilt, waiter's bow, one leg stand and prone knee bend tests were used.

Cohen's *d* (parametric) and Spearman's correlation coefficient (nonparametric) were used to calculate the effect size, and the Chi-square test and Fisher's exact to analyse the lumbo-pelvic movement control data. To establish a statistical significance, the p-value of the study was set at $p<0.05$.

Results

EMG muscle activity during isometric contractions was lower in the erector spinae muscles ($p=0.04$) and biceps femoris muscle ($p=0.02$) of the injured group. Both these findings were statistically significant. There was no statistically significant difference in muscle activity during the functional squat between the study and uninjured groups. The results of the EMG activity in the thirty-metre sprint were determined to be significant as they demonstrated that the hamstring muscle ($p=0.01$) activation in the injured group was decreased in comparison with the uninjured group.

During the performance of the lumbo-pelvic test, no association was found between the two groups in the dorsal pelvic tilt and one leg stand. The performance of the waiter's bow ($p=0.01$) and prone knee bend ($p=0.004$) revealed statistically significant differences between the study and uninjured groups. The majority of the players in the injured group performed both of these functional tests incorrectly (WB n=10; PKB n=14).

Conclusion

The study found that the hamstring muscle is at great risk of injury during eccentric contraction of the hamstring muscles. This can be associated with poor lumbo-pelvic movement control, as the load on the hamstring muscle is increased to provide intersegmental stability around the neutral zone, the area of high spinal flexibility.

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LIST OF ABBREVIATIONS

ACL	Anterior cruciate ligament
BF	Biceps femoris
DPT	Dorsal pelvic tilt
EMG	Electromyography
ES	Erector spinae
FAOS	Foot and Ankle Outcome Score
GM	Gluteus maximus
KOOS	Knee Osteoarthritis Outcome Score
MRI	Magnetic resonance imaging
MVC	Maximum voluntary contraction
OLS	One leg stand
PAR-Q	Physical activity and readiness questionnaire
PKB	Prone knee bend
RF	Rectus femoris
RMS	Root mean square
ROM	Range of motion
SD	Standard deviation
SIJ	Sacroiliac joint
TLF	Thoracolumbar fascia
WB	Waiter's bow

CHAPTER 1: INTRODUCTION AND SCOPE OF THE RESEARCH REPORT

1.1 Introduction

Globally, soccer is a popular activity for athletes of all ages and capabilities (Kucera et al, 2005). Due to the repetitive strides of sprinting, hamstring injuries are a common problem leading to time off training and missed match play. Van Beijsterveldt, van de Port, Vereijken and Backx (2013) noted that some studies cite the incidence of hamstring injuries among soccer players as high as 63%.

The excessive build-up of force in the hamstring muscles during the swing phase of sprinting appears to put the hamstring muscles at great risk of injury. According to Enami, Massoud and Ghamkhar (2014), up to 12% of all soccer injuries reported annually are related to the hamstring muscles. These figures are difficult to assess as there are few standardised methods of describing and reporting the injury. Hamstring injuries have been referred to as hamstring pain, hamstring spasm, posterior leg pain, or hamstring strain, or in combination with lumbo-pelvic movement control dysfunction or hip injuries.

Orchard and Seward (2002) reported that the activity of the hamstring muscles is at its highest during the swing phase of sprinting, a phase during which most hamstring injuries commonly tend to occur. Fletcher (2009) proposed that this manner of injury is more frequent in soccer players whose sprinting techniques are poor, or whose gluteus maximus muscle, the primary muscle that drives hip extension during sprinting, is weak or slow to activation.

During the sprinting action, the hamstring muscles are required to operate as the transducer of power between the hip and the knee joints, providing little contribution to hip extension (Chumanov, Heiderscheit and Thelen, 2011). This transfer of power between the hamstring muscles and the knee and hip joints is necessary to generate explosive movements such as sprinting (Hamner, Seth and Delp, 2010). Hypothetically, the hamstring muscles may be required to contribute additional force to perform hip extension, instead of acting as a transducer of power, in the presence of gluteus maximus muscle inhibition. This potentially predisposes the hamstring muscles to injury (Hoskins and Pollard, 2005).

As speed increases during sprinting, the stance phase duration decreases (Chumanov, Heiderscheit and Thelen, 2011). This action requires more precise lumbo-pelvic movement control in order to minimise energy expenditure and maximise sprinting efficiency (Fletcher, 2009).

Hamner, Seth and Delp (2010) found that the lumbar erector spinae muscle is activated during the first part of the stance phase, possibly as a result of weakness or deficiency in the lumbar erector spinae muscle's activation, which may compromise the stability of the lumbar spine around the neutral zone. The coordination of the flexion motion segment at the neutral zone plays a major part in functional spinal instability (Novacheck, 1997), predominantly as this is the physiological region where motion occurs (Schache et al, 2002). Hoskins and Pollard (2005) concluded that the neutral zone is subjected to increased ranges in the available range of motion, and this has been found to be an early indicator of the onset of possible joint injury.

In addition, Hodges and Moseley, (2003) found that muscle atrophy, a delay in muscle activation, decreased endurance and an increase in fatigue of the multifidus muscle are prominent in low back pain conditions. They proposed that these factors could inhibit the muscle's ability to contract in a coordinated manner to increase spinal stability around the neutral zone.

Increased threshold and a delay in activation of the transversus abdominis muscle have been reported following pain as well as in pain-free situations (Hodges and Moseley, 2003). The delay in activation of the transversus abdominis muscle was found to lead to the earlier activation of the biceps femoris muscle (Hungerford, Gilleard and Hodges, 2003). The delayed activation could potentially cause the biceps femoris muscle to contract in compensation to stabilise the thoracolumbar fascia system, increasing the potential for injury (Hoskins and Pollard, 2005). It can be said that lumbo-pelvic movement control dysfunction could be an indirect link between aberrant movement in the lumbar spine and lumbo-pelvic pain and hamstring injury.

Electromyography (EMG) has been used to assess and record the electrical activity produced by skeletal muscle. This electrical activity can be used for a variety of physical assessments, including the detection of medical abnormalities, activation levels of muscles, sequence of recruitment of muscles and the analysis of biomechanics in human and animal movement

(Kotila, 2014). EMG has rarely been used to measure muscle activity in the erector spinae, gluteus maximus, hamstrings and quadriceps muscles in soccer players.

The assessment of lumbo-pelvic movement control has previously been used to examine the possibility of a link between lumbo-pelvic movement control and injury in cricket pace bowlers (Olivier, Stewart, Olorunju and McKinon, 2015). Lumbo-pelvic movement control assessment has rarely been used to measure a relationship between lumbo-pelvic movement control and injuries in soccer players (Sole, Milosavljevic, Nicholson and Sullivan, 2012).

Additional research comparing soccer players who have sustained recent hamstring injuries with an uninjured group is required to assess the difference in muscle activation, muscle recruitment patterns and lumbo-pelvic movement control. This will provide a better understanding of neuromuscular control and possibly detect those at risk for developing hamstring injuries.

1.2 Problem Statement

While there is a vast amount of research on soccer injuries, limited research has been done on the role of the erector spinae, gluteus maximus, hamstrings (biceps femoris) and quadriceps (rectus femoris) muscle activities, and lumbo-pelvic movement control in relation to hamstring injuries. EMG techniques and lumbo-pelvic movement control have been used to investigate the hamstring muscles, but rarely in soccer players or in comparison with an injury-free group of players (Olivier, Stewart, Olorunju and McKinon, 2015).

Only a few studies have investigated the biomechanical causes of hamstring injuries in soccer players and an investigation into these causes of injury may give a better understanding of the changes that occur in the neuromuscular control of players who suffer from hamstring injuries. Further studies could determine if exercises that focus on improving neuromuscular control could lessen the occurrence and risk of hamstring injuries. The results of this study will thus inform the development of hamstring injury prevention and rehabilitation programmes.

1.3 Research Question

Is there a difference in lower limb muscle activity and lumbo-pelvic movement control between soccer players with recently sustained hamstring injuries compared with uninjured players?

1.3.1 Aim of the Study

The first aim of this research was to examine the difference in muscle activity of the erector spinae, gluteus maximus, hamstrings (biceps femoris) and quadriceps (rectus femoris) muscles between players, with and without hamstring injuries, while performing isometric contractions, a functional squat and sprinting. The second aim was to compare lumbo-pelvic movement control in soccer players with and without recent hamstring injuries.

1.3.2 Objectives of the Study

- To establish the muscle activity using EMG of the erector spinae, gluteus maximus, hamstrings (bicep femoris) and quadriceps (rectus femoris) muscles in soccer players with recent hamstring injuries and in uninjured players during isometric contractions, a functional squat and a thirty-metre sprint.
- To establish and compare the lumbo-pelvic movement control of uninjured soccer players and those with recent hamstring injuries during a dorsal pelvic tilt, waiter's bow, one leg stand and prone knee bend.
- To compare the muscle activities and lumbo-pelvic movement control between soccer players with recent hamstring injuries and uninjured players.

1.4 Significance of the Study

It has been theorised that injuries, particularly in the lower limbs, could be a result of changes in neuromuscular control. Sole, Milosavljevic, Nicholson and Sullivan (2012) speculated that an increase in muscle activation could potentially overload the hamstring muscles, thus leaving them more susceptible to injury.

While EMG data of the activation patterns of the erector spinae, gluteus maximus, hamstrings (biceps femoris) and quadriceps (rectus femoris) muscles, and lumbo-pelvic control reveals an effect on neuromuscular control, there is no study that specifically examines the activation patterns and their effect on soccer players with recent hamstring injuries.

An investigation into these potential injury mechanisms may provide a better understanding of what changes occur in the neuromuscular control of soccer players with recent hamstring injuries. This could precipitate further research on the types of exercises that could improve neuromuscular control and reduce the incidence and risk of injury.

The results of this study will thus provide information for the development of hamstring injury prevention and rehabilitation programmes.

1.5 Organisation of the research report

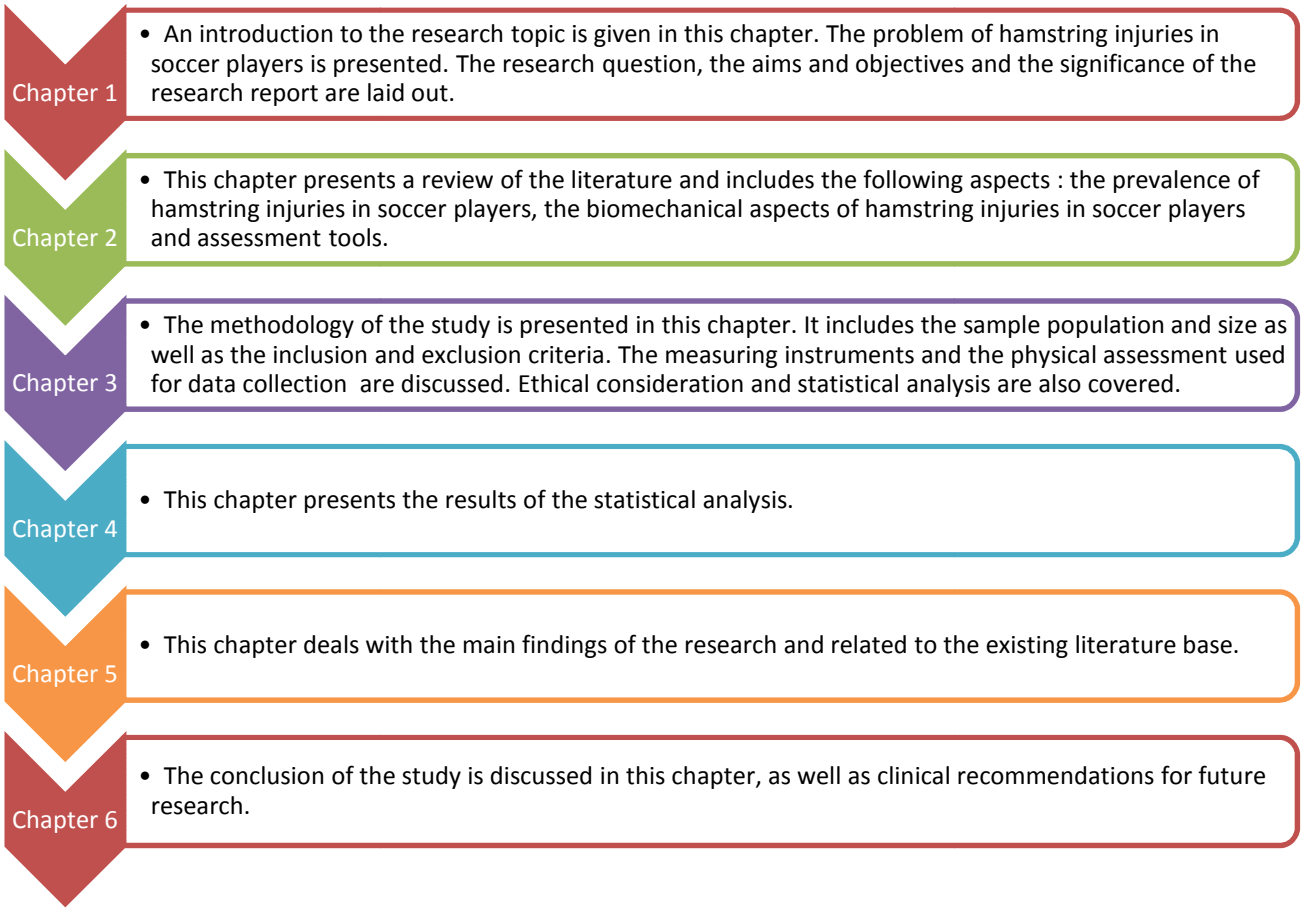


Figure 1.1 Organisation of the research report

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter reviews the current available literature documenting hamstring muscle injuries within the soccer population, and the possible link between the muscle activity of the erector spinae, gluteus maximus, hamstrings (biceps femoris) and quadriceps (rectus femoris) muscles and lumbo-pelvic movement control. The anatomy and biomechanics of the hamstring muscles, including the causes and risk factors for hamstring injuries, are discussed. There is no standard return-to-play protocol governing a hamstring injury, and the criteria directing this are reviewed. The literature review discovered no studies comparing lumbo-pelvic movement control dysfunction in soccer players with and without recent hamstring injuries. Lumbo-pelvic movement control is therefore, discussed. Instrumentation and assessments of muscle activity and lumbo-pelvic movement control are presented and discussed.

Evidence was sourced from online sports medicine and science literature databases, including PubMed, CINAHL, PEDro, Science Direct and Google Scholar, and included English articles published between 2000 and March 2016. Keywords used in the search were soccer, injuries, hamstring, biomechanics, risk factors, isometric control, isotonic control, sprinting, electromyography/EMG and lumbo-pelvic movement control.

2.2 Anatomy and biomechanics of the hamstring muscles

Three muscles make up the hamstring muscle group: laterally the biceps femoris muscle and medially the semimembranosus and semitendinosus muscles. The long head of the biceps femoris muscle and the semitendinosus muscle originate from the inferomedial part of the upper area of the ischial tuberosity, and the short head of the biceps femoris muscle originates from the lateral lip of the linea aspera on the femur. The semimembranosus muscle originates from the superiolateral impression on the ischial tuberosity (Seeley et al, 2000). Each of these three muscles inserts in various areas on the proximal lower leg. The biceps femoris muscle inserts on the head of the fibula laterally while the semitendinosus muscle inserts on the medial surface of the tibia. The semimembranosus muscle inserts on the groove and adjacent bone on the medial and posterior surface of the medial tibial condyle (Seeley et al, 2000) (Figure 2.1).

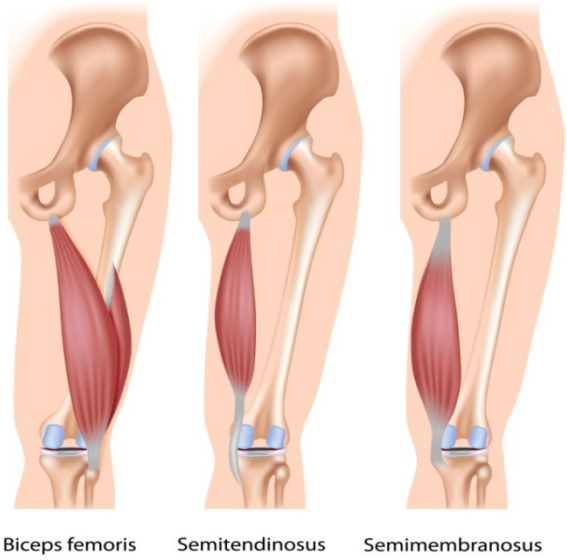


Figure 2.1 Anatomy of the hamstring muscle group (Seeley et al, 2000)

The hamstring muscle group is functionally connected to the lumbo-pelvic area, upper torso, shoulders and skull through the thoracolumbar fascia (TLF) (Hoskins and Pollard, 2005) (Figure 2.2). To thoroughly understand the functional connection of the TLF to the hamstring muscles, the anatomy of the TLF has to be understood. The TLF attaches to the latissimus dorsi, transversus abdominis, internal oblique and rhomboid muscles, splenius capitis and cervicis tendons, lumbar vertebrae and posterior superior iliac spines (Hoskins and Pollard, 2005) therefore functionally connecting the hamstring muscles to the TLF. In a study by Barker et al (2004) on cadaver specimens, it was found that contractures in the muscles that attach to the TLF could cause TLF displacement. Hamstring muscle tension can tighten the TLF and therefore reduce motion in the sacroiliac joint (SIJ) (Van Wingerden, 2004).

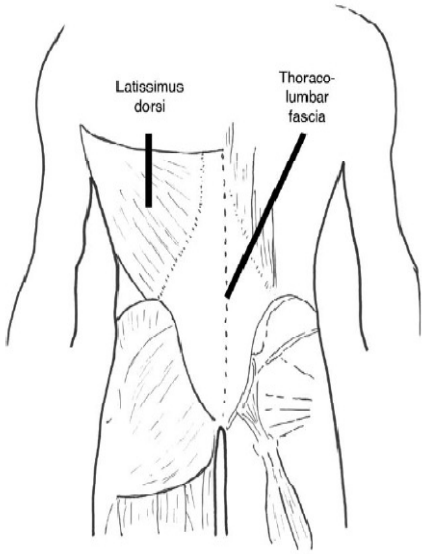


Figure 2.2 Attachment of the TLF to the latissimus dorsi muscle which functionally connects the hamstring muscles with the shoulders and upper torso (Hoskins and Pollard, 2005)

Tensioning of the TLF can be link to the large attachment areas of transversus abdominis muscle (Hoskins and Pollard, 2005). The transversus abdominis muscle originates from the internal surfaces of the seventh to twelfth costal cartilages, TLF, iliac crest and connective tissue deep to the lateral third of the inguinal ligament and inserts into the linea alba with aponeurosis of the interal oblique muscle, pubic crest and pecten pubis via the conjoint tendon (Hoskins and Pollard, 2005). Therefore, it can be seen that there is a continuation of the TLF via the lateral raphe, internal obliques and the aponeurosis of the transversus abdominis muscle (Hoskins and Pollard, 2005). The sacrotuberous ligament originates from the posterior ilium and inserts into the ischial tuberosity where it joins the biceps femoris muscle at its origin (Figure 2.3). This connection functionally connects the biceps femoris muscle to the TLF through the sacrotuberous ligament (Hoskins and Pollard, 2005). The perpendicular forces of the TLF could therefore produce stability to the SIJ. Delayed activation of the transversus abdominis muscle could lead to earlier activation of the biceps femoris muscle to stabilise the TLF (Hoskins and Pollard, 2005). Verral et al (2001) concluded in a study that dysfunction of the lumbar spine, SIJ and pelvis is a predisposing risk factor to hamstring injuries.

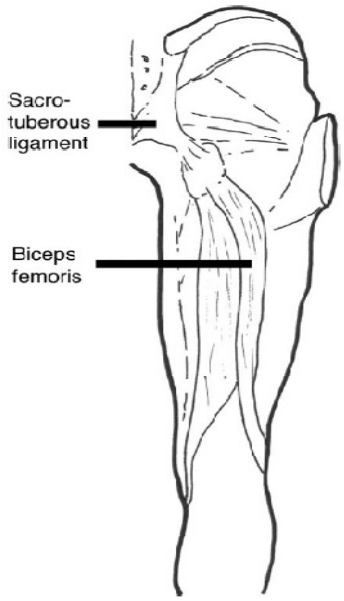


Figure 2.3 Continuation of the biceps femoris muscle to the sacrotuberous ligament, which attaches to the TLF (Hoskins and Pollard, 2005)

The hamstring muscle group is further functionally connected to the knee, ankle and foot due to its insertion on the proximal lower leg. The biceps femoris muscle has a strong fascia connection to the fibularis longus muscle at the fibula head, laterally, functionally connecting

the hamstring muscle group to the ankle and foot (Hoskins and Pollard, 2005) (Figure 2.4). Medially the semimembranosus muscle has expansion extending into the knee joint capsule and the meniscotibial and meniscofemoral formations (Hoskins and Pollard, 2005). This anatomical attachment of the semimembranosus muscle functionally connects the hamstring muscle group to the popliteus muscle and knee joint. The hamstring muscle group is also connected to the knee joint through the hamstring-anterior cruciate ligament (ACL) arc (Hoskins and Pollard, 2005). Hoskins and Pollard (2005) reported that the proprioceptive feedback from the ACL mechanoreceptors and afferent input from the skin and muscles plays a significant role in hamstring muscle activation during sprinting.

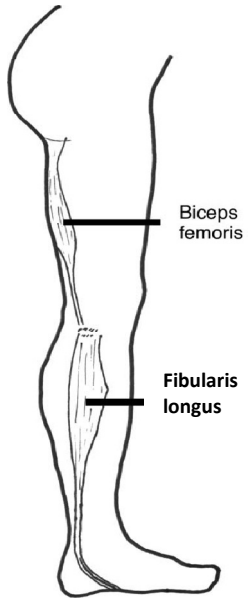


Figure 2.4 Functional connection of the biceps femoris muscle to the fibularis longus muscle (Hoskins and Pollard, 2005)

Due to the functional connection of the hamstring muscle group with the lumbar spine, sacrum, pelvis, knee, ankle and foot, it has been recommended that the hamstring muscle group should not be assessed in isolation but in conjunction with the biomechanics of its functional connection (Ivan, 2012).

2.3 Location and severity of hamstring injuries

Hamstring injuries tend to occur proximal to the distal musculotendinous junction, where the majority of force is concentrated during muscular contraction (Kirkendall and Garrett, 2002). Hoskins and Pollard (2005) reported that injuries within muscle tendon or the musculotendinous junction are more severe than injuries to the muscle belly due to the decreased blood supply to those areas after an injury. The decreased blood supply, therefore,

indirectly influences the length of time required for rehabilitation (Hoskins and Pollard, 2005). Hamstring injuries may include a muscle strain, muscle rupture, cramp or spasm (Enami, Massoud and Ghamkhar, 2014).

The majority of hamstring injuries occur in the biceps femoris muscle with a prevalence of 76% to 87% of cases and, more especially, at the musculotendinous junction of the proximal biceps femoris muscle head (Woods et al, 2004). Even though the highest percentage of hamstring injuries occurs within the biceps femoris muscle, injury to multiple locations is also possible (De Smet and Best, 2000).

Due to the myofascial attachments of the biceps femoris muscle, it could be predisposed to injury, with injuries occurring most commonly at the weakest point of the kinetic chain (Hoskins and Pollard, 2005). The biceps femoris muscle has attachments over two joints and therefore has the longest length of muscle tendon in the hamstring muscle group. Schache (2010) stated the length of the muscle might increase its risk to injury.

The severity of hamstring injuries can be graded into three categories (Table 2.1). This system of classification is not precise, but it rates the disability of injury and can assist in predicting the duration of a rehabilitation programme. Hoskins and Pollard (2005) found the period of rehabilitation to be proportional to the degree of the disability, the grade and the location of the injury.

Table 2.1 Three grades of hamstring injury severity
(adapted from Hoskins and Pollard, 2005)

Grade	Description
1 Mild	Limited fibre involvement with minimal reduction in strength or range of motion (ROM) of the muscle.
2 Moderate	50% of the muscle is involved with high levels of pain, presence of swelling and reduction in muscle strength. There is a noticeable decrease in ROM as a result of pain.
3 Severe	Complete rupture of the muscle belly or the musculotendinous junction. It is associated with severe pain and swelling as well as complete loss of function.

2.4 Causes of hamstring injury

The majority of hamstring injuries occur while the player is sprinting during soccer (Petersen et al, 2011). It has been suggested that the risk of sustaining a hamstring injury has two major components. The first component is stretching and lengthening of the hamstring muscles and

the other is eccentric contraction of the hamstring muscles to decelerate hip flexion and control knee extension (Schache et al, 2009).

Hoskins and Pollard (2005) systematically reviewed the potential connections and contributing factors to hamstring injuries to explore diagnostic issues following a hamstring injury. Evidence was used to discuss the aetiological factor and pathogenesis related to hamstring injuries. Hoskins and Pollard (2005) concluded that the hamstring muscles are at most risk of injury during the terminal swing phase of sprinting while hamstring activity is at its highest and when the hamstring muscles are most biomechanically exposed.

Hoskins and Pollard (2005)'s findings were further explored by Schache et al (2009) during a clinical trial investigating the biomechanical causes of an acute hamstring muscle strain. Schache et al (2009) supported Hoskins and Pollard (2005)'s in their investigation by also concluding that the hamstring muscle is most risk of injury during the terminal swing phase of sprinting before initial heel strike because of an eccentric contraction. In a presentation, Iain Fletcher (2009) stated that this method of injury is more predominant in soccer players whose sprinting techniques are poor, or whose gluteus maximus muscle, the primary muscle that drives hip extension during sprinting, is weak or slow to activation.

During the sprinting action, the hamstring muscles are required to operate as the transducer of power between the hip and the knee joints, contributing little to hip extension (Chumanov, Heiderscheit and Thelen, 2011). This transfer of power between the hamstring muscles and the knee and hip joints is necessary to produce explosive movements such as sprinting (Hamner, Seth and Delp, 2010). Hypothetically, the hamstring muscle may be required to provide additional force to perform hip extension, instead of acting as a transducer of power, in the presence of gluteus maximus muscle inhibition. This potentially predisposes the hamstring muscles to injury (Hoskins and Pollard, 2005).

As speed increases while sprinting, the duration of the stance phase decreases (Chumanov, Heiderscheit and Thelen, 2011). This requires more precise lumbo-pelvic movement control to minimise energy expenditure and maximise sprinting efficiency (Fletcher, 2009). Hamner, Seth and Delp (2010) found that the lumbar erector spinae muscle is activated during the first part of the stance phase, possibly as a result of weakness or deficiency in the muscle's activation, which may compromise the stability of the lumbar spine around the neutral zone.

The coordination of the flexion motion segment at the neutral zone plays a major part in functional spinal instability (Novacheck, 1997), predominantly as this is the physiological region where motion occurs (Schache, et al. 2002). Hoskins and Pollard (2005) concluded that the neutral zone is subjected to increased ranges in the available range of motion, and this has been found to be an early indicator of the onset of possible joint injury.

In addition, Hodges and Moseley (2003) found that muscle atrophy, a delay in muscle activation, decreased endurance of and an increase in fatigue of the multifidus muscles, were prominent in lower back pain conditions. They proposed that these factors could inhibit the muscles from contracting in a coordinated manner to increase spinal stability around the neutral zone.

Hungerford, Gilleard and Hodges (2003) conducted a study on patients with clinically diagnosed sacroiliac joint pain to measure trunk and hip muscle activation during hip flexion in standing. The study included fourteen participants in both the control and study group. The results of the study concluded that delayed activation of the transversus abdominis, multifidus and gluteus maximus muscles on the symptomatic side of the study group has led to earlier activation of the biceps femoris muscle. Therefore, the compensation of the biceps femoris muscle to stabilise the trunk, specifically TLF, can lead to overload of the biceps femoris muscle thus increasing the potential for injury (Hoskins and Pollard, 2005).

2.5 Risk factors predisposing soccer players to hamstring injuries

The hamstring muscle group has a biarticular nature and stretches over two joints. This may partly contribute to the high incidence of hamstring injuries in the sporting population (Orchard and Seward, 2002). An anteriorly tilted pelvis will change the hamstring muscle biomechanics and function in that the ischium is moved further away from the distal insertion of the hamstring muscles, thus stretching the hamstring muscles. This increase in stretch of the hamstring muscles will lead to increased mechanical stress and strain during movement which can result in potential hamstring injuries (Hunter and Speed, 2007).

The hamstring muscles are made up of mainly type II fast twitch muscle fibres that are capable of producing large substantial forces in comparison with other leg and thigh muscles (Engebretsen, 2010) (Table 2.2). The increase in fast twitch type II muscle fibres predisposes a player to hamstring injury.

Table 2.2 Types of muscle fibres (adapted from Hagiwara, 2013)

Fibre type	Fibre name	Characteristics	Example
Type I	Slow twitch Oxidative	Efficient oxygen use, slow to fatigue	10 km run
Type IIa	Fast twitch Oxidative	Uses aerobic and anaerobic metabolism	100/200m sprint
Type IIb	Fast twitch Glycolitic	Anaerobic, fires quickly, fast rate of fatigue	50m sprint

Soccer players who steadily increase their training periods to participate in matches are at increased risk of injury because of the repetitive loading through the lower limbs, especially on the hamstring muscles (Woods et al, 2004). Repetitive training shortens the muscles of the lower limb, particularly the posterior muscles. Shortening in the hamstring muscles has been reported to predispose a soccer player to injury, but may also increase performance as it increases the amount of passive, stored energy that is available for propulsion. This shortening may be a training-induced adaptation to improve sprinting speed (Hoskins and Pollard, 2005). In addition, there are adaptations to training evident in the architecture of the hamstring muscles, including the type of muscle fibres (Engebretsen, 2010).

Due to the increase in soccer participation and hamstring injuries, the examination of the mechanism of injury may play a primary role in identifying the risk factors (Kucera et al, 2005). Woods et al (2004) conducted a study in English professional soccer to analyse hamstring injuries sustained over two competitive seasons. The medical staff of 91 professional clubs documented data over two seasons. Injuries obtained in each club were documented weekly through a questionnaire. Out of the 91 clubs 87% completed the questionnaires in the first season and 76% in the second season. Twelve percent of injuries sustained were to the hamstring muscle with 53% involving the biceps femoris muscle. Most of the injuries occurred toward the end of matches and training session with the greater occurrence of injury during matches (two-thirds). Therefore, fatigue can be concluded as a major risk factor to hamstring injuries (Kalema, 2012).

Greig (2008) reported there was a decrease in peak eccentric flexor torque at high speeds among players who remained seated throughout half-time intervals. Additionally, insufficient warm-up has also been found to be a potential risk factor for hamstring injuries (Kalema, 2012). Therefore, it has been suggested that, during half-time intervals, strategies for re-

warming should be considered as a preventative measure to reduce the negative influences that a passive half-time interval may present (Greig, 2008).

Schache (2010) noted that little research had been done on sprinting techniques and the role they could play in hamstring injury. A common injury mechanism that has been identified is when the player's body is in a forward lean position to achieve extra speed or to maintain speed and, as a result, over-striding tends to occur (Hoskins and Pollard, 2005). The forward lean position has been found to be counterproductive to improved sprinting performance (Hoskins and Pollard, 2005). The characteristic forward lean lurch occurs as a result of a weak gluteus maximus muscle and over-striding may be the effect of this.

The biarticular nature of the hamstring muscle group will predispose the muscle to injury when in the forward lean position because of the increase in the relative length of the muscle. To improve the management and prevention of hamstring injury it has been suggested that motor and running patterns be addressed and optimised. The forward lean gait requires an increase in lumbar erector spinae muscle activity (Hoskins and Pollard, 2005). The recruitment of the lumbar erector spinae muscles has previously been stated to cause lumbo-pelvic dysfunction (Hungerford, Gilleard and Hodges, 2003), therefore linking optimal lumbo-pelvic movement control to the prevention of hamstring injuries.

Woods et al (2004) found the reoccurrence of hamstring injuries within the soccer population to be overly high. Within English professional soccer, the reoccurrence of hamstring injuries ranges between approximately 12% and 48% (Liu, Garrett, Moorman and Yu, 2012). The risk factors implicated as being part of the initial injury are also believed to be the same risk factors associated with injury reoccurrence, but (Croisier, 2004) stated that research on the reoccurrence is limited.

The reoccurrence of hamstring injuries is suspected to arise following an inadequate assessment of the severity of the initial hamstring injury, or the player returning to play prematurely within the remodelling phase of healing, or to inadequate rehabilitation (Liu, Garrett, Moorman and Yu, 2012). The premature return to play can be determined by the theory of scar formation during the healing phase (Table 2.3) after injury (Hoskins and Pollard, 2005).

Table 2.3 The concept of scar formation after injury (Hoskins and Pollard, 2005, p. 100)

Stages of scar formation	Characteristics	Duration
Inflammatory phase Pain caused by chemical irritation of nerve endings, haemorrhage and oedema.	Increased risk of further injury due to muscle weakness. Overly vigorous mobilisation may disrupt phagocytic activity and the formation of new capillaries and collagen tissue.	3 days
Fibroblastic phase Initial collagen production leading to scar formation and regeneration of muscle fibres.	Weak and immature scar tissue. Overly vigorous mobilisation may damage collagen that is forming in the desired direction. Too rapid breakdown of unwanted collagen tissue will increase or re-initiate the inflammatory process. Strength of healing collagen is only 15% of the tensile strength of the surrounding tissue.	Day 4–2 to 3 weeks
Remodelling phase Maturation of scar tissue and regeneration of muscle fibres (continue).	Difference in tissue extensibility due to inelastic scar tissue compared with normal tissue. Therefore, the occurrence of breaks at the interface of old and new tissue. The amount of mobilisation and exercise must be proportionate to the degree of recovery. The aim of the mobilisation and exercise should be to promote scar absorption, improve muscle fibre alignment and to minimise atrophy, loss of strength and extensibility.	From week 2–4 up to 6–12 months

A player could be predisposed to reinjury if there is an accumulation of scar tissue and associated adhesions as a result of the initial injury not being effectively treated (Hoskins and Pollard, 2005). A previously injured muscle has been found to be more susceptible to eccentric damage than a muscle that has not been injured (Hoskins and Pollard, 2005). This backed by the claim that hamstring injuries occur during eccentric loading of the hamstring muscles in the late swing phase of sprinting, when the hamstring contracts eccentrically to decelerate knee extension and control hip flexion.

Limited research regarding the preventative measures of hamstring injuries is available, and future research needs to address this. Sole, Milosavljevic, Nicholson and Sullivan (2012) conducted a study on athletes with hamstring injuries to compare the electromygraphic activity of the gluteal, quadriceps and hamstring muscles during weight bearing tasks against

an injured group. The recruitment pattern of the gluteal, quadriceps and hamstring muscles were recorded from a double to single leg stance.

Sole, Milosavljevic, Nicholoson and Sullivan (2012) concluded that a player may be predisposed to hamstring injury due to the altered hamstring and gluteus maximus muscles firing pattern, explained by the plasticity of the nervous system. This could support their hypothesis that recurrent hamstring injuries could likely lead to an increased sensitisation of the dorsal horn in the spinal cord.

Literature cites age, poor eccentric hamstring muscle strength, loss in flexibility of the hamstring muscles and the lack of neural extensibility as other potential risk factors for hamstring injuries. The risk of hamstring injuries increases with age, which literature states can be independent of a history of previous hamstring injuries (Arason et al, 2007). This is potentially caused by decreased hamstring muscle strength (Croisier, 2004), and muscle imbalances (Kalema, 2012). Poor eccentric hamstring muscle strength between limb strength imbalances and hamstring:quadricep ratios have been associated with the risk of hamstring injuries (Opar et al, 2015).

Coombs and Garbutt (2002) investigated the ratio between the function of the hamstring muscles versus quadriceps muscles in a systematic review using the functional squat as an outcome measure. The function of these muscle groups has been described as a concentric strength. During the functional squat the quadriceps muscle contracts eccentrically during flexion of the lower limbs while the hamstring muscles contract concentrically. Controversially, the quadriceps muscle contract concentrically during lower limb extension and the hamstring muscle contract eccentrically. Evaluation of the isokinetic eccentric antagonistic strength during the functional squat may provide a relationship of value describing the maximal potential of the antagonist muscle group. The hamstring:quadriceps ratio changes throughout range of motion of the lower limbs. It has been concluded by Coombs and Garbutt (2002) that muscular imbalances and asymmetry caused by the change in hamstring:quadriceps ratio may predispose a soccer player to injury.

Limited research on the relationship of hamstring muscle flexibility and the risk of hamstring injuries is available. Donald and Moss (2010) noted that no conclusive link had yet been made between the risk of hamstring injuries and hamstring muscle flexibility.

Woods et al (2004) found there was no difference in flexibility between subjects with a history of hamstring injury and those with no history, but did find a difference in the degree of lumbar lordosis between the uninjured group and the group with hamstring injuries. This is an indication that posture abnormalities rather than flexibility can be linked to hamstring injury (Woods et al, 2004).

Donald and Moss (2010) determined that a lack of neural extensibility is likely to decrease range of motion, and suggested that the slump test should be used alongside other range of motion tests to identify exactly which structure is limiting movement.

2.6 Return to play following a hamstring injury

There is no standard time for return to play following a hamstring injury as every injury is different (Brukner, 2015). Only a few studies have investigated the outcome of various return-to-play criteria in soccer players following a hamstring injury. It does not appear that magnetic resonance imaging (MRI) is a reliable indicator of a player's readiness to return to play as abnormalities on MRI tend to persevere long after soccer players have fully returned to play (Wilson and Myers, 2010).

The length of time before return to play varies according to the severity of the hamstring injury. Generally, a soccer player with a Grade 2 hamstring injury may be able to return to play within 12 to 18 days if the injury is optimally treated (Schmidt, Tim and McHugh, 2012).

It is preferable to define specific criteria for return to play instead of relying on a specific timeframe. Brukner and Khan (2007) recommended the following criteria:

- full range of motion (equal to uninjured leg)
- pain-free maximal contraction
- full strength (equal or almost equal to uninjured leg) – 90% to 95% of eccentric strength of uninjured leg
- completion of a progressive running programme
- functional tests including sprinting from a standing start, abrupt changes of pace during a run, side stepping and activities mimicking specific soccer activities
- successful completion of a full week of maximal training.

Brukner (2015) noted that despite introducing criteria for return to play, a player's risk of reinjury remains high for a considerable length of time. It has been postulated that strength deficit may contribute to the risk of reoccurrence, and strength training has been recommended following return to play.

2.7 Instrumentation and assessment of muscle activity and lumbo-pelvic movement control

2.7.1 Physical activity readiness questionnaire

A Candian questionnaire, the physical activity readiness questionnaire (PAR-Q) is used as a screening tool for physical participation. This seven question questionnaire is designed to determine an individual's physical fitness or ability to participate. On passing the screening test individuals are advised to consult with their physician for further medical clearance before participation.

In a systematic review of the PAR-Q, Bredin, Gledhill, Jamnik and Warburton (2013) found that physicians, physical activity participants, fitness professionals and various organisations had identified a number of barriers to the physical activity participation clearance process. There are many false-positive results with the PAR-Q as it is purposely conservative and thus leads to unnecessary medical referrals. Other barriers include the age restriction of 15 to 69 years, the inconsistent use of the clearance form and individuals with chronic medical conditions.

Friedenreich et al (2006) studied the validity [sensitivity (SE), specificity (SP), positive predicted value (PPV) and negative predicted value (NPV)] of the PAR-Q in a general, sample population of 104 subjects between the ages of 15 and 69 years. The responses were to physicians' examinations using a Chi-square test ($p<0.05$). The sensitivity was 89%, and the specificity was 72%. The positive predicted value and negative predicted value were 78% and 74%, respectively. Therefore, the PAR-Q can be deemed a reliable and valid test of physical activity readiness.

2.7.2 Oslo hamstring injury questionnaire

Andre Hauge Engebretsen developed the Oslo hamstring injury questionnaire at the Oslo Sports Trauma Research Centre during his PhD study on the screening, risk factors and prevention of soccer-related injuries. The Oslo hamstring injury questionnaire was developed

to examine the function of the hamstring muscles following a hamstring injury and adopts the same principles as the Foot and Ankle Outcome Score (FAOS) and the Knee Osteoarthritis Outcome Score (KOOS). It is, however, only specific to the hamstring region and its typical symptoms (Engebretsen, 2010).

The OSLO questionnaire divides twenty-three items into five categories, namely: symptoms; soreness; pain; function; daily living and sports; and quality of life for left and right hamstring injuries. Each item is scored on a rating of zero (best) to four (worst). The subscores for each of the five categories are calculated and presented as a percent of the maximum score in each category. The total score is the mean of the five subscore percentages (Engebretsen, 2010).

Engebretsen (2010) concluded that a history of previous hamstring injuries and decreased function at baseline had the potential to trigger new injuries in the same area the next season. It has been proposed that the Oslo hamstring injury questionnaire is most beneficial when used in conjunction with a physical examination that includes the assessment of the eccentric strength of the hamstring muscle using the Nordic hamstring strength test.

Skaara, Moksnes, Frighagen and Stuge (2013) evaluated the Oslo hamstring injury questionnaire in a heterogeneous population with hamstring injuries ($p<0.001$) and found it to have a high internal consistency ($\alpha=.0.96$) and high test-retest reliability ($r=0.86$). The Oslo hamstring injury questionnaire was also examined in a soccer population with hamstring injuries ($p<0.05$) and it generally demonstrated robust results of internal consistency and construct validity (Engebretsen, 2010). Therefore, the Oslo hamstring injury questionnaire may be considered a reliable and valid questionnaire for hamstring injuries.

Unfortunately, limited research on the use of the Oslo hamstring injury questionnaire in different sporting populations, particularly in the soccer population, is available.

2.7.3 Electromyography

The instrument of electromyography (EMG) may measure electrical activity produced by the neuromuscular system. The neuro-motor units in a muscle cell cause this electrical activity. EMG can be used to analyse biomechanics within human and animal movement, detect medical pathology, activation levels of a muscle and sequence recruitment (Kotila, 2014).

The two types of EMG generally used are surface EMG and intramuscular EMG (needle and fine wire). Intramuscular EMG is considered too invasive or unnecessary in some instances as it observes the activity of only a few muscle fibres (Kotila, 2014). Surface EMG is popular in physiotherapy as it is a non-invasive technique which Tae-Heon, Kyeong-Soon, Dong-Geol and Nam-Gi (2012) reported to be a valid (sensitivity 86%; specificity 89%) and reliable (ICC=0.93) as an indicator for assessing muscle function and recruitment patterns in healthy and injured individuals.

Tae-Heon, Kyeong-Soon, Dong-Geol and Nam-Gi (2012) noted that numerous factors can influence the reliability of surface EMG signalling. This includes the thickness of subcutaneous adipose tissue, sex, subtle changes in posture, interelectrode distance, electrode size and placement, temperature and skin impedance. Therefore, it has been concluded that one should take care in interpreting surface EMG values within individuals.

Normalisation of EMG data involves a process where a reference value is used to normalise the absolute EMG values (mV) to a percentage of the reference (Figure 2.4) (Kotila, 2014). Reliability is increased through EMG normalisation by decreasing variations between muscle in individuals within EMG studies (Tae-Heon, Kyeong-Soon, Dong-Geol and Nam-Gi, 2012; Burden, 2010). Maximal voluntary isometric contraction is a favoured technique of EMG normalisation, and has been adopted as the standard value when comparing different subjects, days, studies and muscles (Tae-Heon, Kyeong-Soon, Dong-Geol and Nam-Gi, 2012; Kotila, 2014).

The submaximal contraction method has been reported by some researchers to improve reliability of EMG normalisation (Kotila, 2014; Burden, 2010). EMG data can be analysed according to maximal voluntary isometric contractions, peak amplitude, mean amplitude or dynamic contraction (Tae-Heon, Kyeong-Soon, Dong-Geol and Nam-Gi, 2012; Kalema, 2012; Burden, 2010). The maximum voluntary isometric contraction method has been found the most reliable. In this research, the maximum voluntary isometric contraction and mean amplitude of dynamic contractions were used.

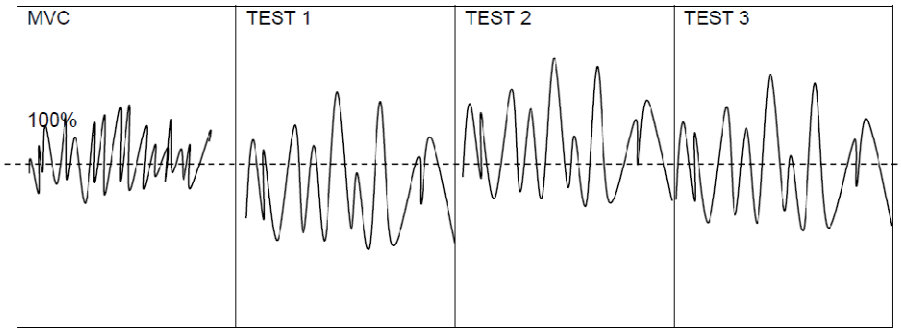


Figure 2.5 Normalisation process

The MVC is 100% and the subsequent tests (test 1 to 3) are converted to a percentage of MVC (Konrad, 2005)

2.7.4 Lumbo-pelvic movement control

The causes of hamstring injuries presented in previous sections of this report are multifactorial. Hoskins and Pollard (2005) reported that there is evidence suggesting that lumbo-pelvic movement dysfunction causes hamstring injuries. Panayi (2010) conducted a systematic review on lumbo-pelvic movement control assessment and treatment based on the anatomical research presented for consideration in the treatment of chronic hamstring injuries. This systematic review supported Hoskins and Pollard's (2005) suggestion that lumbo-pelvic movement dysfunction causes hamstring injuries, noting that muscle imbalances increase the workload on the hamstring muscles by decreasing gluteus maximus muscle activation and increasing tensile stress on the biceps femoris muscle, both caused by an anteriorly tilted pelvis.

One may reason that this could explain the high reoccurrence rate of hamstring injuries. Liu, Garrett, Moorman and Yu (2012) noted the risk of an injury reoccurring was considerable (48%) during the first few weeks after return to play, and Orchard and Best (2002) stated there was a 30.6% risk of reinjury for the rest of the season after return to play.

This could possibly suggest there is a biomechanical factor involved that requires a new approach. According to Hoskins and Pollard (2005) and Panayi (2010), biomechanical factors must be included if efforts to decrease the reoccurrence of hamstring injuries are to succeed.

Woods et al (2004) suggested that the biomechanical assessment of the lumbar spine, sacrum and pelvis should be included in the assessment of hamstring injuries. These assessments should include investigating the influence of lumbo-pelvic movement control, form and force

closure and SIJ function, gluteus maximus muscle and transversus abdominis muscle activation. Furthermore, it would be interesting to investigate if these factors could be part of the multifactorial causes of hamstring injuries.

Hamstring injuries could possibly result from poor functioning of the lumbar spine. Halbertsma et al (2001) noted a restriction in range of motion and a decrease in the extensibility of the hamstrings in those with lower back pain or injury. Increased muscle tone due to poor lumbo-pelvic movement control, lumbar spine and SIJ dysfunction may also be a predisposing factor in sprinters (Devlin, 2000). In a study by Walden and Walters (2005), it was found that 80% of participants with hamstring injuries had a history of lumbo-pelvic movement control dysfunction. Therefore, it can be concluded that the lumbo-pelvic movement control plays a primary role in the coordination and kinematics during the gait pattern (Donald and Moss, 2010).

2.7.4.1 Lumbo-pelvic movement control tests

The identification of the causes of hamstring injuries has become a high priority. One of the causes of hamstring injuries has been found to be lumbo-pelvic movement control dysfunction (Hoskins & Pollard, 2005; Panayi, 2010). This dysfunction has, alternatively, been referred to as motor control impairment, which is defined as *impaired active movement control of the lumbar spine during functional activities* (Luomajoki, 2010, p. 7).

Motor control impairment is classified according to the five direction-based patterns of movement control which include the flexion pattern, flexion or lateral shifting pattern, active extension pattern, passive extension pattern, and multidirectional pattern (Dankaerts and O'Sullivan, 2011; Dankaerts et al, 2006). The lumbo-pelvic movement control tests will be reviewed according to the direction-based patterns of motor control impairments.

The active extension pattern is defined as the tendency to hold the lumbar spine in extension during activities, while the passive extension pattern is defined as the tendency to overextend the lumbar spine at a symptomatic segment (Dankaerts et al, 2006). During assessment of an active extension pattern, the lumbar spine is held in hyperextension at the symptomatic segment with an increase in hip flexion (Dankaerts et al, 2006). During assessment of the passive extension pattern, a positive test will be present once a lack of motor control to extend the thoraco-lumbar spine above the segment is present with a tendency to hinge into extension at the segment (Dankaerts et al, 2006). The following lumbo-pelvic movement

control tests can be used to assess an active and passive extension pattern: dorsal pelvic tilt (Figure 2.6), rocking on all four limbs forward and the prone knee bend (Figure 2.7) (Huysamen, 2016).

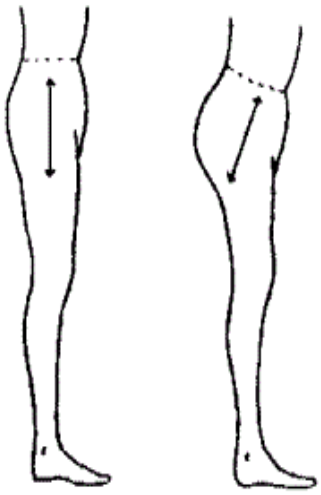


Figure 2.6 Dorsal pelvic tilt (DPT)
http://openi.nlm.nih.gov/detailedresult.phd?img=PMC2164955_1471-2474-8-90-4&req=4

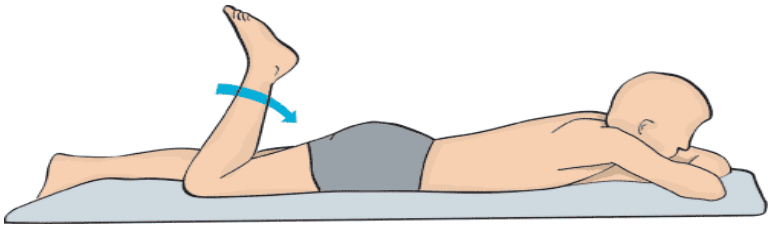


Figure 2.7 Prone knee bend (PKB)
http://bmcmusculokeletaldisord.biomedcentral.com/articles/10.1186.1471-2474-8-90

A flexion pattern is defined as the tendency of the lumbar spine to lose segmental lordosis and present with an abnormal excessive flexion strain (Dankaerts et al, 2006). During assessment of a flexion pattern the test is positive when flexion in the lumbar spine occurs instead of pure hip flexion with a neutral lumbar spine (Luomajoki, Kool, De Bruin and Airaksinen, 2007). The lumbo-pelvic movement control tests that can reveal this lack of control in lumbar lordosis include the waiter's bow (Figure 2.8), sitting knee extension and rocking backwards on all four limbs (Huysamen, 2016).



Figure 2.8 Waiter's bow (WB)
http://bmcmusculokeletaldisord.biomedcentral.com/articles/10.1186.1471-2474-8-90

The one leg stand test (Figure 2.9) has been found to be the only appropriate test to identify a flexion or lateral shift pattern (Huysamen, 2016; Dankaerts et al, 2006). A flexion or lateral shift pattern is defined as the tendency of the lumbar spine to flex and laterally shift at the symptomatic segment (Luomajoki, Kool, De Bruin and Airaksinen, 2007). The one leg stand test is positive when the umbilicus shifts more than 10cm laterally or when a difference of more than 2cm is noted between sides (Luomajoki, Kool, De Bruin and Airaksinen, 2007).

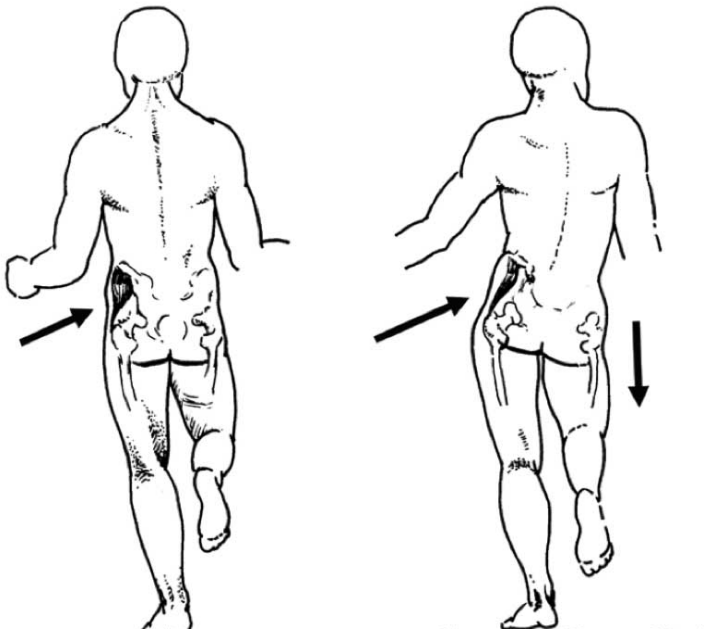


Figure 2.9 One leg stand (OLS)
https://neckandback.com/conditions/walking-disorders-how-nerve-and-joint-injuries-change-gait/#single/0

In a study by Luomajoki, Kool, De Bruin and Airaksinen (2007), the reliability of five lumbo-pelvic movement control tests was assessed. The inter-rater reliability of the five lumbo-pelvic movement control tests used showed substantial agreement. The tests included the one leg stand, dorsal pelvic tilt, waiter's bow, prone knee bend and rocking forward. Four tests [one leg stand, rocking forward, prone knee bend and dorsal pelvic tilt] showed good agreement (k=0.4-0.6) and the waiter's bow showed fair agreement (k<0.4) between assessors (Luomajoki, Kool, De Bruin and Airaksinen, 2007). The reliability and the discriminative validity of the lumbo-pelvic movement control tests have been established which makes these tests appropriate outcome measures to use in the assessment of movement control in a specific sports population (Luomajoki, Kool, De Bruin and Airaksinen, 2007).

Due to the proven reliability and the representation of each direction-based pattern of movement control, the four lumbo-pelvic movement control tests chosen for this research included the dorsal pelvic tilt, prone knee bend, waiter's bow and one leg stand.

2.8 Conclusion to the literature review

Hamstring injuries in soccer players are of significant concern as the population participating in this sport is increasing (Kucera et al, 2005). Soccer players who steadily increase their training periods to participate in matches are at increased risk of injury because of the repetitive loading through the lower limbs, especially on the hamstring muscles (Woods et al, 2004). Injuries may include muscle strain, muscle rupture, cramp and spasm (Enami, Massoud and Ghamkhar, 2014).

The anatomical structures and biomechanical influences around the hamstring muscles appear to contribute to the number of injuries and location of the injuries in these muscles (Ivan, 2012). Repetitive training shortens the muscles of the lower limb, particularly the posterior muscles. Shortening in the hamstring muscles has been reported to predispose a soccer player to injury, but may also increase performance as it increases the amount of passive, stored energy that is available for propulsion. This shortening may be a training-induced adaptation to improve sprinting speed (Hoskins and Pollard, 2005).

In addition, there are adaptations to training evident in the architecture of the hamstring muscles, including the type of muscle fibres (Engebretsen, 2010). Very little research on the effect these aspects have on hamstring injuries in soccer players has been performed to date.

EMG and lumbo-pelvic movement control assessments have value in assessing dysfunctional muscles, especially the hamstrings (Sole, Milosavljevic, Nicholson and Sullivan, 2012). Electrical activities in the hamstring muscles can be reliably recorded by EMG, which provides a portable method of measurement. Other measures such as isometric contractions, functional squats, sprinting and lumbo-pelvic movement control assessments, including the dorsal pelvic tilt, waiter's bow, prone knee bend and one leg stand, can provide valuable information on the function and biomechanics of these muscles in the lower limb.

There is limited knowledge on the biomechanical effect that gluteus maximus muscle activity and lumbo-pelvic movement control play in general and, in particular, with regard to hamstring injuries in soccer players. The muscle structures and lumbo-pelvic movement control need to be considered when comparing injured and uninjured soccer players. More information could assist in lowering the occurrence and risk of hamstring injuries in players.

CHAPTER 3: METHODOLOGY

3.1 Type of Study

This study comprised a quantitative, observational, cross-sectional design with matched groups.

3.2 Subjects

3.2.1 Source of Subjects

The participants recruited for the study comprised 15 soccer players with a recent history of hamstring injuries (injured group) and 15 with no reported injuries (uninjured group). The players were selected from local soccer clubs in the Johannesburg region. Soccer clubs within it Johannesburg area were chosen randomly and those which were approached included: Bidvest Wits, Kaizer Chiefs, Black Acres, Supersport United, University of the Witwatersrand soccer club, University of Johannesburg soccer club and the Tuks soccer club. All soccer club secretaries were emailed the advertisement and requested to forward it on to the club members from which participants were recruited (*Appendix I).*

Players in the injured group were matched with players of similar age, height, weight and playing position in the uninjured group. The players of the uninjured group were carefully chosen to accommodate differences in training demands and exposure.

3.2.2 Sample Selection

The study used data from a previous EMG study that measured hamstring muscle activity in injured and uninjured soccer players (Sole, Milosavljevic, Nicholson and Sullivan, 2012). This was to establish a sample size large enough to provide sufficient statistical power. Hamstring muscle activity, being one of the primary outcome measures for this study, was used to determine the sample size. It was considered that, of all the parameters measured, hamstring muscle activity may also have the greatest variance.

Sole, Milosavljevic, Nicholson and Sullivan (2012) found a mean value of 72.09% (standard deviation – SD 15) in the coefficient variation in the injured group (n=16) while measuring EMG activity of the hamstring muscles, and 48.52% (SD 18) in the uninjured group (n=18). From a statistical calculation using a power of 97% and a level of significance of 5%, an

effective sample size of 30 was deemed an adequate number to detect a variance between the two groups.

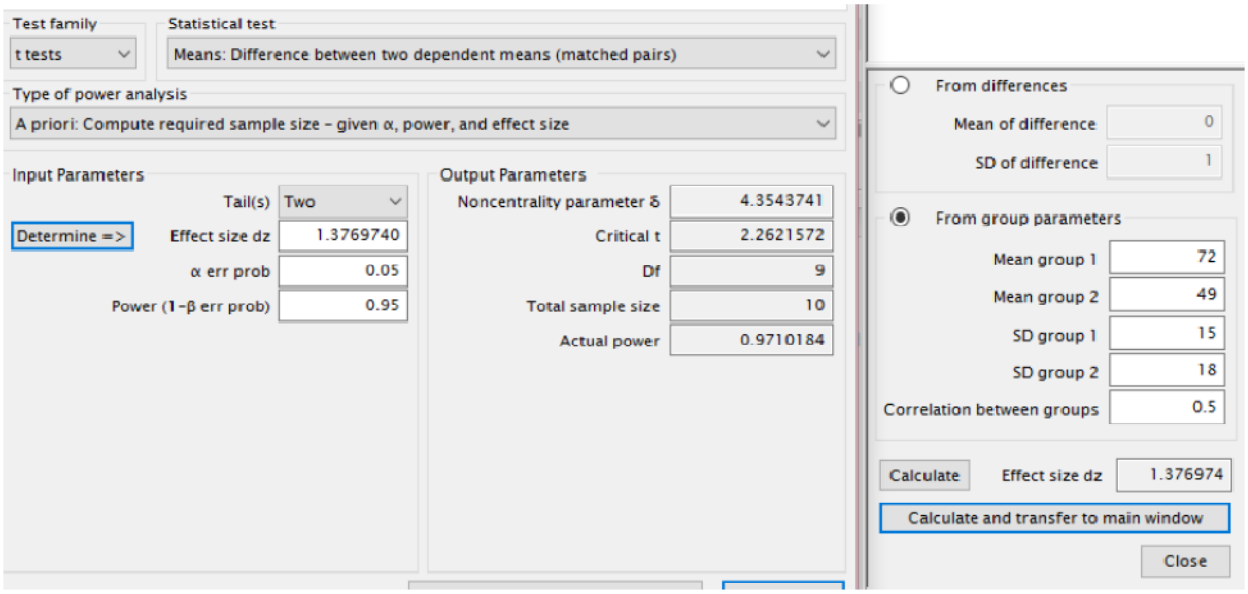


Figure 3.1Effect size and sample size calculation

The data used for the calculation of the effect size were obtaibed form Sole, Milosavljevic, Nicholson and Sullivan, 2012

Inclusion Criteria

The inclusion criteria are outlined in Table 3.1.

Table 3.1 Inclusion criteria of the study

Inclusion criteria – soccer players	
• Male soccer players between the ages of 18 and 30 with the ability to comply and complete instructions as relevant to this study	
Inclusion criteria – injured group	**Inclusion criteria – uninjured group**
• Abrupt onset of posterior thigh pain unrelated to any impact (collision, force, contact, blow) during a match, competition or training within six months prior to the study • A disabling injury requiring the attention of a health professional • A disabling injury that prevented the soccer player from participating in at least one official match, competition or the minimum of one week's regular training • Partial return to soccer training at the time of data collection	• No known incidence of hamstring injury over the past year that necessitated treatment by a health professional • Currently fully active in regular soccer training

Exclusion Criteria

The physical nature of the testing precluded the following players from participating:

- those with recent knee or lumbo-pelvic injury
- those showing adverse medical conditions during the health and physical activity screening (physical activity readiness questionnaire – PAR-Q) *(Appendix II)*, for example high blood pressure or heart abnormalities.

3.3 Instrumentation and Outcome Measures

3.3.1 Physical activity readiness questionnaire

Before performing the physical tests, players completed the physical activity readiness questionnaire (PAR-Q) *(Appendix II)* to determine their general health and assess if any underlying medical conditions necessitated their exclusion from the study. If any of the players had presented with a medical condition they would have been referred for appropriate medical follow up.

Friedenreich et al (2006) found the PAR-Q to be a valid and reliable questionnaire to assess physical activity readiness, as discussed in the literature review (Chapter 2.7.1).

3.3.2 Physical activity, training and injury questionnaire

The physical activity, training and injury questionnaire *(Appendix III)* was a self-developed questionnaire that players completed during the familiarisation session after signing the informed consent forms. The questionnaire, which a panel of soccer and sports physiotherapy experts reviewed to ensure content validity, enquired on demographic information, training records and injury history of each player.

3.3.3 Oslo Sports Trauma Research Centre – hamstring injury screening questionnaire

Players within the injured group completed the Oslo hamstring injury screening questionnaire *(Appendix IV)*. The questionnaire assessed previous hamstring injuries, symptoms, function, and quality of life of these players.

The Oslo hamstring injury screening questionnaire has been found to be a valid and reliable questionnaire for hamstring injuries, as discussed in the literature review (Chapter 2.7.2).

3.3.4 Electromyography

An EMG analysis was performed using the 8 Sensor Trigno Wireless EMG Set (Analogue and Digital Version). Most of the evidence discussed in the literature review (Chapter 2.7.3) found the 8 Sensor Trigno Wireless EMG set as a valid and reliable tool to use during assessments of specific muscle activity.

EMG activity was recorded bilaterally using pairs of surface electrodes placed on the lumbar erector spinae, gluteus maximus, hamstrings (biceps femoris) and quadriceps (rectus femoris) muscles (Table 3.2). Electrodes of 10 mm in size were positioned parallel to the muscle fibres. Hair was removed from the surface area of the skin, which was cleaned with an alcohol swab before the electrodes were attached with Tensospray (adhesive spray) and double-sided tape. The interelectrode spacing (the distance between the centre of two conductive areas of two bipolar electors) was 20mm (www.senniam.org).

Table 3.2 EMG electrode placement on the lumbar erector spinae, gluteus maximus, hamstrings and quadriceps muscles (SENIAM Guidelines)

	Starting posture of the players	Electrode placement	Electrode orientation
Erector spinae	Prone with the lumbar spine slightly flexed	Placed at two-finger width lateral from the proximal spine of L1	Vertical
Gluteus maximus	Prone	Placed at 50% on the line between the sacrum and greater trochanter	In the direction of the line from the posterior superior iliac spine to the middle of the posterior aspect of the thigh
Hamstrings Biceps femoris	Prone with less than 90° knee flexion and slight lateral rotation of the lower limb	Placed at 50% on the line between the ischial tuberosity and the lateral epicondyle of the tibia	In the direction of the line between the ischial tuberosity and the lateral epicondyle of the tibia
Quadriceps Rectus femoris	Sitting on the plinth with the knees in slight flexion and the upper body slightly bend backwards	Placed at 50% on the line from the anterior superior iliac spine to the superior part of the patella	In the direction of the line from the anterior superior iliac spine to the superior part of the patella

Tables 3.3 and 3.4 show the tests that were performed while EMG activity was recorded:

Table 3.3 Description of isometric contractions used during EMG recordings

Test	Muscle Assessed	Movement	Repetitions
Isometric contractions of each muscle individually	Erector spinae	Prone, players were asked to perform lumbar extension by lifting their shoulders off the surface	Each isometric contraction was performed for 30 seconds followed by a one-minute rest
	Gluteus maximus	Prone, players were asked to squeeze their gluteal areas together	
	Hamstrings – Bicep femoris	Prone, players' one leg in 45° flexion – the tester resisted flexion	
	Quadriceps – Rectus femoris	Long sitting, players hyperextended their knee to maximal contraction of the quadriceps	

Table 3.4 Description of the functional squat and 30-metre sprint during EMG recordings

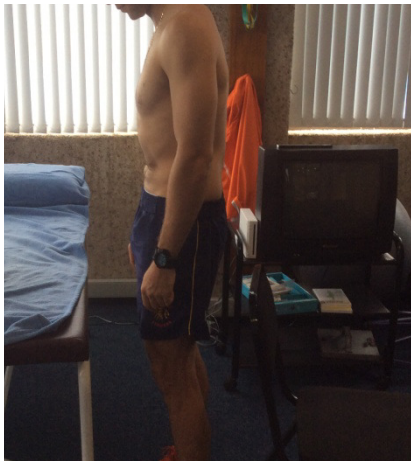
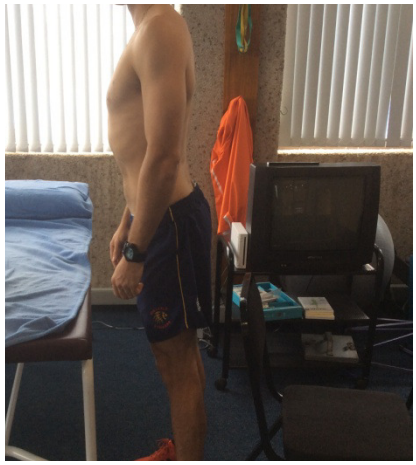
Test	Movement	Repetitions
Functional squat	Players were asked to slowly squat keeping the knees in line with the toes. The knees were required to extend forward at approximately the same rate as the hips extended backward. Body weight was required to be situated over the entire foot throughout the movement. Hips were required to travel lower than the knees. On ascent, the angle of the spine was required not to tilt forward. Players were asked to squat down as far as they possibly could and, upon reaching the end of their range, return to the upright position. No specific timing was required during the downward or upward movement of the functional squat.	Each player was asked to perform one functional squat followed by a 30-second rest before the next test.
30-metre sprint	The players were asked to sprint 30m on a straight course at the tester's command 'go'. Two marked white lines were placed at the beginning and the end of the course to indicate the sprinting distance. The players were instructed to sprint over the last white line and not to stop too early.	Each player completed one sprint.

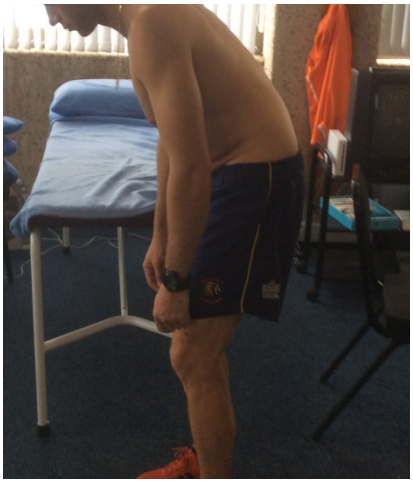
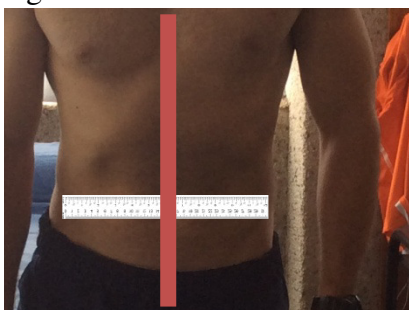
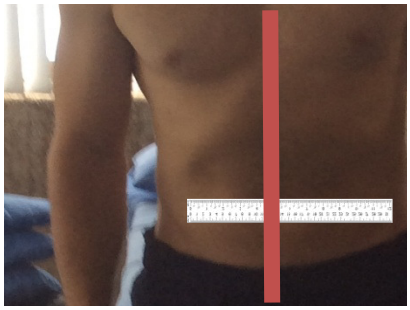
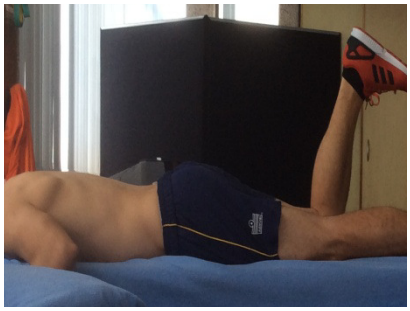
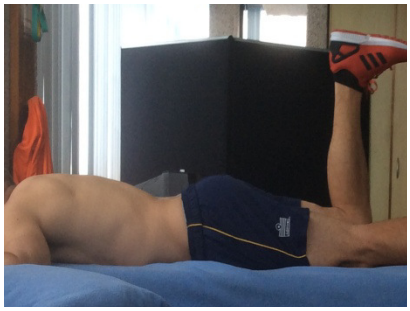
EMG data was analysed using the EMG data analysis package EMGworks Acquisition. The raw EMG signals were rectified and smoothed using the root mean squared (RMS). Maximal voluntary isometric contractions were performed to determine maximal EMG activation for EMG normalisation and the results used for data analysis. Normalised EMG values were calculated as the quotient of the recorded EMG from the functional squat and thirty-metre sprint, and divided by the EMG values recorded from the maximal voluntary isometric contractions. The values were represented as a percentage of the maximal voluntary contraction.

3.3.5 Lumbo-pelvic movement control tests

Lumbo-pelvic movement control was assessed as a measure of lumbo-pelvic stability and to compare if there were significant differences between players with recent hamstring injuries and uninjured players. Table 3.5 shows the four tests used to assess the lumbo-pelvic movement control.

Table 3.5 Description of lumbo-pelvic moment control assessment used during the study (Olivier, Stewart, Olorunju and McKinon, 2015, pp 70-71)

Movement	Correct Movement	Incorrect Movement
Dorsal tilt of the pelvis Dorsal tilt of the pelvis actively in upright standing	Actively in upright standing; keeping thoracic spine in neutral, lumbar spine moves towards flexion 	Pelvis does not tilt or low back moves towards extension or compensatory flexion in the thoracic spine 

Waiter's bow Flexion of the hips in upright standing without movement (flexion) of the low back	Flexion of the hips to 50°-70° without movement (flexion) of the low back 	Limited hip flexion less than 50° with excessive low back movement (flexion) 
One leg stand From normal standing to one leg stance: measurement of lateral movement of the umbilicus (position: feet one third of trochanter distance apart)	The distance of umbilical movement laterally is symmetrical on the left and the right side 	Lateral transfer of the umbilicus more than 10cm or the difference between sides more than 2cm 
Prone knee bend Prone lying active knee flexion	Active knee flexion of at least 90° without movement of the low back and pelvis 	During the knee flexion low back does not stay neutral but moves in extension or rotation 

The author used her own pictures as description to the lumbo-pelvic movement control tests used within this study.

The players received standard verbal encouragement during the tests to ensure maximal performance. Each test was repeated once with a 30-second break between each test. The compensatory movements were recorded.

3.4 Procedure

3.4.1 Pilot Study

The pilot study took place at the Wits Physiotherapy Movement Analysis Laboratory at the University of the Witwatersrand, Parktown, Johannesburg. Two players were recruited for the pilot study through the methods described in the main study. These players matched the inclusion and exclusion criteria, one for the injured group and the other for the uninjured group. The aims of the pilot study were for the researcher and research assistant to become confident with the procedure planned for the main study, assess the time taken to complete the procedure and to identify any challenges before the start of the main study. The players were required to complete the physical activity, training and injury questionnaire end undergo assessment of muscle activity and lumbo-pelvic movement control.

Each of the EMG assessments was performed once with a one-minute rest between each test. The assessments were conducted in the following order: isometric contractions of the erector spinae, gluteus maximus, biceps femoris and rectus femoris muscles, followed by the functional squat and the thirty-metre sprint. The thirty-sprint was performed in the corridor in front of the Wits Physiotherapy Movement Analysis Laboratory.

The four lumbo-pelvic movement control tests were performed once to familiarise the investigators with the tests and sequence of testing. A 30-second rest period was allowed between the tests, which were performed in the following order: dorsal pelvic tilt, waiter's bow, one leg stand and prone knee bend.

No major challenges were encountered during the pilot study and no changes were made to the procedure of the main study. Therefore, the pilot and the main study used the same methodology.

3.4.2 Main Study

Permission to access the players and use the clubs' facilities as a research site (*Appendix V)* was obtained from the managers of local soccer clubs within the Johannesburg region. Advertisements were distributed to recruit the soccer players *(Appendix I)*. Injured and uninjured players were required to attend a familiarisation session and a physical testing session at their local soccer club.

The familiarisation session was held between three and five days prior to the physical testing, and players completed the informed consent form, the physical activity, training and injury questionnaire and the Oslo hamstring injury screening questionnaire under the guidance of the primary investigator. To ensure safety during the physical testing, the PAR-Q (*Appendix II*) form was also completed. After the familiarisation session, each injured player was matched with an uninjured player of similar age, height, weight and playing position.

EMG assessments of the lower limb and lumbo-pelvic movement control tests were conducted during the physical testing session. The PAR-Qs were reviewed with each player to ensure their health status had not changed and that it was safe for them to participate. The activity of the erector spinae, gluteus maximus, hamstrings (biceps femoris) and quadriceps (rectus femoris) muscles were systematically explained to the players throughout the EMG recordings.

The tests were performed in the following order: isometric contraction of the erector spinae, gluteus maximus, biceps femoris and rectus femoris muscles individually, followed by the functional squat and the thirty-metre sprint. The lumbo-pelvic movement control tests were described to the players, who were given the opportunity to practise each test three times. The tests were performed in the following order: the dorsal tilt of the pelvis, waiter's bow, one leg stand and prone knee bend. As each player was matched with another player, the order of the tests was kept constant.

During the physical testing session, the research assistant performed the EMG tests and the primary investigator was in charge of the lumbo-pelvic movement control tests. This ensured that the primary investigator was unaware of the outcome of the EMG tests and prevented bias. The researcher and research assistant captured information on the data capture sheet *(Appendix X)*. The primary investigator was not blinded during the course of this research as the primary investigator analysed all data collected through the use of questionnaires and allocated each participant a study number.

3.5 Ethical Considerations

The Human Ethics Research Committee of the University of the Witwatersrand granted ethical clearance (M150630) *(Appendix VI),* after which the players were invited and selected according to the inclusion and exclusion criteria. The purpose of the research, the testing procedure and the potential risks involved in their participation *(Appendix VII)* were

explained and they were informed of their right to withdraw from the study at any stage. The players gave written, informed consent *(Appendix VIII)* and all the information remained confidential and anonymous. Each player was given a study number to maintain and ensure confidentiality.

The potential risks were explained to the players prior to their signing the informed consent. All players completed the PAR-Q to screen for exclusion criteria and factors that may have increased their risk to injury in the physical tests. All the data obtained from the questionnaires remained confidential and anonymous.

The physical nature of the tests exposed the players to the potential risk of musculoskeletal injury. During the familiarisation session, the players were given the opportunity to practise the tests to reduce their risk of possible injury during the official testing phase. The tests were comprehensively explained and players were instructed to stop immediately if they felt any discomfort or pain. The majority of the tests did not require extreme effort and were similar to those used during training and match environments, for example squats and sprinting. All the data obtained from the physical tests remained confidential and anonymous. The players were given feedback based on their tests *(Appendix IX)*.

3.6 Data Analysis

Data analysis was performed using the statistical analysis package STATA. The Levene's test was used to determine whether the two groups were normally distributed. As the result ($p<0.05$) was significant, it was conclude that the gluteus maximus muscle of the uninjured leg of players during isometric contractions, and the gluteus maximus and rectus femoris muscles of the uninjured leg of the players during the functional squat did not meet the assumption required for parametric testing.

EMG data was analysed by comparing both the injured and uninjured legs of a players in the injured group with the same side legs of a matched, uninjured player in the uninjured group. The injured leg of the injured player was compared with the same side leg of the matched, uninjured player, and the uninjured leg of the injured player was matched with the same side leg of the uninjured player. For example, if a player presented with a dominant hamstring injury within the injured group, the player's dominant leg was matched with the dominant leg of the player within the uninjured group, and the injured player's non-dominant leg with the

uninjured player's non-dominant leg. Leg dominance (dominant or non-dominant side) was taken into account during EMG analysis.

The Fisher's exact was used to analyse the relationship between the lumbo-pelvic movement control tests (Table 3.6). Statistical significance was set at $p<0.05$ and the confidence interval (CI), where tested, at 95%.

Effect sizes were calculated: Cohen's *d* as well as 95% confidence intervals for the effect size are shown for normally distributed data and, where data was not normally distributed, effect sizes were calculated using the Mann-U Whitney's z-score through using the following formula: r=z/sqrt. Effect sizes of 0.2, 0.5 and 0.8 were interpreted as small, medium and large respectively (Cohen, 1992).

Table 3.6 Summary of data analysis used during the study

Independent variables	Dependent variables	Statistical test	
		Independent two sample t-test (parametric)	**Mann Whitney test (nonparametric)**
EMG isometric contractions (continuous data)	Injury – yes/no (binary data)	Erector spinae muscles Gluteus maximus muscle (injured leg only) Biceps femoris muscles Rectus femoris muscles	Gluteus maximus muscle (uninjured leg only)
EMG functional squat (continuous data)	Injury – yes/no (binary data)	Erector spinae muscles Gluteus maximus muscle (injured leg only) Biceps femoris muscles Rectus femoris muscles (injured leg only)	Gluteus maximus muscle (uninjured leg only) Rectus femoris muscle (uninjured leg only)
EMG 30-metre sprint (continuous data)	Injury – yes/no (binary data)	Erector spinae muscles Gluteus maximus muscles Biceps femoris muscles Rectus femoris muscles	
Lumbo-pelvic movement control tests – correct versus incorrect (binary data)	Injury – yes/no (binary data)	Fisher exact: Dorsal pelvic tilt One leg stand Waiter's bow Prone knee bend	

3.7 Conclusion of the methodology

The study design, aims, sample size and inclusion and exclusion criteria have been presented in this chapter. The procedure and method of the study have been described, as well as the data collection, data recording and statistical analysis. The results of the statistical analysis are presented in Chapter 4.

CHAPTER 4: RESULTS

4.1 Participants

Thirty soccer players were recruited for this study and were divided equally into an injured group (hamstring injured) and an uninjured group (hamstring uninjured). No players were excluded from or dropped out of the study. The study sample is shown in Figure 4.1.

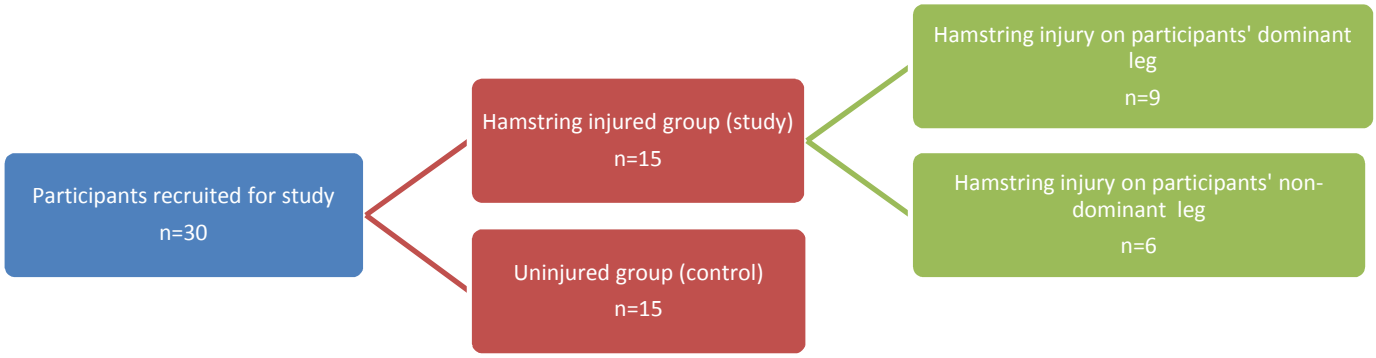


Figure 4.1 Study sample summary

The descriptive characteristics of the study and uninjured groups are shown in Table 4.1. There were no significant differences between the two groups as each player in the injured group was matched with a player of similar age, height, weight and playing position in the uninjured group. Players were carefully matched to counterbalance the variations in physiological determinants, training demands and exposure between them.

Table 4.1 Summary of descriptive characteristics

	Injured group (n=15)	Uninjured group (n=15)	p-value
Age (years) (mean)(±SD)(range)	24.8±5.2 19–25	22.6±5.0 19–24	0.22
Height (m) (mean)(±SD)(range)	1.76±6.5 1.66–1.89	1.83±5.1 1.68–1.84	0.64
Weight (kg) (mean)(±SD)(range)	79.1±8.4 62.4–87.3	80.7±12.0 61.6–85.8	0.0.1
Playing position (n)	2 x striker 7 x midfielder 1 x sweeper 1 x stopper 2 x back 2 x goalkeeper	2 x striker 7 x midfielder 1 x sweeper 1 x stopper 2 x back 2 x goalkeeper	

n – number of players; SD – standard deviation

4.2 Physical activity, training and injury history

This questionnaire, designed by the author, was completed at the familiarisation session after the signing of the informed consent form (*Appendix VIII*). The first section of this questionnaire assessed personal details, level of play and the training history of each player, and the second section assessed the injury history of each player.

All players (n=30) competed at either amateur or professional level. The data obtained from the first section of the questionnaire is summarised in Table 4.2.

Table 4.2 Level of play, time spent training and number of matches played (n=30)

	Injured group	**Uninjured group**
Level of play (n)	13 x amateur 2 x professional	12 x amateur 3 x professional
Training time with team per week (hours)	8 hours per week	11 hours per week
Number of match play per month (days)	5 matches per month	5 matches per month

n – number of players

The data from the second section of the questionnaire is shown in Table 4.3 and covers the mechanism of injury, time of injury, rehabilitation time, return to play time and type of treatment received. Seventy-three percent of players (n=11) in the injured group sustained their hamstring injuries during sprinting. A physiotherapist treated all of the players in the injured group.

Table 4.3 Mechanism and time of injury, type of treatment received, rehabilitation time and return to play following a hamstring injury (n=15)

Information on current hamstring injury	Total
Mechanism of injury	11 x sprinting 1 x kicking of ball 1 x change in direction 2 x explosive training (jumping)
Time of injury	2 x middle of training 1 x start of match 6 x middle of match 6 x end of match
Treatment received	10 x physiotherapy, rest and strapping 5 x physiotherapy, rest, strapping and medication
Rehabilitation time (weeks)	6 weeks (mean) 2–8 weeks (standard deviation)
Return to play (weeks)	4 weeks (mean) 2–6 weeks (standard deviation)

n – number of players

4.3 Hamstring injury outcome

Players in the injured group completed the Oslo hamstring injury screening questionnaire (*Appendix IV)* which assessed their hamstring injuries, symptoms, function, and quality of life in both hamstring muscles. They were asked to indicate their injured leg on the physical activity, training and injury questionnaire according to the parameters of the Oslo hamstring injury questionnaire. A summary of the data is shown in Figure 4.2. The mean calculation for each subscore showed that the most affected sections were symptoms at 35.65% and quality of life at 34.6%. The functions subcategory was the least affected at 22.3%. The standard deviations for each subcategory presented as follows: symptoms 25%–100%; soreness 6.25%–81.25%; pain 9.375%–81.25%; function 0%–2.5%; quality of life 0%–43.75%.

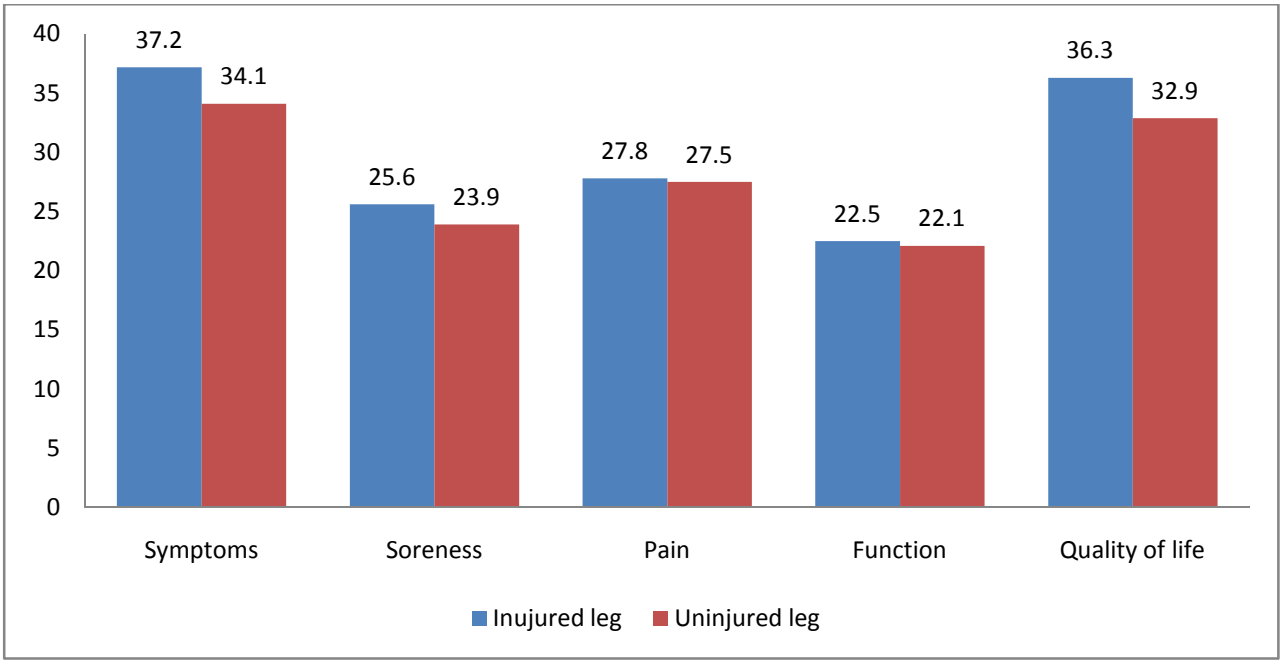


Figure 4.2 Mean subscore calculations from each category of the Oslo hamstring injury questionnaire (n=15)

4.4 Muscle activity

EMG recordings of the activity of the lumbar erector spinae, gluteus maximus, biceps femoris (hamstrings) and rectus femoris (quadriceps) muscles were captured bilaterally using pairs of surface electrodes.

Players in the injured group were matched with players in the uninjured group according to age, height, weight and playing position. The injured leg of each player in the injured group was compared with the same side leg of the matched player in the uninjured group, and the same side uninjured leg of players in both the uninjured and injured groups were compared with each other during the data analysis. Leg dominance was taken into account during the matching of players.

4.4.1 Isometric contractions

Table 4.4 Injured and matched uninjured players during isometric contractions (parametric tests) (n=30)

Maximum voluntary isometric contraction												
Muscle	**Injured side of the player matched with the same side of the uninjured player**						**Uninjured side of the injured player matched with the same side of the uninjured player**					
	Injured player		**Uninjured player**				**Injured player**		**Uninjured player**			
	Mean	**SD**	**Mean**	**SD**	**p-value**	**Cohen's *d* (95% CI)**	**Mean**	**SD**	**Mean**	**SD**	**p-value**	**Cohen's *d* (95% CI)**
Erector spinae muscle	31.12	25.68	31.77	28.79	0.04*	0.02 (-0.77; 0.72)	46.59	8.5	46.86	11.74	0.04*	0.03 (-0.77; 0.72)
Gluteus maximus muscle	67.85	13.77	63.87	15.51	0.74	0.27 (-0.48; 1.02)	Data not normally distributed – nonparametric tests used (Table 4.5)					
Biceps femoris muscle	42.6	6.83	42.67	9.61	0.02*	0.01 (-0.76; 0.74)	50.88	15.91	52.03	14.26	0.94	0.03 (-0.41; 1.09)
Rectus femoris muscle	50.88	15.91	52.03	14.26	0.94	0.03 (-0.41; 1.09)	57.01	10.69	57.92	12.22	0.22	0.08 (-0.67; 0.83)

* denotes statistical significance ($p<0.05$); SD – Standard Deviation

Independent group T-Test between injured and matched uninjured players

Table 4.4 shows the data of the isometric contractions that were normally distributed. There were no statically significant differences found during the isometric contractions of the gluteus maximus and rectus femoris muscles when comparing the injured leg of players in the injured group with the same side leg of their matched players in the uninjured group. A statistically significant difference was found during the isometric contractions of the biceps femoris muscle in the injured side of players in the injured group. No statistically significant difference was found during the isometric contraction of the biceps femoris muscle in the uninjured side of players in both the study and uninjured groups. Statistically significant differences were found during the isometric contractions of the erector spinae muscle in both the injured and uninjured side. Although the differences were statistically significant, the effect sizes were small.

Table 4.5 Injured and matched uninjured players during isometric contractions (nonparametric tests) (n=30)

Maximum voluntary isometric contraction						
Muscle	**Uninjured side of the injured player matched with the same side of the uninjured player**					
	Injured Player		**Matched Uninjured Player**			
	Median	**Range**	**Median**	**Range**	**p-value**	**r (95% CI)**
Gluteus maximus muscle	38.3	143.88	56.56	80.38	0.17	0.25 (-0.14; 0.57)

Mann-Whitney U tests between injured and matched uninjured players

The data obtained from the isometric contraction of the gluteus maximus muscle in the uninjured side of the players was not normally distributed and the nonparametric Mann-Whitney U test was used to interpret the data, as shown in Table 4.5. The isometric contraction of the gluteus maximus muscle in the uninjured side of the players revealed no significant difference.

4.4.2 Functional squat

Table 4.6 Injured and matched uninjured players during the functional squat (parametric tests) (n=30)

Maximum voluntary isometric contraction												
Muscle	**Injured side of the player matched with the same side of the uninjured player**						**Uninjured side of the injured player matched with the same side of the uninjured player**					
	Injured player		**Uninjured player**				**Injured player**		**Uninjured player**			
	Mean	**SD**	**Mean**	**SD**	**p-value**	**Cohen's *d* (95% CI)**	**Mean**	**SD**	**Mean**	**SD**	**p-value**	**Cohen's *d* (95% CI)**
Erector spinae muscle	66.4	34.45	77.31	70.86	0.54	0.22 (-0.53; 0.97)	47.86	8.88	52.1	9.12	0.82	0.47 (-0.29; 1.22)
Gluteus maximus muscle	55.27	40.38	77.37	18.69	0.56	0.57 (-0.19; 1.33)	Data not normally distributed – nonparametric tests used (Table 4.7)					
Biceps femoris muscle	48.04	46.47	42.04	18.26	0.47	0.17 (-0.58; 0.92)	42.18	17.62	43.73	10.63	0.29	0.11 (-0.64; 0.86)
Rectus femoris muscle	46.51	10.96	55.40	9.84	0.34	0.85 (-0.07; 1.63)	Data not normally distributed – nonparametric tests used (Table 4.7)					

* denotes statistical significance ($p<0.05$); SD – Standard Deviation

Independent group T-Test between injured and matched uninjured players

Table 4.6 shows the data of the functional squat that was normally distributed. The functional squat revealed no statistically significant differences in the erector spinae and bicep femoris muscles in both the injured and uninjured side, and the erector spinae and rectus femoris muscles in the injured side. Note that even though the rectus femoris showed no statistically significant difference between the study and uninjured groups, the effect size is large.

Table 4.7 Injured and matched uninjured players during the functional squat (nonparametric tests) (n=30)

Maximum voluntary isometric contraction						
Muscle	**Uninjured side of the injured player matched with the same side of the uninjured player**					
	Injured Player		**Matched Uninjured Player**			
	Median	**Range**	**Median**	**Range**	**p-value**	**r (95% CI)**
Gluteus maximus muscle	72.95	88.37	68.78	56.3	0.41	0.15 (-0.24; 0.5)
Rectus femoris muscle	53.39	216.7	62.92	48.01	0.38	0.16 (-0.23; 0.5)

Mann-Whitney U tests between injured and matched uninjured players

Data obtained from the gluteus maximus and rectus femoris muscles in the uninjured side during the functional squat was nonparametric, and the Mann-Whitney U test was used to interpret the data, as shown in Table 4.7. No statistically significant difference was found in the mean voluntary contraction of these muscles in the uninjured players.

4.4.3 Thirty-metre sprint

Table 4.8 Injured and matched uninjured players during the 30-metre sprint (parametric tests) (n=30)

Maximum voluntary isometric contraction												
Muscle	**Injured side of the player matched with the same side of the uninjured player**						**Uninjured side of the injured player matched with the same side of the uninjured player**					
	Injured player		**Uninjured player**				**Injured player**		**Uninjured player**			
	Mean	**SD**	**Mean**	**SD**	**p-value**	**Cohen's *d* (95% CI)**	**Mean**	**SD**	**Mean**	**SD**	**p-value**	**Cohen's *d* (95% CI)**
Erector spinae muscle	50.63	7.07	51.13	4.83	0.02*	0.08 (-0.67; 0.83)	50.23	9.98	54.03	6.19	0.25	0.46 (-0.3; 1.22)
Gluteus maximus muscle	52.97	17.09	56.52	9.54	0.70	0.26 (-0.5; 1.01)	46.17	14.32	52.33	7.51	0.48	0.54 (-0.22; 1.3)
Biceps femoris muscle	46.47	9.44	46.88	8.3	0.01*	0.05 (-0.7; 0.79)	48.45	5.56	48.23	8.72	0.03*	0.03 (-0.72; 0.78)
Rectus femoris muscle	49.26	6.79	51.12	9.78	0.6	0.52 (-0.53; 0.97)	47.11	5.09	50.25	7.64	0.33	0.58 (-0.28; 1.24)

* denotes statistical significance ($p<0.05$); SD – Standard Deviatios

Independent group T-Test between injured and matched uninjured players

Table 4.8 shows that no statistically significant difference was found in the muscle activity of the erector spinae muscle in the uninjured side and in the gluteus maximus and rectus femoris muscles in both the injured and uninjured side. A statistically significant difference was found in the muscle activity of the erector spinae muscle in the injured side as well as in the biceps femoris muscle in both the injured and uninjured side. Although the differences were statistically significant, the effect sizes were small.

4.5 Lumbo-pelvic movement control

Table 4.9 Summary of the lumbo-pelvic movement control tests between injured and uninjured players (Fisher's exact) (n=30)

	Injured group		Uninjured group		
	Correct	**Incorrect**	**Correct**	**Incorrect**	**P-value**
DPT	2	13	5	10	0.2
WB	5	10	11	4	0.01*
OLS	11	4	13	2	0.36
PKB	1	14	7	8	0.004*

* denotes statistical significance ($p<0.05$); DPT – dorsal pelvic tilt; WB – waiter's bow; OLS – one leg stand; PKB – prone knee bend

As shown in Table 4.9, no association was found in the performance of the dorsal pelvic tilt in the study and uninjured groups ($p=0.2$). Most players performed the dorsal pelvic tilt incorrectly, irrespective of injury. Limited pelvic tilt, low back extension and/or thoracic flexion as compensatory movements were noted as an incorrect movement pattern during the performance of the dorsal pelvic tilt.

A significant association was determined between being injured and performing the waiter's bow incorrectly ($p=0.01$). Injured players were unable to perform hip flexion effectively between 50° and 70° to perform the movement correctly with no compensatory lumbar flexion movement.

No association was found between the groups when performing the one leg stand ($p=0.36$). Most players performed the movement correctly by moving the umbilicus symmetrically to the left and right side, irrespective of injury.

The results of this study established an association between hamstring injury and the incorrect performance of the prone knee bend ($p=0.004$). Injured players were unable to perform active knee flexion to at least 90° without extending the lower back and pelvis in compensation.

4.6 Conclusion of the results

The maximum voluntary isometric contraction was lower in the erector spinae muscle in both the injured (p=0.04) and uninjured (p=0.04) side, and the maximum voluntary contraction of the biceps femoris muscle (p=0.02) was only lower in the injured side. All three of these findings were statistically significant. Both study and uninjured groups showed no statistically significant difference in muscle activity during the functional squat. The results of the EMG activity in the thirty-metre sprint were determined to be statistically significant. These results demonstrated that the hamstring muscle activity in the injured side (p=0.01) was lower in comparison with the uninjured side and that the hamstring activity in the uninjured side of the injured player (p=0.03) was higher than the matched side of the uninjured player. The muscle activity of the erector spinae muscle revealed to be lower in the injured side (p=0.02) when compared with the matched uninjured side.

During the performance of the lumbo-pelvic test, no association was found between the two groups in the dorsal pelvic tilt and one leg stand. The performance of the waiter's bow (p=0.01) and prone knee bend (p=0.004) revealed statistically significant differences between the study and uninjured groups. The majority of the players in the injured group performed both of these functional tests incorrectly (WB n=10; PKB n=14).

CHAPTER 5: DISCUSSION

5.1 Introduction

The first aim of this research was to examine the difference in muscle activity of the erector spinae, gluteus maximus, hamstrings (biceps femoris) and quadriceps (rectus femoris) muscles between uninjured soccer players and those with recent hamstring injuries while performing isometric contractions, a functional squat and sprinting. The second aim was to compare lumbo-pelvic movement control in soccer players with and without recent hamstring injuries.

Chapter 5 deals with the main findings of the research and discusses the descriptive and inferential characteristics of the participating players, and the association of hamstring injuries between the muscle activity of the erector spinae, gluteus maximus, biceps femoris and rectus femoris muscles and lumbo-pelvic movement control.

5.2 Participants

5.2.1 Sample Size

The sample size for this study was 30 soccer players; the uninjured group consisted of 15 players and the injured group of 15 players. Data from a previous study that used EMG activity to measure hamstring muscle activity in injured and uninjured soccer players (Sole, Milosavljevic, Nicholson and Sullivan, 2012) was used to establish a sample size large enough to provide sufficient statistical power. Hamstring muscle activity, being one of the primary outcome measures for this study, was used to determine the required sample size. It was also considered that, of all the parameters measured, hamstring muscle activity may have the greatest variance.

Recent studies investigating EMG activity had sample sizes of between six and 145 participants (Kotila, 2014). The majority of previous EMG studies on the activity of various muscles, including the semitendinosus, semimembranosus, vastus lateralis, vastus medialis and gluteus medius muscles, had small sample sizes of between six and 18 participants (Sole, Milosavljevic, Nicholson and Sullivan, 2012). These studies, however, only investigated lower limb activity and did not examine impaired lumbo-pelvic movement control, or lumbo-pelvic movement control dysfunction.

This study compared both isometric and isokinetic activity of the specific muscles, as well as the differences in lumbo-pelvic movement control between injured and uninjured players. The established sample size had a sufficient power to avoid type II error when considering EMG activity of the hamstring muscle, however, it may not have been sufficiently powered for the other muscles and therefore an effect size was calculated (Figure 5.1).

5.2.2 Descriptive Characteristics

To minimise discrepancies in physical characteristics, players in the uninjured group were carefully matched with players in the injured group according to age, height, weight and playing position. Similar studies in the past used male participants who were either recreationally active or elite sportsmen competing at a professional level (Kalema, 2012; Sole, Milosavljevic, Nicholson and Sullivan, 2012; Engebretsen, 2010).

In a previous EMG study comparing the activity of the gluteal and thigh muscles of sportspeople (with and without recent hamstring injuries) during weight bearing tasks, players were matched according to age, weight, height and body mass index (Sole, Milosavljevic, Nicholson and Sullivan, 2012). These physical attributes (including age, weight and height) were slightly higher in comparison with the players examined in this study. Matching of the players reduces the skewing of results by negating any influential variables and increases the precision of the estimates with an efficient stratified analysis of results.

Carling, Gall and Reilly (2010) reported that a considerable risk of injury exists at the elite level of soccer as the game places high technical, tactical and physiological demands on a player. The players selected for the uninjured group in this study were carefully matched with players in the injured group to counterbalance variations in physiological determinants, training demands and exposure.

Kalema (2012) stated there are an estimated 256 million soccer players worldwide, and Ekstrand, Hagglund and Walden (2011) cited soccer as the largest global team sport that continually attracts new players. Ninety percent of the estimated 265 million players are male, with females making up a mere 10% of the number (Kalema, 2012). Due to the high percentage of male soccer players, participants in this study were all male athletes competing at either an amateur or professional level. By excluding female soccer players, the total changes across the soccer population may be observed as sex-specific changes rather than

changes across the whole soccer population, and results cannot be generalised to include female soccer players.

5.3 Physical activity, training and injury history

The literature review of this report refers to a number of studies that identified sprinting as the leading mechanism for hamstring injuries globally. Small et al (2009) stated that sprinting is responsible for 57% of all hamstring injuries. In this study, 11 of the 15 injured players (73.33%) sustained their hamstring injuries during sprinting. This percentage is higher than the global percentage of 57% reported by Small et al (2009). The percentages reported in this study are significantly higher than those in English football, despite the area covered being smaller (limited to the Johannesburg region of South Africa) and based on only 30 participants, half of whom had suffered a hamstring injury within six months of this study.

Small et al (2009) suggested the risk of hamstring injury might be more prevalent at the end of the stance phase when the muscle is preparing for the swing phase by contracting forcefully to assist hip extension during take-off. This phase has the potential to induce a concentric contraction injury. Alternatively, Kalema (2012) proposed that the hamstring muscles were more susceptible to injury during the terminal swing phase of the sprinting cycle because the biomechanical nature of the muscles allows them to lengthen over two joints while simultaneously working eccentrically to decelerate hip flexion and control knee extension. Hoskins and Pollard (2005) stated that hamstring injuries occur during the terminal swing, due to gluteus maximus muscle inhibition as the hamstring acts as a hip extensor instead of a transducer of power between the hip and the knee joints. Therefore, it more inclined that hamstring injuries occur due to loss in eccentric strength during the terminal swing phase while sprinting, as stated above.

The majority of players in the injured group of this research report sustained their injuries towards the latter phase of a soccer match and training sessions. Twelve of the 15 players (80%) sustained injuries during the middle to end of a soccer match. Ekstrand et al (2011) stated that 42% of hamstring injuries in English professional football occurred during the last 15 minutes of each half. Engebretsen (2010) presumed the injuries were due to tiredness and described fatigue as a predisposing factor to hamstring injury. Earlier literature has concluded that fatigue causes a decrease in strength, which is a significant factor in the occurrence of hamstring injury, and has been associated with decreased eccentric strength (Delextrat,

Gregory and Cohen, 2010). Croiser et al (2008) suggested that strength deficits or imbalances increase the risk of hamstring injury.

In this study, all players with hamstring injuries received physiotherapy after their injuries, including rest, strapping and rehabilitation. Five of the 15 players used medication in conjunction with the physiotherapy treatment. The intensity, frequency and type of physiotherapy received were not in the scope of this research. The impact of physiotherapy treatment is proposed as a possible subject for future research. The fact that all 15 players received physiotherapy after their hamstring injuries indicates they are all aware of the benefits of physiotherapy.

Players returned to play within four weeks of their injuries and continued rehabilitation for a further six weeks. Very few studies have investigated the outcome of return-to-play criteria after a hamstring injury in soccer. Burkner (2015) pointed out there is no standard time for return to play as every injury differs according to its severity and location (musculotendinous junction or muscle belly).

According to Hoskins and Pollard (2005), injuries within muscle tendon or musculotendinous junction are more severe than injuries to the muscle belly due to the decreased blood supply to those areas. The severity of hamstring injuries are graded into three categories: grade 1 presents with limited fibre involvement, grade II presents with 50% muscle involvement and grade III presents with a complete rupture of the hamstring muscle. Hoskins and Pollard (2005) found the period of rehabilitation to be proportional to the degree of the disability, the grade and the location of the injury. The length of time, therefore, is proportional to the severity and location (musculotendinous junction or muscle belly) of the injury. Therefore, it may be concluded that injury of the musclotendinous junction would have a greater recover time as oppose to injury at the muscle belly. Liu, Garrett, Moorman and Yu (2012) considered that eccentric strength deficits may play an important role and, therefore, recommended that training for eccentric muscle strength be introduced upon return to play.

5.4 Hamstring injury outcome

In this study, players with previous hamstring injuries completed the Oslo hamstring injury questionnaire to assess their injuries, symptoms, function and quality of life.

Results indicated that the mean calculation for each subscore showed that the most affected sections of the questionnaire were symptoms and quality of life, with the least affected section being function. This is comparable with participants in the study by Engebretsen (2010), which found that participants with all subscores except soreness, age and player position were at risk for reinjury. Therefore, the Oslo hamstring injury questionnaire includes hamstring-specific clinical examinations and hamstring-specific tests to assist in identifying players that are at risk for reinjury.

Although Engebretsen (2010) concluded that players with acute hamstring injuries were found to be at increased risk for reinjury, their study used the Oslo hamstring injury questionnaire only to determine the presence of the symptoms of the players in the injured group. It should be noted that previously injured players have also been found to be more than twice at risk of reinjury than uninjured players (Engebretsen, 2010).

5.5 Muscle activity

The isometric muscle activity of the erector spinae muscle revealed statistically significant difference on the injured ($p=0.04$) and uninjured ($p=0.04$) side of the players. During the thirty-metre sprint the results of the erector spinae muscle on the injured side were determined to be statistically significant ($p=0.02$). Both the muscle activity was lower on the injured side when compared to the matched uninjured side of the players during isometric contractions, and thirty-metre sprint. Even though statistically significant differences were found the effect size were small during these activities (Cohen's $d=0.02$; Cohen's $d=0.03$; Cohen's $d=0.01$). This could potentially be due to lumbar intersegmental stability around the neutral zone being compromised by muscle weakness or deficiencies in the activation of the lumbar erector spinae muscle. Intersegmental motion control at the neutral zone has been described as an influential factor in spinal instability (Novacheck, 1997) mainly because this is the region in which motion occurs (Schache, et al. 2002). The neutral zone is subjected to an increase in the available range of motion and this, according to Hoskins and Pollard (2005), is an early indicator of the onset of joint injury.

The muscle activity of the erector spinae muscle was found to be higher on the uninjured side of the injured players during the isometric contractions and 30m sprint. This is an aberrant movement pattern due to compensation of the erector spinae muscle in the uninjured side to stabilise the lumbo-pelvic system in the presence of hamstring injury. Delayed activation of the lumbar erector spinae muscles could also potentially cause the biceps femoris muscle to

counteract by contracting to stabilise the thoracolumbar fascia system (Hoskins and Pollards, 2005). The biceps femoris muscle therefore substitutes the lumbar erector spinae muscle and forcefully expends more energy to stabilise the thoracolumar fascia system. This explains the significant difference and increased muscle activity of the biceps femoris muscle in the uninjured side of the injured players when compared with the matched uninjured players. Therefore, the lumbo-pelvic movement control dysfunction could indirectly be linked to atypical movement patterns in the lumbar spine leading to lumbo-pelvic pain and hamstring injury and reinjury.

The functional squat revealed no statistically significant differences. Liebenson (2002) stated the functional squat is able to detect a number of kinetic chain dysfunctions, including pelvic malalignment, excessive trunk flexion, poor knee control and subtalar hyperpronation. The study suggested the cause could have been dysfunctional pelvic movement, a stiff soleus muscle, gluteus medius or maximus insufficiency, or a combination of these malfunctions (Liebenson, 2002). Although a functional squat may reveal a number of dysfunctions, there is no current literature to suggest that the test, if poorly performed, is an indication that any particular type of injury may occur. A possible reason for this could be the test's multi-factorial nature as it assesses multiple joint segments during the movement (Crossley et al, 2011; Clark and Lucett, 2010). A small effect size (Cohen's d=0.22) was noted in the muscle activity of the erector spinae muscleon both the injured and uninjured side compared with the matched uninjured players. Decreased muscle activity in the erector spinae muscle was observed in both the injured and uninjured leg of the injured players compared with the uninjured players. According to Liebenson (2002) this may explain the excessive trunk flexion noted during the functional squat of individuals with kinetic chain dysfunction.

The study revealed a statistically significant difference in the biceps femoris muscle (p=0.02) in the injured side when compared to the matched uninjured side during isometric contractions. No statistically significant differences were noted in the muscle activity of the biceps femoris muscle during the functional squat. The muscle activity of the biceps femoris muscle during the thirty-metre sprint were found to be statistically significant different on both the injured and uninjured side of the players. Despite finding a statistically significant difference in the biceps femoris muscle on the injured side of the players during isometric contraction, and in both the injured and uninjured sides when compared with the matched

player during the thirty-metre sprint, the effect sizes were small (Cohen's *d*=0.08; Cohen's *d*=0.05; Cohen's *d*=0.03).

Several studies have raised deliberations on the significance of hamstring strength in relation to hamstring injury (Kalema, 2012; Engebretsen, 2010; Lui, Garret, Moorman and Yu, 2012). An analysis of the data from this study revealed a significant difference in biceps femoris muscle activity between the injured side and the uninjured side of the matched player during isometric contractions and the thirty-metre sprint. Kalema (2012) stated this difference could be described as the loss in tensile strength of the biceps femoris muscle following a hamstring injury.

During the normal phases of healing, type I collagen fibres are laid down in the fibroblastic phase (day four of between two to three weeks). Laying down of type II muscle fibres occurs during the remodelling phase of healing (from week two through to week four, and up to between six and 12 months). It is in this phase that there is still a deficit of 15% of the tensile strength of the surrounding tissue in the injured muscle. Muscle fibres that have been repaired take between six and 12 months to regain full tensile strength. This supports Kalema's (2012) statement and explains the statistically significant difference between the biceps femoris muscle in the injured and matched uninjured side during isometric contractions and the thirty-metre sprint.

To prevent any overlap, an inclusion criterion for this study was that half the players should have suffered hamstring injuries within six months prior to the study, and the other half no hamstring injuries for at least a year prior to the study. The tensile strength of the hamstring muscles of the players who suffered a hamstring injury within the past six months was thus still constrained at the time of the study.

This explains the difference in the EMG activity of the biceps femoris muscle in the study and uninjured groups. The biceps femoris activity in the injured side was lower than that in the matched uninjured side. The hamstring muscles have a large number of type II muscle fibres that take up to12 months to recover after an injury. The deficit of type II muscle fibres during the study, therefore, would also explain the decrease in EMG muscle activity of the biceps femoris muscle in the injured side of players during isometric contractions and the thrirty-metre sprint (Engebretsen, 2010; Hoskins and Pollard, 2005).

The significant differences in the contraction of the biceps femoris muscle on the injured side of the injured players compared to the matched uninjured players are supported by earlier studies that hamstring injuries often take place during eccentric contraction of the hamstring muscles (Schache et al, 2012; Kalema, 2012; Hoskins and Pollard, 2005). Schache et al (2012) indicated that the terminal swing phase rather than the stance phase of sprinting is the most likely time of injury. The hamstring muscles appear to be biomechanically most exposed during the terminal swing phase. Most of the inertial force acting about the knee joint at this time, is imparted onto the hamstring as they attempt to decelerate the swinging leg. Hamstring muscles are also responsible for generating hip extensor torque (<50%). The hamstring muscles must change form functioning eccentrically to decelerate knee extension in the late terminal swing phase, to concentrically, becoming an active extensor of the hip joint. The rapid changeover from eccentric to concentric function of the hamstring muscles is when the muscle is most vulnerable to injury (Donald, 2010). Peak hamstring muscle electromyography activity during sprinting has been shown to occur during the terminal swing phase. The hamstring muscle-tendon unit undergoes an active lengthening contraction during the terminal swing phase. Eccentric contraction, rather than concentric contraction, has shown to produce some muscle fibre damage (Thelen et al, 2005). The mean voluntary contraction of the biceps femoris muscle of the injured players is lower than the mean voluntary contraction of the matched leg of the uninjured players. This could be explained as a loss in eccentric strength within the hamstring muscle due to muscle fibre damage following a hamstring injury.

The functional squat revealed no statistically significant difference, the muscle activity of the biceps femoris muscle was lower on the injured side of the players when compared to the uninjured players. Even though statistically significant differences were found the effect size were small during these activities (Cohen's d=0.17; Cohen's d=0.11). During the functional squat the quadriceps muscle contracts eccentrically during flexion of the lower limbs while the hamstring muscles contract concentrically. Controversially, the quadriceps muscle contract concentrically during lower limb extension and the hamstring muscle contract eccentrically. The hamstring:quadriceps ratio changes throughout range of motion of the lower limbs. It has been concluded by Coombs and Garbutt (2002) that muscular imbalances and asymmetry caused by the change in hamstring:quadriceps ratio may predispose a soccer player to injury.

The muscle activity of the gluteus maximus in both the study and uninjured groups revealed no statistically significant differences. A small effect size were revealed in the muscle activity of the gluteus maximus muscle in the injured side during isometric contractions and the thirty-metre sprint (Cohen's *d*=0.26). A medium effect size (Cohen's *d*=0.54) was noted in the muscle activity of the gluteus maximus muscle in the uninjured side of injured the players compared with the matched side of uninjured players during the thirty-metre sprint. A decrease in gluteus maximus strength inhibits the muscle during sprinting, driving the hamstring muscles to contribute more force to hip extension instead of acting as a transducer of power, potentially subjecting the hamstring to risk of injury (Hoskins and Pollard, 2005).

The functional squat presented a medium effect size (Cohen's *d*=0.57) in the muscle activity of the gluteus maximus muscle on the injured side of the injured players. If the sample size were larger a statistically significant difference may been noted within the gluteus maximus muscle of the injured leg of the players compared with the matched leg of the uninjured players. Decreased muscle activity of the gluteus maximus muscle in the injured leg may support the fact that gluteus maximus insufficiency could possibly pelvic malalignment and poor knee control (Liebenson, 2002).

The muscle activity of the gluteus maximus muscle was lower on the injured side when compared with the matched uninjured side during the isometric contractions, functional squat and 30m sprint. This would support the hypothesis that a decrease in gluteus maximus strength predisposes a soccer player to hamstring injury due to the increased demand placed upon the hamstring muscle to act as the primary hip extensor and transducer of power between the hip and knee joints (Hoskins and Pollard, 2005).

The muscle activity of the rectus femoris muscle revealed no statistically significant differences in both the study and uninjured groups. The isometric contraction of the rectus femoris muscle in the injured side when compared with the matched uninjured side revealed a medium effect size (Cohen's *d*=0.61). A large sample size (Cohen's *d*=0.85) was noted in the rectus femoris muscle in the injured side of players compared with the matched side of uninjured players, with decreased muscle activity observed in the injured side during the functional squat. This decrease results in a reduction of the hamstring:quadriceps ratio, which predisposes a soccer player to hamstring injury (Coombs and Garbutt, 2002).

During the thirty-metre sprint a medium effect size (Cohen's *d*=0.52; Cohen's *d*=0.58) was noted in the rectus femoris muscle in the injured and uninjured side of both the injured and uninjured players. The medium effect size in both these muscles pointed to the possibility of muscular imbalances, referred to as the lower crossed syndrome. The lower cross syndrome is characterised by tautness in the hip flexors and lumbar erector spinae muscles, and weak, inhibited gluteal and abdominal muscles. This causes an anterior pelvic tilt and increased hip flexion and lumbar lordosis (Janda, 1996). An anterior pelvic tilt shifts the ischium away from the distal insertion of the hamstring, subjecting the hamstring muscle to increased mechanical stress and potential hamstring injury movement (Hunter and Speed, 2007). Engebretsen (2010) identified diminished flexibility of the hip flexor and quadriceps as a risk factor for hamstring injury. The medium effect size in the rectus femoris muscle also supports the hypothesis that a constricted rectus femoris muscle increases the acceleration of hip flexion and knee extension during the mid to late terminal swing phase of sprinting. This action, in turn, needs to be counteracted by the eccentric contraction of the hamstring muscles, which places a greater load on the muscle and increases its chances of injury (Gabbe et al, 2005).

5.6 Lumbo-pelvic movement control

In this study, considerable differences were found between the study and uninjured groups in the performance of the waiter's bow and prone knee bend. No significant differences were found between the groups when comparing the performance of the dorsal pelvic tilt and one leg stand.

The waiter's bow revealed a statistically significant difference in the way the two groups performed the test. The manner in which the waiter's bow was performed was noted primarily to ascertain if it was performed correctly or incorrectly. According to Luomajoki, Kool, De Bruin and Airaksinen (2007), the waiter's bow is performed correctly if an individual can bend forward from the hips with 50°–70° of flexion without moving the lower back in compensation.

The majority of players in the injured group performed the waiter's bow incorrectly. The results of this study therefore illustrate that the majority of the injured players were unable to perform hip flexion effectively between 50° and 70° to perform the waiter's bow with no lumbar flexion as a compensatory movement.

Lumbo-pelvic movement control has previously been assessed in a soccer population, but the study focused on elite players with lower back pain and not those with hamstring injuries (Grosdent et al, 2015). Grosdent et al (2015) used the waiter's bow in their study, the only test similar to those used in this study. This study, however, did not include soccer players affected with low back pain. Future research in this area would be able to establish the discriminant validity of the waiter's bow test in soccer players who have sustained a hamstring injury.

There was a statistically significant difference between the players in the performance of the prone knee bend. The way in which the test was performed was noted primarily to ascertain if it was being performed correctly or incorrectly. Luomajoki, Kool, De Bruin and Airaksinen (2007) described a correct prone knee bend test as being an active knee flexion of 90° without extension of the lower back and anterior tilt of the pelvis.

The test showed that a large percentage of the players overall could not perform this activity correctly. However, the number of injured players unable to perform the movement correctly was greater than the number of uninjured players. Poor control of the pelvic girdle joint during activities requiring optimal lumbo-pelvic movement control is often responsible for apparent hamstring weakness (Lee, 2015). There have been no studies describing the prone knee bend as a test for lumbo-pelvic movement control within a soccer population and further research in this area is needed to establish the discriminant validity of the test in soccer players.

The one leg stand was performed correctly by most of the players, irrespective of hamstring injury. The one leg stand establishes that in the presence of a rotational dysfunction of the pelvis during standing, notable differences can be detected in the sideways shift of the pelvis relative to the trunk of more than 10 cm, as well as more than 2cm between left and right sides (Luomajoki, Kool, De Bruin and Airaksinen, 2007). The test has been standardised using normal stance width, which Luomajoki, Kool, De Bruin and Airaksinen (2007) define as one third of the distances between trochanters.

The one leg stand has not previously been assessed in a soccer population, but Childs et al (2003) used the test on a general population experiencing low back pain. The results revealed a significant difference between participants with low back pain and health control, indicating a side-to-side weight-bearing asymmetry in those suffering low back pain. No significant

difference was found between the study and uninjured groups in this study as players who had sustained a lumbo-pelvic injury had been excluded.

Precise lumbo-pelvic movement control is required to minimise energy expenditure and maximise sprinting efficiency during sprinting (Fletcher, 2009). More injured than uninjured players performed the lumbo-pelvic movement control test incorrectly, indicating that lumbo-pelvic movement control dysfunction is indirectly linked to aberrant movement patterns in the lumbar spine, and can cause lumbo-pelvic pain and hamstring injury. These findings were backed by the study conducted by Grosdent et al (2015) that reported lumbo-pelvic movement control was altered in the presence of pain, although the study was conducted on players with lower back pain.

Previous studies regarding lumbo-pelvic movement control as a contributing factor to hamstring injuries are limited and further research is required in this area.

5.7 Conclusion to the discussion

The maximum voluntary isometric contraction in the erector spinae muscle in the injured and uninjured side showed statistically significant differences. Similarly, differences were observed in the waiter's bow and prone knee bend during lumbo-pelvic movement control tests. This could potentially be due to compromised lumbar intersegmental stability around the neutral zone due to weakness or deficiencies in the activation of the lumbar erector spinae muscle. It can also be associated with poor lumbo-pelvic movement control, as the load on the hamstring muscles is increased to provide intersegmental stability around the neutral zone.

This concludes the differences reported in the maximum voluntary isometric contraction of the biceps femoris muscle. During the thirty-metre sprint, significant differences were found between the mean voluntary contraction of the biceps femoris muscle bilaterally in both injured and uninjured players and the erector spinae muscle in the injured side.

The results of this study have not proved the hypothesis that gluteus maximus muscle weakness is a risk factor for hamstring injuries, even though a small effect size was noted during data analysis. The study found instead that hamstring injuries are prevalent during eccentric contraction of the hamstring muscles and, if lumbo-pelvic movement control is aberrant, could indirectly cause lumbo-pelvic pain and hamstring injury.

CHAPTER 6: CONCLUSION

6.1 Conclusion

This first aim of this study was to compare muscle activity of the erector spinae, gluteus maximus, hamstrings (biceps femoris) and quadriceps (rectus femoris) muscles during isometric activity, a functional squat and a thirty-metre sprint in soccer players with and without recent hamstring injuries. The second aim was to compare lumbo-pelvic movement control in soccer players with and without recent hamstring injuries.

EMG muscle activity during isometric contractions, a functional squat and a thirty-metre sprint in soccer players with and without hamstring injuries was measured. EMG muscle activity during isometric contractions of the erector spinae and biceps femoris muscles were determined as statistically significant. The maximum voluntary isometric contraction was lower in the erector spinae muscle in both the injured and uninjured side whilst the maximum voluntary contraction of the biceps femoris muscle was only lower in the injured side.

The muscle activity during the functional squat was determined to be non-significant between the study and uninjured groups. The results of the biceps femoris muscle activity in both the uninjured and injured side and the results of the erector spinae muscle in the injured side were determined to be statistically significant during the thirty-metre sprint. They demonstrated that the hamstring muscle activity in the injured side was lower in comparison with the uninjured side and that the hamstring activity in the uninjured side of the injured player was higher than the matched side of the uninjured players. The muscle activity of the erector spinae muscle revealed to be lower in the injured side when compared with the matched, uninjured side of the players.

Lumbo-pelvic movement control testing was done to establish if lumbo-pelvic movement control was optimal during the dorsal pelvic tilt, waiter's bow, one leg stand and prone knee bend. It was found that most of the players, irrespective of a hamstring injury, performed the dorsal pelvic tilt incorrectly. The majority of players, irrespective of injury status, performed the one leg stand correctly. The performance of the waiter's bow and prone knee bend revealed statistically significant differences between the study and uninjured groups. The majority of the players in the injured group performed both of these functional tests incorrectly.

The findings of this study correlate with the literature that suggests lumbo-pelvic movement control dysfunction, arising from a weakness or deficiency in the activation of the lumbar erector spinae muscles, could potentially compromise lumbar intersegmental stability around the neutral zone. Delayed activation of the lumbar erector spinae muscles could also potentially cause the biceps femoris muscle to counteract by contracting to stabilise the thoracolumbar fascia system. The biceps femoris muscle therefore, substitutes the lumbar erector spinae muscle and become overactive to stabilise the thoracolumar fascia system. This explains the significant difference and increased muscle activity of the biceps femoris muscle on the uninjured side of the injured players when compared to the matched uninjured players. The decreased muscle activity of the erector spinae muscle on the injured side of the injured participants could be an indication of erector spinae weakness or deficiency prior to hamstring injury. This could be supported by the decrease in muscle activity erector spinae on both the injured and uninjured side of the injured players during isometric contractions. Therefore, lumbo-pelvic movement control dysfunction could indirectly be linked to aberrant movements in the lumbar spine leading to lumbo-pelvic pain and hamstring injury.

6.2 Limitations of the study

A number of limitations within the study should be noted. The biceps femoris muscle was the only hamstring muscle that was assessed during the EMG testing and possible injuries to the semitendinosus and semimembranosus muscles were not considered. All the tests in the pilot study were carried out in the same order as in the main study, with no randomisation, which may mean that the findings of each test were dependent on each other. As the participants of this study were all male, the results are not suitable for generalisation to include a female population. All the participants in the injured group received physiotherapy treatment following their hamstring injuries and the impact of the difference in physiotherapy treatment and the influence of the treatment on muscle activity were not taken into consideration.

6.3 Recommendations for future studies

Future studies on the use of eccentric hamstring strength assessments and lumbo-pelvic movement control tests could provide information for guidelines for the screening of hamstring injuries, preventative measures, and the rehabilitation of hamstring injuries in male soccer players.

In addition, studies on eccentric training of the hamstring muscles after an injury, followed by an EMG of sprinting to ascertain if the activation in soccer players is still amplified in the late swing phase in the thirty-metre sprint, could have a positive influence on determining suitable rehabilitation exercises.

Studies that explore if the risk of hamstring injury decreases when the muscle activity of the erector spinae and biceps femoris muscles are normalised and lumbo-pelvic control is improved could enhance therapeutic management.

This study reported that all the players who had suffered a hamstring injury were aware of the benefits of physiotherapy, therefore the impact of physiotherapy on muscle activity following a hamstring injury could also be investigated. Studies should include participants of different ages, genders, populations and demographics as these factors play an intrinsic role in hamstring injuries.

6.4 Clinical Recommendations

Three notable clinical recommendations for hamstring screening, hamstring injury prevention and hamstring injury rehabilitation arise from this study. The first is to attain maximal eccentric strength of the hamstring muscles during rehabilitation to optimise correct muscle activation and movement control of the kinematic chain for sprinting, and the second is to achieve activation of the erector spinae muscles to control the neutral zone during sprinting for optimal lumbo-pelvic movement control of the biomechanical chain. The third recommendation is to achieve optimal lumbo-pelvic movement to prevent over-active hamstring muscle activity from causing hamstring injury. All three of these recommendations should be considered when screening soccer players for hamstring injury risk.

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Appendix I

Physiotherapy

Faculty of Health Sciences · Private Bag 3, Wits, 2050, South Africa
Tel: +27 11 717 2014 ·Fax :+ 27 86 663 5776 · E-mail:rialiroos@gmail.com

06-07-2015

Club Manager/CEO

To whom it may concern:

Re: Participants invited for a study at the University of the Witwatersrand

I am a masters student at the University of the Witwatersrand. I am conducting a study to investigate the difference in lower limb muscle activity and lumbo-pelvic movement control in soccer players with recent hamstring injuries compared with non-injured players.

I would like to invite soccer players between the ages of 18 and 30 years, who has had a recent hamstring injury within the last six months and also players without any hamstring injuries currently and who are participation in full regular training. The study requires an hour of testing at the participant's soccer club. Ethical clearance has been obtained from the Human Ethics Research Committee of the University of the Witwatersrand. The data collected from the study will be forwarded to the player to assist the medical team with further management of the participants involved in the study. This information may be useful in planning training programmes and other physical activities to prevent hamstring injuries.

I have attached the study advertisement for interested participants and would appreciate your assistance in distributing in to the club members.

Please contact me if you have any questions of concerns, or would like more information regarding this study.

Yours sincerely

Riali Roos
BSc Physiotherapy (Wits)

UNIVERSITY OF THE WITWATERSRAND
JOHANNESBURG

MALE SOCCER PLAYERS WANTED FOR WITS RESEARCH

For a study evaluating the difference in lower limb activity and lumbo-pelvic movement control in soccer players with recent hamstring injuries compared to non-injured players.

STUDY OUTLINE

I am a masters student at the University of the Witwatersrand, investigating the difference between lower limb muscle activation and lumbo-pelvic movement control in soccer players with recent hamstring injuries compared to non-injured players. The study aims to provide information regarding the changes in the recruitment pattern of the lower limb muscles and lumbo-pelvic movement control following hamstring injuries and whether this predisposes the hamstring muscle to occurrence of hamstring injury and recurrent injury.

You will be required to attend one familiarisation session and one testing session of one hour each at your local soccer club. During the two sessions you will be required to complete a questionnaire on your training and competition history, injury history and general physical activity. An EMG will be taken of the lower limb muscles and physical tests to measure the strength, endurance and power of the hamstring muscles and lumbo-pelvic stability.

THOSE INTERESTED TO PARTICIPATE SHOULD:

- Be between the ages of 18 and 30 years
- Have a history of a hamstring injury within the last six months that required medical interventions
- Not have a known history of hamstring injuries in the past year that required medical intervention for the comparison group.

BENEFITS OF PARTICIPATING IN THE STUDY INCLUDE:

- Individual feedback based on your testing
- Advice on risks of hamstring injuries and prevention strategies to medical personnel and physiotherapists involved with your team.

DEADLINE FOR APPLICATIONS: *(to be specified)*

If you are interested in taking part in the study and would like to additional information, please contact:

Riali Roos
Cell: 072 424 2411
Email: rialiroos@gmail.com

Appendix II

PHYSICAL ACTIVIYT READINESS QUESTIONNAIRE:

Name: _____

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

YES ☐ NO ☐

2. Do you feel pain in your chest when you do physical activity?

YES ☐ NO ☐

3. In the past month, have you had chest pain when you were not doing physical activity?

YES ☐ NO ☐

4. Do you lose your balance because of dizziness of do you ever lose consciousness?

YES ☐ NO ☐

5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?

YES ☐ NO ☐

6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

YES ☐ NO ☐

7. Do you know of any other reason why you should not do physical activity?

YES ☐ NO ☐

COMMENTS: _____

_____

_____

_____

_____

Appendix III

MSc Sports Physiotherapy

Lower limb muscle activity and lumbo-pelvic control study

PHYSICAL ACTIVITY, TRAINING AND INJURY QUESTIONNAIRE

The information collected in this questionnaire will only be used for research purposes within the scope of the study. All information will be kept strictly confidential and anonymous.

Instructions

The questionnaire must be completed during the familiarisation session prior to the testing procedure. Please answer each question by filling in the details in the allocated space or ticking one or more of the option boxes. Informed consent must be signed prior to completing the questionnaire and handed in to the investigator.

PERSONAL INFORMATION:

Name:_____ Date of birth: _____ Age: _____

Gender: _____ Height: _____ Weight: _____

Dominance: Upper limb (arms) Left/Right Lower limb (legs) Left/Right (*Circle your dominant side)*

Cell number: _____ Home number: _____

Email address:_____

Occupation:_____

Sport: _____ *Professional/Amateur*

Club:_____ Provincial/National team: _____

PHYSICAL ACTIVITY AND TRAINING

Hours training per week: Personally_____ with team_____

Please specify personal training routine: _____

Days participating in games: Personally_____ with team_____

If participation in games personally, please specify activity or sport participating in:

_____

Days participating in games: per month_____ per year_____

How many hours you exercising in a performance day: _____

INJURY HISTORY

Injury definition: Injuries lead to absence from training or competition for a day at least or that occurred during sporting activity that required medical attention.

Do you currently have any injuries?

YES ☐ NO ☐

If yes, please specify:

1. _____
2. _____
3. _____

Are you currently using any medication for example analgesics or non-steroidal anti-inflammatory drugs?

YES ☐ NO ☐

If yes, please specify:

1. _____
2. _____
3. _____

Have you suffered from previous injuries?

YES ☐ NO ☐

If yes, please specify:

1. _____
2. _____
3. _____

Injured body part and type of injury:

1. _____
2. _____
3. _____

Briefly explain how the injury occurred (mechanism of injury):

1. _____
2. _____
3. _____

What do you think caused these injuries?_____

Were you injured during training? _____

How many times this happened: in the start _____ in the middle _____ in the end _____

How many times this happened: with the presence of trainer _____ without trainer _____

Were you injured in a game? _____

How many times this happened: in the start _____ in the middle _____ without trainer _____

Your opinion for prevention of injury in the sport you exercise: _____

Management of previous injury/injuries:

	Injury 1	Injury 2	Injury 3
Surgery			
Medication			
Physiotherapy			
Strapping			
Brace			
Rest			
No treatment			
Other			

For how long were you unable to fully play/train?

☐ 3 days ☐ 4 – 7 days ☐ 1 – 4 weeks ☐ >4 weeks

Time of rehabilitation: _____

Time of re-entry competition: _____

Appendix IV

OSLO SPORTS TRAUMA RESEARCH CENTRE

HAMSTRING SCREENING INJURY QUESTIONAIRE

Name: _____

INFORMATION OF PREVIOUS HAMSTRING INJURIES

LEFT SIDE

Number of previous acute hamstring strains:

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

If you answered "0" above, skip the next 3 questions regarding the left hamstring and continue at the next section.

Time since most recent injury:

☐ 0-6 months ☐ 6-12 months ☐ 1-2 y

☐ >2 y

For how long were you unable to fully/train?

☐ 1-3 days ☐ 4-7 days ☐ 1-4 weeks

☐ >4 weeks

Have you missed a training/match during the previous season due to symptoms from your hamstring?

☐ No – never

☐ Yes

☐ Rarely ☐ Sometimes ☐ Often

RIGHT SIDE

Number of previous acute hamstring strains:

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

If you answered "0" above, skip the next 3 questions regarding the right hamstring and continue at the next.

Time since most recent injury:

☐ 0-6 months ☐ 6-12 months ☐ 1-2 y

☐ >2 y

For how long were you unable to fully/train?

☐ 1-3 days ☐ 4-7 days ☐ 1-4 weeks

☐ >4 weeks

Have you missed a training/match during the previous season due to symptoms from your hamstring?

☐ No – never

☐ Yes

☐ Rarely ☐ Sometimes ☐ Often

HAMSTRING FUNCTION

INSTRUCTIONS:

This survey asks for your view about your hamstrings. This information will help us keep track of how you feel about your hamstrings and how you function in training, match and daily life.

Please respond to every question by ticking the appropriate box, only one box for each question. If you are unsure about how to answer a question, please give the best answer you can. Remember to answer both for the left and the right hamstrings.

SYMPTOMS

These questions should be answered thinking of the symptoms from your posterior thigh/hamstrings during the **last week**.

1 – Have you experienced soreness/stiffness/had complaints from your posterior thigh/hamstring?

Left side and Right side:

Never	A little	Sometimes	Often	Always		Never	A little	Sometimes	Often	Always
☐	☐	☐	☐	☐		☐	☐	☐	☐	☐

SORENESS

The following questions cover soreness in the posterior thigh region. Report the degree of soreness that you have experienced from your posterior thigh/hamstrings during a typical week.

2 – How sore is your posterior thigh after training?

Left side:					Right side:				
Nothing	A little	Moderate	A lot	Very much	Nothing	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

3 – How sort is your posterior thigh during training?

Left side:					Right side:				
Nothing	A little	Moderate	A lot	Very much	Nothing	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

4 – How sore is your posterior thigh when you wake up in the morning?

Left side:					Right side:				
Nothing	A little	Moderate	A lot	Very much	Nothing	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

5 – How sore is your posterior thigh if you have been sitting still for a while during the day?

Left side:					Right side:				
Nothing	A little	Moderate	A lot	Very much	Nothing	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

PAIN

6 – How often do you experience pain from your posterior thigh?

Left side:

Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐

Right side:

Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐

7 – Do you often sustain small strains in your posterior thigh that resolve quickly?

Left side:

Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐

Right side:

Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐

Report the degree of pain that you have felt from your posterior thigh/hamstrings during the last week when performing the following activities:

8 – Stretching the posterior thigh/hamstrings

Left side:

No pain ☐ A little ☐ Moderate ☐ Considerable ☐ Painful ☐

Right side:

No pain ☐ A little ☐ Moderate ☐ Considerable ☐ Painful ☐

9 – Walking up a ladder/stairs (double step)

Left side:

No pain ☐ A little ☐ Moderate ☐ Considerable ☐ Painful ☐

Right side:

No pain ☐ A little ☐ Moderate ☐ Considerable ☐ Painful ☐

10 – Jogging

Left side:

No pain ☐ A little ☐ Moderate ☐ Considerable ☐ Painful ☐

Right side:

No pain ☐ A little ☐ Moderate ☐ Considerable ☐ Painful ☐

11 – Changing direction while running

Left side:

No pain ☐ A little ☐ Moderate ☐ Considerable ☐ Painful ☐

Right side:

No pain ☐ A little ☐ Moderate ☐ Considerable ☐ Painful ☐

12 – Accelerating

Left side:

No pain ☐ A little ☐ Moderate ☐ Considerable ☐ Painful ☐

Right side:

No pain ☐ A little ☐ Moderate ☐ Considerable ☐ Painful ☐

13 – Braking speed after sprinting

Left side:

No pain ☐ A little ☐ Moderate ☐ Considerable ☐ Painful ☐

Right side:

No pain ☐ A little ☐ Moderate ☐ Considerable ☐ Painful ☐

FUNCTION, DAILY LIVING AND SPORTS

The following questions concern your physical function. For each of the following activities, please indicate the degree of difficulty you have experienced in the last week due to posterior thigh/hamstrings.

14 – Running

Left side:

Nothing ☐ A little ☐ Moderate ☐ A lot ☐ Very much ☐

Right side:

Nothing ☐ A little ☐ Moderate ☐ A lot ☐ Very much ☐

15 – Jumping

Left side:

Nothing ☐ A little ☐ Moderate ☐ A lot ☐ Very much ☐

Right side:

Nothing ☐ A little ☐ Moderate ☐ A lot ☐ Very much ☐

16 – Accelerating

Left side:

Nothing ☐ A little ☐ Moderate ☐ A lot ☐ Very much ☐

Right side:

Nothing ☐ A little ☐ Moderate ☐ A lot ☐ Very much ☐

17 – Braking speed after sprinting

Left side:

Nothing ☐ A little ☐ Moderate ☐ A lot ☐ Very much ☐

Right side:

Nothing ☐ A little ☐ Moderate ☐ A lot ☐ Very much ☐

QUALITY OF LIFE

The following questions concern how problems from your hamstrings restrain you during physical activity. Report the degree of difficulty you have experienced during the last week due to your posterior thigh/hamstrings.

18 – In what degree do you trust your hamstrings during physical activity?

Left side:

Totally ☐ A lot ☐ Moderate ☐ To some degree ☐ Not at all ☐

Right side:

Totally ☐ A lot ☐ Moderate ☐ To some degree ☐ Not at all ☐

19 – Do you sometimes keep from performing 100% due to concerns of sustaining a hamstring strain?

Left side:

Not at all ☐ To some degree ☐ Moderate ☐ A lot ☐ Totally ☐

Right side:

Not at all ☐ To some degree ☐ Moderate ☐ A lot ☐ Totally ☐

SCORING INSTRUCTIONS FOR HAMSTRING AND GROIN FUNCTION SCORES

- Each item is scored from 0 (best score) to 4 (worst score). For example, for the item "How often do you experience pain from your posterior thigh?" a score of 0 is given for "Never", 1 for "Rarely", 2 for "Sometimes", 3 for "Often", and 4 for "Always".
- Sub-scores are calculated for each of the five main categories "Symptoms", "Soreness", "Pain", "Function, daily living and sports" and "Quality of life". The score is calculated in percent of the maximum score in each category, i.e. players without complaints/symptoms would score 100 on each category.
- If desired, the total score is calculated as the mean of the five subscore percentages. For example, a patient scoring 50% of the maximum subscore for "Symptoms", 38% of "Soreness", 47% on "Pain", 25% on "Function, daily living and sports" and 50% on "Quality of life" would receive a total of 42.

Appendix V

Physiotherapy

Faculty of Health Sciences · Private Bag 3, Wits, 2050, South Africa
Tel: +27 11 717 2014 ·Fax :+ 27 86 663 5776 · E-mail:rialiroos@gmail.com

20-04-2015

Club Manager/CEO

To whom it may concern:

Re: Permission to research site

I am currently a masters student at the University of the Witwatersrand. I am conducting a study to investigate the difference in lower limb muscle activity and lumbo-pelvic movement control in soccer players with recent hamstring injuries compared to non-injured players.

I would like to obtain permission from you to use your soccer club as research site as it would increase participation and compliance of the soccer players to the study. Soccer players at your club between the ages of 18 and 30 years, who have had a recent hamstring injury within the last six months, and also players without any hamstring injuries in the past year and who participate in full regular training can voluntarily take part in the study. The study requires one hour of testing at the participants' soccer club, should you allow me to do so. The data collected from the study will be forwarded to the player to assist the medical team with further management of the participants involved in the study. This information may be useful in planning training programmes and other physical activities to prevent hamstring injuries.

In order to obtain ethical clearance from the Human Ethics Research Committee of the University of the Witwatersrand, I require a permission letter from you stating that I may use your soccer club as research/investigation site. Would you possibly be able to allow me to conduct my research at your club with your players? If this is the case, would it also be possible for you to furnish me with a letter stating that you have given me permission to do so?

Please do not hesitate contact me should you have any questions or concerns, or would like more information regarding this study.

Yours sincerely,

Riali Roos
BSc Physiotherapy (Wits)
University of the Witwatersrand

Appendix VI

R14/49 Ms Riali Roos

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M150630

NAME: (Principal Investigator)	Ms Riali Roos
DEPARTMENT:	Physiotherapy Bidvest Soccer Club and Wits Football Club
PROJECT TITLE:	The Lower Limb Muscle Activity and Lumbo-Pelvic Movement Control in Injured and Non-Injured Soccer Players: A Case Control Study
DATE CONSIDERED:	26/06/2015
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr Benita Olivier and Ms Nadia Gillion
APPROVED BY:	Professor P Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	15/06/2015

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.
I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report.**

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix VII

Physiotherapy

Faculty of Health Sciences · Private Bag 3, Wits, 2050, South Africa
Tel: +27 11 717 2014 ·Fax :+ 27 86 663 5776 · E-mail:rialiroos@gmail.com

13-07-2015

MSc Sports Physiotherapy Study: The lower limb muscle activity and lumbo-pelvic control in injured and non-injured soccer players – a matched cross-sectional case study

INFORMATION DOCUMENT

Dear Participant,

I am currently a student completing my masters degree through the Department of Physiotherapy at the University of the Witwatersrand. My research will be focused on injuries that soccer players commonly suffer from. I have found that the most common injury is a hamstring strain. Players with recent hamstring injuries as well as players with no history of hamstring injuries will be considered for this research. I will be conducting a study to determine the difference in the lower limb muscle activation and lumbo-pelvic control in soccer players with recent hamstring injuries compared to non-injured players. Information such as training and competition details will be obtained. Muscle recruitment patterns, strength, endurance and lumbo-pelvic control will be tested. Information obtained within the study will be used to complete my research report as part of the MSc Sports Physiotherapy programme at the University of the Witwatersrand. This study has been given ethical approval by the Human Research Ethics Committee, Faculty of Health Science, and the University of the Witwatersrand (M150630).

Hamstring injuries are common injuries in soccer players leading to time off training and decreased participation in sport during recovery. There is a lack of evidence regarding the cause of these injuries. Possible contributing factors, such as incorrect lower limb muscle activation and poor lumbo-pelvic moment control, has not been investigated to determine their influence on hamstring injuries. Therefore, the possible causes of hamstring injuries need to be investigated further.

I am inviting soccer players from the ages of 18 to 30 to participate in this study. Should you decide to take part in this research, you will be asked to attend a total of two appointments, lasting approximately one hour each, three to five days apart. All the appointments will be held at your local soccer club. Your

participation in this study will help me to complete my research and in addition, further help members of the soccer fraternity in preventing injury and therefore time off play shall be decreased.

The study will be supervised by Associate Professor Benita Olivier and Miss Nadia Gillian from the University of the Witwatersrand.

Familiarisation session:

The familiarisation session will last approximately one hour and will take place at your local soccer club. You will be asked to complete a questionnaire regarding your physical activity levels, training and injury history. Question will also be included to assess your readiness to complete the necessary physical tests. These questions will also screen for any medical conditions which may require further medical attention. Should any medical conditions be detected, you will be referred to the appropriate medical professional. You will be familiarised with all the testing procedures that will be conducted during the study and you will have the opportunity to practice the tests which will be completed on the testing day. The testing procedure will be explained and any questions you may have will be addressed.

On the testing day:

The testing will take approximately one hour to complete and will take place at your local soccer club. On the day of testing (three to five days after the familiarisation session), an analysis will be done on the muscles of the leg. Electrical impulse detectors will be attached to specific sites on your body. During the initial portion of this testing you will be required to contract certain muscles individually. During the second part of the test you will be required to perform a squat and a 30m sprint.

Once that test is completed your lumbo-pelvic movement control will be assessed. During this test, you will be required to perform a dorsal pelvic tilt, waiter's bow, one leg stand and prone knee bent. The dorsal pelvic tilt and waiter's bow will be assessed in upright stance. During the dorsal pelvic tilt you will be asked to move your pelvis. The waiter's bow consists of you bending forward without moving your spine. During the one leg stand you will stand normally and then move onto one leg in order to assess your balance. The prone knee bent will be assessed whilst you are lying on your stomach and you will be asked to bend your knee towards your buttock. Each of these tests will be performed on the right leg first followed by the left leg, and each test will be repeated once.

Potential Risks:

There are no risks associated with the electrical impulse testing and lumbo-pelvic movement control assessment. There is a small risk of injury to your muscles during the physical activity assessment. You will have the opportunity to practice all the tests at the first session which will decrease the risk of injury. I will also ask you to tell me if you feel any discomfort during the testing, so that we can stop immediately if need be. In addition, all of these tests are performed below maximal performance and therefore the chances of

injury are minor. Although every effort will be taken to minimise injury, should you sustain an injury during testing, you will be referred to the appropriate medical care.

Benefits:

You will be given individual feedback on your testing so that the information can be used to create a custom training programme for you or adjust your current training programme to prevent hamstring injuries and the recurrence of these. Advice on the risks of hamstring injuries and prevention strategies will also be provided to your team's medical personnel and physiotherapist to assist in decreasing the occurrence of hamstring injuries to yourself and in your team.

Confidentiality:

All the information obtained during the course of this study is strictly confidential. Data that may be reported in scientific journals will not include any information which identifies you, by name, as a participant in this study. Any details regarding your test results as a result of your participation in this study will be held in strict confidence. You will be informed of any finding of importance to your health or continued participation in this study but this information will not be disclosed to any third party in addition to those listed above, without your permission.

Question and Concerns:

If at any time you have any questions about the study, please feel free to contact me on 072 424 2412 or send an email to rialiroos@gmail.com.

For more information on, or for the reporting of ethical concerns, you may contact the chair of the Human Research Ethics Committee of the University of the Witwatersrand: Prof. Cleaton Jones Tel: 011 717 2700.

Kind regards,

Riali Roos

BSc Physiotherapy (Wits)
Tel: 072 424 2412
Email: rialiroos@gmail.com

Appendix VIII

MSc Sports Physiotherapy Study: The lower limb muscle activation and lumbo-pelvic control in injured and non-injured soccer players – a matched case control study

CONSENT FORM

I_____ (e-mail address:_____ and cell phone number:_____) hereby agree to participate in the study as described to me in the information sheet. By signing this form, I am agreeing to filling in the questionnaires and performing the EMG activities and lumbo-pelvic movement control tests as described in the information sheet.

I am aware that I will not be exposed to any additional risks and that performance is below maximal performance which makes the change of injury small. I can withdraw from the study at any time without suffering any repercussions. I understand that I am not obliged to take part in the study and that participation is voluntary.

Signature of participant: _____ Date: _____

Signature of researcher: _____

For office use only:
Study number:_____

Appendix IX

Physiotherapy

Faculty of Health Sciences · Private Bag 3, Wits, 2050, South Africa
Tel: +27 11 717 2014 ·Fax :+ 27 86 663 5776 · E-mail:rialiroos@gmail.com

14-12-2015

Dear Participant,

Re: Appreciation and feedback on results obtain during the hamstring injury research

I would like to thank you for your participation in this study entitled "The lower limb muscle activity and lumbo-pelvic movement control in soccer player: A matched case control study". As a reminder, the purpose of this study was to identify the difference in lower limb muscle activity and lumbo-pelvic movement control in soccer players with recent hamstring injuries compared to non-injured players.

The data collected during the study contributed to a better understanding of the appropriate direction and future development in preventing and treating hamstring injuries. During the data analysis it has been showed that you present with an increased activity in the hamstring muscles and a decrease gluteus maximus muscle activity. You also performed 3 of the 4 lumbo-pelvic movement conrol tests incorrectly indicating poor lumbo-pelvic movement control. Both the increased hamstring muscles activity as well as the poor lumbo-pelvic movement control predisposed you as an individual to hamstring injuries in future. It is advisable for you to attend rehabilitation in order to correct this biomechanical contribution in order to prevent hamstring injuries.

Please remember that any data pertaining to you as an individual participant were kept confidential.

If you have any questions about the study, please do not hesitate to contact me by email or telephone as noted below. As with all University of the Witwatersrand projects involving human participants, this project was reviewed by, and received ethical clearance through the Human Research Ethics Committee of the University of the Witwatersrand. Should you have any comments or concerns resulting from your participation in this study, please contact Prof Cleaton Jones, the Director at 011 717 2700.

Yours sincerely,

Riali Roos
BSc Physiotherapy (Wits)
Tel: 072 424 2412
Email: rialiroos@gmail.com

Appendix X

Data Analysis Sheets

EMG activity recordings: **Study Number: _____**

Isometric Contractions:

Activity	Muscle	EMG Value – mean voluntary contraction	
		Right	Left
Erector Spinae isometric contraction *Prone, participant performs lumbar extension by lifting his shoulders of the surface.*	Erector Spinae	Max	Max
		Min	Min
Gluteus Maximus isometric contraction *Participants will be asked to squeeze their gluteal area together.*	Gluteus Maximus	Max	Max
		Min	Min
Hamstrings isometric contraction *Participant's one leg in 45° decrease flexion – the tester resists flexion.*	Biceps Femoris	Max	Max
		Min	Min
Quadriceps isometric contraction *Long sitting, participant hyperextends his knee to maximal quadriceps contraction.*	Rectus Femoris	Max	Max
		Min	Min

Functional Squat:

Muscle	EMG value (mean voluntary contraction)	
	Right	Left
Erector Spinae	Max	Max
	Min	Min
Gluteus Maximus	Max	Max
	Min	Min
Hamstrings – Bicep Femoris	Max	Max
	Min	Min
Quadriceps – Rectus Femoris	Max	Max
	Min	Min

30m Sprinting:

Muscle	EMG value (mean voluntary contraction)	
	Right	Left
Erector Spinae	Max	Max
	Min	Min
Gluteus Maximus	Max	Max
	Min	Min
Hamstrings – Bicep Femoris	Max	Max
	Min	Min
Quadriceps – Rectus Femoris	Max	Max
	Min	Min

Lumbo-pelvic movement control assessment:

Movement	Correct Movement	Incorrect Movement	Movement performance
Dorsal tilt of the pelvis *Dorsal tilt of the pelvis actively in upright standing.*	Actively in upright standing; keeping thoracic spine in neutral, lumbar spine moves towards flexion.	Pelvis does not tilt or low back moves towards extension or compensatory flexion in the thoracic spine.	Correct/Incorrect
Waiter's bow *Flexion of the hips in upright standing without movement (flexion) of the low back.*	Forward bending of the hips without movement of the low back. (50°-70° hip flexion)	Angle hip flexion without low back movement less than 50° of flexion occurring in the low back.	Correct/Incorrect
One leg stand *From normal standing to one leg stance: measurement of lateral movement of the umbilicus.(Position: feet one third of trochanter distance apart).*	The distance of umbilical movement laterally is symmetrical on the left and the right side.	Lateral transfer of the umbilicus more than 10cm or the difference between sides more than 2 cm.	Correct/Incorrect
Prone knee flexion *Prone lying active knee flexion*	Active knee flexion at least 90° without movement of the low back and pelvis.	By the knee flexion low back does not stay neutral maintained but moves in extension or rotation.	Correct/Incorrect

Appendix XI

Research Report

ORIGINALITY REPORT

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7	Olivier, B., A.V. Stewart, S.A.S. Olorunju, and W. McKinon. "Static and dynamic balance ability, lumbo-pelvic movement control and injury incidence in cricket pace bowlers", Journal of Science and Medicine in Sport, 2015. Publication	<1%
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83	Chaouachi, Anis, Johnny Padulo, Sofien Kasmi, Aymen Ben Othmen, Moktar Chatra, and David G. Behm. "Unilateral static and dynamic hamstrings stretching increases contralateral hip flexion range of motion", Clinical Physiology and Functional Imaging, 2015. Publication	<1%

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