Relationship between Selected Physical Characteristics and Hamstring Injuries in Male Soccer Players

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A thesis submitted in fulfilment of the requirements for the degree of Magister Scientiae in Biokinetics, in the Department of Sport, Recreation and Exercise Science
University of the Western Cape

Supervisor: Prof Lloyd Leach

November 2018

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DECLARATION

I hereby declare that the study entitled, “Relationship between selected physical characteristics and hamstring injuries in male soccer players.” is my own work, that it has not been submitted before for any other degree in any other university, and that the sources I have used have been indicated and acknowledged as complete references.

Raven Chriscendo Schippers

November 2018

Signed

UNIVERSITY of the WESTERN CAPE

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DEDICATION

To my Family, Andrea (Mother), Lena (Grandmother), Danielle, Clyde and Blade for your constant prayer, support and motivation. To the late Anna (Ouma), I know you’re watching down and smiling. To my Partner, Candice, who always believed in me and this journey, your unmatchable support and love carried me through every step of the way. Thank you.

I would not have wanted this journey to be any different, if it doesn’t challenge you, it won’t change you.

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A very warm-hearted special thank you to Rucia November, I call her my co-supervisor and personal statistical expert. Friend, your journey inspires me every day. Your constant guidance, support, belief, motivation and unselfish ways have been life-changing and immeasurable. Thank you for all the patience and work shown, especially with the statistical analysis.

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<thead>
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<td>%</td>
<td>Percentage</td>
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<td>cm</td>
<td>Centimetres</td>
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<td>Con</td>
<td>Concentric</td>
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<td>°•sec$^{-1}$</td>
<td>Degrees per second</td>
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<td>Ecc</td>
<td>Eccentric</td>
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<td>Kg</td>
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<td>Nm</td>
<td>Newton metres</td>
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<tr>
<td>PT</td>
<td>Peak Torque</td>
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<tr>
<td>MS</td>
<td>Milliseconds</td>
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<tr>
<td>ROM</td>
<td>Range of Motion</td>
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<tr>
<td>SD</td>
<td>Standard Deviation</td>
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<tr>
<td>SR</td>
<td>Strength Ratio</td>
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<tr>
<td>TEM</td>
<td>Technical error measurement</td>
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ABSTRACT

Hamstrings muscle injury is the most frequent soccer-related injury in amateur and professional soccer players. Despite various interventions, the risk of hamstrings re-injury remains high. Several scientific studies examined the potential risk factors and their contribution to the occurrence of hamstrings injuries in male soccer players. The aim of the study was to investigate the relationship between selected physical characteristics, such as time-to-peak torque, hip abduction peak torque, hamstrings-to-quadriceps strength ratio, and hamstrings flexibility and the occurrence of hamstrings injuries in amateur male soccer players. A prospective, quantitative cross-sectional study design was utilized in this study. A total of 89 amateur male soccer players aged 18-35 years were recruited from the Cape Town Football District to perform functional assessments before injury occurred, which included anthropometric measurements, an evaluation of lower extremity isokinetic muscle strength (both knee and hip) and hamstrings flexibility tests. Instruments used to measure the anthropometric data were a calibrated Seca balance beam scale and stadiometer, a skinfold caliper, a sliding caliper, an anthropometer (All Harpenden, UK) and a metal tape measure. The Biodex Pro System 4 isokinetic dynamometer was used to measure lower extremity isokinetic muscle strength and a goniometer to measure hamstrings flexibility. Descriptive statistics included means and standard deviations, and inferential statistics included Pearson product-moment correlation to determine the relationship between selected physical characteristics and the occurrence of hamstrings injuries. Multivariate logistic regression via the forward stepwise method was utilised to predict potential physical characteristics (risk factors) for hamstrings injury in amateur male soccer players. Statistical significance was a p value of below 0.05. The prevalence of hamstrings injury was 4.3 %, with the multivariate
logistic regression analysis indicating that time-to-peak torque was a significant predictor of the occurrence of hamstrings injury (OR = 1; p = 0.027). In conclusion, time-to-peak torque was a significant predictor of the occurrence of hamstrings injury. The players with hamstrings injuries produced a significantly slower time-to-peak torque, which has relevance for soccer players and coaches in addressing this common injury at all levels of competition.

*Keywords:* hamstrings, injuries, flexibility, muscular strength, prevention, isokinetic, soccer, football, amateur
1.1 Introduction

The hamstrings are frequently injured during high speed running by a rapid contraction during a violent stretch, while either accelerating or decelerating and changing directions, and are, therefore, highly vulnerable (Van Beijsterveldt et al., 2013). Hamstrings injury is the most common soccer-related injury in both amateur (Donmez et al., 2018; Fitzharris et al., 2017) and professional soccer (Jones et al., 2017; Stubbe et al., 2015a). Ekstrand et al. (2016) reported a 4% increase annually in hamstrings injuries in male professional soccer players since 2001. There is also a high risk of hamstrings re-injury (Jones et al., 2017; Schuermans et al., 2017; Ekstrand et al., 2016) despite various intervention efforts (van der Horst, 2017; van Beijsterveldt et al., 2012).

Several prospective studies investigated the risk factors for hamstrings injuries in professional and amateur male soccer players through univariate and multivariate statistical analyses (Green et al., 2017; Lee et al., 2018; van Doormaal et al., 2017; van Dyk et al., 2018). The risk factors investigated in the literature included age (van Dyk et al., 2018; van Doormaal et al., 2017; Freckleton et al., 2013), previous hamstrings injury (Lee et al., 2018; Toohey et al., 2017), and flexibility (Green et al., 2017; Lee et al., 2018; van Doormaal et al., 2017; Witvrouw et al., 2003 as cited in van Dyk et al., 2018) and muscle imbalances in the form of hamstrings-to-quadriceps strength ratios (Dauty et al., 2018; Lee et al., 2018; Dauty et al., 2016). These studies produced conflicting results due to the different methodologies and
instruments used. The results in the study by van Doormaal et al. (2017) could not identify hamstring flexibility as a risk factor to predict hamstrings injuries, while the study by Witvrouw et al. (2003) as cited in van Dyk et al. (2018), identified players with increased tightness of the hamstrings as a risk factor that significantly predicted future hamstrings injury. Lee et al. (2018) identified soccer players with a lower hamstrings-to-quadriceps strength ratio (below 50.5 %) to be at increased risk for hamstrings injury, while the results of the study by van Dyk et al. (2016) identified hamstrings-to-quadriceps strength ratio as a weak risk factor for hamstrings injuries.

Time-to-peak torque and hip abduction strength measures have not been previously researched and investigated as possible risk factors in the occurrence of hamstrings injuries in male soccer players (Shield & Bourne, 2018). The limited research on soccer-specific thigh injuries has focused on African players, and more specifically on South African players (Jones et al., 2015).

1.2 Statement of the Problem

Kofotolis et al. (2007) stated that “amateur soccer players may demonstrate poorer athleticism, fitness, and coordination than professional players, such that an impaired awareness of bodily movements can increase the risk of injury” (as cited in Henry et al., 2016). Hamstrings injury is the single most common soccer-related injury in both amateur (Donmez et al., 2018; Fitzharris et al., 2017) and professional soccer (Hagglund et al., 2013 as cited by Green et al., 2018, p.1; Jones et al., 2017; Woods et al., 2004 as cited by Maniar et
al., 2016; Stubbe et al., 2015b; Ekstrand et al., 2011 as cited by Cabello et al., 2015;). There is also a high risk of hamstrings re-injury (Jones et al., 2017; Ekstrand et al., 2016; Schuermans et al., 2017) despite various intervention efforts (van der Horst, 2017; Stubbe et al., 2015b). Ekstrand et al. (2016) reported a 4% increase annually in hamstrings injuries in professional male soccer players since 2001.

Acquiring knowledge of the aetiology of hamstrings injuries is relevant for identifying risk factors related to hamstrings injuries and is essential in understanding their prevention and rehabilitation (Buckthorpe et al., 2018). Injuries during a season or a tournament could have considerable impact on a team’s performance (Drew et al., 2017).

1.3 Aim of the Study

The aim of this study is to investigate the relationship between time-to-peak torque, strength ratios, hamstrings flexibility, hip abduction strength and the occurrence of hamstrings injuries in amateur male soccer players.

1.4 Objectives of the Study

The objectives of the study were the following:

- To measure the hamstrings isokinetic time-to-peak torque, isokinetic strength ratio, hip abduction strength, and hamstrings flexibility in amateur male soccer players.
To investigate the relationship between time-to-peak torque and the occurrence of hamstrings injuries in amateur male soccer players;

To investigate the relationship between strength ratios and the occurrence of hamstrings injuries in amateur male soccer players;

To investigate the relationship between hip abduction strength and the occurrence of hamstrings injuries in amateur male soccer players.

To investigate the relationship between flexibility of the hamstrings muscles and the occurrence of hamstrings injuries in amateur male soccer players;

1.5 Hypothesis of the Study

It is hypothesized that the following physical characteristics will be associated with the occurrence of hamstrings injuries in male soccer players, namely:

- Longer time-to-peak torque;
- Weaker strength ratio;
- Poorer hamstrings flexibility; and
- Weaker hip abduction strength.

1.6 Significance of the Study

In South Africa, the application of scientific knowledge on the description and prevention of injuries in football is lacking at all levels (Calligeris et al., 2015, p.16). There are poorly
developed support structures in soccer in South Africa, particularly at the school and university levels, and the growth of applied science of the local game has been lacking’ (Calligeris et al., 2015, p.16). While a large body of research has been conducted regarding the nature and prevalence of soccer injuries abroad, very little has been done locally or on the African continent to assess the status of injuries incurred at professional or amateur levels (Gebert et al., 2018; Lam et al., 2017; Naidoo, 2007).

The role that various physical characteristics play in the occurrence of hamstrings injuries in soccer players, particularly the time-to-peak torque and hip abduction strength, are not fully understood in the literature. Their contribution to the occurrence of hamstrings injuries, as possible new risk factors, and their importance as a preventative characteristic could be incorporated into isokinetic rehabilitation and general rehabilitation programs of soccer teams, specifically to aid in the prevention of hamstrings injuries.

There is a scarcity of studies that have investigated the relationship between time-to-peak torque and the occurrence of hamstrings injuries in male soccer players, as well as the relationship between hip abduction strength as a possible new risk factor in the occurrence of hamstrings injuries in male soccer players.

1.7 Delimitations of the Study

1.7.1 Inclusion Criteria

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The following inclusion criteria were applied in the study:

- Subjects who sustained a hamstrings injury in the previous season (12 months ago but were fully recovered and pain-free for at least 3 months post-injury).

- Subjects must be amateur male soccer players competing in the amateur leagues of the Local Football Association (LFA) in the Cape Town region that is affiliated to the South African Football Association (SAFA).

1.7.2 Exclusion Criteria

The following exclusion criteria were applied in the study:

- Subjects who were currently injured or in rehabilitation and still recovering from injury.
- Subjects not giving written informed consent.
- No females were tested in the study.
- Subjects under the age of 18 years were not included in the study.

1.8 Definitions of Terms

Concentric contraction refers to a muscle contraction resulting in shortening of the muscle (Padulo et al., 2013).
Eccentric contraction refers to a muscle contraction resulting in lengthening of the muscle (Padulo et al., 2013).

Isokinetic contraction is defined as a dynamic muscular contraction at constant velocity that accompanies the limb movement around a joint (Baltzopoulos & Brodie, 1989). The velocity of movement is maintained constant by a special dynamometer. The resistance of the dynamometer is equal to the muscular forces applied throughout the range of movement.

Muscular strength refers to the capacity of a muscle to actively develop tension irrespective of the specific conditions under which it measured (Chan et al., 1996).

A recordable injury is defined as an injury that occurs during a football match or during training that results in the absence of a player from the next training session or match (time loss injury) (Fuller et al., 2006).

Peak torque is defined as the highest muscular force output at any moment during a repetition (Baltzopoulos, 2017). It indicates the muscle’s maximum strength capability.

Muscle strength ratio (hamstrings-to-quadriceps strength ratio) refers to the reciprocal muscle group ratio and is an indicator of muscular balance or imbalance around a joint (Baltzopoulos & Brodie, 1989). Imbalance may predispose a joint to injury, as the agonist/antagonist muscle balance provides dynamic joint stability (Perrin, 1993).
Hamstrings injury is defined as an acute pain in the posterior thigh, which causes an immediate cessation in match play or training time and/or quality of play (Lee et al., 2018).

Time-to-peak torque (m/sec) describes the ability of the muscles to produce torque quickly (Kowalski, 2003, p.3). It is of interest when assessing athletes who require explosive power (Chan et al., 1996).

Flexibility refers to one element of body movement, namely, the range of motion of different body segments (Gleim and McHugh, 1997).
2.1 Introduction

This chapter focuses on reviewing the literature associated with soccer as a sport, and specifically with the risk factors related to hamstrings injuries. The review addresses the scientific evidence from a global perspective covering risk factors for hamstrings injuries in male soccer players, as the most commonly seen injury in sports participation, but specifically in professional and amateur male soccer players. The review focuses on the risk factors collectively and their relationship to hamstrings injuries in professional and amateur male soccer players during either the pre-season or the in-season.

The chapter starts by presenting the anatomy of the hamstrings and their function, as well as their potential for injury during running. Thereafter, a review of the literature in soccer injury studies, more specifically hamstrings injuries in professional and amateur male soccer players, is presented. Finally, the literature specifically reviews amateur soccer players in South Africa.

Muscle injuries are extremely frequent in professional and amateur sports, particularly a strain of the hamstring’s muscles (Walden et al., 2018; Ingham et al., 2017) leading to a considerable amount of time-loss in play (Ekstrand et al., 2011). It has been reported that hamstrings injuries commonly occur during rapid extension of the knee eccentrically, decelerating the lower leg in the late swing phase of the running gait cycle (Goldman & Jones, 2011). Hamstrings muscle injury is the single most frequent soccer-related injury in amateur

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(Donmez et al., 2018) and professional (Jones et al., 2017) soccer players. Despite various intervention efforts (van der Horst, 2018), the risk of re-injury remains high (Schuermans et al., 2017) with a 4% increase in hamstrings injuries reported in male professional soccer players annually, since 2001 (Ekstrand et al., 2016).

In view of the high incidence and recurrence rate of hamstrings injuries in soccer players, Meeuwisse (1994) stated that to prevent new injuries from occurring, it was important to identify the specific intrinsic and extrinsic risk factors for hamstrings injuries. Cabello et al. (2015) stated that the risk factors for hamstrings injuries that were examined up until recently have not been able to prevent injuries from occurring. Several risk factors for hamstrings injuries have been proposed in the literature including, age (van Dyk et al., 2018; van Doormaal et al., 2017; Freckleton et al., 2013), previous hamstrings injury (Lee et al., 2018; Toohey et al., 2017), flexibility (van Doormaal et al., 2017; Witvrouw et al., 2003 as cited in van Dyk et al., 2018), isokinetically hamstrings to quadriceps strength ratios (Dauty et al., 2018; Lee et al., 2018; Dauty et al. 2016). However, these studies produce conflicting results due to different methodologies and instruments used.

2.2 Statistics on the Game of Soccer

Soccer is the most popular sport played around the world with an estimate of more than 200 000 professional soccer players and 265 million registered amateur players (Count, 2006 as cited by Valenciano, 2018). It is a sport characterized by functional and continuous energy demanding movements like cutting, accelerating, jumping, decelerating, sprinting, back-
pedaling, side-shuffling, kicking the ball, and getting-up off the ground, i.e., physically-demanding activities which all increase the risk of injury (Hägglund et al., 2013).

Soccer is one of the most popular sports in South Africa (Kubayi et al., 2015). The FIFA big count in 2006 reports that South Africa has a total of 4 423 300 male soccer players representing 10.28 % of population), with 1 463 410 as registered players. The statistical summary also reports that South Africa has 1000 professionals and 165 560 amateur (18 years & older) soccer players. Male amateur players form the largest subgroup of soccer players worldwide (Count, 2006) and may demonstrate poorer athleticism, fitness, and coordination than professionals (Kofotollis et al., 2007 as cited in Henry et al., 2016).

2.3 Injuries in Amateur Soccer

Professional and amateur soccer players differ in their level of play, medical staff, exposure to training and matches, playing intensity, and compliance with preventative measures (van der Horst et al., 2015). Poorly developed support structures, particularly at primary and tertiary level, are some of the reasons that the application of scientific knowledge on the injuries in football in South Africa at all levels is lacking (Calligeris et al., 2015). Minimal research has been conducted to evaluate the causes of soccer injuries at an amateur level (Lam et al., 2017; Naidoo, 2007).

The results of the study by Naidoo (2007) emphasized the importance of starting prevention strategies at club level to reduce the high incidence of injury at the professional level.
Considerable research was conducted on professional and amateur soccer players in South Africa in the last 5 years (Bayne et al., 2018; Sentsomedi & Puckree, 2016; Calligeris et al., 2015; Grant et al., 2015; Jones et al., 2015; Mtshali et al., 2015; Aginsky et al., 2014), but with limited research that focussed soccer-specific thigh injuries in Southern African players (Jones et al., 2015).

Amateur players have been shown to possess a higher injury rate when compared to players of a higher skill level (Stubbe et al., 2015a). The overall amateur player’s injury incidence was higher during training when compared to professional players, whereas the injury incidence among professional players was higher during matches (Stubbe et al., 2015a). Bayne et al. (2018) conducted a prospective cohort study of two soccer teams in the Premier Soccer League in South Africa over a 10-month period in 2015/16 and found that the incidence of injury was comparable with data reported in international players, as well as the increased risk of injury during matches versus training. The knee was the most frequently injured body part as opposed to the thigh.

2.4 Hamstrings Anatomy and Function During Running

2.4.1 Hamstrings Anatomy

Hamstrings injury is defined by the anatomical site within the muscle that is affected, and injury must be present in one or more of the component muscles (Goldman & Jones, 2011). The hamstrings muscle group consists of the semimembranosus and semitendinosus muscles.
located medially, and the biceps femoris muscle (short and long head) located laterally with the biceps femoris long head. They cross both the hip and knee joints and are considered two-joint muscles. All of them attach to the top of the ischial tuberosity (Woodley & Mercer, 2005).

The hamstrings tendons are long and thus produce a greater “spring” effect which improves the athlete’s performance, but at the same time they increase the risk of injury. By way of protecting the knee and hip joints, while absorbing kinetic energy, the hamstrings muscles contribute considerably to gait movements, acting as both a hip extensor and knee flexor (Eyers, 2008).

2.4.1.1 Biceps Femoris

The biceps femoris is the muscle injured most often (Brukner et al., 2012; Woods et al., 2004). The biceps femoris has two origins, with the short head acting only on the knee joint, because of its attachment to the linea aspera and the lateral supracondylar ridge of the femur, while the long head originates from the medial part of the ischial tuberosity (hip). The biceps femoris has insertions in the styloid process of the head of the fibula, lateral collateral ligament and the lateral tibial condyle. The two-fold innervation (tibial portion of the sciatic nerve and peroneal portion of the sciatic nerve) of the biceps femoris could result in asynchrony from the intensity of stimulation of the two heads, which explains the reason why this is the most common injured muscle (Brukner et al., 2012).
2.4.1.2 Semitendinosus

The semitendinosus muscle originates from the infero-medial aspect of the ischial tuberosity, as a conjoint tendon with the long head of the biceps femoris. It then curves around the medial condyle of the tibia and passes over the medial collateral ligament of the knee joint, from which it is separated by a bursa, and is inserted into the upper part of the medial surface of the body of the tibia (Woodley & Mercer, 2005).

2.4.1.3 Semimembranosus

The semimembranosus muscle originates from a thick tendon on the superior-lateral aspect of the ischial tuberosity, superior and lateral to the biceps femoris and semitendinosus. The semimembranosus tendon runs medial and anterior to the other hamstring’s tendons. The muscle is recognized by its sharp medial border and cordlike appearance. In contrast, the semitendinosus muscle is a largely thin, band-like tendinous structure after its origin and for most of its length through the thigh. It is inserted mainly into the horizontal groove on the posterior medial aspect of the medial condyle of the tibia (Woodley & Mercer, 2005).

2.4.2 Hamstrings Function During Running

Understanding the biomechanical function of the major lower-limb muscle groups involved in running is important in order to improve current knowledge regarding human high-performance, as well as in identifying potential risk factors related to injury (Schache et al., 2005).
Running is a critical element in almost all sporting activities (Schache et al., 2013).

2.4.2.1 The Running Gait Cycle

The running gait cycle can be sub-divided into a stance phase, a swing phase, and a float phase (Dugan & Bhat, 2005). As shown in Figure 2, the stance phase is divided into sub-phases of initial contact to mid-stance, and mid-stance to toe-off (Dugan & Bhat, 2005). The biomechanical events during running can be explained as follows:

- The stance phase is divided into three major components: (1) initial contact to mid-stance, (2) mid-stance to heel-off, and (3) heel-off to toe-off;

Figure 2.1: The stance phase of the gait.

- The swing phase is divided into the initial swing and the terminal swing components.
The float (airborne) phase occurs at the beginning of the initial swing and at the end of terminal swing.

It is well-documented that elite soccer players cover between 10 and 11 km per soccer match and require various explosive bursts of activity, including kicking, jumping, tackling, changing pace and direction, turning, and sprinting (Stolen et al., 2005). Hamstrings injuries often occur in soccer during high energy-demanding movements, such as sprinting and kicking (Liu et al., 2017).

The hamstrings complete a stretch-shortening cycle during sprinting, where lengthening occurs during the terminal swing phase, and shortening occurring just before foot-strike and continues throughout the stance phase (Schache et al., 2012). The hamstrings undergo a rapid change in function from knee extension (deceleration), in the late swing phase (eccentric contraction), to actively extending the hip joint (concentric contraction) (Chumanov et al., 2012). They eccentrically contract by slowing down the forward swing of the leg to prevent overextension of the knee, while facilitating hip flexion (Tsur, 2015). Soccer players perform
the above-mentioned movements very frequently and, therefore, are highly susceptible to injury (van Beijsterveldt et al., 2014).

Woods et al. (2004) reported injury records from 91 professional English football clubs over 2 seasons. They conducted a detailed analysis of hamstrings injuries which accounted for 12% of all injuries, with 57% of those injuries occurring during running. However, Wong & Hong et al. (2005) systematically reviewed 37 articles on soccer injuries in the lower extremities and displayed conflicting evidence on the mechanism of injury.

2.4.2.2 Phase in the Running Gait Cycle of Highest Hamstrings Injury Risk

Controversy exists in various studies regarding the discrete phase in the running gait cycle, where the highest risk of hamstrings injury occurs (Chumanov et al., 2012; Orchard, 2012). Chumanov et al. (2012) reported the highest risk to be in the late swing phase of sprinting, whereas Orchard (2012) reported it to be in the early stance phase. Liu et al. (2017) reported that both the late swing and early stance phases of sprinting where the most hazardous for hamstrings injuries. The hamstrings muscles oppose hip flexor and knee extensor torques during the terminal swing phase of the gait cycle, especially during soccer activities, such as running and jumping (Tsur, 2015).

Due to the high incidence rates (Hägglund et al., 2016; Schuermans et al., 2017), hamstrings injuries remain a constant problem in male soccer players (Ekstrand et al., 2016). Poorly developed support structures, particularly at primary and tertiary level, are some of the reasons
that the application of scientific knowledge on the injuries in football is lacking at all levels in South Africa (Calligeris et al., 2015).

2.5 Prevalence of Hamstrings Injuries

It has been reported that the highest number of injuries in professional and amateur male soccer players occurred in the lower extremities (Gebert et al., 2018; Walden et al., 2018; Fitzharris et al., 2017; Junge & Dvořák, 2015; Stubbe et al., 2015a). The injuries occurred most frequently in the lower extremity (65.4%), with thigh strain reported as the most frequent type of injury during the 2014 FIFA World Cup in Brazil (Junge & Dvořák, 2015). Muscle injuries contributed 36.4% of all injuries in men’s professional soccer (Stubbe et al., 2015a) and 23% at the amateur level (Lam et al., 2017).

Hamstrings injuries bring huge frustration to the player, because the symptoms are persistent, healing is slow (Petersen et al., 2005), and the rate of re-injury is high (Jones et al., 2017). Hamstrings injury is defined as an acute pain in the posterior thigh, which causes an immediate cessation in match-play or training (Lee et al., 2018), regardless of the need for medical attention or time-loss from football activities (Fuller et al., 2006). It is among the most common injuries occurring in sport (Alzahrani et al., 2015; Mendiguchia et al., 2012) and the single most common soccer-related injury in both amateur (Donmez et al., 2018; Fitzharris et al., 2017) and professional soccer (Hagglund et al., 2013 as cited in Green et al., 2018, p.1; Walden et al., 2018; Jones et al., 2017; Woods et al., 2004 as cited by Maniar et al., 2016; Ekstrand et al., 2011 as cited by Cabello et al., 2015; Stubbe et al., 2015a).
A team consisting of 25 players is expected to suffer about 5–6 hamstrings injuries per season, which is equivalent to more than 80 days of training or matches lost, due to injury (Ekstrand et al., 2011). Ekstrand et al. (2016) reported a 4% increase in hamstrings injuries in professional male soccer players annually and a 2.3% year-on-year increase in the total hamstrings injury rate, since 2001. It has a high risk of re-injury (Jones et al., 2017), despite various intervention efforts (van der Horst, 2018).

Hamstrings injuries accounted for 15.9% of all injuries in amateur male soccer players (van Beijsterveldt et al., 2012), while Schuermans et al. (2017) reported a total of 15 players sustaining hamstrings injuries out of the 51 amateur male soccer players (injury incidence rate of 29%) who underwent prospective data-analysis during the season. In a study by Van de Hoef et al. (2017), a total of 65 hamstrings injuries were reported within one competition among 588 adult amateur male soccer players.

The main goal of the sports medicine physician is to return the athlete to competition, balanced against the challenge of preventing the injury from worsening or recurring (Guermazi et al., 2017). Developing specific evaluations aimed at decreasing the rate of injuries in amateur soccer players could be achieved through an investigation of the injury risk factors (Calligeris et al., 2015). Identifying risk factors is critical for effective prevention of hamstrings injury and in the improvement of rehabilitation outcomes (Opar, 2012).

2.6 Risk Factors of Hamstrings Injuries
Preventing injury is a critical part of any sport (van der Horst, 2017). Research on risk factors of injury is encouraged to help understand why injuries occur and to predict who is at risk of injury (Bahr, 2016). According to Van Mechelen (1992), and Hawkins et al. (2001), the second stage of injury prevention is to identify potential risk factors of injury. Hamstrings injuries are complicated and multifactorial in nature (Mendiguchia et al., 2012).

Understanding the risk factors of injury is of importance for preventive measures in order to reduce the prevalence of sports injuries and to be able to appropriately educate the public or community (Lam et al., 2017). Through a multifactorial approach (Meeuwisse, 1994), one is able to identify the risk factors (Hägglund et al., 2013) that are central to establishing effective prevention programmes. This dynamic model describes how multiple factors interact to produce injury (Meeuwisse, 1994).

Risk factors are divided into modifiable and non-modifiable risk factors (Bahr, 2016). Modifiable risk factors include muscle weakness and imbalance, poor balance and proprioception, poor flexibility, fatigue, and excess body mass. Non-modifiable risk factors consist of age, previous injury, exposure hours, competition level, sex and ethnic origin. Modifiable risk factors can lead to more opportunities for intervention, which makes it more clinically relevant (Bahr & Holme, 2003).

The high injury incidence of hamstrings muscle strains, at both the professional (Ekstrand et al., 2016) and amateur levels (Schuermans et al., 2017), the considerable high recurrence rate of injury (Jones et al., 2017) and the associated financial and time costs (Donmez et al.,
2018), make identifying the risk factors related to hamstrings injuries essential.

Prospective soccer studies recommend utilising multivariate statistical analysis to investigate the contribution of different risk factors, which offers more valid data on hamstrings injury risk factors (Mendiguchia et al., 2012; Bahr & Holme, 2003). The risk factors investigated in the literature included age (van Dyk et al., 2018; van Doormaal et al., 2017; Freckleton et al., 2013), previous hamstrings injury (Lee et al., 2018; Toohey et al., 2017), and flexibility (Green et al., 2017; Lee et al., 2018; van Doormaal et al., 2017; Witvrouw et al., 2003 as cited in van Dyk et al., 2018) and muscle imbalances in the form of hamstrings-to-quadriceps strength ratio (Dauty et al., 2018; Lee et al., 2018; Dauty et al., 2016). These studies produced conflicting results due to the different methodologies and instruments used. The results in the study by van Doormaal et al. (2017) could not identify hamstring flexibility as a risk factor to predict hamstrings injuries, while the study by Witvrouw et al. (2003 as cited in van Dyk et al., 2018) identified players with increased tightness of the hamstrings to be a significant predictor of future hamstrings injuries. Lee et al. (2018) identified soccer players with a significant lower hamstring-to-quadriceps strength ratio (below 50.5%), to be at increased risk of hamstrings injury, while the results of the study by van Dyk et al. (2016) identified hamstrings-to-quadriceps strength ratio as a weak risk factor of hamstrings injuries.

It is vitally important, and in some instances even a legal requirement, for sport governing bodies and the managers of soccer clubs to reduce the level of injury by ensuring that the players maintain an optimum level of health and safety (Fuller et al., 2004). It is very challenging to get an overall report if the injury rate in amateur soccer players, due to the
variation in the provision of medical services at this level of play (Angele et al., 2016). More research should focus on the aetiology and risk factors of injury in amateur soccer players (van Beijstrveldt, 2014; Mendiguchia et al., 2012; Bahr & Holme, 2003).

2.7 Measurement of Physical Characteristics in Amateur Male Soccer Players

2.7.1 Isokinetic Measurements of the Hamstrings Time-to-Peak Torque, Hamstrings-to-Quadriceps Strength Ratio, and Hip Abduction Peak Torque

Isokinetic testing is the gold standard and most reliable tool for assessing and evaluating human performance (Caruso et al., 2012), especially lower limb muscle function (Edouard et al., 2013). Isokinetic dynamometry is an exercise modality involving limb movement at a dynamic, preset fixed velocity, where the resistance of the device equals the applied muscular torque throughout the range of motion, measuring different parameters of muscle function (i.e., peak torque, peak torque/body weight ratio, time-to-peak torque, and agonist-to-antagonist strength ratios) (Baltzopoulos & Brodie, 1989).

The scientific and clinical rationale for the use of isokinetics in the evaluation and rehabilitation of sports injuries plays a significant role in facilitating the examination, treatment, and performance enhancement of the athlete (Ellenbecker et al., 2000). The reliability of isokinetic assessment is fundamental in order to track small, but clinically relevant, changes.
A systematic review by Green et al. (2018) reported that isokinetic strength assessment in identifying the risk of future hamstrings muscle injury was rather limited in sport. Numerous studies have shown the importance of various isokinetic strength variables in predicting the occurrence of hamstrings injuries in professional soccer players (Lee et al., 2018; Dauty et al., 2016; Croisier et al., 2008) while other studies have disagreed (Dauty et al., 2018; van Dyk et al., 2016; Henderson et al., 2010). The results in the above-mentioned studies are inconclusive and contradictory, because of the different testing methods and modes utilised.

Chan et al. (1996) and Wojtyś et al. (1996) state that time-to-peak torque seems to be an important risk factor in injury prevention for athletes. Studies assessing isokinetic muscle recruitment patterns, such as acceleration time, and time-to-peak torque are scarce in the literature. More comprehensive isokinetic assessment is recommended in order to identify muscle recruitment issues and assist with neuromuscular intervention and rehabilitation of the injured athlete (Scattone-Silva et al., 2012). Braci et al. (2011) investigated the relationship between time-to-peak torque and sprint running performance. Hamstrings time-to-peak-torque significantly predicted sprint times at 5 m, 10 m, and 20 m. Shorter sprint times correlated with a hamstring time-to-peak-torque of below 200 msec.

Studies have reported the importance of isokinetic testing in soccer players to predict hamstrings injury occurrence, i.e., deficits in concentric and eccentric muscle torques of the hamstrings and quadriceps, hamstrings-to-quadriceps strength ratio and bilateral differences in torque (Lee et al., 2018; Dauty et al., 2016; Croisier et al., 2008) while others reported results that displayed no association with hamstring injury occurrence (Dauty et al., 2018;
Green et al., 2018; van Dyk et al., 2016; Henderson et al., 2010). Isokinetic hamstrings-to-quadriceps (H/Q) ratios are frequently used to assess knee muscle strength imbalances and the risk of injury in male soccer players (Bakken, 2018). Croisier et al. (2008) stated that “at some exercise intensity, the player surpasses the mechanical limits tolerated by the muscle unit, justifying the analysis of strength imbalance as a risk factor that can lead to hamstrings injuries”.

Isokinetic dynamometers are usually utilised to assess hip strength in soccer players (Lucci, 2017), with isokinetic peak torque the preferred method to evaluate lower limb strength in this population (McQuoid et al., 2017). Lower limb strength is vital to a soccer player, because of the characteristics of the game (Maly et al., 2014). The gluteus medius muscle controls hip and pelvic movements (Wilson et al., 2006). The lumbo-pelvic region has a close anatomical connection (Van Wingerden et al., 1993), and with hamstrings muscles attached directly to the ischial tuberosity of the pelvis and lateral lip of the femur (Woodley & Mercer, 2005), this creates the possibility for the hamstrings muscles to stretch and become injured. Bazett-Jones et al. (2017) identified hip strength as an important risk factor in multiple lower extremity injuries. However, very little scientific evidence exists of a relationship between hip abduction strength and hamstrings injury (Shield & Bourne, 2018).

2.7.2 Hamstrings Flexibility Measurement

A player with limited hamstrings flexibility is assumed to be more at risk for injuring his hamstrings during sprinting than a player who is more flexible (van Doormaal, 2014)
however, other studies report no relationship between hamstrings flexibility and hamstrings injury occurrence in amateur male soccer players (van Doormaal et al., 2017).

Limited hamstring flexibility has been proposed as an intrinsic risk factor for hamstrings injuries in male professional and amateur soccer players, (Fousekis et al., 2011; Engebretsen et al., 2010; Henderson, 2010; Bradley, 2007; Arnason et al., 2004; Witvrouw et al., 2003). However, the relationship between hamstrings flexibility and hamstrings injury remains unclear, with the results obtained in football players being inconclusive or conflicting, due to the different methodologies utilized when measuring hamstrings flexibility as a risk factor for hamstrings injury (van Dyk et al., 2018; van Doormaal, 2017; Fousekis et al., 2011; Engebretsen et al., 2010; Witvrouw et al., 2003).

Time requirements and costs associated with isokinetic testing makes it impractical to apply in many clubs (Opar et al., 2013), and are possible reasons for limited studies focusing on its use in amateur soccer players (Engebretsen et al., 2010). The hamstrings time-to-peak torque, and hip abduction peak torque are considered new contributory factors in the occurrence of hamstrings injuries in male soccer players, but they are not yet fully understood or documented in the literature.

2.7.3 Relationship Between Physical Characteristics (Risk Factors) and Hamstrings Injury in Amateur Male Soccer Players

The aetiology of hamstrings injuries is accepted as multifactorial and complex in nature.
(Mendiguchia et al., 2012). It is strongly recommended multivariate statistical analysis be utilised to investigate the contribution of different risk factors, because it offers more valid data on the risk factors of hamstrings injuries (Mendiguchia et al, 2012; Bahr & Holme, 2003).

2.7.3.1 Relationship Between Hamstrings Time-to-Peak Torque and Hamstrings Injury in Amateur Male Soccer Players

Soccer combines several combinations of movements requiring strenuous effort, such as kicking, accelerating, jumping, decelerating, sprinting, back-pedaling, side-shuffling and getting up from the ground, which all increase the risk of injury (Van Beijsterveldt et al., 2013). High energy-demanding movements depend on the maximum strength of the neuromuscular system, mainly of the lower extremities (Cometti et al., 2001). The ability to produce torque quickly is an important skill in most sports, while time-to-peak torque can be a useful assessment to evaluate the motor unit recruitment pattern of the involved muscles (Dvir, 2004).

Time-to-peak torque is a measure of time from the start of muscular contraction to the point of the highest torque development (Bracic et al., 2011), and indicates the muscles functional ability to produce torque quickly. Other studies investigating time-to-peak torque have investigated particular performance parameters, such as, time-to-peak torque and the relationship with sprint running performance (Braci et al., 2011), or time-to-peak torque and gender differences in the neuromuscular fitness profiles of NCAA Division III soccer players.
(Burfeind et al., 2012), and time-to-peak torque and neuromuscular adaptations in isokinetic, isotonic, and agility training programmes (Wojtys et al., 1996). The time-to-peak torque seemed to be an important risk factor in injury prevention, because it determined how rapidly dynamic control could be activated in order to stabilize the knee against deforming forces (Wright, 2016).

2.7.3.2 Relationship Between Hamstrings-to-Quadiceps Strength Ratio and Hamstrings Injury in Amateur Male Soccer Players

Muscular strength is one of the most important components of physical performance, in terms of both high level competition and injury occurrence (Lehance et al., 2008). Lower limb strength is vital to a soccer player, because of the characteristics of the game (Maly et al., 2014). Several studies have suggested that a strength imbalance between the quadriceps and hamstrings in the form of the hamstrings-to-quadriceps strength ratio is predictive of risk for hamstrings injury in male soccer players (Dauty et al., 2017; Lee et al., 2018; van Dyk et al., 2017; Dauty et al., 2016; van Dyk et al., 2016). In a systematic review and meta-analysis by Green et al. (2017) could not identify isokinetic strength asymmetries or imbalances associated with future risk of hamstrings injury.

Various lower limb strength imbalance ratios are commonly used to monitor rehabilitation programmes and to identify possible risk factors for developing knee or hamstrings injuries and re-injury (Impellizzeri et al., 2007). Isokinetic knee strength ratios represent the most common method of determining muscle strength imbalances, and in predicting hamstrings
injuries in professional and amateur soccer players (Dauty et al., 2017; Lee et al., 2018; van Dyk et al., 2017; Dauty et al., 2016; van Dyk et al., 2016; Fousekis et al., 2011; Henderson et al., 2010; Croisier et al., 2008). Dauty et al. (2016) confirmed that isokinetic tests are useful in predicting hamstrings injury in professional soccer players during a competitive season. In contrast, Van Dyk et al. (2016) reported that the hamstrings-to-quadriceps strength ratio could not be identified as a risk factor for hamstrings injury. A 4-year cohort study by van Dyk et al. (2016) on a total 614 professional soccer players did not support the usefulness of isokinetic testing in identifying the relationship between strength asymmetries and hamstrings injuries.

In professional soccer, hamstrings-to-quadriceps strength ratios of 0.47 and 0.60 are the two thresholds often used as normative cut-off values for knee concentric flexion-extension movements at an isokinetic velocity of $60^{\circ}\cdot\text{sec}^{-1}$ (Dauty et al., 2017; Lee et al., 2018; Dauty et al., 2016; Aginsky et al., 2014; Croisier et al., 2008; Hewet et al., 2008). Isokinetic cut off values are not used consistently to predict hamstrings injury, because some studies show inconsistency when determining cut-off values between the players who are at increased risk and those who are not at risk.

Dauty et al. (2017) found that cut-off values for isokinetic strength ratios could not reliably predict hamstrings injury in 194 professional soccer players. Through univariate analysis of bilateral concentric hamstrings-to-hamstrings ratios at $60^{\circ}\cdot\text{sec}^{-1}$ and eccentric ratios at $30^{\circ}\cdot\text{sec}^{-1}$, two different cut-off values were considered at 0.85 and 0.90, respectively.

2.7.3.3 Relationship Between Flexibility of the Hamstrings Injury in Amateur Male Soccer
Players

Gleim & McHugh (1997) define flexibility as the amount of movement around a joint through its normal plane of movement. They further define static flexibility as the range of movement available to a joint or group of joints, and dynamic flexibility as the ease of movement within the available range of movement.

The knee flexors are frequently used at full range of motion during high speed movements (e.g., sprinting) and may contribute to a higher injury rate in this muscle group in soccer players (Clark, 2008). Sprinting is a requirement in soccer (Stølen et al., 2005), during which the hamstrings musculature acts to decelerate both hip flexion and knee extension at the end of the swing phase and at the beginning of the stance phase (Chumanov et al., 2011). During a sprint movement, a player with limited hamstring flexibility is assumed to be more at risk for injuring his hamstrings than a player who is more flexible (van Doormaal, 2014).

Poor hamstring flexibility is a commonly proposed intrinsic risk factor for soft tissue injury, especially hamstring injuries in male professional and amateur soccer players (van Doormaal, 2014; Fousekis et al., 2011; Engebretsen et al., 2010; Henderson, 2010; Bradley, 2007; Arnason et al., 2004; Witvrouw et al., 2003). However, Cabello et al. (2015) state that the results obtained in football players are inconclusive and conflicting, and is confirmed in other studies (van Doormaal, 2014; Fousekis et al., 2011; Engebretsen et al., 2010; Witvrouw et al., 2003).

Different tests (active and passive knee extension, straight-leg raise, sit-and-reach, or lumbar
spine flexion tests) are commonly used to measure hamstrings flexibility, and this might explain the conflicting findings in the above studies. Van Dyk et al. (2018) state it is important to consider how these different flexibility tests compare with each other when utilised to measure flexibility and the risk to hamstrings injuries. However, the knee extension test is recommended as the most valid and reliable measure of hamstrings flexibility.

Witvrouw et al. (2003) reported limited hamstrings flexibility in male professional soccer players (ROM < 90°) as a potential modifiable risk factor of hamstrings injury. In another study by van Doormaal (2017), hamstrings flexibility of 450 Dutch amateur male soccer players performing a sit-and-reach test (SRT) was measured. The relationship between hamstrings flexibility and the occurrence of hamstrings injuries was assessed through univariate logistic regression analysis. No relationship was found between hamstrings flexibility and hamstrings injury occurrence in amateur male soccer players.

2.7.3.4 Relationship Between Hip Abduction Peak Torque and Hamstrings Injury in Amateur Male Soccer Players

The hip abductors are comprised of the gluteus medius (primary abductor) and the gluteus minimus (Osborne et al., 2012). Muscles of the lumbo-pelvic region have an intimate anatomical connection (Van Wingerden et al., 1993) and control lumbar, pelvic and hip joint positions (Wilson et al., 2006). The hamstrings muscles attach directly to the ischial tuberosity of the pelvis and lateral lip of the femur (Woodley & Mercer, 2005). The gluteus medius controls the hip and pelvic positions and, therefore, has the possibility to cause
hamstrings muscle injury.

Muscle strength testing is often utilized as part of pre-season tests in professional soccer to identify players at risk for injury (McCall et al., 2014) and, together with balance, plays a key role in predicting acute muscle injuries (Lehance et al., 2009). Muscle strength is an important factor predisposing a player to lower extremity injury (Lehance et al., 2009). Lower limb strength is vital to a soccer player, because of the characteristics of the game (Maly et al., 2014), with isokinetic peak torque is said to be the preferred method of evaluating lower limb strength in soccer players (McQuoid et al., 2017).

Osborne (2012) stated that hip abduction weakness has never been documented as a common finding in a healthy group of athletes. Strength testing for hip muscle groups is of importance for the purposes of screening, rehabilitation, and injury-prevention, and it is of paramount importance that a reliable method is utilised for the assessment (Laferu et al., 2007). The concentric and eccentric strength profiles and muscular balances of the hip joint are seen as important parameters for success in soccer (Gerodimos et al., 2015).

Isokinetic dynamometers have been considered as simple, easy and reliable devices for assessing lower limb muscle strength (i.e., of the knee, ankle and hip) in sports like soccer (Meyer et al., 2013; Lee et al., 2018).

Smith et al. (2016) indicated that a high gluteus medius activation during running was a risk factor for hamstrings injuries in elite Australian football players, although the study did not
measure hip strength as a possible risk factor for a hamstring’s injury.

Low hip abduction strength is associated with and has been identified as an important risk factor in multiple lower extremity injuries (Bazett-Jones et al., 2017). Weak hip abductors have been found following ankle sprains (Friel et al., 2006), patellofemoral pain (Earl, 2005), anterior cruciate ligament injury (Hewett et al., 2005), exertional medial tibial pain (Verrelst et al., 2014), and iliotibial band syndrome (Fredericson et al., 2000).

Very few studies document the physiological characteristics of the hip abductor/adductor and extensor/flexor muscle groups among soccer players (Belhaj et al., 2015), although hip muscle strength plays an important role in soccer for executing fundamental skills, such as kicking, accelerating and sudden change of direction (Gerodimos et al., 2015). However, very little scientific evidence exists on the relationship between gluteus medius weakness and hamstrings injury (Shield & Bourne, 2018).
CHAPTER THREE: RESEARCH METHODS

3.1 Introduction

This chapter describes the methods used in the study. The chapter starts with the study design. The sample size and participant selection, the tests performed, and the methods of data collection are also described. Finally, the statistical analyses of the data, as well as the ethical considerations are presented.

3.2 Research Design

A prospective cross-sectional, quantitative study design was used for this study.

3.3 Study Population and Sample Size

Amateur soccer players were recruited through convenient sampling from March 2016 to April 2017 via the local football associations (LFA) of the South African Football Association (SAFA). The soccer teams and clubs are currently competing in the Premier and Super Leagues in the Cape Town district football league. A total of 203 amateur male soccer players were invited to participate in the study. A total of 18 players declined, leaving 185 players who underwent baseline measurements at the start of the soccer season (Figure 3.1). Out of the 185 players who were initially recruited, an additional 96 were excluded from the final analysis, due to football or personal reasons, missing data, changing soccer clubs, or
being a victim of crime due to gang violence. The final analysis was conducted on 89 amateur male soccer players that remained to the end of the study.

Figure 3.1: Flow chart indicating the number of participants involved in study.
3.4 Research Instruments and Procedures

3.4.1 Self-Administered Demographic and Injury Questionnaire

A two-part self-administered questionnaire was administered to the participant at UWC Biokinetics practice on the day of testing, which included measuring the participants demographic information (part one) and their history of previous injury (part two). The demographic questionnaire included questions on the player’s age, playing position, leg dominance, level of competition, and years of soccer playing experience.

The second part of the questionnaire focused on the history of previous hamstrings injuries of the players that included questions on the date of injury, the number of previous hamstrings injuries, aetiology of previous hamstrings injuries, the side injured, date when the last injury occurred, the location where the injury occurred (during a match or training), a description of the circumstances surrounding the injury, and the date of the player’s return to full participation.

3.4.2 Assessment of Hamstrings Injuries

Data on the players’ hamstrings injuries sustained during the prospective soccer season was collected during a 16-month period from June 2016 to October 2017. A senior staff member at each soccer club was trained by the researcher how to record a hamstrings injury during training or matches, using a specific injury report form (Appendix F). Staff members were
trained on the criteria of an injury and how to identify injured players, and how to apply the correct order of documentation. Staff members who were responsible at each club were contacted at end of each week to follow-up on data collection.

3.4.3 Anthropometric Measurements

In order to measure stature (height), body mass, subcutaneous skinfold thickness, girth circumferences and limb lengths, the following instruments were used, namely, a calibrated Seca beam balance scale and stadiometer (Seca model 700, Gmbh & Co., Germany), a Harpenden skinfold caliper (Harpenden, UK), a Harpenden sliding caliper (Harpenden, UK), a metal tape measure (Sanny Medical, HK) and a Harpenden anthropometer (Harpenden, UK).

3.5 Measurement of Stature

Stature is defined as the perpendicular distance between the transverse plane of the vertex of the head and the inferior aspects of the feet and is measured with a stadiometer (Marfell-Jones et al., 2006, p. 54). For the purposes of this study, the stretch stature method was utilized. The participant was asked to remove their shoes and stand with their heels together, with the heels, buttocks and upper section of the back touching the stadiometer. The head was positioned in the Frankfurt plane, which was achieved when the orbitale (lower edge of the eye socket) was in the same horizontal plane as the tragion (the notch superior to the tragus of the ear). This was accomplished by placing the tips of the thumbs on each orbitale and the index fingers on each tragion, then horizontally aligning the two. Once the head were positioned, the thumbs...
were repositioned posteriorly towards the participant’s ears and far enough along the side of the jaw to ensure that upward pressure was transferred to the mastoid process (Marfell-Jones et al., 2006, p.55).

When the participant was aligned, the vertex was the highest point of the skull. The participant was then instructed to take and hold a deep breath, and while keeping the head in the Frankfurt plane, a gentle upward lift through the mastoid processes was applied (Marfell-Jones et al., 2006, p. 55). The headboard was then placed firmly down on the vertex, compressing the hair as much as possible. The measurement was taken before the participant exhaled and was measured to the nearest 0.01cm. The final measurement was calculated from the average of two measurements, provided that the measurements were within 5 mm of each other. If not, additional measurements were taken until the appropriate limit was obtained. The technical error of measurement (TEM) for measuring body stature was 1.0%. Measurements were taken in the evening, since amateur soccer players either work or study full-time, so it was more convenient in the evening.

3.6 Measurement of Body Mass

Body mass is defined as the quantity of matter in the body and is calculated through the measurement of weight (the force that matter exerts in a standard gravitational field) (Marfell-Jones et al., 2006, p. 53). The participant was asked to remove all excess clothing, as well as keys, cellular phones and any other weighted objects. They were asked to stand in the centre of the scale without support, with their weight evenly distributed on both feet. Using the beam
balance scale, the 10 kg sliding weight indicator was positioned first, then the 1 kg sliding weight indicator. Once the movable beam settled voluntarily, the reading of the weight was taken. Body mass was measured to the nearest 0.1 kg. The final measurement was calculated from the average of two measurements, provided that the measurements were within 0.1 kg of each other. If not, additional measurements were taken until the appropriate limit was obtained. The TEM for measuring body mass was 1.0%.

Body mass index was calculated using participant’s weight (kg) divided by their height (m) squared, and expressed in kilograms per square metre (kg\(\cdot\)m\(^2\)).

### 3.7 Skinfold Measurements

A calibrated Harpenden skinfold caliper was used to measure all skinfold measurements according to Marfell-Jones et al., 2006 p. 60. The seven skinfold sites measured included the biceps, chest, subscapular, iliac crest (mid-axilla), supraspinale (supra-illiac), abdominal and thigh. All measurements were taken at least twice for each skinfold site on the right-hand side of the body. When taking skinfolds, the tester measured all measurements once, before repeating them a second or third time. This was done in order to allow the skin time to regain its normal tension and texture. Skinfold measurements were recorded to the nearest 0.01 mm and they were retaken if measurements were not within the 5% TEM. Body fat percentages were determined using the seven-site formula based on a sample between the ages of 18-55 years (Jackson et al., 1980). First, body density was calculated, as follows:
Body Density = 1.097 - (0.00046971 x sum of skinfolds) + (0.00000056 x square of the sum of skinfold sites) - (0.00012828 x age).

Next, the percentage body fat was calculated (ACSM, 2010, p.68), as follows:

Percentage body fat (% body fat) = \( \frac{495}{\text{Body Density}} - 450 \).

3.7.1 Measurement of the Biceps Skinfold

The subject assumed a relaxed position standing with the arms hanging by the side. The skinfold was taken vertically on the ventral aspect of the upper arm over the belly of the biceps. The right arm was relaxed with the shoulder joint slightly externally rotated and the elbow extended by the side of the body. This site was located by measuring the linear distance between the acromiale and radiale landmarks with the arm relaxed and extended by the side. This was accomplished by using a large sliding caliper and a small horizontal mark was made at the mid-point between these two landmarks. This mark was projected around to the anterior surface of the arm as a horizontal line, which marks the site of the biceps when viewed from the side at the mid-acromiale-radiale level (Marfell-Jones et al., 2006, p. 65).

3.7.2 Measurement of the Chest Skinfold

The subject assumed a relaxed standing position with the arms at the sides. This is a diagonal skinfold measured midway between the anterior axillary line and the nipple. The subject stood with the right arm relaxed (ACSM, 2010, p. 67).
3.7.3 Measurement of the Subscapular Skinfold

The subject assumed a relaxed position standing with the arms hanging by the sides. The inferior angle of the scapula was palpated with the left thumb. If there was any difficulty locating the inferior angle of the scapula, the subject was instructed to slowly reach behind the back with the right arm and the inferior angle of the scapula could be felt continuously, as the hand is again placed by the side of the body. A final check of the landmark was made with the hand by the side in the relaxed position. The site was located 2 cm along a line running laterally and obliquely downward from the subscapulare landmark at a 45° angle. The line of the skinfold was determined by the natural fold of the skin. (Marfell-Jones et al., 2006, p. 64).

3.7.4 Measurement of the Iliac Crest Skinfold

The subject assumed a relaxed position with the left arm hanging by the side and the right arm abducted horizontally. First, the iliocristale was located and marked. This was accomplished by locating the most lateral edge of the iliac crest on the ilium, using the right hand. The left hand was then used to stabilise the body by providing resistance on the left side of the pelvis. The landmark was located on the most lateral point at the edge of the ilium. The line of the skinfold generally runs slightly downward from posterior-anterior, as determined by the natural fold of the skin (Marfell-Jones et al., 2006, p. 66).

3.7.5 Measurement of the Supraspinale Skinfold
The subject assumed a relaxed position standing with the arms hanging by the sides. The iliospinale landmark was first located by palpating the superior aspect of the ilium and followed anteriorly and inferiorly along the crest to the anterior superior iliac spine and downward until it runs posteriorly. The landmark is the most inferior or under most part of the tip of the anterior superior iliac spine. If any difficulty was encountered in appraising of the landmark, the subject was asked to lift the heel of the right foot and rotate the femur outward. The right arm of the subject was abducted to the horizontal, after the anterior axillary border was identified. The site was located at the intersection of two lines, i.e., (1) the line from the marked iliospinale to the anterior axillary border, and (2) the horizontal line at the level of the marked iliocristale. The fold runs medially downward at about a 45° angle, as determined by the natural fold of the skin (Marfell-Jones et al., 2006, p. 67).

3.7.6 Measurement of the Abdominal Skinfold

The subject assumed a relaxed position standing with the arms hanging by the sides. This skinfold site was located 5 cm to the right of the omphalion (midpoint of the navel). The measurement was taken in a vertical position. (Marfell-Jones et al., 2006, p. 68).

3.7.7 Measurement of the Thigh Skinfold

The subject assumed a seated position on the edge of a plinth with the torso erect and the arms hanging by the sides. The knee of the right leg was bent at a right angle. The site was marked parallel to the long axis of the thigh at the mid-point of the distance between the inguinal fold
and the superior margin of the anterior surface of the patella (while the leg was bent). The inguinal fold is the crease at the angle of the trunk and the thigh. If there was any difficulty in locating the fold of the subject, the subject was asked to flex the hip to make a fold. A small horizontal mark was placed at the level of the mid-point between the two landmarks. A perpendicular line to intersect the horizontal line was then drawn with this perpendicular line located in the midline of the thigh. The subject was asked to assist by lifting the underside of the thigh with both hands to relieve the tension of the skin (Marfell-Jones et al., 2006, p. 69).

3.8 Circumference Measurements

The waist and hip circumferences were the two girths or circumferences measured in this study. The waist and hip circumference measurements followed the techniques as outlined in the manual of the International Society for the Advancement of Kinanthropometry (Marfell-Jones et al., 2006 p. 75).

3.8.1 Waist Circumference

The subject assumed a relaxed position standing with the arms folded across the thorax. This girth was taken at the level of the narrowest point between the lower costal (10th rib) border and the iliac crest. The non-distensible metal tape measure was passed around the abdomen and the stub of the tape and the housing were then both held in the right hand, while the left hand adjusted the level of the tape at the back to the judged level of the narrowest point. While controlling the stub with the left hand, and using the cross-hand technique, the tape was
positioned in front at the target level. The subject was next instructed to lower their arms to the relaxed position. The tape was then readjusted to ensure that it had not slipped and had not indented the skin excessively. The subject was asked to breathe in normally, and the measurement was taken at the end of a normal expiration. If there was no obvious narrowing of the waist, the measurement was taken at the mid-point between the lower costal border and the iliac crest. Measurement of the waist circumference was taken to the nearest 0.3 cm (Marfell-Jones et al., 2006, p.83). The average of two measurements was used as the final measurement, provided that the measurements were within 5 mm of each other. The TEM for measuring the circumferences was 1.0%.

3.8.2 Hips Circumference

The subject assumed a relaxed position standing with the arms folded across the thorax. The subject was instructed to keep their feet together and to relax the gluteal muscles. The girth was taken at the level of the greatest posterior protuberance of the buttocks, which usually corresponded anteriorly to about the level of the symphysis pubis. The tape was placed around the hips from the side of the subject. The stub of the tape and the housing were then both held in the right hand, while the left hand was used to adjust the level of the tape at the back to the level of the greatest posterior protuberance of the buttocks. The stub was controlled with the left hand, and using the cross-hand technique, the tape was positioned in front so that the tape was held in a horizontal plane at the target level. The tape was then readjusted as necessary to ensure that it did not slip and did not indent the skin excessively. Measurement of the hip circumference was taken to the nearest 0.3 cm (Marfell-Jones et al., 2006, p. 84). The average
of two measurements was used as the final measurement, provided that the measurements
were within 5 mm of each other. The TEM for measuring the circumferences was 1.0%.

3.9 Measurement of Limb Lengths

The trochanterion-tibiale laterale, tibiale laterale, tibiale mediale-sphyrion tibiale and foot
length were the various limb lengths measured. The techniques for measuring these lengths
were those as outlined in the manual of the International Society for the Advancement of
Kinanthropometry by Marfell-Jones et al., 2006 p. 89.

3.9.1 Measurement of the Trochanterion-Tibiale Laterale Length

During this measurement, the subject assumed a standing position with the feet together and
the arms folded across the thorax. This represents the length of the thigh and was taken on
both limbs. The distance between the marked trochanterion and tibiale laterale landmarks
were measured. One end of the anthropometer was placed on the marked trochanterion and the
other end was placed on the marked tibiale laterale site. (Marfell-Jones et al., 2006, p. 99).
The TEM for measuring lengths was 1.0%.

3.9.2 Measurement of the Tibiale Laterale Length

During this measurement, the subject stood on a box, while the base of the anthropometer was
on top of the box and the moving branch was placed on the marked tibiale laterale site. The
anthropometer was held in the vertical plane. A spirit level was used to verify this. The height from the tibiale laterale to the top of the box was then measured. (Marfell-Jones et al., 2006, p.100).

3.9.3 Measurement of the Foot Length

The subject assumed a relaxed standing position with the feet shoulder width apart, and the weight evenly distributed, and the arms hanging by the sides. This is the distance from the tip of the longest toe, which may be the first or second phalanx to the most posterior point on the calcaneus of the foot. Minimal pressure was applied to the large sliding caliper (Marfell-Jones et al., 2006, p.101).

3.9.4 Measurement of the Tibiale Mediale-Sphyrian Tibiale Length

During this measurement, the subject assumed a standing position with the feet together and the arms folded across the thorax. The length of the tibia was measured as the length between the tibiale mediale and the sphyrian tibiale. One branch of the anthropometer was placed on the marked tibiale mediale site and the other branch was positioned on the marked sphyrian site (Marfell-Jones et al., 2006, p.102).

3.10 Measurements of Isokinetic Muscle Parameters
Assessment of the bilateral concentric hamstrings time-to-peak torque, strength ratio, and concentric hip abduction strength were performed at an isokinetic angular velocity of 60°•sec\(^{-1}\) using the Biodex Pro System 4 isokinetic dynamometer (Biodex Medical Systems, Inc., Biodex Corp., Shirley, NY, USA). The warm-up consisted of 10 minutes of cycling without resistance at a subject-specific cycling speed on a Technogym 700iE cycle ergometer followed by approximately five minutes of static stretching of the quadriceps, hamstrings and calf muscles prior to commencing with the procedures for measuring lower extremity isokinetic muscle peak torque.

3.10.1 Isokinetic Knee and Hip Measurements

The subjects were required to perform bilateral concentric isokinetic knee and hip tests on the isokinetic dynamometer using the appropriate knee and hip adaptors for knee flexion and extension and hip adduction and abduction movements. In order to ensure consistency and reliability of the testing, all isokinetic tests were carried out by the same tester using a protocol from previous studies for the knee and hip muscles (Mohammad et al., 2014; Abdel-aziem et al., 2013; Brent et al., 2013; Daneshjoo et al., 2013; Claiborne et al., 2009; Houweling et al., 2009; Croisier et al., 2003). Dynamometer software was used to calculate the time-to-peak torque and the hamstring / quadriceps strength ratio of the knee during the flexion/extension movements. Similarly, hip abduction peak torque was calculated during the hip adduction / abduction movements. Only the tester and the subject were present in the testing room during testing to ensure privacy when testing.
3.10.1.1 Isokinetic Knee Measurement

Bilateral concentric hamstrings time-to-peak torque and concentric hamstring-to-quadriceps strength ratio was assessed at a pre-set isokinetic angular velocity of 60 •sec\(^{-1}\) (Daneshjoo et al., 2013; Houweling et al., 2009; Croisier et al., 2003). The test procedure was communicated to the subject before testing began to ensure that the testing procedure was adhered to by the subject. Subjects were in a sitting position with the chair rotated at 90° to the dynamometer. The uninvolved leg of the subject was always tested first. A knee attachment was fitted to the dynamometer and aligned to the dynamometer (i.e., red dot on the shaft with the red dot on the attachment). The subject was then moved into position and the subject’s axis of rotation of the knee was aligned with the dynamometer shaft. The subject’s knee attachment was adjusted proximal to the medial malleoli, and the straps then secured. The subject was stabilized and strapped to the adjustable seat using the two chest straps, one abdominal strap, and one upper leg strap. The range of motion of the knee was then set between 0° (flexion) and 90° (full extension).

The subject performed two sub-maximal and one maximal trial to get accustomed to the procedure and equipment (Croisier et al., 2008).

The test started with knee flexion and extension movements with 5 maximal repetitions of the uninvolved limb first. A two-minute break was allowed as the machine setting was changed for testing the involved leg. Subjects were encouraged by verbal coaching to produce their best performance with each repetition. The bilateral concentric hamstrings time-to-peak torque
was noted and recorded. The hamstrings-to-quadriceps strength ratio was evaluated by the concentric peak torque of the hamstrings divided by the concentric peak torque of the quadriceps for both limbs.

3.10.1.2 Isokinetic Hip Measurement

Assessment of bilateral concentric hip abduction peak torque was assessed during concentric hip adduction and abduction movements (Abdel-aziem et al., 2013; Brent et al., 2013; Claiborne et al., 2009). Subjects remained in a standing position, which provided less stabilisation, but it was the most functional position. The dynamometer orientation, tilt and seat were all set at 0º. The hip attachment was inserted and secured to the dynamometer. The subject stood facing the dynamometer, while placing both hands on top of the dynamometer for support. The uninvolved leg was tested first. The leg was attached to the dynamometer arm with the Velcro strap, while another strap was placed slightly above the knee. The dynamometer’s rotation axis was aligned medial to the anterior superior iliac spine at the level of the anterior superior iliac spin on the tested leg. The hip attachment length was adjusted to be proximal to the subject’s lateral femoral condyle.

The range of motion was set between 5° (adduction) to 40° (abduction) with a starting position of 5° adduction. The subjects performed two submaximal and one maximal trial to get accustomed to the procedure and equipment. (Gerodimos et al., 2015). The test started with hip abduction and adduction movements with 5 maximum repetitions of the uninvolved limb first. A two-minute break was allowed, as the machine setting was
changed for the involved leg. The bilateral concentric hip abduction peak torque was noted and recorded.

3.11 Flexibility Measurement

The flexibility measurements of the hamstrings on both legs were measured with a goniometer. The straight leg raise was performed with the subject lying in a supine position on a plinth (Witvrouw et al., 2003). One limb was lifted straight up (hip flexion) with knee in full extension, and the measurement was made at the hip. The axis of the goniometer was placed at the level of the greater trochanter of the femur. The stationary arm was then placed horizontal to the plinth and the moving arm pointed in the direction of the extended limb. The reading was taken when the participant felt that he could not move the limb further. Three attempts were taken, and the best performance was used for analysis. The hamstrings flexibility test was performed on both legs (Daneshjoo et al., 2013; Henderson et al., 2010; Witvrouw et al., 2003). Measurements were taken in the evening since amateur soccer players either work or study full-time, so it was more convenient in the evening.

3.12 Reliability and Validity of Instruments

The research instruments used to collect data on all the physical measurements, such as stature, body mass, skinfold measurements, waist circumferences, limb lengths and flexibility, were done with calibrated standard equipment that was specifically allocated for research purposes by the department. The isokinetic measurements were done with the Biodex Pro
System 4 dynamometer that is a precision instrument which is calibrated annually to ensure precision tests and measurements are adhered to at all times.

3.13 Tester Reliability

Reliability and validity of the isokinetic dynamometer and goniometer measurements were moderated by the study supervisor to ensure competency. To ensure tester reliability only one tester was used in the study. The tester measuring the skinfolds was trained by a criterion tester according to the ISAK guidelines (Marfell-Jones et al., 2006, p.59), and the technical error of measurement (TEM) for the tester was established within acceptable limits for research. The requirements of tester accuracy were standardized across all measurements. A test-retest reliability coefficient of 0.8 minimum was achieved to ensure reliable results before the study commenced. The accepted anthropometric TEM was as follows (Pederson & Gore, 1996, pp. 77-95):

- Body mass 0.1 kg
- Height, 3 mm
- Skinfolds, 5%
- Girths, 3 mm

3.14 Statistical Analysis

All raw data collected was first entered into Microsoft Excel (version 2010)
spreadsheet with a double entry format and checked for correctness to ensure accuracy. The Statistical Package for the Social Sciences (SPSS) (version 22) was used for the data analysis. The limb was considered as the unit of analysis, because the risk factors in the current study described the characteristics of limb. Each leg was categorized as either healthy or previously injured, based on its injury history. Each leg was tested separately, which yielded 186 (96 participants x 2) legs of data. Analysis of the data was calculated by making use of descriptive statistics, which included means and standard deviations, as well as inferential statistics, which included a general linear regression model, Pearson product-moment correlation coefficient to calculate the relationship between the time-to-peak torque, strength ratios, hip abduction strength, and hamstrings flexibility, as risk factors, and the occurrence of hamstrings injuries.

Multivariate logistic regression via the forward stepwise method was the statistical method utilised to predict potential physical characteristics (risk factors) for hamstrings injury in amateur male soccer players with a p value of below 0.05 considered to indicate statistical significance.

3.15 Ethical Considerations

Ethical clearance to conduct the study was granted by the Senate Research Ethics Committee of the University of the Western Cape (Ethics Registration Number: 13/9/21). All six Super League and Premier Division soccer clubs currently competing in the Cape Town district football league were sent information letters inviting them to participate in the study.
(Appendix A). Every effort was made to minimize the participants’ risks of injury or re-injury by evaluating the participants’ preliminary information related to the health and physical fitness, and by re-test precautions and safety precautions during testing. Trained personal with level three first aid qualifications were available throughout testing, in case of any injury. Because all subjects were older than 18 years, consent forms (Appendix C) were signed by each participant showing that they understood the test procedures, as well as the risks and possible benefits from the tests (i.e., the participant information letter) (Appendix B). The participants participated voluntarily in the study and they could stop the testing or withdraw from the research at any time without any negative effects.

Each subject was tested privately, when either completing the questionnaire (Appendix D) or being tested (Appendix E), or their test results were kept confidential and used only for the purposes of this research. For ethical reasons, the names of the participants were not recorded, but rather numeric codes were used for each of them. All data was stored in a locked filing cabinet in the supervisor’s office at the university and will be kept for a minimum period of three (3) years, before being destroyed.
CHAPTER FOUR: RESULTS

4.1 Introduction

The chapter initially presents the descriptive statistics of the participants, specifically, information from the questionnaires which includes the player demographics (age, gender, player position, leg dominance, level of competition, years of playing experience, and the players’ history of previous injury. Anthropometric measurements of stature, body mass, subcutaneous skinfold thickness, circumferences (waist and hip) and limb lengths (trochanterion-tibiae laterale, tibiae laterale, tibiae mediale-sphyron tibiae and foot length are also included. The chapter ends by reporting whether isokinetic time-to-peak torque, hamstrings-to-quadriceps strength (H: Q) ratio and hip abduction strength and hamstrings flexibility can predict the risk of sustaining a hamstrings injury.

4.2 Demographics of the Participants

Personal information, years of participation in soccer, and the level of competition covered the demographics of the players. All 89 participants played on the same level of competition and comprised of 6 teams geographically located within the Cape Town region.

4.2.1 Body Composition
The results for age, stature, body mass, lean body mass, body fat mass, body fat percentage, waist circumference, hip circumference and limb lengths of all participants, including that of both the injured and non-injured players are presented in Table 4.1.

The mean ages of the injured and non-injured players were 21.50 ± 2.50 and 23.80 ± 5.71 years, respectively, ranging from 17 to 42 years for both groups. The non-injured players were older than the injured players, but no significant difference was found (p = 0.37). The Mean statures for the injured and non-injured players were 171.97 ± 5.43 and 173.36 ± 6.19 cm, respectively, ranging from 156.00 to 185.20 cm. The non-injured players were taller than the injured players, but no significant difference was found (p = 0.66).

The mean body masses of the injured and non-injured players were 63.30 ± 9.23 and 69.78 ± 11.80 ± 11.73 kg, respectively, ranging from 42.50 to 99.00 kg. The injured players had a lighter mean body mass than the non-injured players, but no significant differences were found (p = 0.28). The mean lean body masses of the injured and non-injured players were 59.89 ± 7.46 and 62.72 ± 8.17 kg, respectively, ranging from 40.66 to 87.28 kg. There was no statistical difference in lean body mass between the groups (p = 0.49), even though the results indicated the non-injured players as being slightly more muscular than the injured players.

The mean body fat masses of the injured and non-injured players were 3.40 ± 2.33 and 7.16 ± 5.50 kg, respectively, ranging from 0.22 to 20.62 kg. The non-injured players were fatter compared to the injured players. No statistical difference was found in body fat mass between
the injured and non-injured groups (p = 0.17). The mean body fat percentages of the injured and non-injured players were 5.16 ± 2.76 and 9.68 ± 6.48 %, respectively, ranging from 0.35 to 27.70 %. The non-injured group had a higher mean body fat percentage than the injured group, but it was not statistically different (p = 0.17).

The mean waist circumferences of the injured and non-injured players were 71.87 ± 8.33 and 78.09 ± 8.13 cm, respectively, ranging from 64.00 to 106.50 cm. Even though non-injured players had a larger waist circumference compared to the injured players, but this difference was not statistically significant (p = 0.13). The injured and non-injured groups mean hips circumferences were 87.12 ± 6.14 and 92.05 ± 8.09 cm, respectively, ranging from 75.00 to 111.00 cm. The result showed that the non-injured players had a larger hip circumference compared to the injured players, but it was not statistically different (p = 0.23).

The mean total leg lengths of the injured group was 284.07 ± 6.76 cm for the right leg and 285.42 ± 8.38 cm for the left leg, ranging from 266.00 to 300.90 cm for both legs. The non-injured players presented with a mean total leg length of 287.11 ± 6.38 and 290.15 ± 25.09 cm for the right and left legs, respectively, ranging from 266.90 to 511.00 cm. The non-injured players had a longer mean total leg length than the injured players. These differences were not statistically significant for the right (p = 0.35) and left (p = 0.70) legs.

4.2.2 Years of Playing Experience
The mean numbers of years of playing football for the injured and non-injured players were 16.25 ± 8.09 and 12.16 ± 5.18 years, respectively. The non-injured players had more playing experience compared to the injured players, these differences were not statistically significant (p = 0.13).

Table 4.1: Baseline demographic characteristics of the injured and non-injured amateur male soccer players presented as means (X) and standard deviations (±SD).

<table>
<thead>
<tr>
<th>Baseline demographic characteristics</th>
<th>All Players (X±SD)</th>
<th>Injured (n = 4)</th>
<th>Non- injured (n = 85)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>23.68 ± 5.62</td>
<td>21.25 ±2.50</td>
<td>23.80 ±5.71</td>
<td>0.37</td>
</tr>
<tr>
<td>Stature (m)</td>
<td>173.30 ± 6.14</td>
<td>171.97 ±5.43</td>
<td>173.36 ±6.19</td>
<td>0.66</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>69.49 ± 11.73</td>
<td>63.30 ±9.23</td>
<td>69.78 ±11.80</td>
<td>0.28</td>
</tr>
<tr>
<td>Body mass index (kg•m⁻²)</td>
<td>23.11 ± 3.51</td>
<td>21.35 ± 2.33</td>
<td>23.19 ± 3.54</td>
<td>0.30</td>
</tr>
<tr>
<td>Lean body mass (kg)</td>
<td>62.59 ± 8.19</td>
<td>59.89 ±7.46</td>
<td>62.72 ±8.17</td>
<td>0.49</td>
</tr>
<tr>
<td>Body fat mass (kg)</td>
<td>6.99 ± 5.45</td>
<td>3.40 ±2.33</td>
<td>7.16 ±5.50</td>
<td>0.17</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>9.48 ± 6.42</td>
<td>5.16 ±2.76</td>
<td>9.68 ±6.48</td>
<td>0.17</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>77.81 ± 8.19</td>
<td>71.87 ±8.33</td>
<td>78.05±8.13+</td>
<td>0.13</td>
</tr>
<tr>
<td>Hips circumference (cm)</td>
<td>91.83 ± 8.05</td>
<td>87.12 ±6.14</td>
<td>92.05 ±8.09</td>
<td>0.23</td>
</tr>
<tr>
<td>Sum of total leg length - left (cm)</td>
<td>289.94 ± 24.58</td>
<td>285.42 ± 8.38</td>
<td>290.15 ± 25.09</td>
<td>0.70</td>
</tr>
<tr>
<td>Sum of total leg length - right (cm)</td>
<td>286.97 ± 6.39</td>
<td>284.07 ± 6.76</td>
<td>287.11 ± 6.38</td>
<td>0.35</td>
</tr>
<tr>
<td>Players with a history of hamstrings injury (%)</td>
<td>32.58 #</td>
<td>25.00</td>
<td>32.94</td>
<td>----</td>
</tr>
<tr>
<td>Playing experience (years)</td>
<td>12.34 ± 5.34</td>
<td>16.25 ± 8.09</td>
<td>12.16 ± 5.18</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Note:
* Indicates statistically significant difference between groups (p< 0.05). All results were nonsignificant.
# 29 players reported previously sustaining 45 hamstrings injuries, with 20 injuries sustained on the left leg and 25 injuries on the right leg.

4.3 Performance Measurements of the Participants

4.3.1 Time-to-Peak Torque
The mean hamstrings times-to-peak torque for the injured right and left legs were 715.00 ± 301.27 and 745.00 ± 250.53 msec, respectively. The non-injured right and left legs produced a mean hamstrings times-to-peak torque of 499.00 ± 196.93 and 496.47 ± 182.55 msec, respectively. The injured legs produced a slower hamstrings time-to-peak torque for both the right and left legs (a higher value indicates a slower time that the injured hamstrings muscles took to reach peak torque), but there were no statistically significant differences for the right (p = 0.39) and left (p = 0.10) legs.

4.3.2 Hamstrings-to-Quadriceps Strength Ratio

The mean hamstrings-to-quadriceps strength ratios for the injured right and left legs were 53.25 ± 7.08 and 46.50 ± 7.54 %, respectively. The non-injured right and left legs were 51.67 ± 10.76 and 48.84 ± 9.50%, respectively. The non-injured players had higher mean hamstrings-to-quadriceps strength ratios compared to the injured players on both the right and left legs. There were no statistically significant differences for the right (p = 0.77) and left (p = 0.62) legs.

4.3.3 Hip Abduction Peak Torque

The mean hip abduction peak torques for the injured right and left legs were 176.45 ± 192.56 and 125.30 ± 90.10 Nm, respectively. The non-injured right and left legs produced peak torques of 137.21 ± 53.86 and 131.04 ± 46.73 Nm, respectively. The mean hip abduction peak on the injured right leg was higher compared to the non-injured right leg. However, on the left
leg, the non-injured group produced a higher mean hip abduction peak torque (PT) compared to the injured group. There were no statistically significant differences between the injured and non-injured right (p = 0.23) and left (p = 0.81) legs.

4.3.4 Hamstrings Flexibility

The mean hamstrings flexibility of the injured right and left legs were 59.00 ± 10.09° and 58.75 ± 10.90 °, respectively. The mean hamstrings flexibility of the non-injured right and left legs were 64.02 ± 10.99° and 62.77 ± 12.52°, respectively. There were no statistically significant differences between the injured and non-injured right (p = 0.37) and left (p = 0.53) legs, even though the non-injured players showed higher mean flexibility scores in both legs.

Table 4.2: Baseline physical characteristics of the injured and non-injured amateur male soccer players presented in the form of means (X) and standard deviations (±SD).

<table>
<thead>
<tr>
<th>Baseline Physical Characteristics</th>
<th>All Players (X±SD)</th>
<th>Injured (n = 4)</th>
<th>Non-injured (n = 85)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-to-peak-torque - right leg (msec)</td>
<td>509.10 ± 205.26</td>
<td>715.00 ± 301.27</td>
<td>499.41 ± 196.93</td>
<td>0.39</td>
</tr>
<tr>
<td>Time-to-peak-torque - left leg (msec)</td>
<td>507.64 ± 191.39</td>
<td>745.00 ± 250.53</td>
<td>496.47 ± 182.55</td>
<td>0.10</td>
</tr>
<tr>
<td>H:Q strength ratio - right leg (%)</td>
<td>51.74 ±10.60</td>
<td>53.25 ± 7.08</td>
<td>51.64 ± 10.74</td>
<td>0.77</td>
</tr>
<tr>
<td>H:Q strength ratio - left leg (%)</td>
<td>48.74 ± 9.40</td>
<td>46.50 ± 7.54</td>
<td>48.84 ± 9.50</td>
<td>0.62</td>
</tr>
<tr>
<td>Hip abduction strength - right leg (Nm)</td>
<td>138.97 ± 64.03</td>
<td>176.45 ± 192.56</td>
<td>137.21 ± 53.86</td>
<td>0.23</td>
</tr>
<tr>
<td>Hip abduction strength - left leg (Nm)</td>
<td>130.79 ± 48.61</td>
<td>125.30 ± 90.10</td>
<td>131.04 ± 46.73</td>
<td>0.81</td>
</tr>
<tr>
<td>Flexibility - right leg (°)</td>
<td>63.79 ±10.95</td>
<td>59 ± 10.09</td>
<td>64.02 ± 10.99</td>
<td>0.37</td>
</tr>
<tr>
<td>Flexibility - left leg (°)</td>
<td>62.59 ±12.43</td>
<td>58.75 ± 10.90</td>
<td>62.77 ± 12.52</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Note:
H:Q = hamstrings-to-quadriceps.
* indicates significant difference between groups (p < 0.05). All results were nonsignificant.
4.4 Relationship Between Physical Characteristics and Hamstrings Injury in Amateur Male Soccer Players

There were six statistically significant correlations illustrated in the correlation matrix (Table 4.3) the relationship between time-to-peak torque (right leg) and time-to-peak torque (left leg) indicate a strong positive correlation that was statistically significant \( (r = 0.74, p = 0.00) \). The relationship between time-to-peak torque (right leg) and hamstrings injury occurrence displayed a statistically significant, but weak positive correlation \( (r = 0.21, p = 0.03) \). The relationship between time-to peak-torque (left leg) and hamstrings injury occurrence also displayed a statistically significant, but weak positive correlation \( (r = 0.27, p = 0.01) \). The relationship between hamstrings flexibility (left leg) and hamstrings-to-quadriceps strength ratio (right leg) displayed a weak negative correlation that was statistically significant \( (r = -0.25, p = 0.01) \). The relationship between hamstrings flexibility (left leg) and hip abduction peak torque (left leg) also displayed a weak positive correlation that was statistically significant \( (r = 0.22, p = 0.03) \). Finally, the relationship between hamstrings flexibility (left leg) and hip abduction peak torque (right leg) displayed a weak positive correlation that was statistically significant \( (r = 0.22, p = 0.03) \).
Table 4.3: The relationship between the physical characteristics and hamstrings injury occurrence in the amateur male soccer players.

<table>
<thead>
<tr>
<th>Physical Characteristics</th>
<th>TPT RL</th>
<th>TPT LL</th>
<th>SR RL</th>
<th>SR LL</th>
<th>Hip Abd RL</th>
<th>Hip Abd LL</th>
<th>Flex RL</th>
<th>Flex LL</th>
<th>Injury occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPT RL (msec)</td>
<td>1</td>
<td></td>
<td>-0.068</td>
<td>-0.061</td>
<td>-0.169</td>
<td>-0.284</td>
<td>-0.199</td>
<td>-0.193</td>
<td>0.219 (0.039)*</td>
</tr>
<tr>
<td>TPT LL (msec)</td>
<td></td>
<td>1</td>
<td>-0.149</td>
<td>-0.106</td>
<td>-0.055</td>
<td>-0.144</td>
<td>-0.133</td>
<td>-0.132</td>
<td>0.271 (0.010)*</td>
</tr>
<tr>
<td>SR RL (%)</td>
<td></td>
<td></td>
<td></td>
<td>0.527</td>
<td>-0.031</td>
<td>0.037</td>
<td>-0.127</td>
<td>-0.250</td>
<td>0.031</td>
</tr>
<tr>
<td>SR LL (%)</td>
<td></td>
<td></td>
<td></td>
<td>-0.063</td>
<td>0.042</td>
<td>-0.050</td>
<td>-0.123</td>
<td>-0.052</td>
<td></td>
</tr>
<tr>
<td>Hip Abd RL (Nm)</td>
<td></td>
<td></td>
<td>0.731</td>
<td>0.312</td>
<td>0.228</td>
<td>0.223</td>
<td>0.363</td>
<td>0.647</td>
<td>-0.096</td>
</tr>
<tr>
<td>Hip Abd LL (Nm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flex RL (°)</td>
<td></td>
<td></td>
<td>0.647</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.067</td>
</tr>
<tr>
<td>Flex LL (°)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injury Occurrence</td>
<td></td>
<td></td>
<td>0.647</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note:
RL = right leg; LL = left leg; TPT = Time to Peak Torque; SR = Strength Ratio; Hip Abd = Hip Abduction; Flex = Flexibility
* indicates statistical significance ($p < 0.05$).
4.5 Prevalence of Injuries in Amateur Male Soccer Players

4.5.1 Location and Type of Injuries

As indicated in Tables 4.4 and 4.5, a total of 23 injuries were reported during the football season June 2016 to October 2017 (16 months) accounting for 21 (23.60 \%) participants being injured out of the 89 players who participated in this study. From the total number of injuries, 52 \% was reported to occur during matches and 48 \% during training. The ankle (34.7 \%) was the most common site of injury, with ligament (65.2 \%) injuries the most frequent injury type.

Table 4.4: Site of injury during the season in amateur male soccer players.

<table>
<thead>
<tr>
<th>Injury Site</th>
<th>Match (%)</th>
<th>Training (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head/Face</td>
<td>1 (4.3)</td>
<td>0 (0)</td>
<td>1 (4.3)</td>
</tr>
<tr>
<td>Neck/Cervical Spine</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Shoulder</td>
<td>1 (4.3)</td>
<td>0 (0)</td>
<td>1 (4.3)</td>
</tr>
<tr>
<td>Upper arm/Elbow</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Forearm/Wrist</td>
<td>1 (4.3)</td>
<td>1 (4.3)</td>
<td>2 (8.6)</td>
</tr>
<tr>
<td>Hip/Groin</td>
<td>2 (8.7)</td>
<td>1 (4.3)</td>
<td>3 (13.0)</td>
</tr>
<tr>
<td>Thigh (Hamstrings)</td>
<td>2 (8.7)</td>
<td>2 (8.7)</td>
<td>4 (17.4)</td>
</tr>
<tr>
<td>Knee</td>
<td>2 (8.7)</td>
<td>2 (8.7)</td>
<td>4 (17.4)</td>
</tr>
<tr>
<td>Lower Leg/Calf/Achilles Tendon</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Ankle</td>
<td>3 (13.0)</td>
<td>5 (21.7)</td>
<td>8 (34.7)</td>
</tr>
<tr>
<td>Foot/Toe</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Total</td>
<td>12 (52)</td>
<td>11 (48)</td>
<td>23 (100)</td>
</tr>
</tbody>
</table>

Table 4.5: Type of injury during the season in amateur male soccer players.

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Match (%)</th>
<th>Training (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle strains</td>
<td>4 (17.4)</td>
<td>3 (13.0)</td>
<td>7 (30.4)</td>
</tr>
<tr>
<td>Fractures and Dislocations</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Joint and Ligament sprains</td>
<td>7 (30.4)</td>
<td>8 (34.8)</td>
<td>15 (65.2)</td>
</tr>
<tr>
<td>Contusions</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Other injuries</td>
<td>1 (4.3)</td>
<td>0 (0)</td>
<td>1 (4.3)</td>
</tr>
<tr>
<td>Total</td>
<td>12 (52)</td>
<td>11 (48)</td>
<td>23 (100)</td>
</tr>
</tbody>
</table>
4.5.2 Prevalence of Hamstrings Injuries in Amateur Male Soccer Players

During the season, a total of four hamstrings injuries were documented among the 89 amateur male soccer players resulting in a hamstrings incidence rate of 4.4%. Furthermore, 50% of the hamstrings injuries occurred equally in the right and left legs, with 50% of the injuries occurring equally during matches and training sessions. None of the players sustained a recurring hamstrings injury during the study period. A total of 29 players reported 45 previous hamstrings injuries with 20 sustaining injury to the left leg and 25 to the right leg.

4.5.3 Predicting Hamstrings Injury

Time-to-peak torque (left leg) was found to be a significant Performance measurement for predicting hamstrings injury in amateur male soccer players, as indicated in the table 4.6 below. Time-to-peak torque was more likely to predict hamstrings injury occurrence (OR = 1.00; p = 0.027). None of the other physical characteristics displayed statistical significance (p > 0.05).

Table 4.6: Logistic regression model predicting the likelihood of hamstrings injury in amateur male soccer players during a season.

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
<th>95% C.I. for EXP(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTP (con/con)-Left Leg</td>
<td>.005</td>
<td>.002</td>
<td>4.894</td>
<td>1</td>
<td>.027</td>
<td>1.005</td>
<td>1.001 – 1.009</td>
</tr>
<tr>
<td>Constant</td>
<td>-5.831</td>
<td>1.554</td>
<td>14.079</td>
<td>1</td>
<td>.000</td>
<td>.003</td>
<td></td>
</tr>
</tbody>
</table>

Note:
TTP = Time to Peak Torque; Con = Concentric; OR = Odds Ratio; 95% C.I. for OR = 95% confidence interval for odds ratio.
* indicates statistically significant difference (p < 0.05).
CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This section discusses the demographics, physical characteristics, and the occurrence of hamstrings injuries in amateur male soccer players. It also discusses the relationship between the performance measurements (risk factors) and the occurrence of hamstrings injuries and whether the physical characteristics (risk factors) can predict hamstrings injury amongst amateur male soccer players. The chapter ends with the strength and limitations of the study, the conclusion, and the recommendations for future research.

A total of 89 amateur male soccer players, aged 18 to 35 years, were examined at preseason and prospectively followed-up for a total of 16 months during the local football association season. The observed high rate of recurring hamstrings injuries and the increasing persistence of hamstrings muscle injuries in amateur male soccer players prompted this study. The present study hypothesised that a longer time to peak torque (i.e., a slower time to reach hamstrings peak torque), a weaker hamstrings-to-quadriceps (H: Q) strength ratio, weaker hip abduction strength, and poorer hamstrings flexibility would be associated with an increased propensity for sustaining hamstrings injury in amateur male soccer players.

The mean age of the injured players in this study was younger than that reported in amateur male soccer players (van Doormaal et al., 2018; Engebretsen et al., 2010). The mean stature of the injured players in this study was shorter than both the injured and non-injured amateur
male soccer players in other studies documenting the occurrence of hamstrings injuries (Schuermans et al., 2017; Stubbe et al., 2015a). In the current study, the injured players weighed less and had a lower body mass index than the participants reported injured in the study by Schuermans et al. (2017).

There was no statistical significance found in age, stature, body mass, lean body mass, body fat mass, body fat percentage, waist circumference, and hip circumference and leg limb lengths between the injured and non-injured participants in the study. Although anatomical and anthropometric asymmetries, such as functional leg length, proprioception asymmetries, concentric and eccentric strength have previously been mentioned as risk factors of lower limb injuries in male soccer players (Read et al., 2018), however, these physical characteristics were not evaluated in the present study.

In the present study, time-to-peak torque was the only significant physical characteristic (risk factor) predicting hamstrings injury in amateur male soccer players. The ability to produce torque quickly is an important skill in most sports, and simultaneously to stabilize a joint to protect it against injury (Wright, 2016). Dvir (2004) stated that that time-to-peak torque was useful in the evaluation of the motor unit recruitment of the muscles involved in a movement.

Braci et al. (2011) investigated the relationship between time-to-peak torque of the hamstrings and sprint running performance, which established gender differences in neuromuscular fitness profiles (i.e., single-leg balance assessment, isokinetic flexion and extension, and flexibility) (Burfeind et al., 2012). Time-to-peak torque seems to be an
important risk factor in injury prevention, because it determines how rapidly dynamic control can be activated in order to stabilize the knee against deforming forces and prevent injury (Wright, 2016). The present study highlights the time-to-peak torque as a risk factor in the prevention and management of hamstrings injuries in amateur male soccer players.

However, in a study by van Dyk et al. (2018), the rate of torque development (time-to-peak torque) and the onset of muscle activity during concentric (60°•sec⁻¹ and 300°•sec⁻¹) and eccentric (60°•sec⁻¹) isokinetic contractions were not associated with the risk of hamstrings injury in male professional soccer players. The difference in methodologies used to measure time-to-peak torque could be the reason for the differences found in results between the studies. The present study measured time-to-peak torque of the hamstrings during both concentric knee flexion and extension strength tests, which was similar to the tests done by van Dyk et al. (2018), who also made use of an isokinetic testing modality, but this was coupled with surface EMG measurements.

In the present study, the time-to-peak torque of the injured players was slower than the non-injured players for both legs and differed with results reported by Burfeind et al. (2012) and Scattone-Silva et al. (2011). The participants in the study by Scattone-Silva et al. (2011) were elite karate sportsman, whereas they were collegiate soccer players in the study by Burfeind et al. (2012). The training regimes for soccer players and karate are different and require different musculatures to perform their respective sports, thereby, also resulting in their different strength and fitness levels. This could be the cause of the differences found between these studies in terms of results, even with the same test speed utilised.
The study by Mattiello-Rosa et al. (2008) proposed that a decreased TPT of the medial rotators of the shoulder can be used as a tool in the early detection of shoulder impingement. Another study by Scattone-Silva et al. (2011) assessed seven male competitive elite karate athletes for bilateral differences in peak torque, acceleration time (AcT) and TPT of the knee and elbow muscles in order to identify risk factors for injury. No bilateral difference was found in TPT between the dominant and non-dominant legs, which is an agreement with findings for TPT in the present study. However, the present study identified an association between TPT and hamstrings injury occurrence. The study by Scattone-Silva et al. (2011), basically, indicated that karate training aids in the increase of strength, especially around the knee joint, which prevents asymmetries and, so, reduces or prevents injury.

Van Dyk et al. (2018) investigated the association between the onset of hamstrings muscle activity and the rate of torque development (TPT) with the risk of hamstrings injury in professional football players in a prospective cohort study. The rate of torque development was not associated with risk of hamstrings injury and, therefore, this parameter was not viewed as a risk factor for hamstrings injury. These results differed with the results in the present study, because TPT was identified as a positive risk factor for hamstrings injury in the present study.

Miller et al. (2006) stated that the assessment of muscle recruitment patterns in athletes may provide better indications of the functional performance than just peak torque. Scattone-Silva et al. (2011) further stated that muscle recruitment problems could be identified and aid in neuromuscular control interventions to prevent injury. Male soccer players in the study by
Burfeind et al. (2012) reported a mean TPT lower (faster recruitment time) than that of the injured players. However, these results were higher (indicating a slower recruitment time) when compared to the findings of the non-injured players in the present study. Similarly, in the study by Scattone-Silva et al. (2011), seven male karate players produced a lower mean TPT lower (faster recruitment time) than the injured players. Once again, these results were also higher (slower recruitment time) than that of the non-injured players in the present study.

Lower limb strength is vital to a soccer player, because of the characteristics of the game (Maly et al., 2014). Several studies have suggested that a strength imbalance in the form of the hamstrings-to-quadriceps strength (H: Q) ratio is predictive of hamstrings strain injury in male soccer players (Dauty et al., 2017; Lee et al., 2018; van Dyk et al., 2017; Dauty et al., 2016; van Dyk et al., 2016). However, a systematic review and meta-analysis by Green et al. (2017) could not identify isokinetic strength asymmetries or imbalances associated with the future risk of hamstrings injury. Less training time and unstructured training methods are well-known to result in insufficient hamstrings strength, which is associated with a higher hamstrings injury risk in recreational football players (Murphy et al., 2003 as cited by Donmez et al., 2018). The results for mean hamstrings-to-quadriceps strength (H: Q) ratio in this study for the injured and non-injured players was lower than that found in South African professional (Aginsky et al., 2014), and other amateur male soccer players at the concentric/concentric angular velocity of 60°•sec⁻¹ (Cometti et al., 2001).

The injured players displayed a higher hamstrings-to-quadriceps strength (H: Q) ratio on the right leg and a lower hamstrings-to-quadriceps strength (H: Q) ratio on the left leg when
compared to the non-injured players. However, no statistical significance was found between right and left legs for hamstrings-to-quadriceps strength (H: Q) ratio. This compares favourably with the results of 13 amateur male soccer players (25.6 ± 3.5 years, 177.7 ± 5.5 cm, 74.9 ± 5.6 kg and 14.8 ± 2.5 years training), with no significant difference found in hamstrings-to-quadriceps strength (H: Q) ratio between the right and left legs for the injured and non-injured players.

Further analysis using multivariate logistic regression in this study could not identify the hamstrings-to-quadriceps strength (H: Q) ratio as a potential performance measurement (risk factor) for hamstrings injury in amateur male soccer players, which agrees with the results of Green et al. (2017).

Muscle strength testing is an important part of pre-season physical tests in professional soccer players in order to identify players at risk of injury (McCall et al., 2014). Isokinetic peak torque is the preferred method to evaluate lower limb strength of soccer players (McQuoid et al., 2017). Lower limb strength is vital to soccer players, because of the characteristics of the game (Maly et al., 2014). Weak hip abduction strength reduces football performance and has been identified as an important risk factor in multiple lower extremity injuries (Bazett-Jones et al., 2017; Verrelst et al., 2014; Friel et al., 2006; Earl, 2005; Hewett et al., 2005; Fredericson et al., 2000).

Very little evidence exists on the relationship between gluteus medius strength (lumbo-pelvic muscles) and hamstrings injury with the results in the study by Smith et al. (2017) adding to
the growing evidence that the lumbo-pelvic muscles may be important to consider in
hamstrings injury prevention programmes. The results for mean hip abduction strength in the
current study for the injured and non-injured players compares favourably to results found in
professional (Belhaj et al., 2015) and amateur (collegiate) male soccer players (Lucci, 2017)

The injured players displayed higher hip abduction strength on the right leg, but a lower hip
abduction strength on the left leg, when compared to the non-injured players. However, no
statistical significance was found between the injured and non-injured players’ right and left
legs for hip abduction strength. The results found in professional soccer players (Belhaj et al.,
2015) differed. They found a statistically significant difference on the dominant and non-
dominant sides between the injured and non-injured participants in the abductor and adductor
peak muscle torques.

The analysis of multivariate logistic regression in this study could not identify hip abduction
strength as a potential performance measurement (risk factor) for hamstrings injury in amateur
male soccer players.

Limited hamstrings flexibility has been proposed as an intrinsic risk factor for hamstrings
injuries in professional and amateur male soccer players (van Doormaal et al., 2017; Fousekis
et al., 2011; Engebretsen et al., 2010; Henderson et al., 2010; Bradley et al., 2007; Arnason et
al., 2004; Witvrouw et al., 2003). However, the relationship between hamstrings flexibility
and hamstrings injury remains unclear, with the results obtained in football players being
inconclusive or conflicting, due to the different methodologies used when measuring

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hamstrings flexibility (van Dyk et al., 2018; van Doornaal et al., 2017; Fousekis et al., 2011; Engebretsen et al., 2010; Witvrouw et al., 2003). The studies above utilised different tests (active and passive knee extension, straight-leg raise, sit-and-reach, and lumbar spine flexion tests) to measure hamstrings flexibility, as well as different statistical methods to predict or evaluate the relationship between hamstring injury and hamstring flexibility.

In the current study, the injured and non-injured players displayed no statistically significant results in hamstrings flexibility for both the right and left legs, despite the injured players displaying lower hamstrings flexibility in both legs. The results for mean hamstrings flexibility in the current study, for both the injured and non-injured players, was lower when compared to other studies that also utilised a standard goniometer to measure hamstrings flexibility (Fousekis et al., 2011; Witvrouw et al., 2003). An analysis of multivariate logistic regression in the current study could not identify hamstrings flexibility as a potential performance measurement (risk factor) for hamstrings injury in amateur male soccer players. This is in agreement with the results found in previous studies (van Doornaal et al., 2017, Henderson et al., 2010; Engebretsen et al., 2010).

There was a total of 23 injuries amongst the 89 participants of the study, with only 4 players (4.4%) each sustaining a hamstrings injury during the season. Al Attar et al. (2017) reported a total of 26 injuries in 144 amateur male soccer players, with only 2 (1.3 %) hamstrings injuries reported and documented. The players were an average age of 18 years, which is different to the average age of the injured players reported in the current study. Studies documenting injuries in amateur male soccer players reported hamstrings injury incidences of

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5.1 % to 29 % (Donmez et al., 2018; Schuermans et al., 2017; van de Hoef et al., 2017; van Doormaal, 2017; Stubbe et al., 2015a; van der Horst et al., 2015). Other studies reported hamstrings injury incidences of 5.1 to 6.2 % (van Doormaal et al., 2017; van der Horst et al., 2015) that was similar to the injury incidence rate reported and documented in the current study (4.4 %).

The TPT on the right leg had a strong positive correlation with the TPT on the left leg that was statistically significant. Furthermore, the TPT on both the right and left legs correlated significantly with hamstrings injury, but the correlation was weak. The hamstrings flexibility on the left leg correlated significantly with (a) the hamstrings-to-quadriceps strength (H:Q) ratio on the right leg, but it was a weak negative correlation; (b) hip abduction strength on the left leg that was a weak positive correlation; and (c) hip abduction strength on the right that was also a weak positive correlation. These were some of the unique results that were statistically significant for the current study that were not reported in any of the previous studies, so it was not possible to make any comparisons with the literature.

5.2 Strengths of the Study

The study followed a prospective cross-sectional, quantitative study design and multivariate logistic regression analysis to address the aim of this study. This study prospectively registered injuries in 89 amateur male soccer players according to a standard definition of injury (Fuller et al., 2006). This study provides valuable and first ever data regarding performance measurements (risk factors) of amateur male soccer players. This study was the first to attempt
to simultaneously measure the effect of performance measurements (risk factors) on the occurrence for hamstrings injury in amateur male soccer players. Since limited research currently exists on hamstrings injuries in Southern African amateur male soccer players, this body of evidence can contribute to broadening the knowledge on the etiology of hamstring injuries and, more especially, on how to prevent or minimize these injuries in future.

5.3 Limitations of the Study

The study followed a relatively small cohort of amateur male players who were recruited by convenience sampling from amateur clubs in the local Northern Suburbs Football Association in the Cape Town region, which negatively affected the external validity of the findings and was gender-specific. This study also did not document nor recorded any training and match exposure times. No specific hamstrings pathology can be implicated by this study, due to no Magnetic resonance imaging evaluations implemented or utilised to confirm pathology. Exposure data was not recorded, i.e. this study did not document or record any training and match exposure times leading or identification of injury incidence rates.

5.4 Conclusion

The TPT was the only significant predictor contributing to the occurrence of hamstrings injury in this study. The hamstring injured players in this study produced a relatively slower TPT result, which is interpreted to mean slower muscle recruitment and force-generation properties and, thereby, displayed a tendency to be susceptible to injury. This is a parameter that is not
fully understood in relation to hamstrings injuries in amateur male soccer players. All other performance measurements were not associated with an increased risk of hamstring injury.

5.5 Recommendations

The results highlight time-to-peak torque as a risk factor in the prevention and management of hamstrings injuries in amateur male soccer players. This study recommends the measurement and evaluation of time-to-peak-torque in pre-season health and performance evaluations of soccer players in order to inform and guide conditioning and injury prevention programs. Future research in this area may consider using different angular velocities that experiment with eccentric and isometric isokinetic contractions in order to develop a more comprehensive understanding of the muscular interactions and balances involved. Hopefully, such research will expand the current knowledge related to isokinetic muscular function and performance in amateur soccer players that can be investigated across both genders and all age groups.
References


Hägglund, M., Waldén, M., & Ekstrand, J. (2016). Injury recurrence is lower at the highest
professional football level than at national and amateur levels: does sports medicine and sports physiotherapy deliver? *British Journal of Sports Medicine*, 50,751-758


Science, 17(4), 213-220.


http://etd.uwc.ac.za/


Mendiguchia, J., Alentorn-Geli, E., & Brughelli, M. (2012). Hamstring strain injuries: are we...
heading in the right direction? *British Journal of Sports Medicine*, 46, 81-85


Orchard, J. W. (2012). Hamstrings are most susceptible to injury during the early stance phase

http://etd.uwc.ac.za/


Champaign IL. USA, 153-158.


trial. *British Journal of Sports Medicine, 46*:1114-1118


Van Mechelen, W., Hlobil, H., & Kemper, H. C. (1992). Incidence, severity, aetiology and


innervation. *Cells Tissues Organs, 179*(3), 125-141


Appendices

Appendix A: INVITATION LETTER

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INVITATION LETTER

Title of Study: Relationship between Selected Physical Characteristics (Risk Factors) and Hamstring Injuries in Male Soccer Players.

Principal Investigator: Raven Schippers, Master Student and Biokineticist, Department of Sport, Recreation and Exercise Science at University of the Western Cape.

Supervisor: Dr L. Leach, Lecturer and Biokinetics Coordinator, Department of Sport, Recreation and Exercise Science at University of the Western Cape.

I, Raven Schippers, a Master’s student in the Department of Sport, Recreation and Exercise Science at University of the Western Cape, would like to invite you to participate in a research project entitled “Relationship between Selected Physical Characteristics (Risk Factors) and Hamstring Injuries in Male Soccer Players”. The purpose of this research project is to investigate the relationship between possible risk factors relating to hamstring injuries in male soccer players because it is essential to reduce the incidence of these injuries in soccer players.

This research should benefit coaches, players, physiotherapists and strength and conditioning coaches, and will include a comprehensive evaluation of the player’s muscular strength and flexibility (risk factors), which could assist in injury prevention and rehabilitation programmes.

Should you wish to participate and have any questions, please contact me on 0726693729 or email ravenschippers@gmail.com

Kind regards,

________________________
Raven Schippers
Master’s Student

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Appendix B: INFORMATION SHEET

UNIVERSITY OF THE WESTERN CAPE
Private Bag X 17, Bellville 7535, South Africa
Tel: +27 21-959 2350, Fax: 27 21-959 3688
E-mail: ntsoli@uwc.ac.za

INFORMATION SHEET

Title of Study: Relationship between Selected Physical Characteristics and Hamstring Injuries in Male Soccer Players.

What is this study about?

This is a research project being conducted by Raven Schippers, as a Master’s student from the Department of Sport, Recreation and Exercise Science at the University of the Western Cape.

This study will investigate the relationship between selected physical characteristics and hamstrings injuries in male soccer players. We are inviting you to participate in this research project, because you meet the following criteria:

- Male soccer player affiliated with SAFA (South African Football Association).
- History of previous hamstring injury.
- Willingness to provide consent

The purpose of this research project is to investigate the relationship between time-to-peak torque, hamstrings to quadriceps strength ratios, hamstring flexibility, hip abduction peak torque and the occurrence hamstring injuries in male soccer players.

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What will I be asked to do if I agree to participate?

You will be required to perform a battery of physical tests which includes isokinetic assessment of both the knee and hip musculature, and flexibility tests of the hamstring muscles. Isokinetic assessments will be performed at the UWC Biokinetics practice, in the Department of Sport, Recreation, and Exercise Science at the university of The Western Cape, whereas the flexibility and anthropometric measurements will be performed at the participant’s field of training. The tests will be performed using specific pieces of equipment for evaluating, but not limited to, your work capacity, muscular strength, muscular endurance, flexibility, and body composition. The exercise resistance is variable, beginning with a high resistance followed by a lower resistance for each leg. You or we may stop the test at any time, because of signs of distress, or discomfort. All testing is done privately, and the information is kept strictly confidential. The duration for each subject’s participation will be between 30-45 minutes.

Would my participation in this study be kept confidential?

We will keep your personal information confidential. To help protect your confidentiality, each subject will be treated as an individual and their test results will be strictly confidential and used only for the purposes of this research. For ethics reasons, the names of the participants will not be recorded, but rather numeric codes will be used. All data will be stored in a locked filing cabinet on the university premises which will only accessible to the researcher. If we write a report or article about this research project, your identity will be protected to the maximum extent possible.

What are the risks of this research?
There may be some risks from participating in this research study. The possibility exists that abnormal changes can occur during the tests. These include abnormal blood pressure, disorder of heart beat, and in rare instances, heart attack, stroke, or death. Every effort will be made to minimize these risks by evaluating preliminary information related to your health and fitness and by observations during testing. If an injury should occur, there will be trained personnel available.

**What are the benefits of this research?**

The benefits to you include assisting in diagnosing injury to the hamstrings or evaluating your neuromuscular efficiency of the knee, quadriceps, hamstring and gluteus maximus strength or identifying imbalances, and hamstring flexibility. The main aim is to reduce the risk of developing hamstring injuries in soccer players, through providing important information on hamstring injury occurrence in male soccer players.

**Do I have to be in this research and may I stop participating at any time?**

Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.

**What if I have questions?**

This research is being conducted by Raven Schippers as a Master’s student in the Department of Sport, Recreation and Exercise Science, at the University of the Western Cape. I encourage you to ask any questions about the research. If you have any questions please contact: http://etd.uwc.ac.za/
Raven Schippers

Cell: 0817909941

Email: ravenschippers@gmail.com

Should you have any questions regarding this study and your rights as a research participant or if you wish to report any problems you have experienced related to the study, please contact:

Supervisor: Dr L. Leach
Department of Sport, Recreation and Exercise Science, UWC
Telephone: (021) 959-2653
Fax: (021) 959-3688
Email: lleach@uwc.ac.za

Dean of the Faculty of Community and Health Sciences: Prof Jose Frantz
University of the Western Cape
Private Bag X17
Bellville
7535
Tel: (021) 959-2631
Email: jfrantz@uwc.ac.za
Appendix C: CONSENT FORM

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CONSENT FORM

Title of the Study: The relationship between selected physical characteristics and hamstring injuries in male soccer players

The study has been described to me in language that I understand and I freely and voluntarily agree to participate. My questions about the study have been answered. I understand that my identity will not be disclosed and that I may withdraw from the study without giving a reason at any time and this will not negatively affect me in any way.

Participant’s name...........................................................................................................................................

Participant’s signature........................................ Date: ……/……./2016…

Witness Name......................................................................................................................................................

Witness Signature................................................. Date: ……./……./2016…

Should you have any questions regarding this study or wish to report any problems you have experienced related to the study, please contact the study supervisor:

Study Supervisor’s Name: Dr L. Leach

Telephone: (021) 959-2653

Cell: 082 200 6987 Fax: (021) 959-3688

Email: lleach@uwc.ac.za

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Appendix D: SELF-ADMINISTERED QUESTIONNAIRE

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QUESTIONNAIRE

A) DEMOGRAPHIC INFORMATION

B) HISTORY OF PREVIOUS HAMSTRING INJURY

A) Demographic Information

Date: __________________________

Participants Name & Surname: ____________________________

Contact Number: ____________________________

Age: (yrs.) ____________________________

Date of Birth: (D/M/Y) ____________________________

Gender: (M/F) ____________________________

Ethnicity: (B, C, I, W) ____________________________
Player Position: (G/D/M/F) | Dominant Leg: (L/R)
____________________________ | ____________________________

Level of Competition: (NFD/VOD/SAB) | Years Playing:
____________________________ | ____________________________

### B) History of previous hamstring injury

Date: _____/_______/2016___________

1) Previous Hamstring injury: Yes/No | Injured Side: L/R
2) Number of previous hamstring injuries: □ 1 □ 2 □ 3 □ 4
3) Previous hamstring injury occurred during: | Training □ / Match □
4) Time since previous hamstring injury: □ 0-6months; □ 6-12months; □ 1-2y; □ >2 y
5) For how long were you unable to fully play/train?
   □ 1-3 days □ 4-7 days □ 1-4 weeks □ >4 week
6) Have you missed training/match during the previous season due to symptoms from your hamstrings?
   □ No – never □ Yes □ Rarely □ Sometimes □ Often

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DATA RECORDING SHEET

### Participants Information

<table>
<thead>
<tr>
<th>Soccer ID number</th>
<th>Participant number</th>
<th>Country</th>
<th>Ethnicity (B, C, I, W)</th>
<th>Sex (male=1, female=2)</th>
<th>Sport</th>
<th>Date of Birth</th>
</tr>
</thead>
</table>

**Previous Hamstring Injury**
(Yes = 1, No = 2)

### TEST

<table>
<thead>
<tr>
<th>Date of Measurement:</th>
<th>Time of Measurement:</th>
<th>Measure</th>
<th>Measure</th>
<th>Measure</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measurements</strong></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>Measures</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stretch stature (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

http://etd.uwc.ac.za/
<table>
<thead>
<tr>
<th>Hip Circumference (cm)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Waist Circumference (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Limb Length (cm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trochanterion-tibiale laterale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Length of thigh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tibiale laterale height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Length of leg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tibiale mediale-sphyrion tibiale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Length of tibia)</td>
<td></td>
<td></td>
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<tr>
<td><strong>Skinfolds (mm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biceps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subscapular</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Axilla</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdomen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supraspinale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thigh</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Isokinetic Testing**

<table>
<thead>
<tr>
<th>Knee Joint (Con/Con)</th>
<th>Extension 60 deg/sec 5 reps</th>
<th>Flexion 60 deg/sec 5 reps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uninvolved</td>
<td>Involved</td>
</tr>
<tr>
<td>Peak torque (N·m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Time to peak torque (msec)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength ratio (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee Joint (Ecc/Con)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Peak torque (N·m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to peak torque (msec)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength Ratio (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip Joint Abduction (Con/Con)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Torque (N·m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength Ratio (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Straight Leg Raise Test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hamstring Flexibility</strong></td>
<td><strong>Left</strong></td>
<td><strong>Right</strong></td>
</tr>
<tr>
<td>Degrees (°)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix F: ETHICS CLEARANCE LETTER

UNIVERSITY OF THE WESTERN CAPE

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ETHICS CLEARANCE LETTER

To Whom It May Concern

I hereby certify that the Senate Research Committee of the University of the Western Cape, at their meeting held on 25 October 2013, approved the methodology and ethics of the following research project by: Mr R Schippers (SRES)

Research Project: Relationship between selected physical characteristics and hamstring injuries in male soccer players.

Registration no: 13/9/21

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

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