The prevalence and risk factors for hamstring injuries among field hockey players at a hockey club in Pretoria, South Africa

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Masters of Science in Physiotherapy.

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DECLARATION

I, Anna Christina Coetzee, declare that this research report is my own work. It is being submitted for the degree of Masters of Science in Physiotherapy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

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Signature Date

ABSTRACT

Background: Hockey is a growing sport worldwide, including in South Africa. Like other sports, field hockey players are susceptible to musculoskeletal injuries, with hamstring strains being common. Even though a high prevalence of hamstring injuries are reported among field hockey players, there is little to no evidence concerning the prevalence of hamstring injuries, their intrinsic risk factors and how they relate to hamstring strain management among such players. **Aim**: To determine the prevalence and intrinsic risk factors for hamstring injuries among field hockey players at a hockey club in Pretoria, South Africa. **Methodology**: This study was cross-sectional in nature. The population consisted of 40 high-performance players from the University of Pretoria's field hockey club. A convenient sample of 33 field hockey players (15 males and 18 females) took part in this research. All those who participated were ≥18 years old and gave their informed written consent. Ethical clearance was obtained prior to the data collection process. Participants completed a questionnaire covering demographic information, injury status and the Hamstring Outcome Score (HaOS). Musculoskeletal tests (the "single leg hamstring bridge", "modified Thomas test", "passive straight leg raise", "ankle range of motion" and "Star Excursion Balance Test") were conducted to screen for intrinsic risk for injuries. Descriptive statistics were obtained to report on the demographics, hamstring injury prevalence, and the associated intrinsic risk factors. Inferential statistics were used to compare the variables, using the Independent-measures t-test and the Chi-square test. A *p-value* of ≤ 0.05 was set to determine the level of significance. **Results**: None of the participants suffered from hamstring injuries at the time of data collection. The participating field hockey players had a highly prevalent history of hamstring strains (45.5%), decreased hamstring function (48.5% left; 51.5% right), decreased hamstring strength (84% left; 87.9% right), decreased hamstring flexibility (75.8% left; 75.8% right) and decreased hip flexor flexibility (48.5% left; 39.4% right). Significantly lower HaOS was found with history of left hamstring strains ($p = 0.006$; $p = 0.028$). The HaOS sub-scores of "pain" ($p = 0.014$; $p = 0.029$) and "function in daily living and sport" ($p = 0.001$; $p = 0.026$) were significant leg-dependent indicators. Significantly decreased hamstring flexibility on the right was found with left hamstring strains ($p = 0.050$). No association were found between the other risk factors, demographics and hamstring injury prevalence. **Conclusion**: History of hamstring strains was prevalent among high-performance field hockey players. Although field hockey players presented with similar intrinsic risk factors as those manifesting in other sports (decreased hamstring function, strength, hip flexor and hamstring flexibility), field hockey players also presented with uniquely less strength and flexibility, as well as asymmetries in their flexibility measures. Prospective aetiological studies are required to confirm the association between these risks and hamstring strains. The HaOS might be used to help clinicians to make return-to-play decisions.

Keywords: hamstring injuries, prevalence, risk factors, field hockey

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LIST OF ABBREVIATIONS

BMI	Body mass index
FAOS	Foot and Ankle Outcome Score
HaOS	Hamstring Outcome Score
KOOS	Knee Osteoarthritis Outcome Score
MRI	Magnetic resonance imaging
SD	Standard deviation
SEBT	Star Excursion Balance Test
SLHB	Single leg hamstring bridge

DEFINITION OF TERMS

Athlete:	"a person who has undertaken training or exercises to become proficient in physical activities such as competitive sports" (Oxford University Press, 2019)
Clinician:	"A physician or other health professional person who treats patients." (Oxford University Press, 2020)
Extrinsic risk factors:	the external environmental factors that may play a role in sustaining an injury, such as factors relating to training habits, surfaces and sport specific activities (van Mechelen, Hlobil and Kemper, 1992; Goldman and Jones, 2010; Brukner *et al.*, 2014)
Field hockey:	a team-based sport consisting of 11 players, played with a ball and stick on grass or a synthetic surface (International Hockey Federation, 2020a)
Hamstring injury:	strain/tear or damage to some or all of the fibres of any of the hamstring muscles (Petersen and Hölmich, 2005; Brukner *et al.*, 2014)
Intrinsic risk factors:	the internal, personal factors that may play a role in sustaining an injury, such as age, body mechanics, weaknesses and inadequate flexibilities (van Mechelen, Hlobil and Kemper, 1992; Goldman and Jones, 2010)
Neuromuscular control:	"the unconscious trained response of a muscle to a signal regarding dynamic joint stability" (Physiopedia contributors, 2019)

CHAPTER 1: INTRODUCTION

1.1 Background

Field hockey is a sport that is enjoyed by many around the world at various levels (Ellapen *et al.*, 2011; Naicker, Coetzee and Schall, 2016). The National South African field hockey teams compete globally, with the men's team currently ranked 14th and the women's team 16th in the world (International Hockey Federation, 2020b). In 2016, field hockey participation in South Africa (±132 400 players) was comparable to that in other countries such as the Netherlands (250 000 players), Germany (80 000 players) and Belgium (37 000 players) (South African Government, 2016; Theilen *et al.*, 2016).

Like other sports consisting of sprinting, quick acceleration and deceleration, field hockey athletes are at risk of sustaining musculoskeletal related injuries (Cross *et al.*, 2010; Naicker, Coetzee and Schall, 2016; Barboza *et al.*, 2018). The lower limb has been documented as the most common site of injury amongst field hockey players, both internationally as well as in South Africa (Murtaugh, 2001; Ellapen, Bowyer and Van Heerden, 2014; Barboza *et al.*, 2018). Frequent lower limb injuries include ankle sprains, knee injuries, contusions, as well as hip, groin and hamstring muscle strains (Murtaugh, 2001; Naicker, Coetzee and Schall, 2016; Barboza *et al.*, 2018; Delfino Barboza *et al.*, 2018).

Hamstring strain incidence rates in the United States among female field hockey players of collegiate age have been reported as 2.95 to 3.79 injuries per 10 000 athlete exposures (Cross *et al.*, 2010; Dalton, Kerr and Dompier, 2015). These incidence rates were comparable to hamstring injury rates sustained by women soccer athletes (Cross *et al.*, 2010). Among both men and women Dutch elite hockey players, hamstring strains were the most common acute injury, accounting for 10% of injuries over one season (Delfino Barboza *et al.*, 2018). Only one study in South Africa reported on specific hamstring strain incidence among elite female field hockey players over one season, where hamstring injuries were recorded as the second-most common injury (12.6%) after ankle injuries (16.1%) (Naicker, Coetzee and Schall, 2016).

Since hamstring strains can be debilitating and frustrating, and also have a high chance of recurrence, various studies (Petersen and Hölmich, 2005; Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009) have investigated possible means to prevent such an injury by identifying the risk factors (Foreman *et al.*, 2006; Freckleton and Pizzari, 2013). Such factors include inadequate warm-up, fatigue, a high level of participation, older age, previous injury and some measurement of decreased strength (Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009; Engebretsen *et al.*, 2010; Freckleton and Pizzari, 2013). Additionally, intrinsic factors such as ethnicity (Aboriginal and Afro-Caribbean descent), decreased ankle dorsiflexion lunge range of motion, poor neuromuscular control, poor proprioception and decreased flexibility measures of the hamstrings, hip flexors and quadriceps have also been found as possible factors associated with hamstring injuries - either in combination or interaction with one another (Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013).

The majority of studies identifying potential risk factors have been conducted within the domains of soccer, Australian football and athletics (Petersen and Hölmich, 2005; Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013). For optimal hamstring strain prevention approaches to be implemented in field hockey, the hockey-specific physical demands should be considered. These include the semi-crouched, asymmetrical and prolonged hip flexion posture that field hockey players are accustomed to, and the influence that these attributes might have on hamstring injury risk (Ellapen *et al.*, 2011; Naicker, Coetzee and Schall, 2016).

However, there are no studies (as far as the researcher’s knowledge is concerned) exploring the specific risk of hamstring injuries among field hockey athletes and how they can be incorporated into preventative measures, management programmes and return-to-sport initiatives in the case of such players. As a result, clinicians working with this population rely on theoretical knowledge, anecdotal literature and clinical reasoning in their approach to hamstring strain injuries (Orchard, Best and Verrall, 2005; Hickey *et al.*, 2017; Barboza *et al.*, 2018).

Therefore, given the popularity of field hockey in South Africa and the high prevalence of hamstring strain injuries among this population (Cross *et al.*, 2010; Naicker, Coetzee and Schall, 2016; Delfino Barboza *et al.*, 2018), further investigation into the relationship between field hockey and the intrinsic risks for hamstring strains is warranted. Consequently, appropriate pre-participation screening tools and return-to-sport criteria following injury could then be established for this population.

1.2 Problem statement and justification

Despite the abundance of research being conducted on hamstring injuries, hamstring strain remains a common injury in sports and has a heightened rate of re-injury. Even though some authors have suggested the high prevalence of hamstring injuries in field hockey in other countries (Cross *et al.*, 2010; Dalton, Kerr and Dompier, 2015; Delfino Barboza *et al.*, 2018), there is limited evidence exploring the prevalence of hamstring strains and their intrinsic risk factors among hockey players in South Africa. Researchers have explored risk factors in other sporting codes, eg. soccer and Australian football, and a combination of risk factors has been suggested (Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013). As such, clinicians have generalised the findings to field hockey when doing pre-participation screening and determining return-to-sport criteria. In this research project, the prevalence of hamstring strains in field hockey is explored in the context of South Africa, as well as further insight into the intrinsic risk factors that can be identified through cost-effective screening tools.

1.3 Research question

What are the prevalence and intrinsic risks for hamstring strains among field hockey players at a hockey club in Pretoria, South Africa?

1.4 Aim

The aim was to investigate the prevalence and intrinsic risks for hamstring injuries among field hockey players at a hockey club in Pretoria, South Africa.

1.5 Objectives

The objectives were to determine:

- the demographic profile of the field hockey athletes;
- the prevalence of hamstring strains among the field hockey athletes;
- the intrinsic risks for hamstring strains among the field hockey athletes;
- the associations and differences between the demographics, injury history status and intrinsic risk factors for hamstring injuries among the field hockey players.

1.6 Significance of the study

The outcomes of this research could be used to assist clinicians to better implement pre-participation risk screening and make decisions regarding return to play post hamstring strain. The data can also be used to make suggestions for baseline measurements when using screening tools specifically among men and women hockey players of collegiate age. Ultimately, by exploring the relationship between field hockey and hamstring injuries, the existing knowledge for preventing hamstring injuries and re-injury among these athletes can be expanded, and in all likelihood possibly decrease the occurrence of hamstring strains all together.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This review attempts to summarise the current literature concerning hamstring strains and their associated intrinsic risk factors among field hockey players.

Using the key words, field hockey, hamstring injuries, prevalence, incidence and risk factors, the current literature was searched, employing the online databases of Pubmed, Google Scholar, PEDro, Cochrane Library and SPORTDiscus up to October 2019.

2.1.1 Background review

Hockey is a popular Olympic sporting activity, played worldwide in 137 countries (International Hockey Federation, 2020a), and also in South Africa at schools, universities, and at club and national levels (Ellapen *et al.*, 2011; Naicker, Coetzee and Schall, 2016; Barboza *et al.*, 2018). As part of the South African government's commitment to promote and professionalise sport in the country, field hockey was the focus during the 2015 - 2016 financial year for promoting financial support for the sport and its growth. At that time, there were 132 441 field hockey players in South Africa, compared to the more than 250 000 players in the Netherlands, the mere 80 000 in Germany, and the 37 000 players in Belgium (South African Government, 2016; Theilen *et al.*, 2016).

Field hockey is a male and female sport, and places various physical demands on the player such as running at high speeds, quick acceleration and deceleration, as well as direction changes (Lidor and Ziv, 2015). In order to manoeuvre the ball with a hockey stick, the field hockey player is prone to semi-crouched, prolonged hip flexion and asymmetrical postures (Ellapen, Bowyer and Van Heerden, 2014; Orooj, Nuhmani and Muaidi, 2016). These physical demands hold inherent implications for the musculoskeletal system which possibly place field hockey players at a high risk for non-contact injuries (Ellapen *et al.*, 2011; Naicker, Coetzee and Schall, 2016; Barboza *et al.*, 2018).

In a systematic review by Barboza *et al.* (2018), hockey injury rates were comparable to those of other sporting codes, with the lower limb documented as the common location of injury (13% - 77% of all injuries). This is in agreement with an earlier study (cross-sectional) on 158 female hockey athletes, where 51% of all injuries were to the lower limb (Murtaugh, 2001). In South Africa, the findings were similar. The lower extremity accounted for 86,2% of recorded musculoskeletal pain amongst female senior national players (Ellapen *et al.*, 2011), and 82% of injuries amongst female adolescent athletes (Ellapen, Bowyer and Van Heerden, 2014). Some of the most common injuries include ankle ligament sprains, hamstring strains, knee related injuries, contusions, as well as strains to the hip and groin muscles (Murtaugh, 2001; Naicker, Coetzee and Schall, 2016; Barboza *et al.*, 2018; Delfino Barboza *et al.*, 2018). Considering the rapid acceleration and deceleration so characteristic of field hockey, it seems possible that hamstring strains may also feature in these lower limb injuries, since hamstring strain injuries are generally associated with sports of this nature (Cross *et al.*, 2010; Freckleton and Pizzari, 2013).

The three muscles that are known together as the hamstrings are the semi-tendinosus, semi-membranosus, and biceps femoris. Together they span across two joints, influencing movements of the hip, as well as of the knee. Any of these three muscles could be injured acutely during a sporting activity, either as a direct contusion injury, or as an indirect strain injury (Petersen and Hölmich, 2005; Brukner *et al.*, 2014).

According to Brukner *et al.* (2014) and Petersen and Hölmich (2005), muscle strains or tears can be classified as the following:

- Grade I (mild) – only a few muscle fibres torn, with minimal swelling and localised pain, with slightly reduced muscle strength;
- Grade II (moderate) – several muscle fibres torn, swelling, pain with contraction of the muscle and decreased strength;
- Grade III (severe) – all muscle fibres are completely torn, with loss of function.

Diagnoses of hamstring strains are usually made on the basis of the history of injury, as well as of a physical assessment. However, magnetic resonance imaging (MRI) and ultrasound may also be helpful when there is doubt concerning the diagnosis (Petersen and Hölmich, 2005; Carlson, 2008; Prior, Guerin and Grimmer, 2009; Liu *et al.*, 2012). Most of the research into the prevalence or incidence rates of hamstring injury however, does not differentiate between the different degrees of strains. Such research also includes various descriptions of diagnosis and often uses time loss from a sporting activity as a way of capturing injury data (Cross *et al.*, 2010; Barboza *et al.*, 2018).

Therefore, to ensure a comprehensive overview of the burden of hamstring strains in the popular field hockey sport, all descriptions and levels of injury may need to be considered.

2.2 Prevalence and incidence rates of hamstring strains

Hamstring strains are of the most common musculoskeletal injuries seen in sport (Prior, Guerin and Grimmer, 2009; Cross *et al.*, 2010; Brukner *et al.*, 2014). As such, various research have explored hamstring strain prevalence among different sports and genders.

Cross *et al.* (2010) investigated hamstring strain incidence among collegiate sports over three years and found women's field hockey to be the only other sporting code with hamstring injury rates comparable to those for women's soccer (3.79 injuries per 10 000 athlete exposures). Although men had increased incidence of hamstring strain injuries all together, there were no injury data available for male field hockey players (Cross *et al.*, 2010). This was also the case in a similar study, where only female field hockey players were included, and reported 2.95 hamstring strain injuries per 10 000 exposures (Dalton, Kerr and Dompier, 2015).

Considering epidemiological studies of field hockey injuries only, increased rates of hamstring injuries are also emerging among both male and female players. Delfino Barboza *et al.* (2018) showed hamstring strain injuries as the most common acute injury sustained by Dutch elite players in that they account for 10% of injuries. Similarly, a cohort study from Germany observed incidence rates of injuries alike for both genders, with the most frequent type of injury being thigh muscle strains (Hollander *et al.*, 2018). In South Africa, hamstring strain injury was recorded among elite female players as the second-most common injury (12.6%) over one season after ankle injuries (16.1%) (Naicker, Coetzee and Schall, 2016).

Although hamstring strain injuries have been labelled less clearly in various other field hockey injury data, the inclusion of this type of injury in broader terms still suggests its prevalence. In an epidemiology study of collegiate female hockey injuries, the majority of practice injuries (26.9%) were recorded as upper thigh muscle-tendon strains, including but not restricted to hamstring strains (Dick *et al.*, 2007). Lynall *et al.* (2018) used comparable terms to describe a decade of female field hockey injuries in the USA among high school and collegiate players. The hip/thigh/upper leg was injured most often (23.6% among high school and 27.4% among collegiate players) and the most common diagnoses pointed to muscle/tendon strains (31.8% among high school and 29.7% among collegiate players) (Lynall *et al.*, 2018). Injury data captured during the 2013 International Field Hockey Federation tournaments grouped thigh injuries together with knee injuries, making direct comparisons between studies difficult. During these above-mentioned tournaments, thigh/knee related injuries were the most prevalent among male field hockey players (28% of injuries), whereas thigh/knee related injuries were reported as 12% of the injuries occurring among female players (Theilen *et al.*, 2016).

Furthermore, specific reporting on hamstring strains among hockey players in South Africa is lacking. While Naicker, Coetzee and Schall (2016) reported hamstring strain injuries as the second-most common injury occurring in female national athletes, Ellapen *et al.* (2011) reported only on musculoskeletal pain from a similar cohort. Pain in the thigh, and therefore not confined to the hamstring muscles, was found to be the fifth most common site of pain (Ellapen *et al.*, 2011), and might have included various diagnoses such as referred pain.

Another study investigated field hockey injuries amongst female adolescent players in KwaZulu-Natal, found knee injuries to be the most prevalent, with thigh injuries accounting for only three percent (3%) of all injuries (Ellapen, Bowyer and Van Heerden, 2014). No injury data were recorded for male field hockey players and there was an age gap between the participants of the above-mentioned studies (mean age 23.8, 23.7 and 15.4 respectively), making the extent of hamstring strain prevalence among South African field hockey players inconclusive (Ellapen *et al.*, 2011; Ellapen, Bowyer and Van Heerden, 2014; Naicker, Coetzee and Schall, 2016).

Although a high prevalence of hamstring strain injuries in field hockey has been found in other countries (Cross *et al.*, 2010; Delfino Barboza *et al.*, 2018), and further suggestions have been made in terms of various male and female field hockey injury data (Dick *et al.*, 2007; Theilen *et al.*, 2016; Hollander *et al.*, 2018; Lynall *et al.*, 2018), there is little to no evidence exploring the connection between hamstring strain prevalence and its predisposing risk factors within this sporting population.

2.3 Risk factors for hamstring strains

The identification of potential risks for any particular injury or sport plays an integral part in the prevention of injuries. Only once risk factors have been identified, can prevention programmes or strategies be implemented to mitigate the burden of injuries and re-occurrences (van Mechelen, Hlobil and Kemper, 1992).

Even though specific literature regarding contributing factors for hamstring strains among field hockey athletes is lacking, certain deductions can still be drawn from the available research among other sporting codes, and is discussed in the paragraphs to follow. Most of the available research investigating contributing factors for hamstring injuries were in the sporting codes of soccer, Australian football, and athletics (Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013). Although no single predisposing factor has been found to cause hamstring strains, a few have been suggested in combination or interaction with one another that would together heighten the risk of injuries (Foreman *et al.*, 2006; Goldman and Jones, 2010; Freckleton and Pizzari, 2013; Sugiura *et al.*, 2017). Traditionally, risk factors have been classified into two groups, namely the extrinsic (external) and intrinsic (internal) factors.

2.3.1 Extrinsic risk factors

Extrinsic risk factors generally relate to the training or playing environment (van Mechelen, Hlobil and Kemper, 1992; Brukner *et al.*, 2014). The extrinsic factors relating to hamstring strains have been suggested as inadequate warm-up, fatigue, type of activity (such as running), level of play and player position (Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013). With regard to field hockey, it has been proposed that the practice of playing on artificial turf has increased the overall speed that the game is played at, and thereby increased the risk of sustaining injuries (Naicker, Coetzee and Schall, 2016). Furthermore, midfielders have been reported to sustain injuries more frequently (Murtaugh, 2009; Barboza *et al.*, 2018). As the extrinsic risk factors fall out of the scope of interest of this study, the intrinsic risk factors are now looked at in greater depth.

2.3.2 Intrinsic risk factors

Intrinsic risk factors are those that relate to the individual athlete (van Mechelen, Hlobil and Kemper, 1992). Amongst the proposed intrinsic risks for hamstring strains, the player's age, previous injury history, and some measurement of strength have been the most consistently reported in the literature (Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009; Engebretsen *et al.*, 2010; Freckleton and Pizzari, 2013; Freckleton, Cook and Pizzari, 2014).

Injury risk appears to be considerably greater for Australian football players older than 23, with an even greater increase above the age of 25 (Orchard, 2001; Gabbe *et al.*, 2005; Prior, Guerin and Grimmer, 2009). Similar findings have also been reported among soccer players (Liu *et al.*, 2012). Although there were no field hockey studies available for inclusion in the systematic reviews that found age to be a contributing factor (Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013), the mechanism by which age contributes to risk may still be considered in field hockey. Gabbe *et al.* (2005) suggested age-related muscle changes, such as the reduction in size of the type II muscle fibres and denervation, which might lead to decreased muscle strength and thereby increase the susceptibility of the player to muscle injury. Other theories include longer exposure to other risks and the effect that age-related lumbar degeneration might have on nerve roots, influencing hamstring muscle function in terms of activation and coordination (Prior, Guerin and Grimmer, 2009).

Previously injured athletes in soccer and Australian football were shown to be two to six times more prone to sustain a recurrent injury (Prior, Guerin and Grimmer, 2009; Engebretsen *et al.*, 2010). This might possibly be due to their premature return to play, the residual presence of other risk factors, scar tissue formation or the inadequate rehabilitation of dynamic muscle strength, as in the case of eccentric muscle strength (Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009; Maniar *et al.*, 2016; Hickey *et al.*, 2017).

While decreased hamstring muscle strength has been implicated as a risk in various studies of multiple sporting codes, the variety of outcome measures used to measure strength makes conclusive comparisons between studies difficult. Systematic reviews by Foreman *et al.*, (2006) and Prior, Guerin and Grimmer (2009), found reduced hamstring strength compared to quadriceps strength and strength imbalances to be potential risk factors. However, the meta-analysis in a third systematic review by Freckleton and Pizzari (2013) did not support hamstring strength as a risk factor to that extent. In a later study, hamstring strength, measured in terms of functional capacity and incorporating endurance parameters, showed decreased values to be predictive of hamstring strains (Freckleton, Cook and Pizzari, 2014).

However, there were possible confounding variables and a low injury rate altogether (Freckleton, Cook and Pizzari, 2014).

Positive results have also been found with eccentric strength training as a preventative intervention (Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009), which correlates with the proposed mechanism of hamstring strains during sprinting. It has been suggested that hamstrings are most vulnerable to injury while sprinting, during the terminal swing phase, when the muscles require eccentric strength to counteract and decelerate hip flexion and knee extension (Croisier *et al.*, 2008; Schache *et al.*, 2009). Considering the nature of field hockey (high-speed running, with sudden deceleration), together with high rates of non-contact thigh injuries among field hockey players (Hollander *et al.*, 2018), strength as a risk factor to this population needs further exploration.

Other potential intrinsic risks for hamstring injuries are also emerging in research studies but the findings are still inconclusive. These intrinsic risk factors include ethnicity (Aboriginal and Afro-Caribbean descent), decreased hamstring flexibility, decreased quadriceps flexibility, increased quadriceps torque, decreased hip flexor flexibility, poor neuromuscular control, poor proprioception and decreased dorsiflexion lunge range of motion (Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013).

Sportsmen of Aboriginal descent and Afro-Caribbean origin sustained more hamstring strain injuries, which were theoretically attributed to these players having more type II muscle fibres and/or pronounced anterior pelvic tilts, thus influencing the length-tension relationship of the hamstring muscle (Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009). Similarly, with decreased hamstring flexibility, the possibility of less length change with force absorption might lead to failure of the hamstring muscle during the swing phase (Prior, Guerin and Grimmer, 2009; Cross *et al.*, 2010). On the other hand, decreased quadriceps flexibility and heightened quadriceps torque, as contributing factors for hamstring strains, support theories similar to those relating to hamstring weakness. Increased quadriceps torque and decreased quadriceps flexibility (where increased passive recoil of quadriceps follows on hip extension and knee flexion) contribute to the higher loads that the hamstring needs to withstand eccentrically before failure (Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009). Prolonged hip flexion postures, as in the case of field hockey players, may lead to decreased hip flexor flexibility and ultimately also influence the resting length-tension relationship of the hamstrings via pelvic positioning (Ellapen *et al.*, 2011).

In addition, adequate neuromuscular control is needed at the trunk, hip and pelvis to optimise function and prevent the suboptimal length-tension relationship of hamstring muscle that may make it vulnerable to injury (Prior, Guerin and Grimmer, 2009). Neuromuscular control however, requires proprioception for movement and joint position sense, and the coordination of muscular contraction to optimise positioning (Foreman *et al.*, 2006).

Decreased range of movement during the ankle lunge test was reported to be related to hamstring strains among Australian football players (Gabbe *et al.*, 2006). However, the exact mechanism by which ankle dorsiflexion range of motion may contribute to hamstring injury remains unclear and speculations point to it as an unknown indicator for other factors, such as poor proprioception or sprinting mechanics (Gabbe *et al.*, 2006).

According to the available literature, the sport-specific demands of field hockey appear to hold a close relation to the extrinsic and intrinsic factors for hamstring injuries. Although age, history of previous injury, and strength have been the only consistent intrinsic contributing factors for hamstring injuries thus far, the mechanism by which the other factors relating to hamstring strains are so inter-related that they deserve consideration in further investigations.

2.4 Hamstring screening and outcome measures

Once the risks for hamstring injuries have been found, pre-participation risk screening can be conducted as the first step in injury management in an attempt to prevent injury by eliminating or reducing the risks (van Mechelen, Hlobil and Kemper, 1992; Gabbe *et al.*, 2004). Unfortunately, there are currently no hamstring-specific screening tools validated for field hockey players, leaving clinicians to adopt outcome measures from general screening practices or other sporting codes (Dallinga, Benjaminse and Lemmink, 2012; Barboza *et al.*, 2018). Generally, pre-participation screening protocols involve some form of questionnaire to be completed by the player, as well as a physical examination, or a musculoskeletal assessment performed by a health care professional (Brukner *et al.*, 2014).

2.4.1 Questionnaire and Hamstring Outcome Score

From a pre-participation questionnaire, a medical team is able to discover certain risk factors associated with hamstring strains, such as warm-up habits, level of participation, player position and age (Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013). For example: if a player is older, he/she can be identified and offered additional hamstring injury prevention strategies[1]. Another risk factor that can be identified by means of a questionnaire is the previous hamstring strain history. Although there is the concern of recall bias with questionnaires, Gabbe *et al.* (2003) reported good validity in terms of the previous 12 months' injury status as to whether the injury had occurred or not, among Australian football players.

Furthermore, the Hamstring Outcome Score (HaOS) is a risk-screening tool/questionnaire that was developed to determine injury history and hamstring function under the subsections of "symptoms", "soreness", "pain", "function in daily living and sports", as well as "quality of life" (Engebretsen *et al.*, 2008). Each item under the subsections is scored from best to worst (0-4), and the total score can be calculated as the mean percentage of the five subsections (Engebretsen *et al.*, 2008). Although its own validity and reliability have not been assessed, the HaOS was developed from two previously shown valid and reliable outcome scores, the Foot and Ankle Outcome Score (FAOS) and the Knee Osteoarthritis Outcome Score (KOOS). In addition to ascertaining the hamstring injury history, the HaOS was also reported to be able to detect decreased hamstring function (less than 80% of the total score), that was associated with subsequent hamstring strain among male soccer athletes (Engebretsen *et al.*, 2008). The HaOS total score (p = 0.005) and scores of the four out of five subsections (p = 0.003-0.03) were reported as significant leg-dependent risk for hamstring strain (Engebretsen *et al.*, 2010).

To date, the HaOS is the only patient-reported outcome specific to hamstring risk screening (Reurink, Whiteley and Tol, 2015). However, to the author's knowledge, its use among field hockey players has not been documented.

[1] Such strategies will be discussed in Section 2.5.1.

2.4.2 Strength outcome measures

Although strength is frequently associated with hamstring strain risk, there is inconclusive evidence on the best outcome measure to use as a strength measurement during screening protocols (Freckleton and Pizzari, 2013). Given the lack of strength measures investigated among field hockey players, it would be sensible to explore the available outcome measures validated among other sporting codes before considering the most appropriate for hockey.

Perhaps one of the most studied and most common outcome measures is thigh muscle isokinetic assessment, using different parameters of angular velocities and/or contraction modes (Green, Bourne and Pizzari, 2018). While an earlier systematic review and meta-analysis by Freckleton and Pizzari (2013) found heightened quadriceps peak torque to be a contributing factor for hamstring strains, the meta-analysis in a more recent review (Green, Bourne and Pizzari, 2018) concluded that only isokinetic eccentric knee flexor strength, measured at a slow speed, to have limited predictive value for hamstring strains. Shortly after, Lee *et al.* (2018) supported decreased eccentric hamstring strength as a significant risk among professional soccer players. Contrary to the earlier systematic reviews (Freckleton and Pizzari, 2013; Green, Bourne and Pizzari, 2018), a lower hamstring to quadriceps strength ratio was also significantly related to hamstring strain risk (Lee *et al.*, 2018). Tokutake *et al.* (2018), on the other hand, reported no relationship between isokinetic strength measures and subsequent hamstring strains among track and field athletics. Evidently, additional research is required to confirm the predictive validity of isokinetic strength testing, but considering the time and costs involved with these tests, its practical use as a screening tool across different sporting codes and levels of participation is debatable (Green, Bourne and Pizzari, 2018; Lee *et al.*, 2018).

Other outcome measures for eccentric hamstring strength have also emerged as screening tools in recent years, but with inconsistent results. Given the positive results that the Nordic hamstring exercise (using hamstrings to eccentrically lower the upper body) have had on injury prevention, Engebretsen *et al.* (2010) investigated its usefulness as a screening tool. Visual assessment was used to determine the point of failure during the exercise; however, no association was found with subsequent hamstring strains (Engebretsen *et al.*, 2010). Subsequently, a device was developed to measure individual leg force production during the Nordic hamstring test, but its ability to predict the risk of hamstring strain remains inconclusive (Van Dyk *et al.*, 2017).

Individual studies have examined the usefulness of hand-held dynamometry and strength endurance tests as part of hamstring-screening protocols (Freckleton, Cook and Pizzari, 2014; Goossens *et al.*, 2015). While the majority of strength assessments measure peak torque as an outcome, the “single leg hamstring bridge test” (SLHB) includes endurance parameters to account for the role that fatigue might play as an injury risk for hamstring strains (Prior, Guerin and Grimmer, 2009; Freckleton, Cook and Pizzari, 2014). The SLHB is a reliable clinical test, and is measured in repetitions with <20 repetitions considered poor, 25 average and >30 good. Deficits in SLHB repetitions have been associated with hamstring strain injuries ($p = 0.029$) in Australian rules football players (Freckleton, Cook and Pizzari, 2014).

One risk factor study among South African field hockey players included a leg press (measuring the repetition maximum) as a measurement of strength. It was not associated with any injuries or risks for hamstring strain (Naicker, Coetzee and Schall, 2016).

Although there have been some positive results from isokinetic strength testing among other sporting codes, it may not be applicable for the on-field or clinical screening of large groups of athletes (Dallinga, Benjaminse and Lemmink, 2012; Green, Bourne and Pizzari, 2018). Barboza *et al.* (2018) further expressed the need for cost-effective prevention strategies specifically among the growing sport of field hockey. Therefore, the SLHB might be considered for further investigation among field hockey players for its easy, inexpensive implementation, reliability, and its association with hamstring strain injuries (Freckleton, Cook and Pizzari, 2014).

2.4.3 Flexibility and range of motion

Screening protocols adopted by clinicians working with field hockey players generally include flexibility and range of movement measurements as part of musculoskeletal testing (Dallinga, Benjaminse and Lemmink, 2012; Brukner *et al.*, 2014; Naicker, Coetzee and Schall, 2016).

Decreased hamstring flexibility explored as a risk for hamstring injury has been measured in different ways in the past, but with mixed results (Dallinga, Benjaminse and Lemmink, 2012). According to a systematic review and meta-analysis study, hamstring length, as measured using an “active knee extension test”, was not reported to be predictive of injury, although one study found an association with recurrent hamstring strains (Freckleton and Pizzari, 2013). Furthermore, another meta-analysis study concluded that there was no association between hamstring strains and length measurements using a “passive knee extension test” (Freckleton and Pizzari, 2013). Two other studies however, found soccer players with decreased hamstring length to be more likely to suffer a hamstring strain injury (Freckleton and Pizzari, 2013). One of the studies used pre-season video analysis, while the other used a “passive straight leg raise test”, assessing the point of maximal hip flexion with a goniometer to determine hamstring flexibility (Witvrouw *et al.*, 2003; Freckleton and Pizzari, 2013). Hip flexion of less than 90° was associated with subsequent hamstring strain injury ($p = 0.02$) (Witvrouw *et al.*, 2003).

The goniometer measurements with the “modified Thomas test” have also been used as common screening tools for hip flexor and quadriceps flexibility (Clapis, Davis and Davis, 2008). With the “modified Thomas test”, a hip flexion angle above the horizontal (thus greater than 0°) is considered to be an indication of decreased flexibility, and was found to be associated with subsequent hamstring injuries (Clapis, Davis and Davis, 2008; Freckleton and Pizzari, 2013). Decreased quadriceps flexibility (≤51° knee flexion angle) was found to increase the probability of getting hamstring strains ($p = 0.022$) among Australian football players (Gabbe *et al.*, 2005; Freckleton and Pizzari, 2013).

A single study found a heighted risk of sustaining hamstring injuries among athletes in Australian football with decreased range of motion in an ankle dorsiflexion lunge position (Gabbe *et al.*, 2006). The “ankle dorsiflexion lunge range of motion test” measures the maximal dorsiflexion achieved by the ankle joint in a weight-bearing position, and is captured as the distance between the big toe and a wall. A distance of ≤10cm was associated with subsequent hamstring strain injuries (relative risk = 2.23, 95% confidence interval 0.97-5.56, $p = 0.047$) (Gabbe *et al.*, 2006). Given the inclusion of this test in screening practices for other common field hockey injuries, such as ankle sprains (Dallinga, Benjaminse and Lemmink, 2012; Barboza *et al.*, 2018), the association between the “ankle dorsiflexion lunge range of motion test” and hamstring strains among field hockey players merits additional investigation.

2.4.4 Neuromuscular control and proprioception

Although neuromuscular control and proprioception have been associated with the prevention and rehabilitation of hamstring strains, screening for deficiencies in this domain remains challenging (Foreman *et al.*, 2006; Prior, Guerin and Grimmer, 2009; Shield and Bourne, 2018). A reason for this might be the range of factors that contributes to neuromuscular control and the difficulty of measuring such interactions with quantifiable tests (Foreman *et al.*, 2006). A few stability tests are available. However, their reliability in screening for poor neuromuscular control as a potential risk for hamstring injury has not been assessed (Shield and Bourne, 2018).

Considering the influence that prolonged hip flexion postures of field hockey players might have on lumbo-pelvic positioning, screening for dynamic postural stability and lower limb joint position sense may be considered (Ellapen *et al.*, 2011; Hollander *et al.*, 2018). The "Star Excursion Balance Test" (SEBT) is one such test used in research settings and clinical screening, and has proved to produce both reliable and valid results (Gribble, Hertel and Plisky, 2012; Gribble *et al.*, 2013). Basketball players with reach differences - left to right - were 2.5 times more prone to injuries of the lower limb ($p < 0.05$) (Dallinga, Benjaminse and Lemmink, 2012). The SEBT has also been used among field hockey players, but not in relation to the risk of hamstring strain injuries (Bhat and Moiz, 2013; Hoch *et al.*, 2017).

2.5 Management of hamstring strains

Literature regarding the current approach to the management of hamstring strains among field hockey players is lacking. Clinicians are therefore reliant on their general knowledge of muscle strain injuries and/or management strategies borrowed from other sporting codes for prevention, treatment and rehabilitation guidelines.

2.5.1 Prevention

Owing to the nature of hamstring strains being multi-factorial, the prevention of such an injury remains difficult, and there is insufficient evidence pointing to a single preventative intervention (Prior, Guerin and Grimmer, 2009; Goldman and Jones, 2010). As discussed in the preceding paragraphs, screening for potential risk factors forms part of hamstring injury prevention in that it identifies the risk factors that could possibly be modified (van Mechelen, Hlobil and Kemper, 1992; Gabbe *et al.*, 2004). Ideally, an individualised intervention can then be tailored to the player's specific risk profile (Goldman and Jones, 2010).

However, given the time and resource requirements of individualised interventions, field hockey players might resort to general prevention programmes (Barboza *et al.*, 2018). Recently, in an attempt to reduce lower limb injuries in general, a preventative intervention programme in the Netherlands was developed specifically for field hockey players (Gouttebarge and Zuidema, 2018). The programme is age and gender-specific and consists of a 12-minute warm-up to be performed biweekly. It includes aspects of agility, flexibility, stability, strength and speed in field hockey situations (Gouttebarge and Zuidema, 2018). Barboza *et al.* (2019) investigated its effectiveness in reducing injury rates among young field hockey players in a quasi-experimental study; however, the injury rates proved to be similar in the control and intervention groups. Although fewer acute injuries occurred in the intervention group, the researchers did not capture injury diagnoses, thus leaving the applicability of this programme in hamstring injury prevention unclear (Barboza *et al.*, 2019).

Studies investigating eccentric knee flexor strengthening programmes among other sporting codes have had positive findings and have therefore been widely accepted as significant components in hamstring injury prevention (Prior, Guerin and Grimmer, 2009; Hickey *et al.*, 2017). Single studies, on the other hand, found thermal pants and manual therapy effective in lowering the occurrence of hamstring injuries. However, these findings were neither significant nor conclusive (Upton, Noakes and Juritz, 1996; Prior, Guerin and Grimmer, 2009; Goldman and Jones, 2010). In addition, Sugiura *et al.* (2017) found a decline in occurrences of hamstring strains among sprinters when agility and flexibility exercises were combined with a preventative strengthening programme. Since agility tests have been found to correlate with subsequent non-contact injuries in amateur field hockey players, agility as part of hamstring prevention strategies in this population justifies further consideration (Liu, Sassi and Thierie, 2016; Gouttebarge and Zuidema, 2018).

2.5.2 Treatment and rehabilitation

The acute treatment of hamstring strains follows the same treatment principles as for any muscle injury and is no different among field hockey players. The initial treatment and subsequent rehabilitation should be guided by the phases of muscle healing (Figure 2.1) (Hoskins and Pollard, 2005; Brukner *et al.*, 2014). During the acute stages, field hockey players can be advised to follow the regime of PRICE ("protection, rest, ice, compression and elevation") that is commonly used in practice (Brukner *et al.*, 2014; Hotfiel *et al.*, 2018).

Using non-steroidal anti-inflammatory drugs remains controversial and, according to expert opinion, should not generally be resorted to (Erickson and Sherry, 2017; Hotfiel *et al.*, 2018).

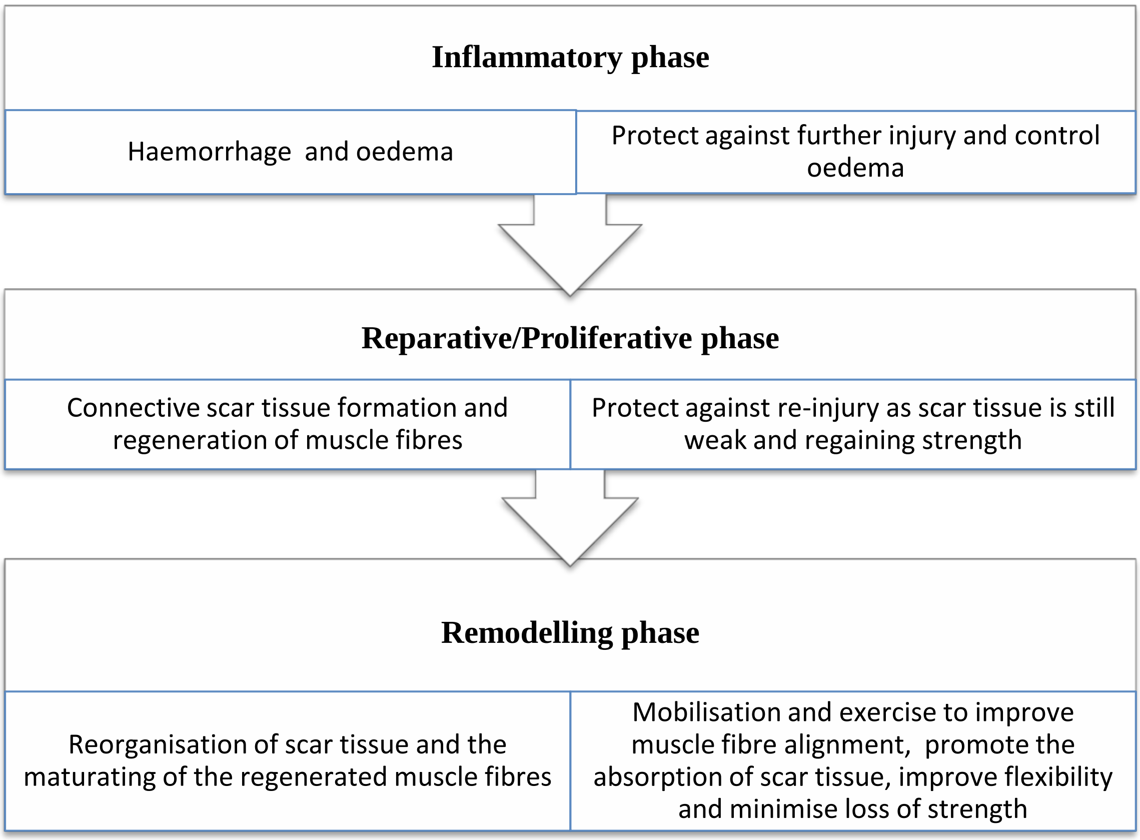


Figure 2.1: Phases of muscle healing

Since the phases of healing overlap, the progression of treatment and rehabilitation should be based on individual requirements (Petersen and Hölmich, 2005; Hickey *et al.*, 2017). Although only a few randomised controlled studies have investigated different rehabilitation protocols, the use of early, pain-free muscle activation and mobility exercises has generally been reported (Sherry and Best, 2004; Brukner *et al.*, 2014). In fact, a systematic review study of the rehabilitation guides following hamstring strain injuries determined that the alleviation of pain before progression is a common practice although this criterion is lacking in supportive empirical evidence (Hickey *et al.*, 2017).

While the early components of treatment and rehabilitation are based on the physiological restoration of muscle function, they are not sport specific. Mainly based on theoretical principles, these components should, according to expert opinion, include elements of stretching, neural mobilisation, soft tissue therapy, strengthening and neuromuscular control exercises (Brukner *et al.*, 2014; Erickson and Sherry, 2017).

In addition, holistic therapies, such as spinal mobilisation and cross-training activities to maintain fitness, have been suggested (Brukner *et al.* 2014; Petersen and Hölmich 2005). Positive results have also been found with the inclusion of a functional rehabilitation programme among participants from various sports (Sherry and Best, 2004). Although hockey was poorly represented, rehabilitation in this respect included progressive agility exercises and exercises for trunk stability that correlate with the sport-specific physical demands of field hockey players as discussed previously (Sherry and Best, 2004; Liu, Sassi and Thierie, 2016; Gouttebarge and Zuidema, 2018).

2.5.3 Return to play

Returning the field hockey player to sport has proven to be a difficult final phase in hamstring strain management (Croisier, 2004; Askling, Nilsson and Thorstensson, 2010; Brukner *et al.*, 2014). As frequently seen with hamstring strains, subjecting the athlete to the intensity of sport-specific activities too soon might lead to recurrent injuries (Sherry and Best, 2004; Brooks, 2006).

A systematic review concluded that the most common criteria for return to sport are based on an athlete's pain perception during the assessments or performance tests, and the clinician's interpretation thereof (Hickey *et al.*, 2017). Across the nine studies, the majority of participants were soccer players, Australian football players, and track and field athletics, while the rest did not report on specific sporting codes (Hickey *et al.*, 2017). Clinical assessments to guide return to play incorporated aspects such as normalisation or the optimisation of strength and flexibility (Brukner *et al.*, 2014; Hickey *et al.*, 2017). These aspects also correlate with the known risks for hamstring strains and are therefore deemed logical indicators of re-injury risks at the time of return to play (Erickson and Sherry, 2017; Hickey *et al.*, 2017). However, the subjectivity of these tests and the lack of normative values for field hockey players in relation to the risks of hamstring injuries, leave the clinician without a strong evidence base for decision making.

Performance tests might not directly relate to known injury risks, but the absence of hamstring strain symptoms during these tests has also been used as a factor to determine whether a player is ready to return to play (Hickey *et al.*, 2017). Such performance tests generally include running, accelerating to full speed, directional changes and sport-specific tasks without the presence of pain or stiffness (Orchard, Best and Verrall, 2005; Brukner *et al.*, 2014; Hickey *et al.*, 2017). Considering the nature of field hockey, performance tests to include aspects of agility and neuromuscular control or stability measures should then also be incorporated (Sherry and Best, 2004; Liu, Sassi and Thierie, 2016; Gouttebarge and Zuidema, 2018).

Additional objective measurements such as isokinetic dynamometry and magnetic resonance imaging to assist prognosis in rehabilitation planning have also been suggested, but the cost-effectiveness and value of these techniques in deciding on the actual time for return to play have yet to be supported (Orchard, Best and Verrall, 2005; Carlson, 2008; Hickey *et al.*, 2017). The Askling H-test on the other hand is a reliable active hamstring flexibility test associated with lower re-injury rates - as long as it is combined with clinical assessment (Askling, Nilsson and Thorstensson, 2010; Hickey *et al.*, 2017). The test relies on the patient's willingness to perform an active straight leg raise to end range and thereby dynamically stretching the hamstring muscle without pain or apprehension (Askling, Nilsson and Thorstensson, 2010). However, before the Askling H-test can be implemented as part of the return-to-sport criteria in a wider population of sporting codes, including amongst others, field hockey, further validation is needed (Hickey *et al.*, 2017).

Evidently, the current approach to hamstring strain management among field hockey players is based mainly on theoretical knowledge and anecdotal literature. Treatment, rehabilitation and the decision to return an athlete to sport is highly dependent on the attending therapist's clinical reasoning in terms of risk management or reduction strategies, and is not necessarily specific to any sporting code (Orchard, Best and Verrall, 2005).

2.6 Conclusion

The burden and multi-factorial nature of hamstring strain injuries have been well documented in sports and further only suggested in the domain of field hockey. Although a high prevalence of hamstring strains has been found among field hockey players in other countries, the majority included only female players. Furthermore, in South Africa, there is a lack of injury data available for male hockey athletes, as well as for players between the ages of 16 and 22. The intrinsic risk factors for hamstring strains explored in other sporting codes appear to be closely related to the sport-specific demands of field hockey. However, there are no studies to date which have explored the specific intrinsic risks as they relate to pre-participation screening, preventative measures, management programmes and return to sport among hockey athletes. In order to improve the management of hamstring strains in this population, the sport-specific relationship between hamstring strain prevalence and its intrinsic risk factors needs to be determined.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter discusses the study design, setting, population and sample selection process. The outcome measures are presented, together with the reliability and validity of each test, while a description of the data collection procedures and the ethical matters that were considered in the process follows. Together with the statistical tests that were used, the data capturing and analytical process are also explained.

3.2 Study design

This study was cross-sectional in nature and followed a single method, quantitative design. A quantitative study design was chosen in order to use empirical data collected by means of valid and reliable testing, to describe the prevalence of hamstring injuries and its intrinsic risk factors. By using empirical investigation, it was possible to use statistical analysis to describe the differences and associations between demographics, injury history and intrinsic risk factors. In addition, this study concerned field hockey players of a particular club at one point in time. Therefore, in order to answer the research question, a cross-sectional, quantitative design was chosen.

3.3 Research setting

This research was conducted at the clubhouse and training facilities of the field hockey club at the University of Pretoria. The data collection process was conducted indoors, at the physiotherapy unit, and in a separate room with sufficient floor space without external distractions. The room was equipped with a table and chair for completion of a questionnaire, as well as a plinth, exercise mat and a 60cm-high wooden box for the musculoskeletal screening of the intrinsic contributing factors for hamstring injuries.

3.4 Population and sample

The population comprised of 40 registered high-performance hockey athletes recruited from the hockey club based at the University of Pretoria. A convenient sampling method was used. According to the Raosoft sampling tool (http://www.raosoft.com/samplesize.html), with a confidence level of 95% and a marginal error of five percent (5%), a sample of 37 participants was considered for this study. Male and female hockey athletes were recruited.

Thirty three field hockey athletes volunteered to take part in this research project. The inclusion and exclusion criteria were as follows:

Inclusion criteria

- Registered members of the University of Pretoria's field hockey club
- Required to have had experience in playing field hockey for at least one season (8 months)

Exclusion criteria

- Players younger than 18 years of age
- Players with a current disabling injury (other than hamstring injury) that would prevent them from participating in musculoskeletal testing

3.5 Outcome measures

3.5.1 Questionnaire

The first two objectives of the study were achieved through a two-part questionnaire. Section A of the questionnaire was formulated by the researcher who based it on the content of various literature sources (Gabbe, Bennell and Finch, 2006; Engebretsen *et al.*, 2010; Freckleton, Cook and Pizzari, 2014; Delfino Barboza *et al.*, 2018). It was used to determine the demographics of the athletes, the hamstring strain prevalence, as well as the participants' injury history in general (Appendix A). To ensure its content validity, Section A was sent to five experts for face and content validity. Section B was a hamstring-injury screening questionnaire, the Hamstring Outcome Score (HaOS), that was developed by Engebretsen *et al.* (2008). This section was aimed at collecting data regarding previous hamstring strains and hamstring function under the subsections of "symptoms", "soreness", "pain", "function in daily living and sports", as well as "quality of life" (Appendix B).

The HaOS, as discussed in the literature review (Chapter 2.4.1), was developed from two valid and reliable outcome scores, however its own validity and reliability had not been assessed. The HaOS was selected for this study as it is the only patient-reported outcome specific to hamstring injury and its typical symptoms (Engebretsen *et al.*, 2008; Reurink, Whiteley and Tol, 2015). It also shown to be successful in identifying the history of specific hamstring strains in male soccer players that placed them at heightened risk of further strains (Engebretsen *et al.*, 2008). Gabbe *et al.* (2003) supports the validity of a self-report questionnaire to determine the presence of a previous injury.

Although the HaOS's association with hamstring strain risk was determined among male soccer athletes (Engebretsen *et al.*, 2008, 2010), the items under each subsection could still be considered applicable to field hockey and its sport-specific demands (accelerating, braking speed, direction changes while running). Each item could be scored from best to worst (0-4) for the left and right legs independently, followed by a calculation of the percentage for each subsection. The total score could then be calculated as the mean percentage of the five subsections (Appendix B). A total score of less than 80% was considered as decreased hamstring function and high risk for injuries (Engebretsen *et al.*, 2008).

3.5.2 Musculoskeletal tests

Musculoskeletal tests aimed at identifying the intrinsic risks were selected based on the potential intrinsic risks found in the literature (Chapter 2.3.2 and 2.4). The following outcome measures were used:

"Single Leg Hamstring Bridge" (SLHB)

The SLHB test for hamstring strength has been reported to have a low predictive validity for hamstring strains among Australian football athletes (Freckleton, Cook and Pizzari, 2014). Although poor scores on the SLHB test were significantly associated with subsequent injury (p = 0.029), the authors highlighted age and previous injury as confounders (Freckleton, Cook and Pizzari, 2014). Hallet (as cited in Freckleton, Cook and Pizzari, 2014) found this test reliable (inter-tester intraclass correlation coefficient [ICC] = 0.89-0.91; intra-tester ICC = 0.77-0.89;). The SLHB test is measured in repetitions, where less than 20 repetitions are considered poor, 25 average and greater than 30 good (Freckleton, Cook and Pizzari, 2014).

"Modified Thomas Test"

The "modified Thomas test" for flexibility of the hip flexors and knee extensors was used as described by Harvey (1998), with a test-retest of 0.91-0.94, and an inter-tester of 0.90-0.92, as reported by Gabbe *et al.* (2004). Decreased flexibility and thereby a high risk of hamstring strain injury were considered if the hip flexion angle was above the horizontal (>0°) and/or the knee flexion angle was below or equal to 51° (Gabbe *et al.*, 2005; Clapis, Davis and Davis, 2008; Freckleton and Pizzari, 2013).

"Passive Straight Leg Raise"

A "passive straight leg raise" to determine hamstring flexibility (mean correlation coefficient = 0.97) (Lombard, 2004) was used. Decreased muscle flexibility as a contributing factor for hamstring strains was considered with hip flexion angles of less than 90° (Witvrouw *et al.*, 2003).

"Ankle Dorsiflexion Lunge Range of Motion"

The "ankle dorsiflexion lunge range of motion test" has been demonstrated to be a reliable measurement method (inter-tester = 0.96, intra-tester = 0.98) (Dennis *et al.*, 2008). A high risk for hamstring strain injury was captured for distances ≤10cm, a moderate risk for distances of 10.1cm to 13.9cm, and a low risk for distances of ≥14cm (Gabbe *et al.*, 2006).

"Star Excursion Balance Test" (SEBT)

According to a systematic review conducted by Gribble, Hertel and Plisky (2012), the SEBT was reported valid and reliable (test-retest ICC = 0.84-0.92) to screen for dynamic postural control deficits and to relate to lower extremity injury risk. Furthermore, Gribble *et al.* (2013) determined an inter-tester ICC of 0.86 to 0.94. Initially, the SEBT consisted of eight reach directions, but later, because of redundancy, recommendations were made for only three reach directions (Gribble, Hertel and Plisky, 2012). Inter-rater reliability values for anterior direction (ICC = 0.88), posterior-medial direction (ICC = 0.89) and posterior-lateral direction (ICC = 0.86) reach were also established (Stiffler *et al.*, 2015). An anterior reach difference of more than four centimetres (cm) right to left was categorised as posing a high risk for injury (Gribble, Hertel and Plisky, 2012). "Anterior, posterior-medial and posterior-lateral" reach distances were also normalised as a percentage of body height (Gribble, Hertel and Plisky, 2012).

3.6 Data collection procedure

3.6.1 Pilot study

A pilot study was carried out among five participants in order for the researcher to familiarise herself with the procedures and to determine whether participants experienced any problems with the questionnaire or the musculoskeletal tests. No changes to the data collection instruments and procedures were required following the pilot study. Therefore, the data collected during the pilot study were then included as part of the main study.

3.6.2 Main study

An appropriate time for data collection during the training sessions was arranged in advance with the club managers and coaches. Contact was made with the potential participants in person during the respective team meetings and by means of electronic invitations through the club's administrative personnel. Additional invitational posters were also pinned up at the training facilities. Potential participants were given information regarding the study which also explained the procedure, requested their participation (Appendix C), and their voluntary consent (Appendix D). Arrangements were made with potential participants on an appointment basis for data collection before the training sessions. Data collection per team was conducted over the course of two weeks, to limit vast conditioning changes among the participants. To limit other confounding variables, all testing was done in the afternoon in a closed-off space (physiotherapy unit) at the club's facilities, before training at the beginning of the field hockey season.

During the arranged appointment time, the voluntary consent of the participants was obtained and after being assigned a study number, each participant completed the questionnaire on which the corresponding study number was indicated. Clarification was offered if needed. The completed questionnaire was then placed by the participant in a sealed box, so that, to avoid bias, the researcher would be blinded to the injury history until after the data collection process had been completed.

The participant then did warm-up for five minutes, with 20 seconds' rest between tasks, as follows:

- Walking on toes for one minute, at own pace;
- Lifting knees to chest, alternating between each leg for one minute;

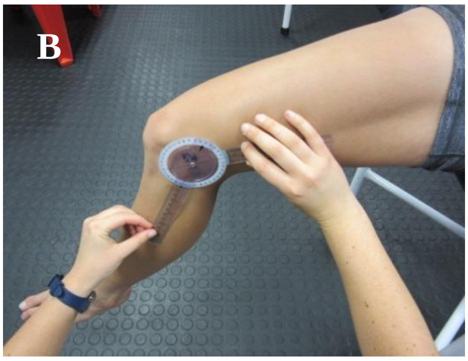
- Bending knees (butt kicks), alternating between each leg for one minute;
- Swinging legs forward and back, 30 seconds with the left leg and 30 seconds with the right.

To ensure consistency, the musculoskeletal screening tests were conducted by the researcher in the following order: the “single leg hamstring bridge test” (Figure 3.1), “modified Thomas test” (Figure 3.2), “passive straight leg raise” (Figure 3.3), “ankle dorsiflexion lunge range of motion” (Figure 3.4), and “Star Excursion Balance Test” (Figure 3.5). Measurements were recorded for both the left and the right sides (Appendix E).

Participants were also informed in advance that a stretch sensation during muscle length testing and mild exertion from the strength test might be experienced. For that reason, the warm-up exercises were done prior to testing to reduce discomfort. Testing was terminated if pain was experienced and the participant was able to pull out from the testing at any given point. The results of the musculoskeletal tests were made available to the participants on request.

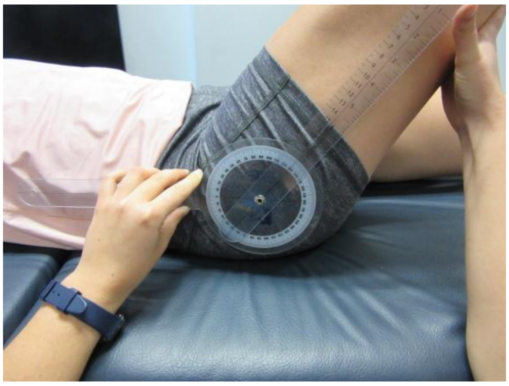
	The participant lies on his/her back with his/her foot on a 60cm surface and holding his/her knee held in about 20° flexion. The non-working leg is lifted and held motionless. The participant is then asked to lift the hips to 0° hip extension and to do as many repetitions as possible until failure after one warning. The maximum number of repetitions is recorded for the left and the right.

Figure 3.1: The single leg hamstring bridge



The participant is asked to sit on the edge of a plinth and to then roll back, holding both his/her knees close to the chest. The non-testing leg is held in maximal hip flexion by the participant, while the leg being tested is passively let down towards the floor. For measuring the flexibility of the hip flexors, the angle of the hip is measured with a goniometer (A), while the knee range of motion is assessed to determine flexibility of the quadriceps (B).

Figure 3.2: The modified Thomas test

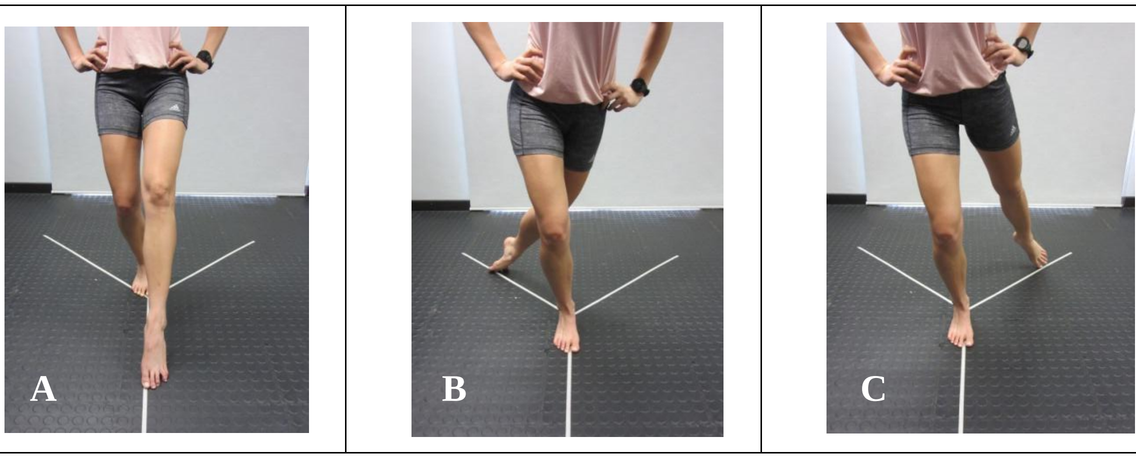


The participant lies supine while the tester lifts the side being tested passively, with an extended knee. When the point of maximal hip flexion is reached, without compensatory knee flexion or posterior pelvic tilt, the hip flexion angle is measured with a goniometer.

Figure 3.3: Passive straight leg raise

The participant stands facing a wall. The examiner holds his/her heel down while the participant does the forward lunge until his/her kneecap reaches the wall. The maximal distance that is reachable is then recorded with a tape measure from the big toe to the wall.

Figure 3.4: Ankle dorsiflexion lunge range of motion



The participant stands on one leg and reaches forward with the opposite leg along an anterior line to lightly reach the floor with his/her most distal part of the reaching foot (A). The movement is repeated four times while maintaining balance and without shifting the stationary foot. The maximal distance is measured and then also repeated in a posterior-lateral (B) and a posterior-medial (C) direction in relation to the stationary leg.

Figure 3.5: Star Excursion Balance Test

3.7 Data analysis

Subsequent to the data collection process, the data was captured into Microsoft Office Excel 2007 and later transferred into SPSS software version 25.0. Table 3.1 provides details of the tests used that analysed the data according to the type of data and the respective variables.

Descriptive statistic tests (frequencies, mean and standard deviations) were run first to report on the demographics and hamstring strain prevalence, followed by an analysis of the inferential statistics for the purpose of comparison and exploring associations. As determined by previous literature sources concerning other sporting codes, the results from the musculoskeletal tests were categorised and coded according to the respective level of risk associated with hamstring strain injury. Since the cut-off values for these tests were determined among other sporting codes, with none concerning field hockey players, the results from the musculoskeletal tests were also captured as continuous data and used for inferential statistical purposes (Independent-measures t-test). The *p-value* of $p \leq 0.05$ was set for significance.

TABLE 3.1 Summary of data analysis

Objectives	**Variables**	**Type of data**	**Statistical test**
Demographic profile	Independent variables: • age, weight, height, BMI • gender, leg dominance, race	• continuous data • categorical data	Descriptive, including the calculation of frequencies, means and standard deviations
Prevalence of hamstring injury	Dependent variable: injury history	Categorical data	Descriptive, including the calculation of frequencies
Intrinsic risk factors	Independent variables: hamstring strength, flexibility of hip flexors, flexibility of quadriceps, flexibility of hamstrings, ankle range of movement, neuromuscular lower limb control, and hamstring function score	Categorical and continuous data	Descriptive statistics, including the calculation of frequencies
Comparison and association between demographics, injury history and risk factors	• age, weight, height, BMI, intrinsic risk factors and injury history (previously injured group and uninjured group) • gender, leg dominance, race and injury history	• continuous and categorical data • categorical data	Inferential statistics, including the Independent-measures t-test (between continuous and categorical with two groups) and the Chi-square test (for categorical data)

3.8 Ethical considerations

The ethical matters that were observed are as follows:

- Ethical clearance (M180277) was provided by the University of the Witwatersrand (the Human Research Ethics Committee [Medical]) prior to data collection (Appendix F).
- Permission was also requested from and given by TuksSport at the University of Pretoria to approach their hockey athletes and for the use of their premises for conducting the study (Appendix G).
- Potential participants were given an information document to inform them of the nature of the study (Appendix C) before they gave their written voluntary consent (Appendix D).
- Upon granting their voluntary consent, participants were assigned a study number that reflected on both their questionnaire and musculoskeletal test form to ensure confidentiality.
- Testing did not interfere with normal training and lasted around 30 minutes per participant.
- The warm-up prior to testing was done to reduce discomfort from muscle length and strength testing. Testing was terminated if pain was experienced and the participants were able to withdraw from the study at any given point.
- No remuneration was given for participation in this study.
- Records were handled by the researcher alone and kept separately to keep the information confidential and the interviewee anonymous.

CHAPTER 4: RESULTS

4.1 Introduction

This chapter provide report on findings from the data collected with the two-part questionnaire and musculoskeletal tests, as described in the previous chapter. The descriptive results are given as frequencies, means and standard deviations (SD) in the relevant tables. Statistically-significant ($p \leq 0.05$) associations were determined by means of the Chi-square test and the Independent-measures t-test where continuous data were compared between previously injured and non injured players.

4.2 Demographic profile of participants

The response rate for this study was 89%. Only 33 of the 37 field hockey players participated in this study because four did not show up for testing and were unable to reschedule an appointment time within the data collection period because of tests or class schedules. None of the players withdrew from the study during the data collection process.

Fifteen (45.5%) of the participants were males and 18 (54.5%) females. The majority of the participants were white (24, 72%), right-leg dominant (30, 90.9%), with a mean age of 19.3 (SD ±1.43), weight of 66.82kg (SD ±8.65), height of 1.71m (SD ±0.09), and a mean body mass index of 22.78kg/m^2 (SD ±2.21). Most of the participants were defenders (12, 36.4%), competed at either provincial (16, 48.5%) or national level (15, 45.5%), and had 11.09 years (SD ±2.49) of field hockey experience. Only one participant competed in another sporting code (athletics) at a higher level than field hockey. A summary of the demographics can be found in Table 4.1.

TABLE 4.1: Demographic profile of field hockey players. Continuous data are presented as means and standard deviations. Categorical data are presented as the number of players and percentage of total players.

Variable	Categories	All (n=33)	Male (n=15)	Female (n=18)
Age (years)	-	19.30 (±1.43)	19.40 (±1.45)	19.22 (±1.44)
Race	Black	5 (15.2)	1 (6.7)	4 (22.2)
	Coloured	4 (12.1)	1 (6.7)	3 (16.7)
	White	24 (72.7)	13 (86.7)	11 (61.1)
Weight (kg)	-	66.82 (±8.65)	73.53 (±5.30)	61.22 (±6.68)
Height (m)	-	1.71 (±0.09)	1.78 (±0.06)	1.66 (±0.06)
Body mass index (kg/m^2)	-	22.78 (±2.21)	23.37 (±2.31)	22.29 (±2.06)
Leg dominance	Right	30 (90.9)	13 (86.7)	17 (94.4)
	Left	3 (9.1)	2 (13.3)	1 (5.6)
Field hockey experience (years)	-	11.09 (±2.49)	10.53 (±2.10)	11.56 (±2.75)
Level of field hockey participation	Club	2 (6.1)	-	2 (11.1)
	Provincial	16 (48.5)	7 (46.7)	9 (50.0)
	National	15 (45.5)	8 (53.3)	7 (38.9)
Player position	Forwards	5 (15.2)	1 (6.7)	4 (22.2)
	Midfielders	6 (18.2)	4 (26.7)	2 (11.1)
	Defenders	12 (36.4)	7 (46.7)	5 (27.8)
	Goalkeepers	2 (6.1)	2 (13.3)	-
	Multiple positions	8 (24.2)	1 (6.7)	7 (38.9)

4.3 Prevalence of hamstring strain injuries

None of the participants suffered from a hamstring strain at the time the data was being collected. However, 15 (45.5%) participants presented with a past history of acute strains, 11 (33.3%) of which had been sustained within the last two years and four (12.1%) more than two years ago. Six males (18.2%) and nine females (27.3%) had histories of acute strains. Half of all females had a past history of acute hamstring strains (Table 4.2). Nine (27.3%) participants presented with a past history of multiple strains, either on the same side, the other side, or bilaterally. A total number of 41 acute hamstring strains was reported by participants and these were virtually equally distributed between males and females.

TABLE 4.2: Prevalence of hamstring strain history (n = 33)

	History of acute hamstring strains Participants (%)	**No history of acute hamstring strains** Participants (%)
Male	6 (18.2)	9 (27.3)
Female	9 (27.3)	9 (27.3)
Total	15 (45.5)	18 (54.5)

4.4 Demographic profile and hamstring strain injuries

The inferential statistics for demographic profile and history of acute hamstring strains emerging from the Chi-square test and Independent-measures t-test are presented in Table 4.3. Neither gender (p = 0.566), age (p = 0.711), ethnicity (p = 0.627), nor level of play (p = 0.848), was strongly associated with the history of hamstring strain injury. Similarly, no statistically significant differences were found between other demographic factors in those with a history of hamstring strain injury and those with no history of hamstring strain injury.

TABLE 4.3: Hamstring strain history and demographic profile (n = 33)

Demographics	Categories	History of acute hamstring strains			p^*
		Frequency (n)	Percentage (%)	Mean (±SD)	
Gender	Male	6	18.2	-	0.566†
	Female	9	27.3	-	
Age (years)	-	-	-	19.2 (1.1)	0.711††
Race	Black	2	6.1	-	0.627†
	Coloured	1	3.0	-	
	White	12	36.4	-	
Weight (kg)	-	-	-	65.6 (9.2)	0.469††
Height (m)	-	-	-	1.7 (0.1)	0.492††
Body mass index (kg/m^2)	-	-	-	22.7 (2.5)	0.828††
Leg dominance	Left	1	3.0	-	0.658†
	Right	14	42.4	-	
Field hockey experience (years)	-	-	-	11.3 (2.5)	0.618††
Level of field hockey participation	Club	1	3.0	-	0.848†
	Provincial	8	24.2	-	
	National	6	18.2	-	
Player position	Forwards	3	9.1	-	0.624†
	Midfielders	1	3.0	-	
	Defenders	6	18.2	-	
	Goalkeepers	1	3.0	-	
	Multiple positions	4	12.1	-	

**p-value* represents result of history of hamstring strains versus no history of hamstring strains
† Chi-square test
†† Independent-measures t-test

4.5 Hamstring Outcome Score (HaOS) and musculoskeletal tests

The descriptive results of the Hamstring Outcome Score and the musculoskeletal tests are presented first. They are followed by the inferential statistical results (Independent-measures t-test) in terms of the history of hamstring strain injury.

4.5.1 Descriptive results of associated risks

A descriptive summary of the intrinsic risks among participants can be found in Table 4.4. Cut-off values for the respective screening tests found in the literature concerning other sporting codes associated with hamstring strain injuries were used to categorise the results according to risk of injury (see Chapter 3.5.2).

Decreased hamstring function (<80% total HaOS) was recorded by 16 (48.5%) participants on the left leg, and 17 (51.5%) participants on the right. In summary, as determined by the HaOS, 33 of the 66 limbs (50%) presented with an increased risk for hamstring strains.

The majority of participants presented with decreased hamstring strength (left = 28, 84%; right = 29, 87.9%), as well as decreased hamstring flexibility (left = 25, 75.8%; right 25, 75.8%), both of which factors would place them at high risk for hamstring strain injuries. Decreased hip flexor flexibility was found among 16 (48.5%) participants on the left leg, and among 13 (39.4%) participants on the right. Nineteen (57.6%) and 17 (51.5%) participants presented with ankle dorsiflexion lunge range of motion measurements on the left and right legs respectively that would place them at moderate risk for injury. According to the SEBT, only four (12.1%) participants presented with dynamic lower limb postural control deficits that would make them vulnerable to injury.

TABLE 4.4: Intrinsic risk factors associated with hamstring strains among field hockey players (n=33)

Test	Risk categories	Left n (%)	Right n (%)
Hamstring Outcome Score	High risk: <80%	16 (48.5)	17 (51.5)
	Low risk: >80%	17 (51.5)	16 (48.5)
Single Leg Hamstring Bridge	High risk: <20 repetitions	28 (84.8)	29 (87.9)
	Moderate risk: 20-30 repetitions	5 (15.2)	4 (12.1)
	Low risk: >30 repetitions	-	-
Modified Thomas Test			
Hip Flexor Flexibility	High risk: > 0° hip flexion	16 (48.5)	13 (39.4)
Quadriceps Flexibility	High risk: ≤ 51° knee flexion	6 (18.2)	12 (36.4)
Passive Straight Leg Raise	High risk: <90° hip flexion	25 (75.8)	25 (75.8)
	Low risk: >90° hip flexion	8 (24.2)	8 (24.2)
Ankle Dorsiflexion Lunge ROM	Low risk: ≥ 14cm	10 (30.3)	12 (36.4)
	Moderate risk: 10.1-13.9cm	19 (57.6)	17 (51.5)
	High risk: ≤ 10cm	4 (12.1)	4 (12.1)
Star Excursion Balance Test	High risk: Anterior reach difference >4cm right to left	-	4 (12.1)

4.5.2 Hamstring strain history and associated risk factors

To eliminate the risks involved by generalising the normative data from other sporting codes that was used to determine the risk categories, continuous data was used for inferential statistics to allow for specific trends to emerge from field hockey data.

Participants with a past history of left hamstring strains were likely to score low on the total HaOS on the left leg (65.3 ±16.9; p = 0.006) and on the right (66.9 ±18.5; p = 0.028) (Table 4.5). Participants with a history of right hamstring strains were also likely to record low total HaOS on the right leg (68.8 ±16.7; p = 0.068), but less likely to score low on the left (72.5 ±20.7; p = 0.308). The mean hamstring flexibility on the right leg (77.7° ±7.4; p = 0.050) was statistically different in participants with a history of left hamstring strains compared to players with no history of left hamstring strains. No other statistically different means were found with the proposed intrinsic risk factors between previously injured and previously uninjured participants.

TABLE 4.5: History of acute hamstring strains and associated intrinsic risk factors (n = 33)

Associated risk factor	Categories	Left hamstring strains n = 11		Right hamstring strains n = 12	
		Mean (±SD)	***p****	**Mean (±SD)**	***p****
Hamstring Outcome Score (%)	Left	65.3 (16.9)	0.006**	72.5 (20.7)	0.308
	Right	66.9 (18.5)	0.028**	68.8 (16.7)	0.068
Single Leg Hamstring Bridge (repetitions)	Left	12.7 (4.1)	0.571	13.1 (5.0)	0.790
	Right	12.5 (4.5)	0.242	12.8 (5.0)	0.361
Modified Thomas Test					
Hip Flexor Flexibility (°)	Left	0.6 (8.6)	0.694	0.3 (7.4)	0.809
	Right	0.0 (8.2)	0.567	-1.0 (7.2)	0.985
Quadriceps Flexibility (°)	Left	56.0 (6.2)	0.509	56.5 (6.0)	0.669
	Right	56.0 (7.5)	0.903	57.0 (8.8)	0.764
Passive Straight Leg Raise (°)	Left	80.4 (7.7)	0.163	82.2 (7.6)	0.596
	Right	77.7 (7.4)	0.050**	80.8 (9.2)	0.571
Ankle Dorsiflexion Lunge ROM (cm)	Left	13.1 (3.3)	0.479	13.1 (2.7)	0.525
	Right	13.2 (3.0)	0.711	13.2 (2.6)	0.645
Star Excursion Balance Test (reach distance as % of height)	Left Anterior	37.0 (2.9)	0.582	36.8 (2.5)	0.878
	Right Anterior	37.4 (2.9)	0.268	37.2 (2.7)	0.361
	Left Posterior-lateral	40.9 (4.2)	0.668	41.4 (3.6)	0.943
	Right Posterior-lateral	42.1 (4.7)	0.636	42.4 (4.0)	0.397
	Left Posterior-medial	45.2 (3.4)	0.761	45.5 (3.8)	0.930
	Right Posterior-medial	44.7 (3.7)	0.621	44.1 (3.8)	0.799

* *p-value* represents the result of Independent-measures t-test between history of hamstring strains group versus no history of hamstring strains group

** Statistically significant ($p \leq 0.05$)

Considering the individual subsections of the HaOS (Table 4.6), univariate analysis revealed the "pain" sub-score and "function in daily living and sport" sub-score to be leg-dependent predictors of hamstring strain history. Statistical differences were found for lower left (36.4 ±23.4; p = 0.006) and right (36.4 ±23.4; p =0.010) "symptom" scores, left (67.3 ±21.1; p = 0.014) and right (68.5 ±21.2; p = 0.041) "pain" scores, as well as left (67.0 ±19.6; p = 0.001) and right (71.0 ±24.3; p = 0.017) "function in daily living and sport" scores in participants with history of left hamstrins strains. Lower right "pain" scores (68.5 ±18.3; p = 0.029) and right "function in daily living and sport" scores (72.4 ±20.4; p = 0.026) were also statistically different in participants with history of right hamstring strains.

TABLE 4.6: History of acute hamstring strains and Hamstring Outcome Score (HaOS) subsections (n = 33)

HaOS Subsection		**Left hamstring strains** n = 11		**Right hamstring strains** n = 12	
		Mean (±SD)	***p****	**Mean (±SD)**	***p****
Symptoms (%)	Left	36.4 (23.4)	0.006**	54.2 (36.7)	0.720
	Right	36.4 (23.4)	0.010**	43.8 (26.4)	0.115
Soreness (%)	Left	71.6 (22.4)	0.060	76.6 (24.3)	0.373
	Right	73.3 (23.9)	0.116	76.0 (23.5)	0.282
Pain (%)	Left	67.3 (21.1)	0.014**	71.4 (22.4)	0.106
	Right	68.5 (21.2)	0.041**	68.5 (18.3)	0.029**
Function in daily living and sport (%)	Left	67.0 (19.6)	0.001**	72.9 (20.5)	0.055
	Right	71.0 (24.3)	0.017**	72.4 (20.4)	0.026**
Quality of life (%)	Left	84.1 (16.9)	0.558	87.5 (16.0)	0.755
	Right	85.2 (17.5)	0.925	83.3 (17.1)	0.685

[*] *p-value* represents the result of Independent-measures t-test between history of hamstring strains group versus no history of hamstring strains group
[*] Statistically significant ($p \leq 0.05$)

4.6 Conclusion of results

A high prevalence (45.5%) of past history of hamstring strains was reported among participants, with a mean age of 19.3 years (SD ±1.43) and approximately 11.09 years (SD ±2.49) of field hockey experience. Intrinsic risks associated with these injuries in other sporting codes were also highly prevalent among field hockey players. Left (p = 0.006) and right (p = 0.028) HaOS were statistically lower with a history of left hamstring strains, whereas the right sub-scores of “pain” (p = 0.029) and “function in daily living and sport” (p = 0.026) were statistically lower with a history of right hamstring strains. Decreased hamstring flexibility on the right (p = 0.050) was found with a history of left hamstring strains.

CHAPTER 5: DISCUSSION

5.1 Introduction

The aim of this research study was to determine the prevalence and intrinsic risks for hamstring strains among field hockey players at a hockey club in Pretoria, South Africa. The main findings are discussed in this chapter with regard to the demographic profile, the prevalence of hamstring strain injuries and their intrinsic risk factors among the participants, as well as how these variables are related to one another.

5.2 Participants

The population consisted of 40 high-performance field hockey players. The response rate was 89%, with a total of 33 hockey athletes participating in this study. Attempts were made to reschedule data collection with the non-responders, but this was not possible due to the players' other commitments during the data collection time frame.

Previous epidemiology studies on field hockey injuries that used questionnaires as part of the data collection process reported response rates of 61% and 87% respectively (Delfino Barboza *et al.*, 2018; Hollander *et al.*, 2018), whereas one study from South Africa reported a 100% response rate (Naicker, Coetzee and Schall, 2016). However, in this study, the population consisted of only 30 female field hockey players from a single team. Gabbe *et al.* (2003) investigated the validity of athletes to report past-injury status themselves and found good 12-month recall accuracy. Only 82% of their sample completed the baseline questionnaire and were included in the final analysis (Gabbe *et al.*, 2003).

Since the primary outcome measures of the present study were questionnaire-based (demographics, current injury status, a past hamstring strain and HaOS) similar to previous epidemiology studies as mentioned above, a response rate of 89% was considered acceptable for representing the required sample of players from the field hockey club at the University of Pretoria. Considering the specific associations between the risks and hamstring strains, however, the current sample of 33 would have limited statistical power (Bahr and Holme, 2003).

Forty five percent of participants were males and 54% were females. Previous studies reporting on injuries among hockey athletes in South Africa focused on female players only

(Ellapen, Bowyer and Van Heerden, 2014; Naicker, Coetzee and Schall, 2016), making this current study the first to report on male field hockey players. Although recent epidemiology studies among field hockey players in other countries included hamstring injury data for both men and women, the percentage of male and female participants was somewhat skewed with 35% males in one study and 68% in another (Delfino Barboza *et al.*, 2018; Hollander *et al.*, 2018). Therefore, careful consideration are required when injury data are presented and interpreted as combined values from male and female players.

The above-mentioned studies reporting on hamstring strain injuries among both genders also covered the same age range as was found among the high-performance players of the field hockey club at the University of Pretoria (19.3 years of age ± 1.43). Elite field hockey players surveyed in a Netherlands study ranged from 15 to 31 years of age (Delfino Barboza *et al.*, 2018), while club players from Germany had a mean age of 20 ± 4.8 years for men and 22 ± 4.3 years for women (Hollander *et al.*, 2018). Earlier studies among South African field hockey players on the other hand, found mean ages of 15.4 ± 0.4 years and 23.8 ± 3.16 years respectively (Ellapen, Bowyer and Van Heerden, 2014; Naicker, Coetzee and Schall, 2016). The findings of the current study might possibly be related to those of other studies with collegiate sports investigating hamstring strain prevalence among different sporting codes (Cross *et al.*, 2010; Dalton, Kerr and Dompier, 2015; Lynall *et al.*, 2018). The specific ages of participants in these studies however, were not recorded (Cross *et al.*, 2010; Dalton, Kerr and Dompier, 2015; Lynall *et al.*, 2018).

The mean weight and stature of field hockey players in South Africa (weight 66.82 ± 8.65kg; height 1.71 ± 0.09m; BMI 22.78 ± 2.21kg/m^2) appear to be slightly less than those for players from Europe. Delfino Barboza *et al.* (2018) reported a mean weight of 68.1kg (50.8 – 85.4) and height of 1.75m (1.58 – 1.91), while Hollander *et al.* (2018) reported the mean BMI among male players as 23.1 ± 2.8kg/m^2 and 22.8 ± 2.3kg/m^2 among female players. Previous reports on collegiate field hockey players from India, however, showed lower overall weight (62.76 ± 7.18kg) and height values (1.68 ± 0.07m) (Bhat and Moiz, 2013). The distribution of race among players participating in the current study correlates with that for school-aged field hockey players from Kwazulu-Natal (white: 79%; black: 15%; coloured: 4%) (Ellapen, Bowyer and Van Heerden, 2014). The inclusion of ethnicity in the present study was based on its possible association with the prevalence of hamstring strains as found among athletes of Aboriginal and black descent (Freckleton and Pizzari, 2013).

The participating field hockey players reported 11.09 years (±2.49) of playing experience, which suggests that the majority of high-performance players from the University of Pretoria started playing field hockey at primary school level. When adjusting for mean ages, the same conclusion can be drawn from earlier studies from South Africa, as well as from the Netherlands (Ellapen, Bowyer and Van Heerden, 2014; Delfino Barboza *et al.*, 2018). The distribution of player positions as found in this study can be related to existing literature and is representative of the composition of a field hockey team (Ellapen, Bowyer and Van Heerden, 2014; Naicker, Coetzee and Schall, 2016; Delfino Barboza *et al.*, 2018).

Therefore, the demographic profile of the participants in the current study seems to correspond well with earlier reports on field hockey players. Furthermore, since a high prevalence of hamstring strain injuries have been previously reported among collegiate sports in both genders (Cross *et al.*, 2010; Dalton, Kerr and Dompier, 2015), the current demographic appears to be suitable for making comparisons.

5.3 Prevalence of hamstring strains

Hamstring injuries are the problematic types of injury seen in sports involving intermittent sprinting and directional changes (Prior, Guerin and Grimmer, 2009; Cross *et al.*, 2010; Brukner *et al.*, 2014). Sports injury prevention forms part of a sequence, starting with identifying the extent of the problem (van Mechelen, Hlobil and Kemper, 1992). Only limited research as to the extent of specific injuries among field hockey players are available and consensus on injury surveillance methods must still be reached (Barboza *et al.*, 2018). In order to facilitate this process, clear definitions in injury reporting are required (van Mechelen, Hlobil and Kemper, 1992; Barboza *et al.*, 2018).

In this study context, the criterion for a hamstring strain was an acute hamstring injury that had occurred during a match or training, and which limited the participation in sport or training for at least one day, or resulted the participant to consult a medical professional. This definition was derived from previous research on hamstring strain epidemiology and field hockey injuries (Cross *et al.*, 2010; Engebretsen *et al.*, 2010; Barboza *et al.*, 2018).

Although none of the high-performance field hockey players presented with a current hamstring strain at the time of data collection, a history of previous hamstring strains were highly prevalent (45.5%). Although prevalence of more than 50% has been documented amongst elite soccer players, prevalence among footballers (Australian rules football, as well as soccer) generally ranges between 8% and 25% (Prior, Guerin and Grimmer, 2009). The range of prevalence may possibly be explained by the different levels of participation. Hamstring strains have been reported up to 20% more frequently in professional Australian rules football players as opposed to such injuries in amateur participants (Prior, Guerin and Grimmer, 2009). Since the majority of field hockey players in the current study competed at provincial and national levels, it may explain why this population was at the higher end of the reported prevalence of hamstring strains.

The high history of previous injuries in this study is also in agreement with the outcomes of the research by Cross *et al.* (2010), which found hamstring injury rates among collegiate women's field hockey comparable to those for women's soccer. A reason for this might be the similarities between field hockey and soccer in terms of running requirements, field size and the general flow of the game (Cross *et al.*, 2010). Although Dalton, Kerr and Dompier (2015) reported male student athletes to generally present with higher hamstring strain incidence as opposed to such injuries in female student athletes, there were no data for male field hockey injuries for sport-specific comparisons to be made. In the current study, however, 40% of the male participants had a past hamstring strain history compared to the 50% of female participants. Because this is the first report on hamstring strain injuries among both genders of collegiate field hockey athletes, further studies are necessary to confirm whether the high hamstring strain history among female field hockey players is an isolated finding. It should also be kept in mind that the sampled female athletes in the current study included slightly more female players than male players.

Earlier epidemiology studies on field hockey injuries have documented injury rates over one season (Delfino Barboza *et al.*, 2018; Hollander *et al.*, 2018) and might not be directly comparable to the findings concerning hamstring strain prevalence and injury history of this study. However, the findings from the current study still support hamstring injuries as a frequent acute injury diagnoses reported among both males and females athletes (Naicker, Coetzee and Schall, 2016; Delfino Barboza *et al.*, 2018; Hollander *et al.*, 2018). Therefore, the extent of hamstring strain injuries in field hockey can be extended, further suggesting the need for research into hamstring injury prevention among these players.

5.4 Intrinsic risk factors for hamstring strains

Field hockey players presented with the same intrinsic risks for hamstring strains as were reported in the sporting codes of soccer, Australian football, and athletics, to which most of the research pertains (Prior, Guerin and Grimmer, 2009). Apart from the difference in sport-specific skills, the running requirements in these sports are similar and would therefore require similar hamstring functions (Cross *et al.*, 2010; Sugiura *et al.*, 2017). In addition to high-speed running, field hockey and soccer make use of similar field sizes. Thus, players require running endurance as well (Cross *et al.*, 2010). This might explain the similarity in injury risk considering that fatigue has previously been related with hamstring strains (Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013).

The Hamstring Outcome Score (HaOS) determines self-reported hamstring function under various subsections, which are usually associated with hamstring strains and how they present (Engebretsen *et al.*, 2008; Reurink, Whiteley and Tol, 2015). In this study, 48.5% of the participants presented with decreased hamstring functions (HaOS <80%) on the left, and 51.5% on the right, suggesting that, according to the self-reported function, these players are at high risk of sustaining strains to hamstrings. Among soccer athletes, the same cut off was used as that which found the HaOS to be associated with subsequent hamstring strains (Engebretsen *et al.*, 2010). The ability of the HaOS to capture similar function scores for both sporting codes, namely hockey and male soccer, could be attributed to the items under each subsection relating to the activities of both sporting codes. Items such as confidence, symptoms and pain while jogging, accelerating, braking speed and changing direction, reflect on hamstring function (Engebretsen *et al.*, 2008). More specifically, these items reflect on the ability of the hamstring muscles to cope with the forces placed upon them during these physical activities before failure or injury. However, seeing that hamstring strains are multi-factorial in nature (Freckleton and Pizzari, 2013), and the subjective nature of the HaOS, the use of the HaOS in conjunction with the identification of other risk factors is still to be recommended (Engebretsen *et al.*, 2010).

Strength as a contributing factor has received much attention in the research community. In theory, the hamstring muscles need to be able to endure and slow down hip flexion and knee extension while running at high speeds (Croisier *et al.*, 2008; Schache *et al.*, 2009). The SLHB tests hamstring in an endurance strength capacity with the hip and knee positioned in functional angles (Freckleton, Cook and Pizzari, 2014). On the basis of this test, the majority of the field hockey players from the current study scored poorly (<20 repetitions) with both limbs, regardless of gender. Similar results at "poor" levels that were associated with subsequent hamstring strain injuries were found among Australian rules football athletes (Freckleton, Cook and Pizzari, 2014). However, the injury rate in their study was low, which therefore limited the accuracy of the regression analysis to account for possible confounders, such as age and past injury history (Freckleton, Cook and Pizzari, 2014). Furthermore, there are no comparable values for female athletes to determine whether fewer than 20 repetitions are truly a measure of decreased strength among these players.

Gender differences might also be considered in conjunction with flexibility measures. With regard to research into hamstring strains, the majority of studies included male participants to determine the cut-off values for injury risk (Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013). Male soccer players showed a heightened risk for hamstring strains with decreased hamstring flexibility (<90° hip flexion with a "passive straight leg raise") (Witvrouw *et al.*, 2003). Using the same criterion, 75.8% of male and female hockey athletes in this research tested as having decreased hamstring flexibility. However, some researchers have used different cut-off values for male (80°) and female (90°) hamstring flexibility in respect of other injuries (Kunene, Ramklass and Taukobong, 2018). More studies are required to confirm the sensitivity of the "passive straight leg raise test" among both genders in relation to risks of sustaining hamstring strains.

Given the semi-crouched and bent-over posture that field hockey players must assume, players might be prone to decreased hip flexor flexibility (Ellapen *et al.*, 2011; Orooj, Nuhmani and Muaidi, 2016), and thereby the heightened risk of hamstring injuries (Freckleton and Pizzari, 2013). Previously, flexibility of the hip flexors, as determined by means of the "modified Thomas test", was found as an independent contributor to hamstring strain (Gabbe, Bennell and Finch, 2006). In the present study, 48.5% of the field hockey players presented with decreased hip flexor flexibility on the left and only 39.4% on the right. Although no normative data is available for hockey players via the "modified Thomas test", these findings correspond with those relating to Australian football players (Gabbe, Bennell and Finch, 2006). At-risk field hockey players also had ≥11.91° less flexibility than healthy elite athletes from the domains of rowing, basketball, running and tennis (Harvey, 1998). The unequal distribution of hip flexor flexibility between left and right leg as found in the current study, confirms previous discussions on the semi-rotated and asymmetrical postures of field hockey players and their biomechanical implications (Ellapen *et al.*, 2011; Ellapen, Bowyer and Van Heerden, 2014; Orooj, Nuhmani and Muaidi, 2016). It may also relate to leg dominance. Majority of participants (90.9%) were right leg dominant and might favour their dominant leg to "push-off" out of the semi-crouched posture, leading to asymmetries in hip flexibility measures.

Other potential intrinsic risks of hamstring injuries that were tested in this study were found to be less prevalent. Only a few participants had decreased quadriceps flexibility (18.2% on the left and 36.4% on the right) as a contributing factor for injury, utilising the cut-off values determined among Australian football players (Gabbe *et al.*, 2005). Reduced flexibility of quadriceps as a contributing factor for injury has also been found among soccer athletes (Witvrouw *et al.*, 2003), but different methods of measurement were used and are therefore not directly comparable to the current findings. Although the majority of participants had a level of ankle range of movement that would place them at moderate risk of hamstring injuries (left = 57.6% and right = 51.5%), only 12.1% were at high risk. Amongst Australian football players, moderate risk was not statistically-significant predictor of hamstring injury (OR = 0.96; p = 0.942) compared to high risk (OR = 2.53; p = 0.094) in the case of multivariate analysis (Gabbe *et al.*, 2006).

Although the "Star Excursion Balance Test" (SEBT) has not been used in association with the risk of hamstring strains, its ability to detect dynamic postural control deficits and proprioception is promising (Gribble, Hertel and Plisky, 2012). Using criteria associated with lower limb injuries in the past (Dallinga, Benjaminse and Lemmink, 2012), only 12.1% of field hockey players had anterior reach differences associated with injury risk. However, Earl and Hertel (2001) demonstrated increased hamstring muscle activity, as measured through electromyography, during the posterior-reach directions. With the forward lean and hip flexion movement, hamstring muscles need to contract eccentrically to control and maintain balance (Earl and Hertel, 2001). Together with the proposed risk factor of decreased neuromuscular control of the length-tension forces around the pelvis (Prior, Guerin and Grimmer, 2009), reasoning suggests that to merely look at anterior-reach differences as hamstring injury risk might result in false negatives (Type II errors). Further research is needed for normative data concerning field hockey players (Gribble, Hertel and Plisky, 2012) and subsequently, whether associations can be determined with hamstring strain risk.

This research study established that the participating field hockey players presented with intrinsic risk factors for hamstring strains that were similar to those associated with other sporting codes. However, the lack of normative data for these players is clear. Common screening tests might be applicable in the case of field hockey players but need further confirmation from prospective aetiological studies of hamstring strains specifically in this cohort. Since the majority of athletes in this study presented with decreased HaOS, hamstring strength, hamstring flexibility and hip flexor flexibility, screening tests for these risk factors should be prioritised in future research. While decreased levels of quadricep muscle flexibility and ankle range of movement with a dorsiflexion lunge were not that prevalent among field hockey players, the SEBT in theory remains promising for detecting neuromuscular control deficits.

5.5 Demographics, injury history status, and intrinsic risk factors

Even though time and resources are being devoted to research into hamstring strain and its management and prevention across sporting codes, such injuries remain frequently occurring with a high rate of recurrence (Freckleton and Pizzari, 2013; Erickson and Sherry, 2017). Possibly, a reason for the paucity between research findings and practice outcomes may be the poor compliance of athletes when it comes to the implementation of preventative measures (Goldman and Jones, 2010; Barboza *et al.*, 2019). Goldman and Jones (2010) suggest the development of techniques or strategies to improve compliance with preventative interventions. A possible solution would be to target specific demographic or identifiable risk factors to prevent players from being overloaded with ambiguous management practices for hamstring strains. With that in mind, injury and re-injury preventative measures among field hockey players would benefit from the identification of the possible associations between demographics, the prevalence of hamstring strain and its risk factors.

Another critical finding of this research was a prevalent history of previous acute hamstring strains among participants. Since earlier studies reported hamstring strain risk to increase above the ages of 23 and 25 (Prior, Guerin and Grimmer, 2009; Van Dyk *et al.*, 2017), the prevalent history was higher than expected for players with mean age 19.3 (±1.43). Age factor, however, has been researched among predominately male athletes competing in various codes of football (Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013). On the other hand, field hockey epidemiology studies with an increased incidence of hamstring strains, have reported on players of both genders with ages ranging between 15 and

31 and mean age of 20.7 (±4.7) respectively (Delfino Barboza *et al.*, 2018; Hollander *et al.*, 2018).

A possible reason for the prevalent history of hamstring strains among a younger group of athletes might be their level of participation and their longer exposure to other risks (Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013). The field hockey players in the current study had an average of 11.09 years (±2.49) of playing experience and were competing at high levels (48.5% provincially; 45.5% nationally). Although no statistically significant differences or associations could be found between age, playing experience, level of play and hamstring strain injuries, it should be kept in mind that the sample was small and showed little variance. Future research is needed among field hockey players to determine whether age-related muscle changes and/or whether longer exposure to other risk factors poses the same intrinsic risk for hamstring strains, as in the case of other sporting activities, eg. Australian rules football and soccer (Gabbe *et al.*, 2005; Prior, Guerin and Grimmer, 2009).

Previous hamstring strain is consistently shown to be a risk for future hamstring strains and might be due to various factors (Prior, Guerin and Grimmer, 2009; Freckleton and Pizzari, 2013). Some of these include the premature return to sport and the residual presence of other risk factors (Prior, Guerin and Grimmer, 2009; Maniar *et al.*, 2016). Given the significant differences in the HaOS between previous hamstring strains versus no strains, as established in this study, the HaOS might possibly be an indicator of those factors on a functional level.

The total left and right HaOS (p = 0.006; p = 0.028) were significantly lower in previously strained hamstrings of the left leg, while the total right HaOS (p = 0.068) were marginally different in previously strained hamstring of the right leg. Additional inferential statistics revealed the sub-scores of "pain" (p = 0.014; p = 0.029) and "function in daily living and sport" (p = 0.001; p = 0.026) to be the most significant leg-dependent indicators. This is in agreement with Engebretsen *et al.* (2010), who determined total HaOS scores and four out of five subsections, including the "pain" and "function in daily living and sport" subsections, to be potential leg-dependent risks for hamstring strains. Furthermore, a recent paper among baseball players determined the total HaOS, as well as all the sub-scores, to be significantly related with a history of hamstring injuries (p = 0.001-0.042) (Zachazewski *et al.*, 2019).

Considering the difficulty in returning an athlete to sport and the emphasis placed on the absence of hamstring strain symptoms during functional tests (Hickey *et al.*, 2017), the HaOS might be an easy, low-cost addition to assist in decision making. However, the ability of the HaOS to detect change subsequent to the implementation of prevention programmes or rehabilitation has not been assessed and should therefore be used with caution.

One of the main objectives in hamstring rehabilitation is to restore flexibility and strength before return to sport and thereby mitigate re-injury risk (Erickson and Sherry, 2017; Hickey *et al.*, 2017). In individual cases, the strength of the uninjured side can be used as the target level of strength (Brukner *et al.*, 2014). However, in terms of screening for decreased strength as an injury or re-injury risk, there is a need for normative strength values. Although limited research has associated decreased strength determined through the SLHB test with hamstring strain injuries (Freckleton, Cook and Pizzari, 2014), there is as yet no normative data for field hockey athletes. Participants in this study, scored between 12.5 ±4.6 and 15.1 ±4.9 repetitions, which were considerably lower than the benchmarks proposed in the literature (<20 repetitions poor, 25 average and >30 good) (Freckleton, Cook and Pizzari, 2014). There were no significant differences in the results of the SLHB test according to previous hamstring strain history. These results suggest that using the SLHB test among field hockey players might require different benchmarks for the level of hamstring strain risk. Further prospective aetiological studies are needed.

The majority of field hockey players (75.8%) presented with decreased flexibility of hamstrings as a risk for hamstring strain. With the "passive straight leg raise", at-risk field hockey players presented with approximately 10 degrees less flexibility (79.8° ±6.0 and 78.0° ±5.8) than at-risk male soccer players (88.1°) (Witvrouw *et al.*, 2003). To account for sport-specific differences that might exist, continuous values were used for the analysis of the inferential statistics to determine whether there were any difference in hamstring flexibility between a history of hamstring strain injuries and no history. Interestingly, decreased right hamstring flexibility was found with left hamstring strain history (p = 0.050). These results however, are based on retrospective injury data and cannot, therefore, account for flexibility measures as a cause or result of injury. Since hamstring flexibility, as measured with the "passive straight leg raise", normalises within 50 days (Maniar *et al.*, 2016), the presence of decreased right hamstring flexibility found with left hamstring strain injury history might be more indicative of the biomechanical consequence of asymmetries among field hockey players (Ellapen, Bowyer and Van Heerden, 2014).

Even though similar asymmetries were found with hip flexor flexibility among field hockey players in the current study, no significant differences emerged from the analysis of the inferential statistics. Comparable observations were made in a cohort study among Australian football athletes that found flexibility measures to correlate with age as a predictor of hamstring injuries (Gabbe, Bennell and Finch, 2006). Decreased hip flexor flexibility was found to be a contributing factor for hamstring strains among Australian football athletes with ages ≥25 but not in those of ≤20 (Gabbe, Bennell and Finch, 2006). Therefore, the mean age of the current sample (19.3 years ±1.43) might explain why decreased flexibility of hip flexors, although present, was not associated with a history of injuries.

The SEBT is one of the few screening tests that has been studied among field hockey players in the past, although not in relation to hamstring injury risk. There were no significant reach differences (percentage of height) between the left and right sides, irrespective of hamstring injury history. This lack of association suggests that the possibility of dynamic postural control deficits as a result of injury had normalised in respect of the uninjured side and that there would be no way of knowing whether there were deficits prior to the injury. Previous research has shown that the SEBT is able to detect dynamic postural control improvements after intervention (Gribble, Hertel and Plisky, 2012). Given the inclusion of neuromuscular control and stability exercises in the prevention and rehabilitation programmes for hamstring injury (Sherry and Best, 2004; Gouttebarge and Zuidema, 2018), the SEBT might be useful in tracking progress. In addition, Hoch *et al.* (2017) found no systematic change in dynamic postural control over one season among female collegiate field hockey players, thus supporting its use as a pre-seasonal screening test (Hoch *et al.*, 2017). Therefore, results from the current study might be a starting point for establishing normative values as a percentage of height for future hamstring risk screening and rehabilitation goals.

5.6 Conclusion to the discussion

The demographic characteristics of high-performance field hockey players from the University of Pretoria were similar to previous reports on field hockey players from South Africa, as well as from international players. This report is also the first from South Africa to report on male field hockey athletes and players of collegiate age.

This research study showed that the participating athletes presented with a highly prevalent history of hamstring strains. This reported history are comparable to the sporting codes of soccer and Australian football, both of which are associated with similar hamstring functions and running requirements. The prevalent hamstring strain history in the current study serves to supplement injury data from earlier field hockey studies, thus extending the informational domain of hamstring injuries in this population and the need for preventing such injuries among these athletes.

The intrinsic risk factors for hamstring strains (decreased HaOS, hamstring strength, hamstring flexibility and hip flexor flexibility) were also found to be highly prevalent among field hockey players, although the lack of normative data in respect of these players is evident. Since field hockey players generally record lower strength and flexibility scores, caution should be taken when using cut-off values such as those that were determined among predominately male soccer and Australian football players.

The HaOS (total score and sub-scores of "pain" and "function in daily living and sport") and the history of previous hamstring strains showed statistically significant differences. The HaOS might be a potential indicator of residual risk factors following previous hamstring strains at a functional level. The statistically significant lower right hamstring flexibility in left hamstring strain history compared to no history, support the phenomenon of asymmetry in field hockey players and the biomechanical influence it might have on injury risk.

No associations were reported between the demographics of the selected field hockey players, hamstring strain injuries, and other intrinsic risk factors. Common screening tests might be applicable in field hockey but they need further confirmation from prospective aetiological studies of hamstring strains that specifically apply to this cohort.

CHAPTER 6: CONCLUSION

6.1 Conclusion

The multi-factorial nature of hamstring strain injuries has been well documented in sports generally but further only suggested in the domain of field hockey. Furthermore, the intrinsic risks for hamstring injuries, as explored in other sporting codes, appear to be closely related to the sport-specific demands of field hockey. Therefore, the aim was to investigate the prevalence of and the intrinsic risks pertaining to hamstring strains among field hockey athletes at a hockey club in Pretoria, South Africa.

The criterion for hamstring injury was derived from previous literature on hamstring strain epidemiology and field hockey injuries. The condition for its inclusion in this research study was that it must have been an acute sporting injury that resulted in time loss from a sporting activity. With that as the basic premise, the participating field hockey players presented with a high prevalence (45.5%) of hamstring injury history. However, no participants suffered from a hamstring strain at the time of data collection. Since this is the first report from South Africa to include field hockey injury data on males and on players of collegiate age (18 to 22), the extent of hamstring injuries in this population can be expanded.

The HaOS for this sampled group of field hockey players was completed and musculoskeletal tests (the SLHB, "modified Thomas test", "passive straight leg raise", "ankle dorsiflexion lunge range of motion" and SEBT) were conducted to assess for intrinsic risks for hamstring strains. Lower HaOS (total score and sub-scores of "pain" and "function in daily living and sport") were found with previous hamstring strains. While decreased hamstring strength, decreased hamstring flexibility, and decreased hip flexor flexibility were also highly prevalent among the participating field hockey players, only right hamstring flexibility was found with previous hamstring strains of the left leg.

The results from the current study correlate well with previous field hockey epidemiology studies that found hamstring strain injury as a common injury diagnosis. In addition, the prevalence of this type of injury was comparable to those in the case of elite soccer and Australian football. Given that these sports involve similar hamstring functions and running requirements to those in field hockey, this might explain why field hockey players present with similar intrinsic risk factors. However, field hockey players generally present with lower strength and flexibility measures, as well as unique asymmetries in flexibility.

These findings suggest that although common screening tests might be applicable to field hockey players, further studies are needed to determine the normative data for these players and the cut-off values associated with the risk of hamstring strains. Data from the current study could be used for baseline measurements in future studies and novel pre-participation risk screening. Considering the risk that previous hamstring strain injury has on future injuries, and its association with the HaOS, the HaOS might be used to help clinicians in making return-to-play decisions.

6.2 Limitations

There are a few limitations to this project that should be considered. In the first place, the prevalence of hamstring strain history was reliant on the participants' recall accuracy. Furthermore, the sample was relatively small and would therefore limit the statistical power of the associations. In addition, logistic regression analysis was not possible with the current sample size and research design, which means that this study could not account for confounding variables. Since all of the participants were high-performance field hockey players of collegiate age, the findings cannot, therefore, be generalised to amateur players and players of other age groups.

6.3 Recommendations for future studies

Future studies on the aetiological nature of hamstring strains among field hockey players could include a larger cohort with different age ranges and levels of participation. The prospective capturing of injury data could be compared to baseline measurements of musculoskeletal tests to ascertain whether sport-specific associations (such as the asymmetries in field hockey) are predictors of hamstring strains. Furthermore, such studies could then determine whether different cut-off values should be used among field hockey players when pre-participation risk screening is conducted.

Studies on the HaOS could explore its reliability in capturing improvements in hamstring function after the implementation of prevention programmes or rehabilitation. By doing so, the value of the HaOS in assisting return-to-play decisions could be established.

6.4 Clinical recommendations

Given the prevalence of hamstring strain injuries, prevention strategies for these injuries could be prioritised among field hockey clubs or associations. Based on the findings of this study, clinicians working with field hockey players should not exclude players from injury prevention programmes based on their younger age. Intrinsic risk factors associated with hamstring strains in other sporting codes (decreased HaOS, hamstring strength, hamstring flexibility and hip flexor flexibility) were detectable among field hockey players using cost-effective screening tools. The use of these tools can therefore be recommended among field hockey players for baseline measurements. Since low HaOS were significant with history of previous hamstring injuries, the HaOS might be used as an additional measurement to screen for residual decreased function after an injury. Expert opinion suggests the inclusion of neuromuscular control and stability exercises in hamstring strain prevention and rehabilitation. Therefore, the SEBT could be used to track progress and normalisation following a hamstring injury.

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Appendix A: Questionnaire Section A

Study Number: ………….

Please complete the following form by placing a tick ☑ where appropriate and filling in the blanks. Please note that the information provided will be used for research and statistical purposes only and will not negatively reflect on you whatsoever.

Gender: Male ☐ Female ☐ **Age:** …………………….

Height: …………….........m **Weight:** ……………...kg

Leg dominance: Left ☐ Right ☐

Race: Black ☐ Coloured ☐ White ☐ Asian ☐ Indian ☐ Other ☐

Years of field hockey experience: …………………………………..

Highest level of field hockey participation:

Recreational ☐ Club (School/University/Regional) ☐ Provincial ☐ National ☐

What position/s do you play: ....

Are you competing in another sporting code other than field hockey? Yes ☐ No ☐

If you answered "yes" to the previous question, please answer the following:

What other sporting code/codes are you competing in: …………………………………….

……………………………………………………………………………………………..

Highest level of participation in another sporting code:

Recreational ☐ Club (School/University/Regional) ☐ Provincial ☐ National ☐

Do you normally warm up before;

Matches? Yes ☐ No ☐

Training? Yes ☐ No ☐

Do you normally cool down after;

Matches? Yes ☐ No ☐

Training? Yes ☐ No ☐

Are you currently suffering from a hamstring (posterior thigh) injury? Yes ☐ No ☐

(Injury definition: An injury that occurred during a match or training that prevented you from participating in training or matches for at least one day OR led you to seek out medical attention [doctor, physiotherapist, paramedic, etc.])

Please complete the table below regarding injuries:

Body region	**State Left or Right**	**Current injury** (yes/no)	**Was this injury in the last 12 months?** (yes/no)	**Is this injury resolved?** (yes/no)	**Type of injury:** (eg. muscle strain, ligament sprain/tear, fracture, unknown, etc.)	**Treatment received:** (eg. none, physio, surgery, medication, rehab/exercises etc.)
Neck						
Thoracic spine						
Lower back						
Sacro-iliac joint						
Hip/Groin						
Quadriceps						
Knee						
Shin/lower leg						
Ankle						
Foot						
Other:						

Appendix B: Questionnaire Section B, the Hamstring Outcome Score

OSLO SPORTS TRAUMA RESEARCH CENTER
HAMSTRING INJURY SCREENING QUESTIONNAIRE

3A - Information on previous hamstring strains

LEFT SIDE

Number of previous acute hamstring strains:
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

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

Time since most recent injury:
☐ 0-6 months ☐ 6-12 months ☐ 1-2 y ☐ >2 y

For how long were you unable to fully play/train?
☐ 1-3 days ☐ 4-7 days ☐ 1-4 weeks ☐ >4 weeks

Have you missed a training/match during the previous season due to symptoms from your hamstrings?
☐ No - never
☐ Yes
☐ Rarely ☐ Sometimes ☐ Often

RIGHT SIDE

Number of previous acute hamstring strains:
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

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

Time since most recent injury:
☐ 0-6 months ☐ 6-12 months ☐ 1-2 y ☐ >2 y

For how long were you unable to fully play/train?
☐ 1-3 days ☐ 4-7 days ☐ 1-4 weeks ☐ >4 weeks

Have you missed a training/match during the previous season due to symptoms from your hamstrings?
☐ No - never
☐ Yes
☐ Rarely ☐ Sometimes ☐ Often

3B - Hamstrings function

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

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

Symptoms

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

1- Have you experienced soreness/stiffness/had complaints from your posterior thigh/hamstrings?

Left side:					Right side:				
Never	Rarely	Sometimes	Often	Always	Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Soreness

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

2- How sore is your posterior thigh after training?

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

3- How sore is your posterior thigh during training?

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

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

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

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

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

Pain

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

Left side:					Right side:				
Never	Rarely	Sometimes	Often	Always	Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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

Left side:					Right side:				
Never	Rarely	Sometimes	Often	Always	Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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

8-Stretching the posterior thigh/hamstrings

Left side:					Right side:				
No pain	A little	Moderate	Considerable	Very painful	No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

9-Walking up a ladder/stairs (double steps)

Left side:					Right side:				
No pain	A little	Moderate	Considerable	Very painful	No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

10-Jogging

Left side:					Right side:				
No pain	A little	Moderate	Considerable	Very painful	No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

11-Changing direction while running

Left side:					Right side:				
No pain	A little	Moderate	Considerable	Very painful	No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

12-Accelerating

Left side:					Right side:				
No pain	A little	Moderate	Considerable	Very painful	No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

13-Braking speed after sprinting

Left side:					Right side:				
No pain	A little	Moderate	Considerable	Very painful	No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Function, daily living and sports

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

14-Running

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

15-Jumping

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

16-Accelerating

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

17- Braking speed after sprinting

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

Quality of life

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

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

Left side:					Right side:				
Totally	A lot	Moderate	To some degree	Not at all	Totally	A lot	Moderate	To some degree	Not at all
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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

Left side:					Right side:				
Not at all	To some degree	Moderate	A lot	Totally	Not at all	To some degree	Moderate	A lot	Totally
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Scoring instructions for the Hamstring and Groin function scores

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

Appendix C: Information document

Department of Physiotherapy

Faculty of Health Sciences, Department of Physiotherapy · Private Bag 3, Wits, 2050, South Africa
Tel: +27 11 717 73702 · Fax : 27 11 7173719 · E-mail: maryanne.cannon@wits.ac.za · www.wits.ac.za

WITS UNIVERSITY

INFORMATION DOCUMENT

Study title: The prevalence and associated intrinsic risk factors for hamstring injuries among field hockey players at a hockey club in Pretoria, South Africa

Dear Field Hockey Player,

I, Anna Christina Coetzee, am doing research on hamstring injuries among field hockey players. Research is just the process of learning the answer to a question. In this study we want to learn how common hamstring injuries are among field hockey players. We also want to learn which physical features, such as muscle strength and muscle length, are related to hamstring injuries. The physical features that are found to relate to hamstring injuries can then be tested with pre-participation screening and emphasised during training to lessen the likelihood of sustaining a hamstring injury. The information collected in this study will also be beneficial in establishing baseline measurements specifically for field hockey players at university level when doing pre-participation screening.

We are inviting you to participate in this research study. Please note that there will be no cost or payment for participating in this study. The project is scheduled to take place January 2019 through to March 2019.

Who can participate in this study?
Male and female field hockey players registered at the TuksHockey Club, over the age of 18 years, with at least one season (8 months) of field hockey experience.

What can be expected of this study?
Testing will be done at your hockey club's facilities during the afternoon on an appointment basis. During your appointment time, you will be asked to complete a questionnaire inquiring demographic information (eg. age, weight, height) as well as hamstring muscle injury history, symptoms and function. You will then be expected to do a 5 minute warm-up consisting of toe walking, knee lifts, butt kicks and leg swings, after which musculoskeletal screening test consisting of three muscle length tests, a strength test and a balance test will be done. The entire testing should not take longer than 30 minutes.

Are there any risks to taking part in this study?
There will not be any additional risks other than the risks you would normally be exposed to by performing a physical activity. You might experience a stretch sensation during muscle length testing and mild exertion from the strength test. Testing will be terminated if any pain is experienced and you will also be able to withdraw from the study at any time without consequence. Participation in this study is voluntary.

What are the benefits of participating in this study?
The findings of your screening tests will be made available to you on request. After completion of the study, the outcome of the study will also be available to the participants. The general, anonymous injury risk profile for hamstring injuries of the hockey club as a whole will be offered to the club management to improve injury prevention conditioning.

Will information be handled confidentially?
Efforts will be made to keep personal information confidential. You will only be required to sign your name on the consent form, after which you will be assigned a study number. Your consent form will be kept separate from the questionnaire and screening test by the researcher. Research records might be inspected by the Research Ethics Committee for quality assurance. Information collected will be used for the purposes of this study only.

For further information, feel free to contact me on 0725897096 or send an email to anricoe@yahoo.com. The supervisors on this project are:

Siyabonga Kunene (MSc) siyabonga.kunene@wits.ac.za (011) 717 3707	and	Sadiya Ravat (MSc) sadiya.ravat@wits.ac.za (011) 717 3728

This study has been approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, Johannesburg. A principal function of this committee is to safeguard the rights and dignity of all human subjects who agree to participate in a research project and the integrity of the research.

If you have any concern over the way the study is being conducted, please contact the Chairperson of this Committee who is Professor Clement Penny, who may be contacted on telephone number 011 717 2301, or by e-mail on Clement.Penny@wits.ac.za. The telephone numbers for the Committee secretariat are 011 717 2700/1234 and the e-mail addresses are Zanele.Ndlovu@wits.ac.za and Rhulani.Mukansi@wits.ac.za.

Thank you for reading this Information Document.

Kind regards,

Anna Christina Coetzee

Appendix D: Informed consent form

CONSENT FORM

Study title: The prevalence and associated intrinsic risk factors for hamstring injuries among field hockey players at a hockey club in Pretoria, South Africa

I, ____, hereby volunteer and agree to take part in this study as described to me in the information document. I hereby agree to complete the questionnaire and give consent to the musculoskeletal screening tests.

I understand that there are no additional risks to taking part in this study other than the risks I would normally be exposed to by performing a physical activity. I am aware that I might experience a stretch sensation and mild exertion during the tests, but will be able to discontinue participation at any point without consequence.

Signature of Field Hockey Player: ________________________ Date: ___________________

Signature of Researcher: _______________________________

For office use only:

Study number: ………………….

Appendix E: Musculoskeletal screening test form

Study Number: ………….

Test	Left	Right
Single Leg Hamstring Bridge Participant lying on his/her back with heel on 60cm high surface and knee in approximately 20° flexion. The non-working leg is lifted and held motionless. He/she is then instructed to lift the hips off the floor to 0° hip extension and do as many repetitions as possible until failure after one warning.	…………. Repetitions	…………. Repetitions
Modified Thomas Test Participant sitting on the edge of a plinth and then rolling back, holding both knees to the chest. The non-testing hip is held in maximal flexion by the participant while the leg being tested is lowered towards the floor. To determine hip flexor flexibility the angle of the hip is measured with a goniometer. Similarly, to determine quadriceps flexibility the angle of the knee is measured.	………….° hip flexion ………..° knee flexion	………….° hip flexion ………..° knee flexion
Passive Straight Leg Raise Participant lying in a supine position. The examiner passively lifts the leg with the knee held in extension. The angle of hip flexion is measured with a goniometer.	………….° hip flexion	………….° hip flexion
Ankle Dorsiflexion Lunge Range of Motion The participant stands facing a wall. The examiner holds his/her heel down while the participant lunge forward until his/her knee touches the wall. The maximal distance is measured from the great toe to the wall with a tape measure.	…………....cm	…………....cm
Star Excursion Balance Test The participant stands on one leg and reaches forward with the opposite leg along an anterior line to lightly touch the floor with the most distal part of his/her reaching foot. The movement is repeated four times while maintaining balance and without shifting the stationary foot. The maximal distance is measured and repeated in a posterior-medial and a posterior-lateral direction.	Anterior: ………………....cm Posterior-medial: ………………...cm Posterior-lateral: ………………cm	Anterior: ………………....cm Posterior-medial: ………………...cm Posterior-lateral: ………………cm

Appendix F: Ethical clearance certificate

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

R14/49 Miss Anna Coetzee

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M180277

NAME: (Principal Investigator)	Miss Anna Coetzee
DEPARTMENT:	Physiotherapy University of Pretoria, TuksSport, Field Hockey Club
PROJECT TITLE:	The prevalence and intrinsic risk factors for hamstring injuries among field hockey players at a hockey club in Pretoria, South Africa
DATE CONSIDERED:	23/02/2018
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Mr Siyabonga Kunene and Mrs Sadiya Ravat
APPROVED BY:	CPenny Prof C Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	02/07/2018

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

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 301, Third floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in February and will therefore be due in the month of February each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature ____________________ Date ____________________

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix G: Permission from TuksSport at the University of Pretoria

Department of Physiotherapy

WITS UNIVERSITY

Faculty of Health Sciences, Department of Physiotherapy · Private Bag 3, Wits, 2050, South Africa
Tel: +27 11 717 73702 · Fax : 27 11 7173719 · E-mail: maryanne.cannon@wits.ac.za · www.wits.ac.za

28/11/2017

Mr. Steven Ball
Deputy Director: Coaching and Performance Management TuksSport
TuksSport Complex
University of Pretoria
Pretoria
0002

Dear Sir,

I, Anna Christina Coetzee, am doing research on the prevalence and associated intrinsic risk factors for hamstring injuries among field hockey players. In this research study, we want to recruit male and female field hockey players over the age of 18, to complete a demographic and hamstring injury history questionnaire. The participants will also be screened with musculoskeletal tests for intrinsic risk factors for hamstring injuries in order to compare its relationship to demographics and hamstring injury prevalence.

I would hereby like to request your permission to approach the field hockey players from the TuksHockey club at the University of Pretoria and to do the data collection at the TuksHockey club for the convenience of the players. Arrangements will be made with the club management as to not interfere with their training program, at the beginning of the season. No intervention will be given to the participants; however the results of the screening tests will be made available to the participants on request. After completion of the study, a general, anonymous injury risk profile for hamstring injuries of the club will be offered to the club management/coaching staff.

Please find attached the information document and consent form that would be provided to the potential participants prior to inclusion in this study.

In order to apply for ethical clearance, may I please have a written/typed reply should you grant me permission to recruit these players?

Feel free to contact me if you need further information.

Kind regards,

Anna Christina Coetzee
anricoe@yahoo.com
0725897096

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

TuksSport

5th December 2017

To Whom It May Concern:

RE: Permission for Study within TuksSport

This letter serves as confirmation that TuksSport, through my office, has been approached by the following student and his supervisor requesting permission to approach our various TuksSport specific clubs for the purpose of the research stated below.

Title of Research : The prevalence and associated intrinsic risk factors for hamstring injuries among field hockey players.

Degree purposes : Master of Physiotherapy (MPhysT)

Student : Ms. Anna Christina Coetzee

We hereby grant permission for the student to approach the Hockey club, as agreed upon with myself. We suggest that this drive is done through my office, so as to encourage the coaches participation and endorsement of the research. The specific sporting code and levels of participation can be discussed with myself and the research team.

At TuksSport, we are encouraging the practical research application into our club systems, which aligns with the University of Pretoria's 2025 strategic vision and plan and ultimately aid and enhance our sporting performances on the field of play.

Please feel free to contact me if you have any questions.

Yours Sincerely

Ball

Mr S. Ball

DEPUTY DIRECTOR: Coaching & Performance Management

Building and Room no: TuksSport Complex
University of Pretoria
PRETORIA 0002
Republic of South Africa

Tel: (012) 420 6927

Fax: 086 636 4014

Email address: steven.ball@up.ac.za

www.up.ac.za

Appendix H: Turnitin Plagiarism Scan

Research Report

ORIGINALITY REPORT

13%	6%	3%	11%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Edge Hill University Student Paper	1%
2	Submitted to University of Witwatersrand Student Paper	1%
3	Submitted to University of Kent at Canterbury Student Paper	1%
4	Submitted to University of Bath Student Paper	<1%
5	Submitted to University of Central Lancashire Student Paper	<1%
6	Submitted to Sheffield Hallam University Student Paper	<1%
7	Submitted to University of Salford Student Paper	<1%
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12	orbi.uliege.be Internet Source	<1%
13	"Sports Injuries", Springer Science and Business Media LLC, 2015 Publication	<1%
14	Submitted to Kean University Student Paper	<1%
15	Submitted to University of Wales Institute, Cardiff Student Paper	<1%
16	Submitted to Leeds Beckett University Student Paper	<1%
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