An investigation into normative values for the Functional Movement Screen^{TM} (FMS^{TM}) and its association to injury in female premier league hockey players in KwaZulu-Natal

By

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I, Anneke Jooste, do declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate to the contrary)

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DEDICATION

I would like to dedicate this dissertation to my parents, Jo and Johan Jooste, who have always supported me in everything I do and have given me so much love and guidance. I am forever grateful. I would also like to dedicate this dissertation to my husband, Crispian Mclintock Lees. Without his love and support this would not be possible.

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ABSTRACT

Background

The Functional Movement Screen (FMS^{TM}) is a pre-participation screen consisting of seven tests that rate a player's functional movement. The screen may be used as an indicator for injury susceptibility in sports people. This may be implemented for preventative measures and improving or sustaining performance in sport.

Objectives

This research aimed to identify normative values on the FMS^{TM} for female premier league hockey players and assess the association between FMS^{TM} scores and incidence of seasonal injuries. Secondary to this, the research also undertook to assess dependence of the FMS^{TM} on other risk factors identified in the study such as age, number of years playing hockey, height, weight, BMI and position. These risk measures were also tested for association to injury susceptibility.

Method

The research evaluated the FMS^{TM} score in female premier league hockey players in KwaZulu-Natal prior to the commencement of the competitive season and then tracked the incidence, frequency and distribution of injuries that were sustained during the season. All nine teams in the KwaZulu-Natal female premier hockey league were approached and the players voluntarily participated provided that they fitted the inclusion criteria. In total 74 players between the ages of 18 and 35 were assessed. SPSS version 20 was used in the data analysis to test for statistical significance of the results.

Results and conclusions

The research sample revealed a mean FMS^{TM} score of 14.39 with a standard deviation of 2.4. The difference in average FMS^{TM} score between the 18 players who sustained non-contact injuries during the course of the season and the 56 players who did not was shown to not be statistically significant at a 95% confidence level. Therefore, this research shows that no association can be made between a low score on the Functional Movement Screen^{TM} and injury susceptibility. The FMS^{TM} score was shown to be an independent metric when compared to the other injury risk measures identified in the study and the other risk measures were also found to not reliably indicate injury susceptibility. Having said this, the association of weight, FMS^{TM} and BMI with injury susceptibility warrants further investigation as these measures indicated a degree of association.

Key words: Functional Movement Screen, Pre-participation screen, Female, Field hockey, Injury, Risk factors.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACL	**:**	Anterior cruciate ligament
BMI	**:**	Body mass index
CI	**:**	Confidence interval
cm	**:**	Centimetre
df	**:**	Differential
F	**:**	Fisher’s exact test
FMS™	**:**	Functional movement screen
FMS’s™	**:**	Functional movement screen’s
kg	**:**	Kilogram
KZN	**:**	KwaZulu-Natal
m	**:**	metre
N	**:**	Sample number
No.	**:**	Number
OR	**:**	Odd ratio
p	**:**	Significance value
ROM	**:**	Range of motion
SEBT	**:**	Star excursion balance test
SD	**:**	Standard Deviation
Sig.	**:**	Sigma Two-tailed test
SLB	**:**	Single Leg Balance
SOAPE	**:**	Subjective, Objective, Assessment, Plan, Education

DEFINITIONS

Acute injury: Is an injury that has a sudden onset with severe symptoms but usually has a short duration (Saunders 2009).

Anthropometric: The science that deals with the measurement of the size, weight, and proportions of the human body (Saunders 2009).

Artificial turf: Is a surface of synthetic fibers made to look like natural grass. It is most often used in arenas for sports that were originally or normally played on grass (Hockey 101 2014).

Asymmetry: The lack or absence of symmetry. Example: The one side of the body performs better than the other side of the body (Saunders 2009).

Bilateral: Having two sides (Saunders 2009).

Body Mass Index (BMI): Is a measure for human body shape based on an individual's mass (kg) and height (m). It is defined as the individual's body mass divided by the square of their height (Hodge *et al.* 1994).

Chronic injury: Is an injury that develops slowly over time, is persistent and long-lasting, or constantly recurring. Many chronic injuries have mild symptoms and low-grade pain (Saunders 2009).

Continuous variables: Are numeric variables. Observations can take any value between a certain set of real numbers. Continuous variables can be measured in whole units or fractional units. Examples of continuous variables include height, time, age, and temperature (Lomax and Hahs-Vaughn 2012).

Current injury: For the purpose of the research, a current injury was defined as all non-painful injuries that did not preclude the player from practices or games but were present at the time of conducting the Functional Movement Screen™.

Discrete variables: Are numeric variables. Observations can take a value based on a count from a set of distinct whole values. A discrete variable cannot take the value of a fraction between one value and the next closest value. Examples of discrete variables include the number of players on a hockey field or the number of positions in a hockey game (Lomax and Hahs-Vaughn 2012).

Functional Movement Screen™: Is a pre-participation screen consisting of seven tests that rate a player's functional movement (Cook *et al*. 2006a).

Hockey: Hockey in this research refers to field hockey. Field hockey is a team sport played on a grass or a synthetic turf between two teams of 11 players. Hockey is a stick and ball game. Two teams compete using 'hooked' sticks to hit, push, pass and dribble a small, hard ball with one aim in mind, to score a goal by getting the ball past the goalkeeper (Hockey 101 2014).

Hockey positions:

- *Forwards; Have an attacking role with the main aim to score goals*
- *Links; Are also known as midfielders and have both an attacking and defending role. Their main role is to pass the ball from the defenders to the forwards*
- *Defenders; Their role is to defend the goal and oppose the other team's forwards*
- *Utility players; Can play any position on the field*
- *Goalkeeper; Stands in front of the goal to block shots with their body and stick*

(Hockey 101 2014).

Mobility: Range of motion in a joint (Bergmann and Peterson, 2010).

- *Hypomobility:* Lesser than normal range of motion in a joint (Bergmann and Peterson 2010).
- *Hypermobility:* Greater than normal range of motion in a joint (Bergmann and Peterson 2010).

Injury: Based on Chorba *et al.'s* (2010) injury definition and for the purpose of this research, injury was defined as: any acute or chronic injury that prevents a player from playing to their full potential or causes them to miss practices or games.

For the purpose of this research:

- *Mild injury:* is a minor injury that does not prevent a player from participating in practices or games and usually resolves within three days.
- *Moderate injury:* A moderate injury is an injury that usually lasts more than 3 days and results in loss of practice or game time during that period.

- Severe injury: A severe injury prohibits a player from playing sport and usually last more than 3 weeks.

Intra-rater reliability: In statistics, intra-rater reliability is the degree of agreement among multiple repetitions of a diagnostic test performed by a single rater (Minck *et al.* 2010).

Inter-rater reliability: Is the degree of agreement among raters (Minck *et al.* 2010).

Low back: The area between the lowest ribs and gluteal creases (Chen *et al.* 2012).

Lower extremity: Is the region of the lower limb, extending from the gluteal region to the foot, and including the buttock, hip and leg (Derrickson and Tortora 2009).

Mean: The average value (Saunders 2009).

Median: Is the midpoint between the lowest and highest value of the set (Saunders 2009).

Modal: The most frequently occurring value in a distribution (Saunders 2009).

Previous injury: For the purpose of this research, previous injuries are all injuries that a player incurred during previous practices / games. It happened in the past (Saunders 2009).

Premier league hockey player: The highest level of club competition (Hockey 101 2014).

Proprioception: Is defined as a specialized variation of the sensory modality of touch that encompasses the sensation of joint movement (kinesthesia) and joint position (joint position sense) (Lephart *et al*. 1997; Bergmann and Peterson 2010).

Prospective: Is a study that follows participants over time to determine the outcome of the study (De Vaus 2005).

Quantifiable risk factors: Is a risk factor that can be measured to determine value and quantity. This refers to something that is capable of being expressed in terms of numbers through calculation of volume, density and mass. It may also be used to establish a range or limit of something (Lomax and Hahs-Vaughn 2012).

Range: Span of values over which your data set occurs (Saunders 2009).

Rater: A person qualified to rate a participant on a specific task or test using a marking rubric and determining the participants score (Schneiders *et al*. 2011).

Real-time scoring: Refers to scoring a participant as the participant performs the test, not relying on video tape analysis to assist with the scoring (Schneiders *et al*. 2011).

Retrospective: Takes a look at the past to determine the results of the study (De Vaus 2005).

Standard deviation: A measure of the dispersion of a set of data from its mean. The more spread apart the data, the higher the deviation. Standard deviation is calculated as the square root of variance (Lomax and Hahs-Vaughn 2012).

Symmetry: Correspondence in size, form and arrangement of parts on opposite sides of a plane or around an axis (Saunders 2009).

Upper extremity: Refers to the upper limb and is the region extending from the deltoid region to the hand, including the arm, axilla and shoulder (Derrickson and Tortora 2009).

CHAPTER ONE:
INTRODUCTION

1.1 Introduction

This research undertook to investigate normative values for the Functional Movement Screen^{TM} (FMS^{TM}) and its association to injury in female premier league hockey players in KwaZulu-Natal.

Field hockey is one of the most popular team sports in the world (Murtaugh 2001). The game has developed into a faster game with increased risk for injury (Murtaugh 2001).This is attributable to the synthetic playing surface (Podgórski and Pawlak 2011) and increased technical requirements of the modern game (Naicker *et al.* 2007).These factors have placed greater physiological demands on the players. Correct conditioning for players (pre-season and during the season) has become increasingly important (Podgórski and Pawlak 2011).

Despite the popularity of the sport and the fact that most schools and universities participate in field hockey, there are still limited statistics and injury profiles available for female field hockey (Murtaugh 2001; Naicker *et al.* 2007; Podgórski and Pawlak 2011). Rishiraj (2009) found that the highest numbers of injuries, in female field hockey players, were sustained from non-contact situations. The most common injuries in female field hockey players were low back injuries, ankle/foot injuries, knee injuries and muscle strains (Murtaugh 2001; Rishiraj 2009). Research by Appaneal *et al.* (2009) revealed that injuries had a high psychological effect on female hockey players. Injuries also limited a player's participation time (practice and game time) and injuries caused a player to miss work (Marshall *et al.* 2003).

These injuries and their effects can all be prevented if players at risk for injury could be identified early in the season. In this context, the Functional Movement Screen^{TM} was developed by Cook (2012).The FMS^{TM} is a pre-participation screen consisting of seven tests that assesses quality of movement and identifies limitations and asymmetries in athletes (Cook *et al.* 2006a). The tests are based on proprioceptive and kinesthetic awareness principles. Athletes with imbalances and weakness may use compensatory movement patterns during their sporting activity. The FMS^{TM} tests can be used to identify players at risk for injury, in order to prevent injuries (Cook *et al.* 2006a; Cook *et al.* 2006b).

The FMS™ has not been utilised in hockey to determine a normative value and to determine if there is a link between injury and a particular FMS™ score.

Research relating to the FMS™ scores and injury predictability has been conducted in the past, but has focused on lower extremity sport and male dominated sports (Kiesel *et al.* 2007; Chorba *et al.* 2010).The limitations of previous research includes small sample sizes (Kiesel *et al.* 2007; Chorba *et al.* 2010; Cuson 2010), the utilization of a retrospective approach (Kiesel *et al.* 2007) and limitations regarding injury definition (Kiesel *et al.* 2007; Chorba *et al.* 2010; Cuson 2010).

Hockey is a very popular sport amongst females. Players suffer from many non-contact injuries (Rishiraj 2009) that could be prevented if player's pre-season risk for injury could be identified and corrected. The FMS™ has not been utilised in hockey to determine a normative value and to determine if there is a link between injury and a particular FMS™ score. This research addressed the limitations of previous studies by increasing the sample size, keeping the sample homogenous, clarifying the injury definition and adopting a prospective approach. This research design was of a quantitative, descriptive nature with prospective data collection from a cohort of female premier league hockey players in KwaZulu-Natal. All nine teams in the KwaZulu-Natal female premier hockey league were approached and the players voluntarily participated, provided that they fitted the inclusion criteria. A total of 74 players between the ages of 18 and 35 were assessed using the FMS™ prior to the commencement of the hockey season. Participants were tracked during the season and their injuries were recorded (injury was defined as any acute or chronic injury that prevented a player from playing at their full potential or caused them to miss practices or games (Chorba *et al.* 2010)). SPSS version 20 was used in the data analysis to test for statistical significance of the results and to determine if a correlation existed between a low FMS™ and injury susceptibility in female premier league hockey players.

1.2 Aims

To determine the normative values for the FMS™ in female premier league hockey players in KwaZulu-Natal (KZN) and to determine if an association between a low score on the FMS™ and injury susceptibility exists.

1.3 Objectives

a. To evaluate the FMS^{TM} score in a sample of female premier league hockey players (pre-season).
b. To determine the incidence, frequency and distribution of injuries throughout the competitive season for female premier league hockey players.
c. To assess the association between FMS^{TM} scores and incidence of injuries sustained by female premier league hockey players during the course of a season.
d. To assess the association between other identified risk factors and incidence of injuries sustained by female premier league hockey players during the course of the season. The other identified risk factors were player's age, number of years playing hockey, height, weight and position.

1.4 Hypotheses

Hypothesis: A low score on the FMS^{TM} is a predictor of injury in female premier league hockey players in KZN.

Null hypothesis: A low score on the FMS^{TM} is not a predictor of injury in female premier league hockey players in KZN.

1.5 Rationale

Increased participation in sport has led to an increase in musculoskeletal injuries (Plaugher 1993; Shephard 2003), as participating in sport carries a risk of injury (Reid 1992; Sahrmann 2002; Marshall *et al.* 2003; Hyde and Gengenbach 2007). Knill-Jones (1997), Dallinga *et al.* (2012) and Sanders *et al.* (2013) state that there is a need to use an evidence based approach to reduce injuries and that this must be a priority for all sport physicians. In order to reduce injuries, the physician needs to be able to identify players that are at risk and then use this information to develop preventative strategies to protect players. The main goal of a pre-participation screen is to promote health and safety in athletes in training and competition and to identify athletes at risk for injury (Sanders *et al.* 2013). Literature indicates that current pre-participation screens are not standardized or sport specific and cannot reliably identify athletes at risk for injury (Wingfield *et al.* 2004). The research on screening tests is currently inconsistent on whether pre-participation screens, performance screens or fitness tests have the ability to decrease injury rate, improve performance or enhance quality of living (Webborn 2012).

According to Cook *et al.* 2006a and Cook *et al.* 2006b the Functional Movement Screen^{TM} was designed to identify developed compensatory movements in the kinematic chain by noting asymmetry, instability and changes (hyper/hypo) in mobility. These compensatory movements, when present, are noted as risk factors that can contribute to injury (Reid 1992; Sahrmann 2002; Marshall *et al.* 2003; Hyde and Gengenbach 2007). In addition, previous related studies showed that the FMS^{TM} could reliably indicate injury risk in football (Cuson 2010), basketball (Kiesel *et al.* 2007), volleyball and soccer players (Chorba 2010). However, due to the fact that the FMS^{TM} is a relatively new assessment tool, there is a requirement for further research to validate its use as an assessment tool for other sports and, more generally to validate its use as a pre-participation screen altogether (Schneiders *et al.* 2011).

To focus the study and contribute to existing research related to the FMS^{TM}, it was decided to base this research on female premier league field hockey players. Hockey was chosen due to the fact that it is one of the most popular team sports in the world (Murtaugh 2001). To keep the research sample homogenous, female players were selected, as Rishiraj *et al.* (2009) indicated that females are more prone to sports injuries. The latter would allow for an increased likelihood in detecting changes and testing the Functional Movement Screen^{TM}. The selection of premier league players was based on the consistency of the intensity of the games played at this higher level (Rishiraj *et al.* 2009). This would rule out variation in injury due to inconsistency of play.

1.6 Benefits

Managers and coaches can use the information from the FMS^{TM} to identify players at risk of injury early on in their season. This can then be used to develop injury prevention strategies for these players. This has the potential to markedly decrease the incidence of injuries in the sport and could provide an invaluable strategic tool to increase the length of a player's hockey career and general health. Preventing injuries in hockey will also promote the development of hockey as a safe, but fun sport both recreationally and competitively. In addition, this research will contribute to the body of knowledge on the FMS^{TM} to determine if it can be reliably used as an injury prediction tool in female field hockey players and in general.

1.7 Limitations

1. Accurate reporting by the respondents (players) (Mouton 2006):
    a. The research had to rely on the players recall and honesty when they completed the Players Questionnaire (Appendix D) and also when reporting on injuries sustained during the season in the Injury Profile Sheet (Appendix E).
2. Accurate reporting by the coaches (Mouton 2006):
    a. The research had to rely on the coaches to accurately complete the Attendance Record Sheet (Appendix G).

1.8 Conclusion:

On the basis of frequent use of the FMS^{TM} (Cook *et al.* 2006a) and with the paucity of literature regarding the use of the FMS^{TM} in field hockey, this research aimed to determine the normative values for the FMS^{TM} in female premier league hockey players and to determine if significant correlations exist between a player's FMS^{TM} score and their susceptibility to injury.

The research highlights the need for an intervention programme in female field hockey players and outlines the various injuries that female field hockey players commonly sustain in a hockey season. The research then discusses pre-participation screens and finally the FMS^{TM} and how it can be used to identify players that are at risk for injury.

CHAPTER TWO:
LITERATURE REVIEW

2.1 Introduction

Chapter two aims to give the reader insight into female field hockey and the types of injuries hockey players commonly sustain during their field hockey season. The chapter reviews injury risk factors for hockey players, injury prediction strategies and pre-participation screens in general. Finally, the FMS^{TM} is reviewed in terms of its use as a pre-participation screen in female hockey players and in other sporting spheres.

2.2 Hockey

Field hockey is one of the most popular team sports in the world (Murtaugh 2001). Over time, the game has developed into a faster game with increased risk for injury (Murtaugh 2001).This is partly attributable to the synthetic playing surface also known as Astroturf (Podgórski and Pawlak 2011). According to Naicker *et al.* (2007), the increased technical requirements of the modern game have also placed greater physiological demands on the player. The latter has shown the importance of correct conditioning for players (pre-season and during the season) so that they are ready for the intensity of the sport and the change in posture required during training and games (Podgórski and Pawlak 2011).

Despite the popularity of the sport and the fact that most schools and universities participate in field hockey, there are still limited statistics and injury profiles available for female field hockey (Murtaugh 2001; Naicker *et al.* 2007; Podgórski and Pawlak 2011).

2.3 Injuries in female hockey

2.3.1 Prevalence of injuries

Dick *et al*. (2007), who reviewed 15 years of National Collegiate Athletic Association injury surveillance data for women's field hockey, ranked the top 5 injuries sustained during games as:

1. Ankle ligament sprains 13.7%
2. Knee internal derangement injury 10.2%
3. Concussion 9.4%
4. Upper leg strains 7.0%
5. Finger fracture 6.5%

Dick *et al.* (2007) also assessed injuries related to practices and found the top 4 injuries to be:

1. Upper leg muscle strain 26.9%
2. Ankle ligament sprain 15.0%
3. Pelvis-hip muscle strain 9.9%
4. Knee internal derangement injury 7.8%

As the above data taken from Dick *et al.* (2007) shows, ankle ligament sprains accounted for 14% of game and 15% of practice injuries and were a frequent cause of severe injuries that prevented a player from taking part in activity for more than ten days. Naicker *et al.* (2007) focused on ankle sprains in female field hockey players and found that 50% of players who suffered from ankle injuries missed two to four weeks of games and 16.7% were unable to participate for six to eight weeks. An epidemiological study carried out by Murtaugh (2001) on female field hockey players revealed that the low back, ankle/foot and the knee were the most vulnerable areas to injury. Muscle strains were also very common (Rishiraj *et al.* 2009).

Irrespective of the type of injury, Murtaugh (2001) indicates that the players' position influences the rate of injury. This is outlined in that goalkeepers, links and/or utility players had the highest injury rate. Research by Korporaal (2002) and Dick *et al.* (2007) showed that defenders and links were at greater risk for injuries when compared to other positions on the field.

2.3.2 Non-contact injuries

Rishiraj (2009) found that the highest number of injuries in female field hockey players was sustained from non-contact situations. This concurs with the work of Reilly and Seaton (1990), who indicated that a player's body position may be a contributing factor; especially to low back pain. The player is flexed forward in a semi-crouched posture while dribbling the hockey ball and stopping the ball during the game. This posture causes physiological strain and spinal loading (Reilly and Seaton 1990; White and Panjabi 1990; Norkin and Levangie 1992).See Figure 1.

(Haydt *et al*. 2014)

FIGURE 1: EXAMPLE OF A STRESSFUL POSTURE ASSUMED BY A FEMALE FIELD HOCKEY PLAYER

2.3.3 Contact injuries

Field hockey players are prone to hand/finger injuries due to the bent over posture and the fact that the player’s hands are exposed and are in close contact with the ground and ball during the game. A report by Dick *et al.* (2007) stated that 15% of all severe injuries are due to finger or thumb fractures and players lose up to ten or more days of hockey activity due to injury. It has been suggested that hand and finger injuries are underestimated in the literature, particularly in terms of severity and long term recovery. These injuries can result in permanent disability, loss of function, early onset osteoarthritis, work sick leave and high costs to players (Dick *et al.* 2007). To this end, the use of a close fitted posterior padded glove is often recommended to prevent such injuries or reduce the severity there-of (Dick *et al.* 2007).

Although less likely, head and facial injuries are amongst the more serious injuries sustained in hockey and consist of contusions, lacerations and/or concussions. In a study by Murtaugh (2001), 7.7% of a sample group of 158 female hockey players reported having sustained concussions and a study by Dick *et al.* (2007) showed that 5.4% of all concussions were classified as serious injuries.

2.4 Impact of injuries

Research by Smith (1996) shows that sports injuries have a psychological effect on the competitive sports player by causing depression, tension and self-esteem issues. Additionally, injuries limit a player's participation time (practice and game time) and injuries can even cause a player to miss work (Marshall *et al.* 2003).

In a study by Appaneal *et al.* (2009) who measured post injury depression amongst male and female competitive athletes, it was revealed that depression ratings of athletes with injuries were higher than athletes without injuries and female athletes also experienced higher post injury depression compared to male athletes. This outcome supports the work of Vinciguerra (1994) who investigated 98 female intercollegiate field hockey players. They were examined for changes and differences in mood states. Injured players were compared to non-injured players and the findings showed that injured players scored substantially higher on anger, fatigue, confusion, tension and depression when compared to uninjured players.

According to Bartlett (1999), injuries are directly linked to performance. To improve performance players need to train as a team and practice tactical game plans together (Podgórski and Pawlak 2011). When team players suffer from injuries during the season it affects the performance of the team as well as the player who, when returning to play, will have decreased fitness levels and have a lack of understanding of the tactical game plan (Podgórski and Pawlak 2011). These injuries and their effects could all be prevented if players at risk for injury could be identified earlier (pre-injury) (Dick *et al.* 2007).

2.5 Injury risk factors

Injury risk factors can be divided into intrinsic and extrinsic risk factors (Micheli 2010). An intrinsic risk factor is an internal factor that can predispose an athlete to injury (Micheli 2010). Extrinsic risk factors are external factors that can influence an athlete's susceptibility to injury (Neely 1998).

Intrinsic and extrinsic risk factors can be further classified as modifiable and non-modifiable risk factors (Micheli 2010). Modifiable risk factors can be altered by preventative strategies to reduce injury (Neely 1998; Micheli 2010). Non-modifiable risk factors cannot be altered, but are also important to identify so that the athlete is aware of what factors may predispose them to injury (Neely 1998; Micheli 2010).

Sport injuries occur as a result of the interaction between extrinsic and intrinsic risk factors which is coupled with a trigger event (Micheli 2010). For example, an intrinsic factor (previous injury) can predispose an athlete but the athlete must be exposed to the extrinsic risk factor such as a slippery playing surface followed by the triggering event of rolling an ankle (Neely 1998; Micheli 2010; Nessler 2013).

Some identified risk factors inherent to female field hockey players that need to be considered are reviewed in section 2.5.1 to 2.5.4 below.

2.5.1 Intrinsic, modifiable risk factor

Increased Body Mass Index (BMI) is an intrinsic, modifiable risk factor. It is a measure of human body shape based on an individual's mass (kg) and height (m) (Hodge *et al.* 1994). BMI is defined as the individual's body mass divided by the square of their height. The outcome can range from below 18.5 to above 30 with the underweight range being below 18.5, normal range being 18.5-24.9 overweight range being 25.0-29.9 and obese range being from 30 and above (Hodge *et al.* 1994). A high BMI can result in a more extended lower extremity position with decreased knee flexion upon landing which changes the mechanics of movement and predisposes the athlete to injury (Alentorn-Geli *et al.* 2009; Dallinga *et al.* 2012). BMI is in part a modifiable risk factor as weight can be corrected with an improved nutrition : exercise ratio (Micheli 2010).

Another important risk factor for injury is previous injury (Neely 1998; Arnason *et al.* 2004; Micheli 2010). Proper rehabilitation may break the injury-re-injury cycle, only if emphasis is placed on restoring full function rather than just relieving symptoms (pain relief) (Nessler 2013).Thus, if full recovery is possible, previous injury can be classified as a modifiable risk factor (Neely 1998).

The degree of coaching a player receives is also regarded as an intrinsic modifiable risk factor as improved coaching and conditioning can improve a player's physical readiness for a sport (Podgórski and Pawlak 2011). Physical readiness is also required in order to become proficient in a sport as the player needs to acquire the necessary technical skills of the sport through repeated practice and correct coaching. During this period a player is more vulnerable to injury. Skill level is also important as elite athletes, who have superior technique, are better conditioned and train more often compared to inexperienced players and are usually less prone to injury. However this does not exclude elite players from potentially over training resulting in overuse syndromes (Webborn 2012).

2.5.2 Intrinsic non-modifiable risk factor

Some evidence suggests that increasing age may be a risk factor for sustaining hamstring strains and ankle sprains (Neely 1998; Dallinga *et al.* 2012; Haydt *et al.* 2012). Additionally, Rishiraj *et al.* (2009) found that females are more prone to sports injuries. Alentorn-Geli *et al.* (2009) attributes this risk factor to female sex hormones (viz. oestrogen and progesterone), which have an increased effect on ligament laxity and tensile strength. Female sex hormones also affect neuromuscular functioning and decrease quadriceps femoris muscle strength, muscular relaxation and motor co-ordination (Sarwar *et al.* 1996; Zazulak *et al.* 2006). Further to this, evidence indicates that female sex hormones increase muscular fatigability and negatively affect isokinetic strength, anaerobic/aerobic capacity and high intensity endurance (Sarwar *et al.* 1996). The literature indicates that both age and gender can be regarded as intrinsic non-modifiable risk factors.

2.5.3 Extrinsic non-modifiable risk factor

Extrinsic non-modifiable risk factors include environmental factors which cannot be controlled in an outdoor environment. Factors such as humidity, wind, rain and excessive sun/heat can place players at increased risk for injury as these factors can affect a players physical state and the surface on which the game is played (Micheli 2010). Rain for example can result in a slippery playing surface (whether it be grass or artificial turf) or, in the case of a grass field, lead to an uneven surface that puts a player’s lower extremities under increased strain (Neely 1998).

2.5.4 Extrinsic Modifiable risk factor

In a similar manner to the non-modifiable risk factors, the modifiable risk factors pose an inherent risk for injury. Examples include the use of particular sports equipment (type of boots, type of stick) and protective equipment (gloves, helmet, gum-guard, shin guards) (Micheli 2010). The use of these various protective agents can protect a player from injury or cause injury if the equipment is incorrect (for example, incorrect boots, with limited grip). Coaching can also be seen as a modifiable risk factor as correct coaching can reduce the number of injuries a player sustains whereas incorrect coaching can increase the number of injuries a player sustains (Neely 1998).

2.6 Injury prediction

In order to develop mechanisms for injury prediction, Dallinga *et al.* (2012) conducted a systematic review to determine which screening tools could predict injury in lower extremity team sports.

Common injuries were identified and suitable screening tools were considered, as per the following categories:

Anterior cruciate ligament injury

According to a study by Myer *et al*. (2008) on female athletes, a positive knee hyperextension test increases the odds of an ACL injury status by five times. Myer *et al*. (2008) also determined that for every 1.3 mm increase in side-to-side difference in anterior-posterior knee displacement, the odds of an ACL injury status increases fourfold.

Hamstring strain

The combination of age (older than 23) and a decrease in hamstring flexibility was a predictor for a hamstring strain in male soccer players (Arnason *et al*. 2004; Gabbe *et al.* 2005).

Ankle injuries

According to Trojian and McKeag (2006), the Single Leg Balance (SLB) test was a good predictor for ankle sprains in men's and women's soccer and women's volleyball. They showed that a positive SLB test increased an athlete's risk of an ankle sprain. Pefanis (2009) showed that BMI and age of an athlete could also predict ankle sprains. Further to this, a study by Hadzic *et al.* (2009) indicated that increased strength of plantar flexors and a decreased range of motion in dorsiflexion are significant risk factors for ankle sprains.

General predictive test for lower extremity injuries

A study conducted by Plisky *et al.* (2006) on high school basketball players showed the reliability of the Star Excursion Balance Test (SEBT) as a good general predictor for lower extremity injuries. Similar results were found by Filipa *et al.* (2010) when testing young female athletes. In female senior soccer players, general joint laxity and age over 25 years were predictive of leg injuries (Otenberg and Roos 2000).

The above screening tools are recommended to coaches and medical staff to identify players with a predisposition for injury. Tests such as the side-to-side difference in anterior-posterior knee displacement and strength ratio tests are expensive and time consuming to administer to all members of the team and multiple teams (Dallinga *et al.* 2012). Additionally, these screening tools are more appropriate for a clinical setting and cannot easily be administered next to the field (Myer *et al*. 2008). Thus, according to Dallinga *et al.* (2012) more research is needed to identify applicable, appropriate and reliable screening tools.

2.7 Pre-participation screens

Pre-participation screens, also known as pre-participation examinations or sport screening tests, generally comprise of pre-participation medicals and performance tests (Cook *et al.* 2006a; Sanders *et al.* 2013). The main goal of a pre-participation screen is to promote health and safety in athletes in training and competition and to identify athletes at risk for injury (Sanders *et al.* 2013).

Screens should be completed prior to an athlete's participation in sport (Sanders *et al.* 2013) and should be easy to administer at practises, standardized, quick and inexpensive (Dallinga *et al.* 2012). They should be evidence based and specific for a particular sport, having acceptable inter-rater and intra-rater reliability. Screens should have the ability to predict injury so that they can ultimately be used to set up injury preventative strategies (Cook *et al.* 2006b; McBain *et al.* 2012; Sanders *et al.* 2013). Current pre-participation screens are, however, not standardized, reliable or sport specific and cannot reliably identify athletes at risk for injury (Wingfield *et al.* 2004).

In a typical pre-participation screen, the pre-participation medical examination is performed first and consists of assessing vital signs and conducting a cardiovascular examination (Sanders *et al.* 2013). Once an athlete passes these evaluations, they are then asked to perform performance tests that generally comprise of sit-ups, push-ups, endurance runs, sprints and then sport specific drills (Cook *et al.* 2006a). The results are compared to normative data for individuals of the same gender, age and sport specific norms (Wingfield *et al.* 2004; Singh and Surujlal 2010; Sanders *et al.* 2013). Most performance tests only test for a minimum level of performance to determine whether the athlete is ready to participate or must be excluded from participation. Performance tests generally do not assess efficiency and effect of movement (Cook *et al.* 2006a). For example, two athletes could score the same on the performance test with one athlete using perfect movement patterns and the other athlete using compensatory movement patterns to achieve the same result (Cook *et al.* 2006a; Sanders *et al.* 2013). Thus, it is important that the basic movement patterns be assessed first before assessing performance as compensatory movement patterns can lead to injury (Cook *et al,* 2006a).

The research on screening tests is currently inconsistent on whether pre-participation screens have the ability to decrease injury rate, improve performance or enhance quality of living (Webborn 2012). Wingfield *et al.* (2004) conducted a study on pre-participation evaluations and concluded that there is a lack of standardization in pre-participation evaluations both in the content of the evaluation and the administration of the evaluation.

In a study by Singh and Surujlal (2010) who assessed the current risk management practises in high school sport in South Africa, it was reported that:

- 23% of coaches and administrators do not liaise with medical personnel regarding prevention of injury in sport and
- 16% of coaches and administrators did not have the ability to recognise the symptoms that are suggestive of injury.

In response to the need to develop a simple and effective measure that coaches and administrators could employ, Cook and Burton (2012) developed a screening tool referred to as the Functional Movement Screen ™.

2.8 The Functional Movement Screen™

2.8.1 Theory of the FMS™

Athletes that participate in sport need the correct functional movement to perform their chosen sport (Cook *et al.* 2006a). It is important that functional movement analysis is thus incorporated into pre-participation screens to determine an athlete's strengths and shortcomings (Cook *et al.* 2006a). The FMS™ attempts to fill the gap between the pre-participation physicals and performance tests to give a more individualized and comprehensive approach to injury prevention (Cook *et al.* 2006a). According to Micheli (2010), an understanding of the movement patterns and body positioning in sporting technique is the first step in determining how an athlete achieves performance and how these movements and positions predispose them to injury.

This relatively widely used pre-participation screening tool determines whether an athlete has the essential movement needed to participate in an activity at a decreased risk for injury (Cook *et al.* 2006a; Cook *et al.* 2006b). Seven fundamental movement patterns are used in the screen which is based on proprioceptive and kinesthetic awareness principles (Cook *et al.* 2006a; Cook *et al.* 2006b; Schneiders *et al.* 2011). Each test requires the appropriate functioning of the bodies linking systems (Cook *et al.* 2006a) including adequate proprioception which plays a vital connecting role in this system (Derrickson and Tortora 2009). Fundamental movement patterns are assessed and scored for weakness, imbalance and pain. The goal is to determine compensatory movement patterns that can be a risk factor for injury (Cook *et al.* 2006a; Cook *et al.* 2006b; Derrickson and Tortora 2009). This is achieved by placing the athlete in extreme positions where weakness and imbalances become noticeable if compensatory movements are utilized (Cook *et al.* 2006a; Cook *et al.* 2006b). Athletes with imbalances and weakness may use compensatory movement patterns during their sporting activity and therefore place themselves at risk to micro- and macro-injuries (modifiable, intrinsic risk factors) (Cook *et al.* 2006 a; Cook *et al.* 2006 b).

Thus, the FMS™ assesses four critical categories of athletic performance: proprioception, flexibility, core stability and asymmetries (Cuson 2010; Cook *et al.* 2006a). Currently research suggests asymmetries, poor mobility, stability and a lack in core strength, are all risk factors for injury (Baumhauer *et al.* 1995; Sahrmann 2002; Kiesel *et al.* 2007; Peate *et al.* 2007). Research by Leach (2004) also suggests that previous injuries may cause a decrease in proprioception which could lead to asymmetry and a decrease in mobility and stability, all of which, according to Cook *et al.* (2006a), are tested in the FMS™.

The pre-participation screens and the assessments that are currently in use are based on impairments and performance (Dallinga *et al.* 2012). By contrast, Nessler (2013) indicates that the number one risk factor for musculoskeletal injuries is previous musculoskeletal injuries. This implies that the rehabilitation process was not complete and that treatment / intervention potentially focused principally on decreasing pain and symptoms and not on the re-establishment of proper and co-ordinated movement patterns (Cook *et al.* 2010; Nessler 2013). Athletes who then train with poor or incorrect movement patterns create movement deficiencies that potentially lead to injury (Cook *et al.* 2006a). Thus, screening movement patterns can pin-point limitations and prevent injury (Cook *et al.* 2006a). Compensatory movements also result in increased energy usage that can lead to increased fatigue and injury (Cook *et al.* 2010).

2.8.1.1 The Components of the FMS™

The FMS™ consists of seven main tests (Cook *et al.* 2006a); the deep squat, the hurdle step, the in-line lunge, the active straight leg raiser, the shoulder mobility test, the trunk stability push-up and the quadruped rotary stability test. Each test is scored out of three; zero indicating pain and three indicates perfect movement. The total score is out of 21 (Cook *et al.* 2006a). Five of the tests in the FMS™ are bilateral tests and are designed to identify asymmetry. Three tests have additional clearing tests that are used to identify pain in a participant. There are thus 17 tests overall (Cook *et al.* 2006a). It was noted by Sorenson (2009) that the FMS™ tests were based on the developers clinical experience, thus requiring more scientific research to support the validity, reliability and relevance of the screen (Cook *et al.,* 2006a; Cook *et al.,* 2006b). Therefore the following discussions outline what has been documented since 2006.

2.8.2 Validity of the FMS™

Validity is the "soundness of the interpretations of test scores" or the degree to which a test measures what it is supposed to measure (Etzel 2012). For the results of the FMS™ to be significant it must be determined that the screen is valid (Schneiders *et al.* 2011; Etzel 2012). For the screen to be valid it must be relevant, reliable and reproducible (Mouton 2006). The FMS™ is a fairly new screen that was introduced in 1995 (Cook and Burton 2012), therefore, limited research is available to determine its relevancy and reliability within specific sporting contexts (Schneiders *et al.* 2011; Etzel 2012).

2.8.3 Reliability of the FMS™

Reliability is the ability of a test to detect consistent and precise differences between subjects across test occasions (Wood 2011). It is vital that the screen reflects intra-rater and inter-rater reliability (Etzel 2012).

According to Minck *et al.* (2010) the FMS™ showed high inter-rater reliability. Minick *et al.* (2010) videotaped 39 college students performing the FMS™. Four raters (two expert raters with 10 years' experience and two novice raters with two years' experience) scored the college students. The Kappa statistic was used to determine the ratio of times the raters agreed. It was corrected for chance and the maximum number of times the raters could agree. The novice raters showed excellent agreement on 6 of the 17 tests, substantial agreement on 8 of the 17 tests and moderate agreement on 3 of the 17 tests. The experts displayed excellent agreement in 4 of the 17 tests, substantial agreement in 9 of the 17 tests and moderate agreement on 4 of the 17 test. This meant that there was more variance in the expert raters scores compared to the novice raters. The novice and expert raters combined indicated excellent agreement for 14 out of 17 tests and substantial agreement on three of the tests. The variance in the scores could be due to the raters varied experience or the unclear midrange scoring criteria (Minick *et al.* 2010). The in-line lunge, hurdle step and quadruped rotary stability test yielded moderate agreement between raters. These tests do not have clearly defined descriptors for midrange performance. The extremes of these tests are easily distinguishable; however intermediate scores are less clear. The possibility that raters had different viewing perspectives of the patient was excluded as a cause of variance as the raters were all exposed to the same videotaped assessments. Minick *et al.* (2010) recommends that future research should evaluate the reliability of real-time scoring of the FMS™ as this method is more appropriate for a field setting.

Subsequently, Schneiders *et al.* (2011) assessed 209 active individuals between the ages of 18 and 40 years old to determine if there was a difference in the scores between: males and females; between those individuals with a previous history of injury and the real-time inter-rater reliability of the FMS™. In this study, the participant's average FMS™ score was 15.7 out of a possible 21. No statistical difference between males and females and participants that had suffered a previous injury were noted. Inter-rater reliability of the Schneiders *et al.* (2011) study supported the strong inter-rater reliability of the Minick *et al.* (2010) study. Schneiders *et al.* (2011) used the inter-class correlation coefficient and calculated a score of 0.971 which represents excellent agreement between raters as complete agreement equals 1.0. Raters agreed on 12 of the 17 tests (excellent agreement) and yielded substantial agreement for the other 5. Both the raters in the Schneiders *et al.* (2011) study had the same amount of experience and training on scoring the FMS™. There were only slight differences in the methodology of Minick *et al.* (2010) versus Schneiders *et al.* (2011) study, where Minick *et al.* (2010) used videotape analysis to score the participants in contrast to Schneiders *et al.* (2011) who used real-time scoring. In both studies the raters had training in order to conduct and score the FMS™.

The previous studies (Minick *et al.* 2010; Schneiders *et al.* 2011) showed excellent inter-rater reliability but did not analyse for intra-rater reliability. The only research regarding intra-rater reliability is research by Sorenson (2009) which analysed both intra- and inter-rater reliability. Sorenson (2009) conducted an unofficial FMS™ training programme and trained certified athletic trainers. The investigator video recorded 15 participants while they completed the FMS™ tests. The video was shown to the athletic trainers who scored the participants once and then again after a two week break. Statistically, the scores were compared for both inter- and intra-reliability. Sorenson's (2009) research concurred with Minick *et al.* (2010) and Schneiders *et al.* (2011) on high inter-rater reliability and also showed acceptable intra-rater reliability for the FMS™.

The study by Sorenson (2009) showed that intra-reliability of the FMS™ is acceptable and thus supports this research study's methodology as this research relied on intra-reliability (with the researcher as the only rater who conducted the FMS™ scoring in this research). Similarly, the research by Schneiders *et al.,* (2011), who used real-time scoring, supports the methodology of this research. This is because their method of scoring is more true to life and does not compromise on the study's reliability scores, unlike Minick *et al.* (2010) and Sorenson's (2009) studies who used videotape analysis. Despite the differences in the analysis or real-time scoring, the raters in Sorenson (2009), Minick *et al.* (2010), and Schneiders *et al.* (2011) studies all underwent FMS™ training, as did the researcher for this study, before conducting and scoring the participants.

2.8.4 Relevancy of the FMS™

According to Etzel (2012) relevancy is the closeness of agreement between what a test measures and what it is ideally supposed to measure and the appropriateness of the measuring tool. The FMS™ is a management tool intended to detect areas of movement pattern limitation and asymmetry that can predispose a person to injury (Cook *et al.* 2006a) so that corrective strategies can be employed to prevent injury. The relevancy of the FMS™ then depends on whether the screen can successfully detect dysfunctional movement and asymmetries and whether this can be effectively correlated to injury susceptibility (Etzel 2012).

To determine if the FMS™ measures dysfunctional movement one must consider the definition of motion versus movement. Motion tests the range of flexibility within a single body segment or group of segments whereas movement is the act of a functional body as it changes position under its own power from point A to point B (Bergmann and Peterson 2010). All seven tests in the FMS™ score a functional body as it changes position under its own power. Thus, the FMS™ measures movement rather than motion (Singh and Surujlal 2010; Sanders *et al.* 2013). When an athlete cannot perform the correct movement they use compensatory movements, and raters score the athlete's movement dysfunction (Cook *et al*. 2006a).

To further confirm the FMS™'s relevancy, it must be able to determine asymmetry in an athlete. Five of the seven tests (hurdle step, in-line lunge, shoulder mobility, active straight-leg raise, and quadruped rotary stability) in the FMS™ test for asymmetry. The rater of the test, scores both sides of the body to determine if the athlete has symmetry or a lack thereof (Cook *et al.* 2006a). Thus, the FMS™ tests symmetry of movement to predict injury predisposition as a result of symmetry mismatch.

The next most important factor to look at in establishing relevancy is the efficacy of the FMS™ as an indicator for injury susceptibility in sports people. This is particularly important as Cook *et al.* (2010) suggests that a low score on the FMS™ can be improved after corrective strategies are employed. Kiesel *et al.* (2011) conducted a seven-week off-season intervention programme to determine if this would improve the FMS™ scores in professional American football players. Pre and post-intervention scores were obtained for sixty-two players. Seven players scored above 14/21 prior to the intervention and 39 players scored above 14/21 after the intervention. 41 players were free of asymmetries post intervention as opposed to 31 at pre-test. Kiesel *et al*. (2011) showed that an intervention/rehabilitation programme can effectively improve dysfunctional movement (Kiesel *et al.* 2011). Having said this, Kiesel *et al.* (2011) suggested that further research is needed to determine if injury risk is reduced when a player's score improves after an intervention programme.

2.8.5 FMS™ as an indicator for injury

2.8.5.1 The FMS™ in sport

A number of studies relating FMS™ scores and injury susceptibility have been conducted in a variety of sports; these include the studies by Kiesel *et al.* (2007), Cuson (2010) and Chorba *et al.* (2010).

Kiesel *et al.* (2007) conducted a study assessing the FMS™ in 46 professional male football players at the end of their season and compared their scores to injuries sustained during the season. A score of 14 or less out of 21 showed susceptibility to injury. Due to the retrospective nature of this study, the significance of the results with regards to injury prediction is limited. Another limitation of the Kiesel *et al.* (2007) study was the fact that the injury definition was unclear. The study defined injury as membership on the injured reserve bench for at least three weeks. In this way, not all injury types were included and contact injuries were not excluded from the study. With football being a high contact sport, contact injuries are a significant confounding factor as they cannot necessarily be prevented by correction of functional movement patterns.

A few years later, Cuson (2010) conducted a prospective study assessing the FMS™ scores as a predictor for acute lower extremity injury in 29 first division intercollegiate basketball players. The players underwent the Functional Movement Screen™ prior to the season and then their injuries during the season were recorded. Analysis showed that there was no significant difference between the FMS™ score of injured players versus non-injured players. The researcher attributed the results to a number of deficiencies in the methodology, which included the fact that the clearing tests had been excluded from the administered FMS™, as a result of the fact that the study focused only on acute lower limb injuries. This is in contrast to the intended design of the FMS™ which was structured to identify both acute and chronic injuries as well as upper and lower extremity injuries (Cook *et al.* 2006a). Concurrently, Chorba *et al.* (2010) wanted to determine if the use of the FMS™ could predict injury in female collegiate athletes who took part in soccer, volleyball and basketball. The study screened 38 athletes and found that their mean FMS™ score was 14.3 out of 21. Seventeen lower extremity and one low back injury were recorded over the competitive season. It was concluded that a score of 14 or less on the FMS™ resulted in a four-fold increase in risk for a lower extremity injury in a female collegiate athlete. The recommendations of their research indicated the need for a larger and more diverse sample size, including subjects participating in more upper-extremity intensive sports in order to test the more general applicability of the FMS™. The recommendation for a diverse sample is not supported by Chorba *et al.* (2010), who pointed out that because every sport demands different movement patterns, there is a likelihood that every sport has the potential to generate different normative values. The use of participants participating in three different sports in this research negated the ability to make sport specific recommendations (Chorba *et al.* 2010).

2.8.5.2 The FMS™ in fire service and law enforcement

The FMS™ has also been used (since 2007) in the Orange County Fire Academy to identify recruits that are at risk for musculoskeletal injury (Hamel 2013). Results achieved indicated that a score of 14 or less predisposed recruits to injury. The research showed that a recruit who scored below this threshold was twice as likely to be injured during the academy training. Although not conducted in a sporting context, this was similar to research conducted by Kiesel *et al.* (2007) and Chorba *et al.* (2010). One hundred and thirteen recruits from four consecutive fire academies were screened. Of these, 47% of the recruits scored 14/21 or less and of this group 72% sustained musculoskeletal injuries. These injuries accounted for 85% of the total cost to treat injuries by the fire academy (Hamel 2013).

The Anaheim Police Department and the Glendale Police Department use the FMS™ as part of their wellness programme and both these departments agree that the FMS™ is a useful tool in identifying officers at risk for musculoskeletal injuries (Hamel 2013).

2.9 Conclusion of literature review

The FMS™ has been used in different sporting disciplines as well as two occupational settings. Notwithstanding the pitfalls discussed, the authors of these studies (Sorenson, 2009; Minick *et al.,* 2010; Schneiders *et al.,* 2011) indicate that the FMS™ has shown to be reliable in indicating athletes who are susceptible to injury.

Many non-contact injuries could be prevented if the player's pre-season risk for injury could be identified and corrected (Rishiraj *et al*., 2009). As hockey is a very popular sport amongst females and players suffer from a variety of contact and non-contact injuries, it is important to determine their physical readiness to participate. The FMS™ has, however, not been utilised in hockey to determine normative values for this sport and to determine if there is a link between injury and a particular FMS™ score. In addition, research in this context would address limitations of previous research in order to strengthen the outcomes obtained for hockey players. The outcomes would then either support or negate the use of the FMS™ as a predictor for injury in this context.

In summary, the limitations of the previous research studies included:

- Kiesel *et al.* (2007), Cuson (2010) and Chorba *et al.* (2010) used a small sample size.
- Kiesel *et al.* (2007) utilized a retrospective approach.
- Kiesel *et al.* (2007) used an unclear injury definition.
- Cuson (2010) excluded the clearing tests from her research methodology as well as excluding upper extremity injuries.
- Chorba *et al.* (2010) used participants from three different sports, negating the ability to make sport specific recommendations.

Taking the above mentioned limitations of previous studies into account, this study used:

- A larger sample size, to improve the significance of the results.
- A prospective approach, as this approach is congruent with the intended application of the screen.
- A clear definition of “injury” (any acute or chronic injury that prevents a player from playing at their full potential or missing practices or games) which will allow for more injuries to be recognised in the research.
- All clearing tests in the research methodology as the clearing tests are deemed important to identify pain in a participant.
- A more homogenous sample, defined as female, premier league hockey players in KwaZulu-Natal, so that sport specific recommendations can be made.

Taking into account the above measures to improve on the current literature, this study aimed to investigate the normative values for the FMS^{TM} and its association to injury in female premier league hockey players in KwaZulu-Natal.

CHAPTER THREE:
RESEARCH METHODOLOGY

3.1 Introduction

This research methodology discusses the research design, the sampling method, the research procedure, the measurement tools utilised and finally the statistical method used to analyse the results of the research.

3.2 Research Design

The study design was of a quantitative, descriptive nature with prospective data collection from a cohort of female premier league hockey players in KwaZulu-Natal.

3.3 Sampling

3.3.1 Participant recruitment / permissions

Ethical clearance was granted by the Durban University of Technology, Institutional Research Ethic Committee (Appendix P).

The researcher contacted the KwaZulu-Natal Hockey Association (KZNHA) to ask for permission to conduct the research and to grant permission for the use of the Queensmead Stadium Astro as the venue where data capturing would take place (Appendix A).

The researcher requested written consent (Appendix A) from KZNHA (also see Appendix L for a signed copy of “in principle permission” to conduct the research by the KZNHA).

Once permission was obtained from the KZNHA, the researcher contacted the managers and coaches of the female premier league hockey clubs and explained the proposed research and requested written consent (Appendix B) to conduct the FMS™ on their players and to request assistance in the administration of the Attendance Record Sheet (Appendix G).

Subsequently, after receiving the abovementioned permissions, the researcher spoke to and received informed consent from all the players who participated in the study (Appendix C).

3.3.2 Sampling method

The researcher approached all nine female premier league hockey teams in KwaZulu-Natal and self-selection (Mouton 2006) took place as players agreed or declined to participate.

3.3.3 Sample size

In principle, if all players had agreed to participate, then the total sample would have been:
Total sample: N= 9 club teams x (+/-11 players per team) = 99 players.

3.3.4 Sample characteristics

3.3.4.1 Inclusion criteria

a. Players were only included if they signed the Letter of Information and Informed Consent (Appendix C).
b. Only players between the ages of 18-35 years were allowed to participate (Korporaal 2002).
c. Participants had to be Premier league hockey players on the basis that they play a high intensity game (Rishiraj 2009) and train at least twice a week with one game every weekend. This allowed the researcher to assess the players at practices.
d. Participants must be female hockey players to keep the sample homogeneous (Mouton 2006).

3.3.4.2 Exclusion criteria

a. Players that joined any of the hockey clubs after the FMS^{TM} had been conducted.
b. Players that left the hockey clubs after the FMS^{TM} had been conducted.
c. Players who did not sign the Letter of Information which gave informed consent (Appendix C).
d. Players who presented with pain due to a current injury.

3.4 Procedure

3.4.1 Overview of research procedure

- The researcher contacted the KZNHA to ask for permission to conduct the research.
- Once permission was obtained from the KZNHA (Appendix A), the researcher contacted all nine female premier league hockey clubs through club managers and

coaches, explained the proposed research and asked for written consent to conduct the study on their team (Appendix B).

- After consent was received, the researcher asked for written informed consent from each player (Appendix C). The players that granted their consent formed the research sample and were required to undertake the Functional Movement Screen™ test prior to the start of the season.
- The researcher set up the FMS™ at the team's practice venue as arranged with the coaches and managers of each team.
- Each player completed all seven tests and was scored by the researcher.
- Their scores were recorded on the FMS™ score sheet.
- The coaches were given the Attendance Record Sheet (Appendix G) to complete during the season for player absenteeism from practises and games.
- After this initial assessment, whenever the player sustained an injury (during a hockey practice or game), the player was asked to contact the researcher and schedule an appointment at the Durban University of Technology Chiropractic Day Clinic.
- The injured players received three free treatment vouchers from the Durban University of Technology Chiropractic Day Clinic. The treatments were administered by 6th year Chiropractic students under the supervision of a qualified chiropractor as per standard Durban University of Technology Chiropractic Day Clinic treatment protocol. During these treatments, players' injuries were recorded for the purposes of the research by completing the Injury Profile Sheet (Appendix E).
- Injured players who did not make use of the clinic treatments were interviewed by the researcher at their games or practises. Players' injuries were recorded with the use of the same Injury Profile Sheet (Appendix E) that was used in the clinic.
- Correlations between injuries sustained, FMS™ score and other personal descriptors were analysed to determine whether or not the screen can be reliably implemented as a pre-participation screen for injury susceptibility.

3.4.2 Participant questionnaire

Once informed consent was granted, the players were asked to complete the Player's Questionnaire (Appendix D). This was designed to collect identified injury risk factors for each player. These main risk factors for hockey players could influence injury frequency (Murtaugh 2001; Dick *et al*. 2007; Rishiraj *et al.* 2009).

These included:

- Personal descriptors such as a player's age, club affiliation, position and number of years playing hockey.
- Anthropometric measure such as height and weight.
- Injury profiles which included previous injuries and current injuries.

The main factors influencing injury frequency are mapped out in Figure 2 below.

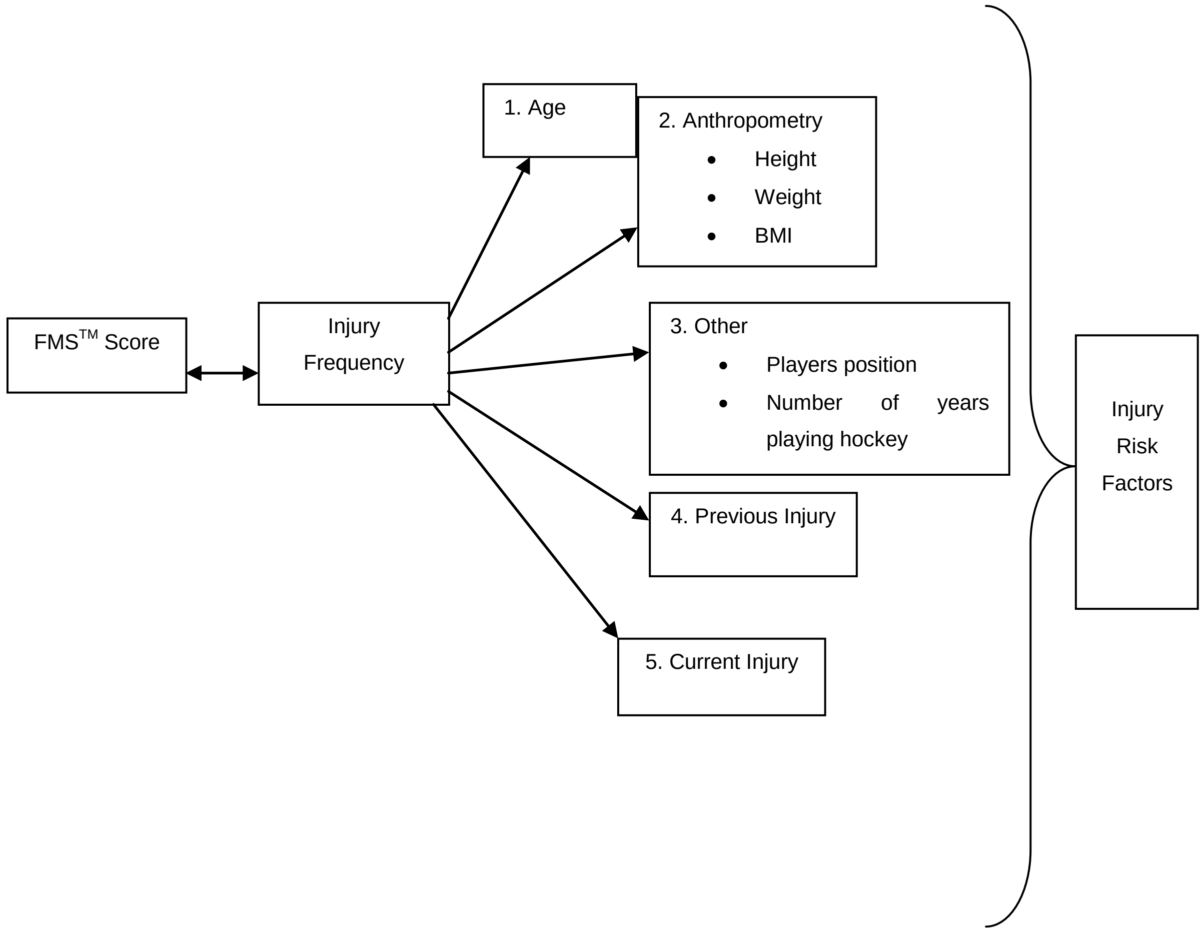


FIGURE 2: RISK FACTORS INFLUENCING INJURY FREQUENCY

For the purpose of the research players positions were categories using the following terms (Hockey 101 2014):

- Forwards: Have an attacking role with the main aim to score goals.
- Links: Are also known as midfielders and have both an attacking and defending role. Their main role is to pass the ball from the defenders to the forwards.
- Defenders: Their role is to defend the goal and oppose the other team's forwards.
- Utility players: Can play any position on the field.

- Goalkeeper: Stands in front of goal to block shots with her body and stick. Must have quick reflexes and ability to communicate defensive strategies to teammates.
- Some players played more than one position and in this case both positions were stated.

Once this data was collected for each player, they then underwent the FMS™.

3.4.3 Functional Movement Screen™

3.4.3.1 Overview

The researcher set up the FMS™ at the teams' practice venues as arranged with the various coaches. The FMS™ tests were set up on the artificial turf or next to the field. The players were asked to perform all seven tests including the recommended clearing screens. The researcher had the necessary training to conduct and score the FMS™ (Appendix M).

The seven tests (Appendix J) consist of (Cook *et al.* 2006a; Cook *et al.* 2006b):

- the deep squat,
- the hurdle step,
- the in-line lunge,
- the active straight leg raiser,
- the shoulder mobility test,
- the trunk stability push up and
- the quadruped rotary stability test.

A simple three to zero scoring system was used. A score of three was given if the participant was able to complete the movement perfectly. A score of two was given if the participant could complete the movement but with compensatory movements. A score of one was given if the participant was not able to complete the movement, and a score of zero was given if there was pain with the movement at any point or if the subject failed the clearing screen associated with that test (Cook *et al.* 2006a; Cook *et al.* 2006b).

Each player's score per exercise was recorded on the FMS™ Score Sheet (Appendix F) and then tallied to make up a total score out of 21 (See Appendix H for more on the FMS™ scoring method).

The three clearing tests (Appendix J) consisted of (Cook *et al.* 2006a; Cook *et al.* 2006b):

- the Shoulder mobility Clearing Test,
- the Extension Clearing Test and
- the Flexion Clearing Test.

Each clearing test is linked to one of the seven screen tests. If a player scored a zero for a clearing test then an automatic zero was awarded for the test with which it was paired (Cook *et al.* 2006a; Cook *et al.* 2006b).

The following test in the FMS™ test left and right sides respectively;

- the hurdle step,
- the in-line lunge,
- the active straight leg raiser,
- the shoulder mobility test and
- the quadruped rotary stability test

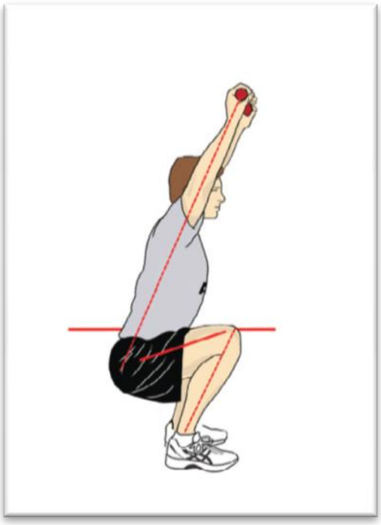
3.4.3.2 Description of the FMS™

The FMS™ consists of seven tests and three clearing tests and are described below (for more detail on the components of the FMS™ refer to Appendix J and Appendix H).

3.4.3.2.1 The deep squat

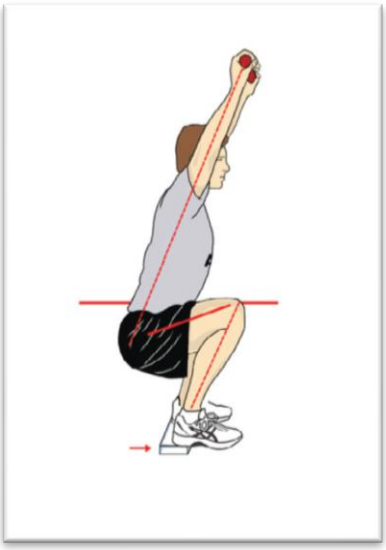
The deep squat mimics the ready position in hockey and challenges total body mechanics (Cook *et al.* 2006a).

The participant must place his/her feet shoulder width apart with toes facing forward.
The participant must adjust his/her hands on the dowel to assume a 90 degree angle of the elbows with the dowel overhead. The participant must then extend his/her elbows and press the dowel overhead. The participant is then instructed to descend slowly into a squat position. The participant's heels must be on the floor, the head and chest facing forward and the dowel pressed maximally overhead. See Figure 3 for illustration of the deep squat (Holder 2014). If the participant cannot successfully complete the test, the participant is asked to perform the test with a 15.5cm x 147.5cm wooden board under their heels (Cook *et al.* 2006a). See Figure 4.



(Holder 2014)

FIGURE 3: DEEP SQUAT, LATERAL VIEW



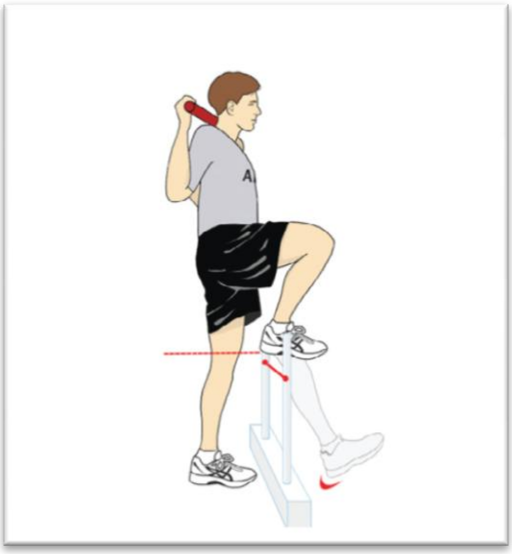
(Holder 2014)

FIGURE 4: DEEP SQUAT, WITH WOODEN BOARD BELOW HEELS

3.4.3.2.2 The hurdle step

The hurdle step challenges the participants proper stride mechanics during the stepping motion as well as single leg stability. Stride mechanics is important for any athlete (Cook *et al.* 2006a).

The participant starts by placing their feet together with his/her toes touching the base of the hurdle. The hurdle is then adjusted to the height of the participant's tibial tuberosity by the tester. The dowel is positioned across the shoulders and below the neck of the participant. The participant is then requested to step over the hurdle with one leg. On the other side of the hurdle his/her heel must touch the floor while maintaining the stance leg in a straightened (extended) position. The moving leg is then returned to the starting position. This is a bilateral test and both the left and right sides are tested and scored, the lower score is used when calculating the final score for the hurdle step (Cook *et al.* 2006a). See Figure 5 below.



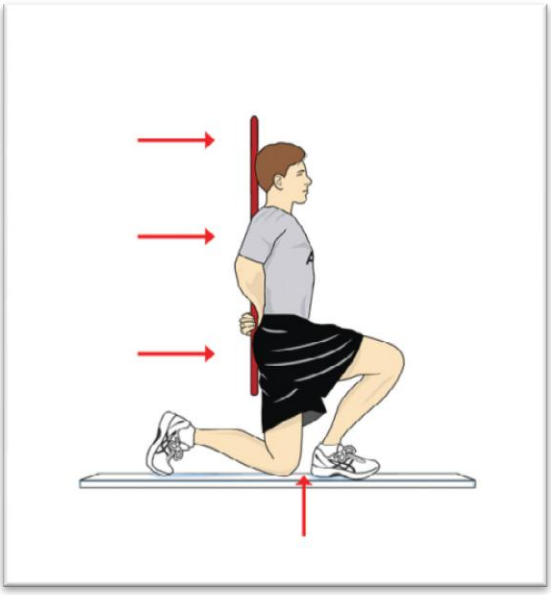
(Holder 2014)

FIGURE 5: THE HURDLE STEP, LATERAL VIEW

3.4.3.2.3 The in-line lunge

The in-line lunge challenges the body's trunk and extremities to resist rotation and maintain proper alignment (Cook *et al.* 2006a).

The tester first attains the individual's tibia length (from the floor to the tibial tuberosity). The participant then places the end of his/her heel on the end of the board. The tibia measurement is then applied from the end of the participant's toes (of the foot on the board) and a mark is made on the board. The participant must then place the dowel behind his/her back. The dowel must touch his/her head, thoracic spine and sacrum. The hand on the same side of the back foot should be the hand grasping the dowel at the cervical spine. The other hand grasps the dowel at his/her lumbar spine. The participant is then requested to step out onto the board placing the heel of the opposite foot at the indicated mark. The participant must then lower his/her back knee enough to touch the surface behind the heel of the front foot. The participant must then return to the starting position. See Figure 6. This is a bilateral test and both the left and right sides are tested and scored, the lower score is used when calculating the final score of the in-line lunge (Cook *et al.* 2006a).



(Holder 2014)

FIGURE 6: THE IN-LINE LUNGE, LATERAL VIEW

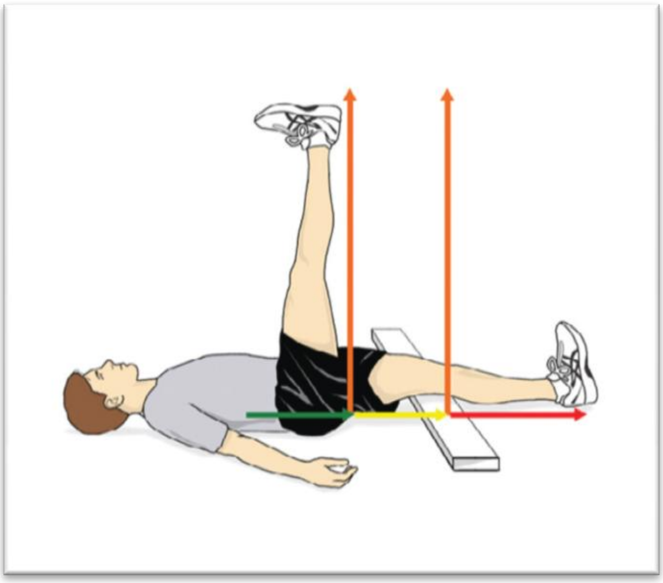
3.4.3.2.4 The active straight leg raiser

This test assesses active hamstring and gastroc-soleus flexibility while maintaining a stable pelvis and active extension of the opposite leg (Cook *et al.* 2006b).

The participant must first assume the starting position by lying on his/her back with his/her arms next to his/her body, palms facing up and head flat on the floor. The tester identifies the three different regions (see Figure 7 below):

- The region between mid-thigh and anterior superior iliac spine (ASIS) of the opposite lower extremity (green region).
- The region between the mid-thigh and knee joint line of the opposite lower extremity (yellow region).
- The region below the knee joint line of the opposite lower extremity (red region).

The participant is requested to lift his/her test leg with his/her ankle dorsiflexed (toes pointed upwards) and knee extended (leg straight).The opposite knee must remain in contact with the ground, the toes should be pointed upwards and the hands must be flat on the floor. Once the end range position is achieved, the tester will identify in which zone the malleolus of the test leg is located. See Figure 7. This is a bilateral test and both the left and right sides are tested and scored, the lower score is used when calculating the final score of the straight leg raiser (Cook *et al.* 2006b).



(Holder 2014)

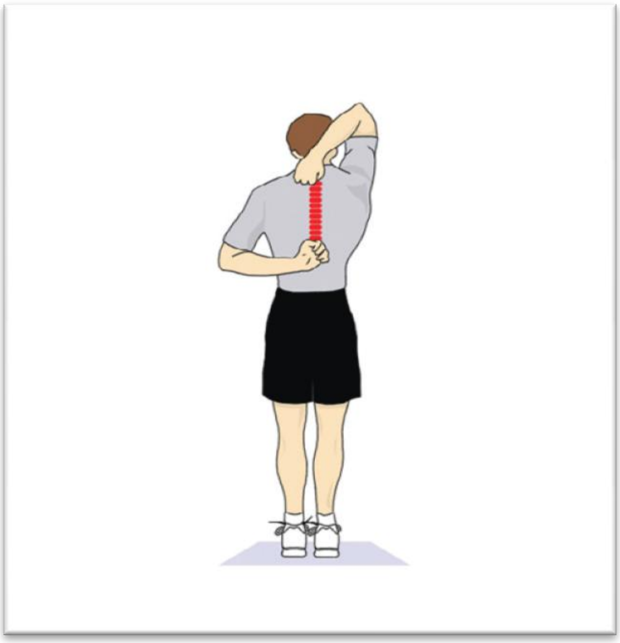
FIGURE 7: THE ACTIVE STRAIGHT LEG RAISER

3.4.3.2.5 The shoulder mobility test

This test assesses bilateral shoulder range of motion, scapular mobility and thoracic spine extension (Cook *et al.* 2006b).

The tester first defines the hand length of the participant by measuring the distance from the distal wrist crease to the tip of the third digit in centimetres.

The participant is then requested to make a fist with each hand, placing his/her thumb inside his/her fist. The participant's hands must remain in this position throughout the test. The participant's test arm must reach up above their head, and they must bend his/her elbow and reach down their back. The other arm must drop down next to his/her body; he/she must bend his/her elbow and reach up his/her back. The tester must then measure the distance between the two closest bony prominences (Cook *et al.* 2006b). See Figure 8.



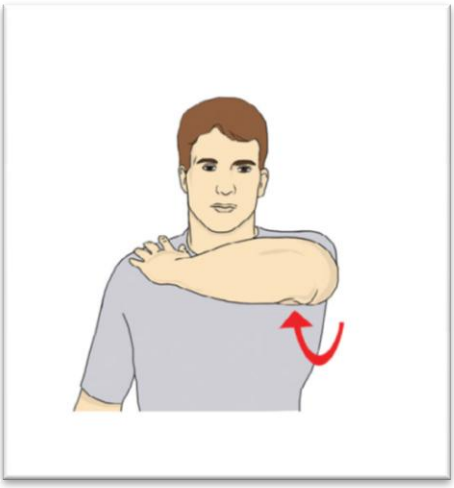
(Holder 2014)

FIGURE 8: THE SHOULDER MOBILITY TEST

3.4.3.2.5.1 Shoulder mobility clearing test

The clearing test is preformed after the shoulder mobility test. This test is simply performed to observe a pain response. This test is important as shoulder impingement can go undetected by shoulder mobility testing alone (Cook *et al.* 2006b).

The participant places his/her hand on the opposite shoulder and then attempts to point his/her shoulder upwards. If pain is associated with the movement, a score of zero is given to the entire shoulder mobility test (the clearing screen over-rides the score on the rest of the test) (Cook *et al.* 2006b). See Figure 9 below.



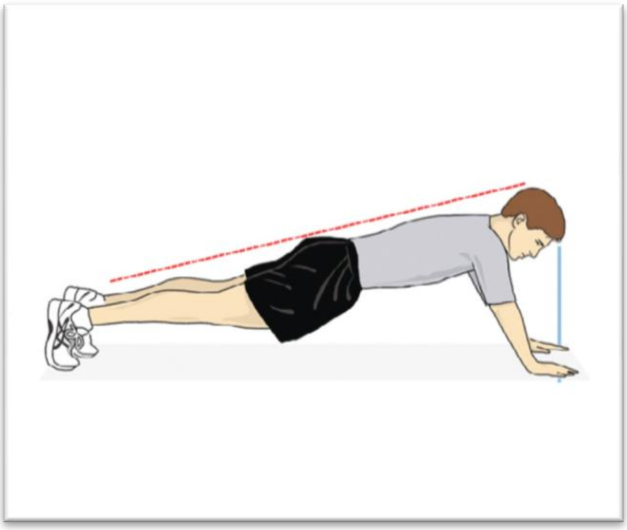
(Holder 2014)

FIGURE 9: SHOULDER MOBILITY CLEARING TEST

3.4.3.2.6 The trunk stability push-up test

The trunk stability push-up test assesses the participant's ability to stabilize the spine while an upper-extremity movement is performed (Cook *et al.* 2006b).

The participant starts by lying on their stomach (prone) with their feet together. His/her hands must be placed shoulder width apart with his/her thumbs aligned with his/her chin. The participant must fully straighten (extend) his/her knees and point his/her toes to the ground (dorsiflex ankles). The participant must then lift his/her body as a unit (push-up). There must be no "lag" in the lumbar spine. If the individual cannot perform a push-up in this position, then his/her thumbs must be aligned with his/her clavicles and the participant must re-attempt the push-up (Cook *et al.* 2006b). See Figure 10 below.



(Holder 2014)

FIGURE 10: THE TRUNK STABILITY PUSH-UP

3.4.3.2.6.1 Extension clearing test

This clearing test is performed after the trunk stability push-up test. This test is simply performed to observe a pain response. This test is important as back pain can go undetected during movement screens (Cook *et al.* 2006b).

The participant must lie on his/her stomach and push up with their arms, until his/her elbows are straight. If pain is associated with the movement, a score of zero is given to the entire trunk stability push-up test (the clearing screen over-rides the score on the rest of the test). See Figure 11.

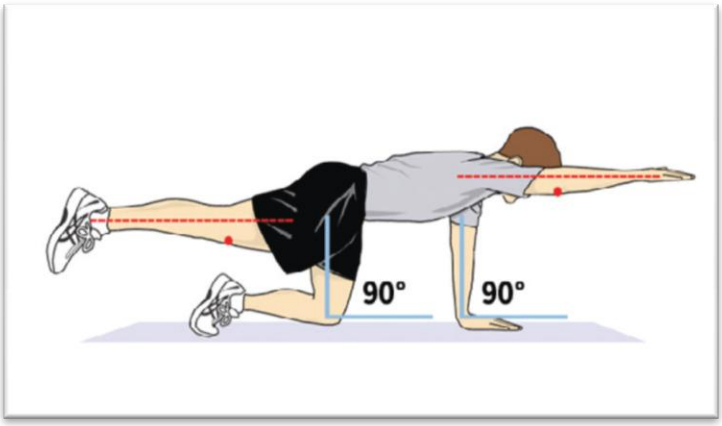
(Holder 2014)

FIGURE 11: THE EXTENSION CLEARING TEST

3.4.3.2.7 The quadruped rotary stability test

This test assesses trunk stability during a combination of lower and upper extremity movement (Cook *et al.* 2006b).

The participant's starting position is on all fours (Quadruped position), with shoulders and hips at 90 degrees relative to the participant's chest. The participant's knees are positioned at 90 degrees and their toes are pointed into the ground (ankles dorsiflexed). The participant must then lift his/her one arm and reach out in front of them (flex the shoulder).The participant must then straighten the knee on the same side as the arm that they just lifted (extend the same side hip and knee).The participant must only lift the leg and hand approximately 15cm off the floor. The same arm must then bend at the elbow and at the knee, enough for the elbow and knee to touch. If the participant cannot achieve this, he/she must perform a diagonal pattern using the opposite shoulder and hip in the same manner as described above (Cook *et al.* 2006b). See Figure 12.



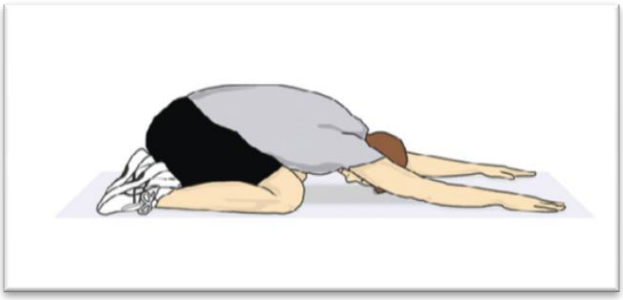
(Holder 2014)

FIGURE 12: THE QUADRUPED ROTARY STABILITY TEST

3.4.3.2.7.1 Flexion clearing test

This clearing test is performed after the quadruped rotary stability test. This test is simply performed to observe a pain response. The test is important as back pain can go undetected during movement screens (Cook *et al.* 2006b). .

The participant must stay in the same quadruped position as for the quadruped rotary stability test. The participant must then rock back touching his/her buttocks to his/her heels and they must move his/her chest to their thighs. The participant must keep his/her hands in front of his/her body and reach out as far as possible (Cook *et al.* 2006b). See Figure 13 below.



(Holder 2014)

FIGURE 13 : THE FLEXION CLEARING TEST

3.4.4 Attendance Record Sheet

An Attendance Record Sheet was completed by the coach of each team at practices and games (Appendix G). The attendance record sheet was used to record absenteeism from practices or games throughout the season so that correlation between low attendance and injuries sustained during the season could potentially be drawn.

3.4.5 Injury Profile Sheet

In the event of a player having sustained an injury during a hockey practice or during a hockey game, they were requested to contact the researcher who scheduled an appointment with a 6th year chiropractic student at the Durban University of Technology Chiropractic Day Clinic. Injury was defined as any acute or chronic injury that prevented a player from playing at their full potential or caused them to miss practices or games (Chorba *et al.* 2010).

At this point the player became an out-patient in the clinic and normal clinical paper work was completed (viz. History, Physical, appropriate regional and SOAPE note). In addition the Chiropractic student that administered the treatment in the clinic then also completed the Injury Profile Sheet for that specific patient (Appendix E). The researcher also attended league games and practices and interviewed injured players that elected not to receive treatment at the Chiropractic Day Clinic. This information was recorded on the Injury Profile Sheet (Appendix E) and included in the study.

The Injury Profile Sheet was designed to collect information on the injuries that female hockey players sustained. The following information was requested:

- Diagnosis of injury,
- Severity of injury,
- Time lost at practices, games and work due to injury,
- Type of treatment received for the injury,
- Type of training that the players undertook before the injury occurred.

3.5 Measurement tools

3.5.1 FMS^{TM} Kit

The kit included the following items (Cook *et al.* 2010):

- One wooden dowel (135.5cm),
- One 15.5cm x 147.5cm wooden board,
- One hurdle (two vertical wooden beams (59.5cm) and rubber band) and
- One measuring tape.

3.6 Statistical analysis

3.6.1 Methodology

SPSS version 20 was used for data analysis. Demographic data were represented with averages, means, ranges and standard deviations. A *p* value of less than 0.05 was considered as statistically significant. Pearson's chi squared tests and correlation coefficients, as well as ANOVA, t-tests and Fisher's exact tests were used to assess associations between demographics and outcomes, and to compare variables. The outcome of injury susceptibility was defined as non-contact injuries sustained during the season. Scores of the components of the FMS^{TM} were compared with injury susceptibility using non-parametric Mann-Whitney tests because the scores were ordinal and not normally distributed.

3.6.2 Statistical goals

In line with the research aims and objectives it was undertaken to statistically analyse for:

- the normative values of the FMS^{TM}.
- correlation between total FMS^{TM} score and injury incidence/susceptibility.
- correlation between other identified injury risk factors (age, anthropometry, position, injury profile) and injury incidence/susceptibility.

The research also recognised the need to test for dependence between the FMS^{TM} and other risk factors in order to determine whether the FMS^{TM} is an independent metric. To do this each risk factor was statistically tested for correlation with the FMS^{TM}. Further to this, a statistical investigation was undertaken to determine whether the FMS^{TM} was the best indicator for injury susceptibility out of the identified injury risk factors. This was achieved by testing for relationships between each risk factor and injury incidence/susceptibility.

CHAPTER FOUR:
RESULTS AND DISCUSSION

4.1 Introduction

This study was undertaken to determine the normative values for the Functional Movement Screen^{TM} (FMS^{TM}) in female premier league hockey players in KwaZulu-Natal (KZN) and to determine if there is an association between a low score on the FMS^{TM} and injury susceptibility. In order to draw such conclusions it was identified in the objectives at the outset of this dissertation that the research needed to:

a. Evaluate the FMS^{TM} score in a sample of female premier league hockey players (pre-season).
b. Determine the incidence, frequency and distribution of injuries throughout the competitive season for female premier league hockey players.
c. Assess the association between FMS^{TM} scores and incidence of injuries sustained by female premier league hockey players during the course of a season.
d. Assess the association between other identified risk factors and incidence of injuries sustained by female premier league hockey players during the course of the season. The other identified risk factors were player's age, number of years playing hockey, height, weight and position.

In this results section, a summary of the sample characteristics is presented and thereafter the statistical analysis of the data is presented in the same order as was outlined in the research objectives. The results are presented per objective and discussed as and when they appear in this dissertation to promote flow and avoid repetition.

4.2 Research sample breakdown

The flow of participants from start to finish, as suggested by Moher *et al.* (2010).

Total potential sample:
N= (9 club teams) x (+/-11 players per team)
= 99 players

↓

- 23 players where under 18 years old
- 1 player was over 35 years old
- 1 player declined to participate

↓

Total number of participants=74

FIGURE 14: RESEARCH SAMPLE BREAKDOWN FLOW CHART

4.3 Demographics of research sample

The 74 female premier league hockey players that participated in the study were on average 21.86 years of age (range 18-32 years, SD ±2.94 years). In terms of height and weight, the average height of the sample was 1.64 metres (range 1.30-1.76m, SD ±0.08) with the average weight being 60.95 kg's (range 45-95kg, SD ±9.12).This led to an average body mass index for the sample of 22.56 kg/m^2 (range 17.6-32.9, SD ±2.85). Distributions of club affiliation, age and position for the sample are reflected in Figure 15, Figure 16 and Figure 17 below.

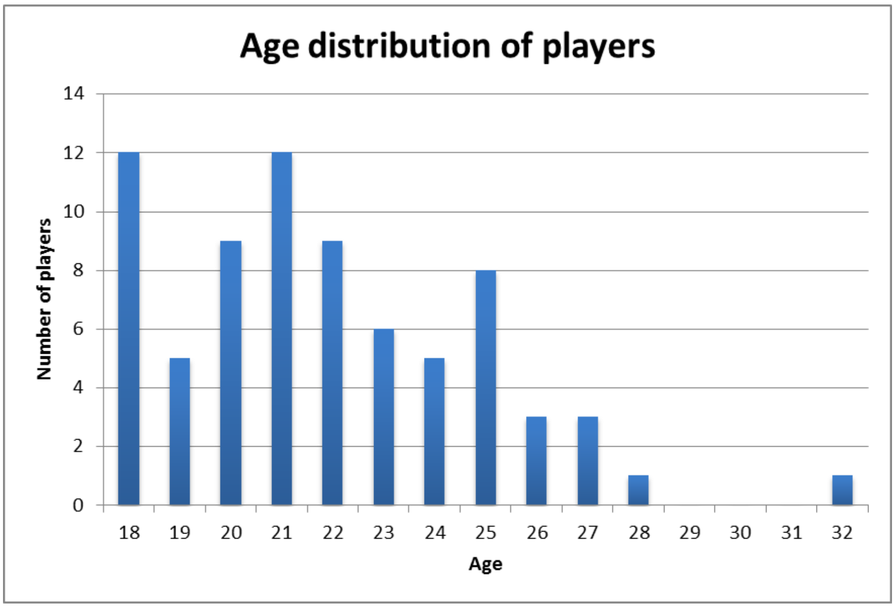


FIGURE 15: AGE DISTRIBUTION OF THE PLAYERS THAT PARTICIPATED IN THE STUDY

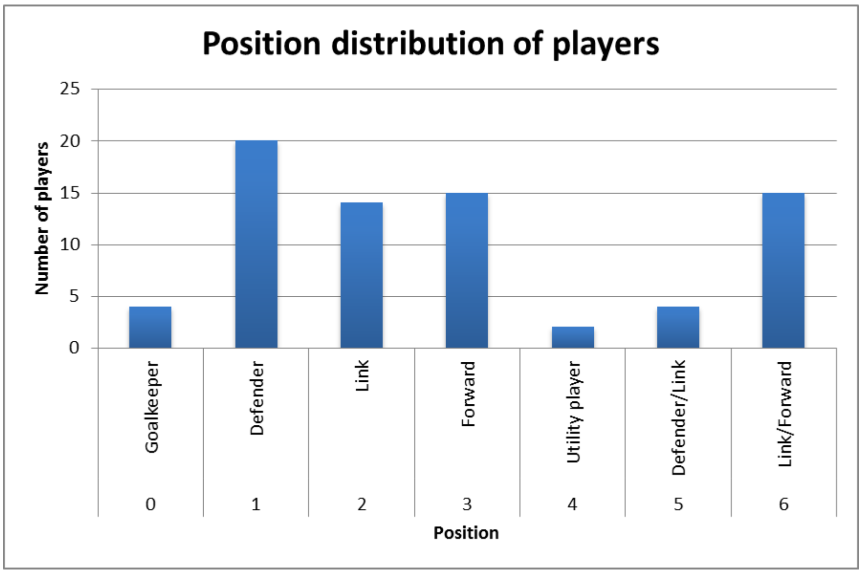


FIGURE 16: POSITION DISTRIBUTION OF THE PLAYERS THAT PARTICIPATED IN THE STUDY

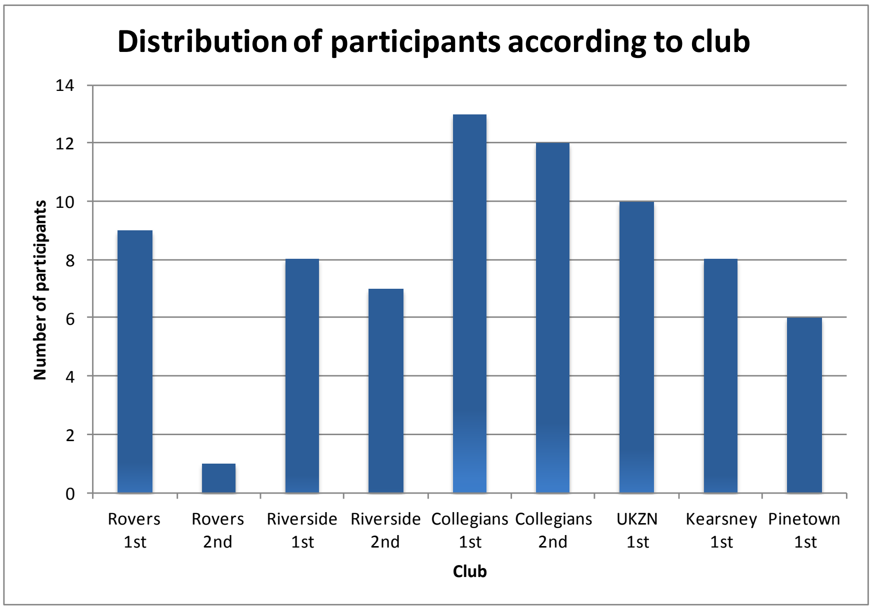


FIGURE 17: DISTRIBUTION OF THE PLAYERS THAT PARTICIPATED IN THE STUDY ACCORDING TO CLUB

The results in Figure 15 above show that most of the players were aged 18 or 21. Only one player was over the age of 30. Figure 16 shows that most players that participated in the study were Defenders followed by Forwards and Forward/Links and the least participated players were Utility Players. In terms of participation, Figure 17 shows that Collegians Hockey Club showed the greatest level of participation with a combined total of 25 players from their 1st and 2nd teams participating in the premier league. Rovers 2nd team showed low levels of participation which can mainly be attributed to the fact that most of their players were under the age of 18 and therefore they did not meet the inclusion criteria set out for the study.

4.3.1 Discussion

The demographics of this study can be compared to the study of Chorba *et al.* (2010) and to that of Schneiders *et al.* (2011). Chorba *et al.* (2010) tested 38 female collegiate athletes who participated in soccer, volleyball and basketball. Their mean age was 19.24 years (SD ±1.20), height 1.72m (SD ±8.51), weight 67.45kg (SD ±9.58) and BMI 22.8 kg/m^2 and when looking at only the soccer players, which is fundamentally the closest sport to hockey, their mean age was 18.93 years (SD ±1.10), height 1.66m (SD ±6.14), weight 61.64kg (SD ±5.64) with a BMI of 22.2 kg/m^2. The demographics of this study are also similar to that of Schneiders *et al.* (2011), whose sample presented with an average age of 21.2 years (range 18-40, SD ±3.0), an average height of 1.66m (range 1.50-1.81m, SD ±6.7) and an average BMI of 23.9 kg/m^2 (range 17-35, SD ±3.2)

These similarities would allow for comparisons between studies as participants had similar demographics and in all three studies, only female participants were assessed. The fact that most players were either aged 18 or 21 can likely be attributed to strong participation from high school and university players. This research also revealed that future research should consider amending the inclusion criteria to include players from the age of 16. Not only will this facilitate an increase in the sample size, but may also be more reflective of the hockey playing population.

4.4 Normative values of the FMS™ in female premier league hockey players

The Functional Movement Screen™ was performed pre-season on players between the ages of 18 and 35 from nine female premier league hockey teams in KwaZulu-Natal. Participation from players in the screen was on a voluntary basis and in total 74 players participated and their FMS™ scores were recorded. In Table 1 below, the summary statistics for the sample captured in this research are displayed.

TABLE 1: SUMMARY STATISTICS FOR FMS™ SCORES OF THE RESEARCH SAMPLE

Sample Characteristic	Value
Sample size	74
Mean FMS™ score	14.39
Median FMS™ score	14.5
Modal FMS™ score	17
Range of FMS™ scores	8 – 19
Standard deviation of FMS™ scores	2.40

The research sample revealed a mean FMS™ score of 14.39 out of 21 with a standard deviation of 2.4. The FMS™ score with the highest frequency (mode) was 17/21 with 14 out of the 74 players achieving a score of 17/21 on the screen.

In order to assess the dependence of the FMS™ score on a player's position (which is discussed later on in the results chapter), it was also necessary to determine the mean FMS™ score of the players in each position along with the standard deviation of that group. These results are presented in Table 2 below.

TABLE 2: MEAN AND STANDARD DEVIATION OF FMS™ SCORE FOR EACH POSITION

Player's Position	FMS™ Score		
	Number of players per position group	Mean	Standard deviation
Utility player	2	15.5	0.7
Link	14	15.3	2.0
Forward	15	14.7	2.7
Defender	20	14.6	2.2
Defender/Link	4	13.8	2.4
Link/forward	15	13.6	2.6
Goalkeeper	4	12.3	2.4

4.4.1 Discussion

In this research, the mean FMS™ score was 14.39. This is comparable to the results of Chorba *et al.* (2010) who recorded 14.3 as a mean FMS™ score for female collegiate athletes. Kiesel *et al*. (2007), Chorba *et al.* (2010) and Hamel (2013) determined in their studies that a score of 14 or less increased a player's risk for injury. The mean FMS™ scores for the various positions identified in the study revealed that, for this study, utility players scored highest on the FMS™ with a mean score of 15.5. Goalkeepers, on average, scored lowest (mean of 12.3), with link/forwards (mean of 13.6) and defender/links (mean of 13.8) scoring 2nd and 3rd lowest respectively. These results may give an indication of the conditioning that players in the various positions undergo (Korporaal 2002). Goalkeepers are not required to do much running during the course of a game and the position does not require high degrees of fitness. The position does, however, require a high degree of flexibility and reflex. These results imply that, in general, goalkeepers are not as well conditioned with respect to functional movement when compared to the other positions. Utility players, who scored (on average) highest on the FMS™, were defined as players who played various positions from defender to link to forward (Korporaal 2002). The ability to play various positions requires some versatility in terms of body conditioning because these positions demand high degrees of fitness, mobility and strength (Korporaal 2002). Enhanced body conditioning of utility players may be the reason for these players scoring, on average, 1.1 points higher than the overall average of the sample. These differences were not tested for statistical significance.

The definition of a player as a utility player is also an area that warrants discussion. As was mentioned above, utility players were defined as players who played various positions from defender to link to forward. Other position definitions were also made in the research such as defender/link and link/forward. These classifications could, by other definitions, be regarded as utility players since these players play across single position boundaries. For the purposes of this research, utility players, defenders/links and links/forwards were regarded as separate classifications, as per team designations. It is, however, recommended that future research considers grouping these classifications into one utility player classification or classifying players according to their functional ability. The reduction in position categories may help to draw more definitive conclusions regarding a player's position (viz. improve chances of statistical significance). While the large number of categories, with regard to position, is noted as a shortcoming in this research, it was not pursued any further as it did not contribute to the primary aim of this study.

4.5 Injury incidence, frequency and distribution

This section is divided into previous injuries, current injuries and injuries sustained during the season. Previous injuries and current injuries are discussed together and injuries sustained during the season are discussed independently as it formed part of the focus of the study. All injuries were classified into 11 broad categories identified by the researcher in order to enable statistical analysis. The 11 broad categories were:

- Fracture
- Sprain
- Strain
- Muscle tear
- Ligament tear
- Repetitive strain
- Joint dysfunction
- Joint dislocation
- Contusion
- Other pathology
- Concussion

4.5.1 Previous and current injuries

4.5.1.1 Previous injuries

Previous injuries are all injuries that a player incurred during previous practices / games. The researcher recorded all the players' previous injuries on the Player Questionnaire (Appendix D) at the time that the FMS^{TM} was conducted. Some players had never incurred a previous injury or injuries and there were no players with more than five previous injuries.

TABLE 3: RECORDED NUMBER OF PREVIOUS INJURIES PER PLAYER

Previous injury	Number of injuries	Number of players sustaining Injuries	Percentage of sample with injury
Fracture	0	56	75.7%
	1	13	17.6%
	2	2	2.7%
	3	3	4.1%
Sprain	0	41	55.4%
	1	27	36.5%
	2	5	6.8%
	5	1	1.4%
Strain	0	54	73.0%
	1	16	21.6%
	2	4	5.4%
Muscle tear	0	68	91.9%
	1	6	8.1%
Ligament tear	0	59	79.7%
	1	12	16.2%
	2	3	4.1%
Repetitive strain	0	59	79.7%
	1	12	16.2%
	2	1	1.4%
	4	2	2.7%
Joint dysfunction	0	58	78.4%
	1	15	20.3%
	3	1	1.4%
Joint dislocation	0	68	91.9%
	1	6	8.1%
Contusion	0	69	93.2%
	1	4	5.4%
	2	1	1.4%
Other pathology	0	70	94.6%
	1	4	5.4%
Concussion	0	72	97.3%
	1	2	2.7%

The most common previous injuries sustained were (in descending order); sprains (with 44.6% of players reporting previous sprains), strains (with 27% of players reporting previous strains), fractures (with 24.3% of players reporting previous fractures) and joint dysfunction (with 21.6% of players reporting previous joint dysfunction) (Table 3).

4.5.1.2 Current injuries

Current injuries were defined as all non-painful injuries that did not preclude the player from practices or games but were present at the time of conducting the FMS^{TM}. Players reported current injuries in the Player Questionnaire (Appendix D) at the time that the FMS^{TM} was conducted. Some players suffered from one (primary) injury but never more than two (concomitant/secondary) injuries. See table 4 below.

TABLE 4: DIAGNOSIS OF CURRENT INJURIES

Type of injury		**Number of players sustaining an injury**	**Percentage of players with injury %**
Primary injury	No injuries	50	67.6%
	Joint dysfunction	8	10.8%
	Strain	6	8.1%
	Repetitive strain	5	6.8%
	Contusion	1	1.4%
	Fracture	1	1.4%
	Sprain	1	1.4%
	Joint dislocation	1	1.4%
	Other	1	1.4%
	Concussion	0	0.0%
	Ligament tear	0	0.0%
	Muscle tear	0	0.0%
Concomitant/Secondary injuries	No injuries	70	94.6%
	Joint dysfunction	2	2.7%
	Repetitive strain	1	1.4%
	Other	1	1.4%
	Fracture	0	0.0%
	Sprain	0	0.0%
	Strain	0	0.0%
	Muscle tear	0	0.0%
	Ligament tear	0	0.0%
	Joint dislocation	0	0.0%
	Contusion	0	0.0%
	Concussion	0	0.0%

The results reflected in Table 4 above revealed that 67.6% of the players were completely injury free at the time that FMS^{TM} was administered. The remainder of the players reported minor injuries which did not restrict them from taking part in the study as they were reported to be pain free. Joint dysfunction (10.8%), strain (8.1%) and repetitive strain (6.8%) were the most commonly reported current injuries (Table 4).

However, the results also indicated that 32.4% of the sample was affected by current injuries at the time that the FMS^{TM} was administered. This percentage was composed of 27% that had a single primary current injury and 5.4% that had two concomitant injuries. These results are reflected in Table 5.

TABLE 5: TOTAL NUMBER OF CURRENT INJURIES

Number of current injuries	Frequency	Percentage %
0	50	67.6
1	20	27.0
2	4	5.4
Total	74	100.0

The researcher then determined if the current injuries affected the functional movement of a player. Of the 24 players who presented with a current injury, almost all the players (96%) had injuries which had the potential to affect functional movement.

4.5.1.3 Discussion

According to the results of this research, the most common previous injuries that female premier league field hockey players sustained were (in descending order); sprains, strains, fractures and joint dysfunction. Joint dysfunction included all injuries that related to abnormal functioning of any joints and that could not be classified as either a strain or a sprain. Ankle and knee dysfunction are very common in hockey players which lead to the high incidence of joint dysfunction in this research. Murtaugh (2001) and Korporaal (2002) concurs with the abovementioned results indicating that ankle/foot and knee sprains were very common. By contrast, Rishiraj et al. (2009) found that muscle strains were most common which is in agreement with Dick *et al.* (2007), who reviewed 15 years of National Collegiate Athletic Association Injury Surveillance Data for women's field hockey and found that muscle strains and joint sprains were equally common in female hockey players. It is, however, noted that with the reported joint sprains, ankle sprains were the most common (Dick *et al.,* (2007). These latter results concur with the findings of this research.

By contrast, Reilly and Seaton (1990) and Murtaugh (2001) indicated that hockey players injured their low back the most. In this study however, only one player suffered from sacro-iliac syndrome (viz. low back pain).

Current injuries were noted as the sequelae of previous injuries as participants were required to be pain free to participate in this study (see 3.3.4.2 Exclusion criteria). Notwithstanding this definition, the results are very similar to the previous injuries with joint dysfunction, strain and repetitive strain being the most common current injuries. The low incidence of concomitant/secondary injuries found in the study could possibly be attributed to the fact that players stop practising and playing games when injured which reduces their risk of sustaining a secondary injury. This could be an indication of good injury management by clubs in female premier league hockey.

4.5.2 Injuries sustained during the season

After the FMS™ was conducted, the players continued with their hockey season and reported injuries to the researcher that occurred during the season (see Section 3.4.5). Some players suffered from one (Primary) injury but never more than two (Concomitant/Secondary) injuries. The injuries were then divided into 11 broad categories to draw statistical conclusions.

TABLE 6: DIAGNOSIS OF INJURIES SUSTAINED DURING THE SEASON

Type of injury		Number of player sustaining injury	Percentage of population sustaining injury %
Primary injury	No injuries	53	71.6%
	Repetitive strain	7	9.5%
	Joint dysfunction	5	6.8%
	Strain	4	5.4%
	Sprain	3	4.1%
	Fracture	1	1.4%
	Muscle tear	1	1.4%
	Ligament tear	0	0.0%
	Joint dislocation	0	0.0%
	Contusion	0	0.0%
	Concussion	0	0.0%
	Other	0	0.0%
Concomitant/Secondary injury	No injuries	73	98.6%
	Joint dysfunction	1	1.4%
	Fracture	0	0.0%
	Sprain	0	0.0%
	Strain	0	0.0%
	Muscle tear	0	0.0%
	Ligament tear	0	0.0%
	Repetitive strain	0	0.0%
	Joint dislocation	0	0.0%
	Contusion	0	0.0%
	Concussion	0	0.0%
	Other	0	0.0%

The most common injuries sustained during the season were repetitive strains, joint dysfunction, strains and sprains.

TABLE 7: TOTAL NUMBER OF INJURIES SUSTAINED DURING THE SEASON

Number of follow-up injuries	Frequency	Percentage
0	53	71.6%
1	20	27.0%
2	1	1.4%
Total	74	100.0%

The results indicate that 21 out of 74 players sustained injuries during the course of the competitive season. One player incurred a Concomitant/Secondary injury. Injuries were further classified into contact or non-contact injuries. The research worked under the assumption that a player's functional movement could only impact on their susceptibility for a non-contact injury and therefore making a distinction between contact and non-contact injuries was imperative for data analysis.

TABLE 8: INJURIES SUSTAINED DURING THE SEASON; TYPE AND SEVERITY

		Count	Column N %
Type	**Non-contact**	18	85.7%
	Contact	3	14.3%
Severity	**Moderate**	10	47.6%
	Severe	7	33.3%
	Mild	4	19.0%

The type of injuries revealed that 18 out of the 21 injuries sustained during the competitive season were non-contact injuries and therefore modifiable (Neely 1998; Arnason *et al.* 2004; Micheli 2010). The majority of the injuries were classified as moderate or severe.

Based on the 21 sustained injuries, the players also reported game and practice time lost due to injury. The median time lost was three days, with the range being zero to 30 days. Further to this, the non-contact injury distribution across the various positions was also noted to analyse for an association between position and injury susceptibility. The results of this cross tabulation are reflected in Table 9.

TABLE 9: CROSS TABULATION BETWEEN PLAYERS POSITIONS AND RATE OF NON-CONTACT INJURIES

Position * non-contact injuries Cross tabulation					
			Non-contact injuries		**Total**
			No injuries	**Non-contact injuries during season**	
Position	**Goalkeeper**	**Count**	4	0	4
		%	7.1%	0.0%	5.4%
	Defender	**Count**	16	4	20
		%	28.6%	22.2%	27.0%
	Link	**Count**	11	3	14
		%	19.6%	16.7%	18.9%
	Forward	**Count**	11	4	15
		%	19.6%	22.2%	20.3%
	Utility player	**Count**	1	1	2
		%	1.8%	5.6%	2.7%
	Defender/Link	**Count**	3	1	4
		%	5.4%	5.6%	5.4%
	Link/forward	**Count**	10	5	15
		%	17.9%	27.8%	20.3%
Total		**Count**	56	18	74
		%	100.0%	100.0%	100.0%

*Pearson's chi squared test= 2.97, p=0.812

Due to there being seven position categories, the data was diluted which made it difficult to draw statistical conclusions. If however, defender/link and link/forward fell under utility players then it would have had a more significant injury count and the possibility for significant statistical conclusions relating to players' positions and injuries would increase. This being said, the position that sustained the most non-contact injuries in this sample was link/forward.

4.5.2.1 Discussion

With reference to Table 6 the most common injuries sustained during the season, in descending order, were repetitive strains (9.5%), joint dysfunction (6.8%), strains (5.4%) and sprains (4.1%). These results correspond with the work of Murtaugh (2001), Korporaal (2002), Dick *et al.* (2007) and Rishiraj et al. (2009) for being typical hockey injuries.

The type of injuries revealed that 18 out of the 21 injuries where non-contact injuries (Table 8) and the majority of the injuries were classified as moderate or severe injuries (Neely 1998; Arnason *et al.* 2004; Micheli 2010). These results correspond well with research by Rishiraj et al. (2009) who found that the highest number of injuries in female field hockey players were sustained from non-contact situations.

The median time lost in which a player was unable to practice due to injury was 3 days with a range of 0 to 30 days. This result indicates that although one player was unable to play for 30 days due to their injury, the remainder of the players were absent from practices/games for less than three days. Time lost to injury restricts a player from practicing; however the duration of time depends on the type of injury and its severity (Micheli 2010).

Murtaugh (2001) indicated that the player's position influences the rate of injury. According to Murtaugh (2001), goalkeepers, links and utility players had the highest injury rate. Research by Dick *et al.* (2007) also showed that defenders and links were at greater risk of injury when compared to other positions on the field. In contrast, this research revealed that link/forward, forwards and defenders suffered the most injuries in the season. Even though these trends were observed, there were too many position categories in this research to draw significant conclusions and it is suggested that either the position categories are condensed in future studies or future studies consider increasing the number of players per category.

4.6 Association between FMS™ scores and injury susceptibility

In analysing whether there was a correlation between injury susceptibility and FMS™ scores, questions surrounding the independence of the FMS™ scores from anthropometric measures (e.g. height and weight) and other identified risk factors (age, number of years playing hockey, injury profile and position) were raised. The efficacy of the other identified risk factors for predicting injury susceptibility as compared to the FMS™ score was also questioned. To answer these questions, the research tested the correlation of the FMS™ score with other injury risk measures and then the correlation of these measures to injury susceptibility. The outcome of injury susceptibility was defined as non-contact injuries sustained during the season.

4.6.1 Independence of the FMS™ score from other quantifiable injury risk factors

In order to determine whether the FMS™ score was independent of other quantifiable risk factors identified and recorded in the study, relationships between these risk factors and FMS™ scores were assessed. The following risk factors were tested against the FMS™ scores to determine whether any correlation and therefore dependence existed:

a) Age versus total FMS™ score
b) Player's position versus total FMS™ score
c) Number of years playing versus total FMS™ score
d) Height versus total FMS™ score
e) Weight versus total FMS™ score
f) BMI versus total FMS™ score

Significantly, the other quantifiable injury risk factors could be divided into continuous variables and discrete variables. All injury risk factors except “player’s position” were considered as a continuous variables with “player’s position” considered as discrete. The difference in nature of this data necessitated different statistical tests.

- For the continuous variables, the Pearson Correlation Coefficient and the Sigma Two-tailed test were used to test for dependence.
- For the discrete variable (player’s position), the mean and variance of the FMS™ score for each position was determined and analysis of variance (ANOVA) was undertaken to determine whether the FMS™ scores were significantly different for different positions.

The Pearson Correlation Coefficient is a statistical measure that ranges between -1 and 1 and indicates correlation between two variables with a value of -1 indicating a strong negative correlation, a value of 1 indicating a strong positive correlation and a value near zero indicating no correlation. The Sigma two-tailed test, at a 95% confidence level, was used.

TABLE 10: CORRELATION OF INJURY RISK FACTORS TO FMS™ SCORE

Injury Risk Factor	Sample Size (N)	Pearson Correlation Coefficient	Sigma Two-tailed test
Height (m)	73[1]	0.02	0.866
BMI (kg/m²)	72[1]	-0.083	0.489
Weight (kg)	73[1]	-0.084	0.478
No. of years playing hockey	74	0.157	0.181
Age (years)	74	0.191	0.103

The Pearson Correlation Coefficient and the Sigma Two-tailed test revealed no significant correlations between the continuous variables and FMS™ score (Table 10). This is interpreted from the fact that the Pearson Correlation Coefficients are all near zero indicating little to no correlation and the *p* value for the Sigma Two-tailed tests are all greater than 0.05 which indicates a lack of statistical significance.

[1] There was a difference in sample sizes in Table 10 and Table 11 due to the fact that one participant did not reveal their height and one participant did not reveal their weight. The height and weight category thus only had 73 participants. The BMI could thus not be calculated for two participants, reducing the sample size to 72 participants.

TABLE 11: ANALYSIS OF VARIANCE BETWEEN PLAYER'S POSITION AND FMS™ SCORE

ANOVA

FMS™ Total Score

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	45.045	6	7.507	1.343	.251
Within Groups	374.590	67	5.591		
Total	419.635	73			

Analysis of variance, as depicted in Table 11 above, revealed no significant difference in mean FMS™ score between the player's positions.

4.6.1.1 Discussion

The results from Table 10 and Table 11 above indicate that there is no dependence of FMS™ score on any of the other injury risk factors recorded in the study. This suggests that the FMS™ score is an independent metric that is not affected by the other injury risk factors identified such as age, number of years playing hockey, height, weight, BMI and position. This is an important result in that it indicates that the FMS™ score is a unique measure of particular relevance to the movement dysfunction of the participants.

4.6.2 Correlation between FMS™ score and injury susceptibility

The study considered non-contact injuries sustained during the season as a measure of injury susceptibility. In analysing the data for the dependence of injury susceptibility on FMS™ score, the sample was divided into those participants that sustained non-contact injuries during the season and those participants that did not sustain non-contact injuries. The mean FMS™ scores of the two groups were then statistically tested for significant differences. Parts of the FMS™ screen were also then assessed for their efficacy in indicating injury susceptibility. Asymmetry was tested as an indicator for injury as were each component of the FMS™ screen.

It was found that out of the 74 players that constituted the sample, 18 of them sustained non-contact injuries during the course of the season. This meant that 56 players were either not injured or sustained contact injuries during the season. In fact, 53 players were not injured during the course of the season and 3 players sustained contact injuries.

4.6.2.1 Functional Movement Screen™ total score as a predictor for injury

With reference to Table 13 below it could be seen that the average FMS™ score for the 18 players who sustained non-contact injuries during the course of the season was 13.6. The average FMS™ score for the 56 players who did not sustain non-contact injuries was 14.6. The results therefore show that for this sample, players who did not sustain non-contact injuries during the course of the season on average scored one point higher on the pre-season FMS™. This result was tested for statistical significance and it was found that the differences in average FMS™ scores for player's who sustained non-contact injuries during the season and those who did not, was not significant. A follow-up study is recommended with a larger sample size to further test this significance.

4.6.2.1.1 Discussion

Although the results were not significant, they can be compared against Kiesel *et al.* (2007) and Chorba's *et al.* (2010) studies.

- Kiesel *et al.'s* (2007) study determined that if professional male football players scored 14 or less they were more susceptible to injury. The players in this research who sustained non-contact injuries scored, on average, 13.6 on the FMS™.
- In Chorba *et al.'s* (2010) study, it was concluded that a score of 14 or less on the FMS™ resulted in a four-fold increase in risk for a lower extremity injury in a female collegiate athlete. This result is also comparative to the outcome of this study. In this sample, 37 players scored 14 or less on the pre-season FMS™ while the remaining 37 subjects scored more than 14 on the screen. Out of the 37 players who scored 14 or less, 12 sustained non-contact injuries during the season (32%). Out of the 37 players who scored more than 14 on the FMS™, only 6 sustained non-contact injuries (16%). For this research sample, one can interpret this as a score of 14 or less on the FMS™ resulted in a two-fold increase in risk for a non-contact injury.

4.6.2.2 Components of the FMS™

Five of the seven tests in the FMS™ are bilateral tests and thus asymmetry was tested. Other studies have identified asymmetry as being an injury risk factor (Baumhauer *et al.* 1995; Sahrmann 2002; Kiesel *et al.* 2007; Peate *et al.* 2007). This research wanted to determine if asymmetry on the FMS™ tests could predispose a player to injury. As was mentioned previously, injury susceptibility was defined as non-contact injuries sustained during the season.

TABLE 12: COMPONENTS OF THE FMS^{TM}: ASYMMETRY VS INJURY SUSEPTABILITY

		Injuries sustained during the season				*p* value*
		No injury		Injury		
		Count	Row N %	Count	Row N %	
Asymmetry hurdle step	No asymmetry	43	75.4%	14	24.6%	1.000
	Asymmetry	13	76.5%	4	23.5%	
Asymmetry inline lunge	No asymmetry	48	77.4%	14	22.6%	0.470
	Asymmetry	8	66.7%	4	33.3%	
Asymmetry active raise	No asymmetry	42	73.7%	15	26.3%	0.540
	Asymmetry	14	82.4%	3	17.6%	
Asymmetry shoulder mobility	No asymmetry	42	76.4%	13	23.6%	1.000
	Asymmetry	14	73.7%	5	26.3%	
Asymmetry rotary stability	No asymmetry	45	75.0%	15	25.0%	1.000
	Asymmetry	10	76.9%	3	23.1%	

*Fisher's exact *p* values

This research did not reveal a significant association between asymmetry and injury susceptibility.

4.6.2.2.1 Discussion

This research did not reveal a significant association between asymmetry and injury susceptibility. Research by Baumhauer *et al.* (1995); Sahrmann (2002); Kiesel *et al.* (2007); Peate *et al.* (2007); on the other hand showed asymmetry as a risk factor for injury. Reasons for not finding an association in this study may include the fact that there were very low numbers of participants that had both asymmetry and an injury. Thus, the outcome of this analysis did not carry significant statistical power to attain a significant relationship. Therefore, further research needs to be done on the accuracy of testing for asymmetry using the FMS^{TM}, particularly with increased numbers of injured players and comparing players with injuries to those without injuries.

4.6.2.3 Efficacy of other risk factors as indicators of injury susceptibility

The other risk factors identified and recorded in the study were also tested against injury susceptibility in the same manner as was described in the previous section (Section 4.6.2.1 Functional Movement Screen^{TM}). This was to see whether any of the other risk factors could indicate injury susceptibility more reliably than the FMS^{TM} score. The results of these tests are reflected in Table 13 below.

TABLE 13: RISK FACTORS VERSUS INJURY SUSCEPTIBILITY

	Injuries sustained during the season				*p* value (t-test)
	No injury		Injury		
	Mean	Standard Deviation	Mean	Standard Deviation	
BMI (kg/m^2)	22.9	3.0	21.6	2.3	0.103
FMS Total Score	14.6	2.3	13.6	2.7	0.113
Weight (kg)	61.8	9.7	58.0	6.7	0.135
Height (m)	1.6	0.1	1.6	0.1	0.614
Age (years)	21.9	3.2	21.6	2.3	0.679
No. Of years playing hockey	13.5	3.8	13.8	3.0	0.766

Statistically, at a 95% confidence level, there was no difference between the average measure for each risk factor of the players that sustained non-contact injuries and players that didn't.

4.6.2.3.1 Discussion

The above results imply that none of the injury risk factors mentioned in Table 13 above can be used to reliably indicate injury susceptibility. Of interest are those injury risk factors which came the closest to a significant difference between those players who sustained non-contact injuries and those that did not. With the t-test having been used, a *p*-value of less than 0.05 indicated a significant difference at a 95% confidence level.

Looking at Table 13 above, the risk factors that resulted in a *p*-value closest to 0.05 were (in descending order):

- weight
- FMS^{TM} score
- BMI

This would indicate that it would be worthwhile to assess these risk factors further as indicators of injury susceptibility particularly in larger sample groups.

Statistical analysis was also undertaken to determine whether players in different positions were at a greater risk for non-contact injuries. Pearson's chi squared test was the most appropriate statistical analysis to carry out, but due to multiple categories (too many player positions) with low frequencies, the chi squared test was rendered as invalid and no conclusion could be drawn. It is recommended that future research combine the position classifications of defender/link and link/forward into the utility player category.

4.7 Conclusion of results and discussion

This research set out to answer the objectives of this research.

The results indicated that the mean FMS^{TM} score in a sample of female premier league hockey players (pre-season) was 14.39 out of 21 with a standard deviation of 2.4. The FMS^{TM} score's highest frequency (modal value) was 17/21 with 14 out of the 74 players achieving this score on the screen.

The research revealed that the most common injuries were strains, repetitive strains, joint dysfunction and sprains.

The average FMS^{TM} score for the 18 players who sustained non-contact injuries during the course of the season was 13.6. The average FMS^{TM} score for the 56 players who did not sustain non-contact injuries was 14.6. The results therefore show that, for this sample, players who did not sustain non-contact injuries during the course of the season on average scored one point higher on the pre-season FMS^{TM}. This result was tested for statistical significance and it was found that the difference in the FMS^{TM} scores, on average, was not significant.

Therefore with the given hypothesis (Section 1.4) of a low score on the FMS^{TM} being a predictor of injury in female premier league hockey players in KZN; and the resultant null hypothesis indicating that a low score on the FMS^{TM} is not a predictor of injury in female premier league hockey players in KZN. The results of this research reject this hypothesis.

CHAPTER FIVE:
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study determined that the normative value for the Functional Movement Screen^{TM} in female premier league hockey players in KwaZulu-Natal is 14.39/21. There was no statistical significance found between the difference in average FMS^{TM} scores of player's who sustained non-contact injuries during the season and those who did not sustain injuries. Therefore, no association can be made between a low score on the FMS^{TM} and injury susceptibility. This outcome was not affected by the anthropometric and demographic risk factors such as age, number of years playing hockey, height, weight, BMI and player's position. Thus, this research on the FMS^{TM} score showed it to be an independent metric that was not affected by the other injury risk factors. This is an important result in that it indicates that the FMS^{TM} score is a unique measure in this population group and given a larger sample size may allow for more specific injury prediction rules to be determined. For this research sample, it can be concluded that a score of 14 or less on the pre-season FMS^{TM} resulted in a two-fold increase in risk of sustaining a non-contact injury during the competitive season.

This research revealed that the other injury risk factors (age, number of years playing hockey, height, weight, BMI and player's position tested in this research cannot reliably indicate injury susceptibility in female premier league hockey players in KwaZulu-Natal. Having said this, the association of FMS^{TM}, weight and BMI with injury susceptibility warrants further investigation.

5.2 Recommendations

5.2.1 Methodological recommendations

a. Future research should amend the inclusion criteria to include players from the age of 16, as this will not only facilitate an increase in the sample size, but may also be more reflective of the hockey playing population in the female premier league. A larger sample size will amplify results to determine if there is a significant difference in the average FMS^{TM} scores for player's who sustain non-contact injuries during the season and those who do not. Position categories could also be condensed in future studies by grouping defender/link and link/forward categories into the utility category.
b. Future studies could also consider increasing the number of players per position category to enable meaningful statistical testing on the association of position and injury susceptibility.

5.2.2 Future research considerations

a. A follow-up study is recommended with a larger sample size to further test the significance of the difference in FMS^{TM} scores of players who sustain non-contact injuries and those that do not.
b. Future research should assess weight and BMI as indicators for injury susceptibility.
c. Further research needs to be done on the accuracy of testing for asymmetry using the FMS^{TM}, particularly with increased numbers of injured players and comparing those with injuries to those without injuries.

5.2.3 Practical implications of the research and implications for use in female premier league hockey in KwaZulu-Natal

Although there was no statistical significance found between a low FMS^{TM} score and injury susceptibility, the female premier league hockey coaches in KwaZulu-Natal could use this screen as a tool to potentially reduce non-contact injuries during the hockey season by using a conservative cut-off score of above 15 (out of a total of 21) in deciding which players are fit to compete, bearing in mind that this value is a suggestion and requires further investigation.

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APPENDICES

Appendix A: Letter of information to the KZN hockey association

LETTER OF INFORMATION

Dear Mr Botha,

Thank you for considering this letter and taking the time to read it.

Title of the Proposed Research Study: An investigation into normative values for the Functional Movement Screen^{TM} and its association to injury in female premier league hockey players in KwaZulu-Natal.

Principle Investigator: Anneke Jooste
Co-Investigator: Dr N Gomes (M. Tech: Chiropractic; M.MedSci(Sports Science)

<u>Brief Introduction and Purpose of the Study:</u>

Outline of the Procedures:
The Functional Movement Screen^{TM} consists of seven tests that are used as a pre-participation screen to identify players who are using incorrect movement patterns to perform basic movements which can predispose the individual to injury. The study aims to determine normative values for the FMS^{TM} in female premier league hockey players and determine what score could be a predictor for injury.

The researcher will set up the FMS^{TM} at the team's practice venue as arranged with their coach. The players will be asked to perform all seven exercises that comprise of the FMS^{TM} at a pre-season practice. A simple three to zero scoring system will be used. A score of three is given if a player is able to complete the movement perfectly, a score of two is given if the player can complete the movement but with compensatory movement, a score of one is given if the player is not able to compete the movement, and a score of zero is given if there was pain with the movement at any point. The players score per exercise will be recorded and then their total score out of 21 will be calculated and recorded.

Each coach will be asked to complete an attendance sheet which will record attendance of each player at their practise and games during the season. This will also be collected by the researcher at the end of the season.

In the event of the player sustaining an injury during a hockey practice or during a hockey game the player will be asked to contact the researcher within 24hours to set up an appointment at the Durban University of Technology Chiropractic Day Clinic where their condition can be diagnosed by the researcher/6th year Chiropractic student and the player can receive three free treatments. The players will be included in the study if they have signed the letter of consent and are between the ages of 18-35.

Risks or Discomforts to the Subject:
There is minimal risk involved. If the player experiences any pain during a test, the test is stopped and a score of zero is given.

Benefits:
The player will benefit by learning about function movement and where their strengths and weaknesses lie in the functional movement tests. Hockey players in general will benefit from the study if normative values can be established and an association between a low score on the functional movement screen and injury risk can be developed. If the study is successful then an injury prevention program can be set up for hockey players that score low on specific test or the FMS^{TM} in total. The benefit for the researcher is to produce a dissertation and publication in a peer reviewed journal.

Reason/s why the Player May Be Withdrawn from the Study:

- The player will be withdrawn from the study if they leave the hockey club after the FMS^{TM} has been conducted.
- The player will be withdrawn if they suffer from any injury that is not sustained while playing hockey.
- The player will be withdrawn if they suffer from any illness that prevents them from playing hockey during the season.
- The player or coach may withdraw at any time during the study and there will be no penalty.

Remuneration:
The player will not receive payment for participation in the study.

Costs of the Study:

No costs to the player or the clubs involved. Also no costs to the KZN Hockey Association.

Confidentiality:

The players information will be kept confidential at all times and will remain anonymous in the reporting of the study. The players Injury profile and FMS™ scores will not be divulged to coaches, managers or selectors.

Research-related Injury:

There are no anticipated research related injuries expected. As noted above, should a player experience pain when doing the tests, these tests will be stopped to avoid any injury.

Persons to Contact in the Event of Any Problems or Queries:

Dr Charmaine Korporaal:
M. Tech: Chiropractic, CCFC, CCSP, ICSSD
Senior lecturer and Clinic Director: Department of Chiropractic and Somatology
Durban University of Technology
P.O. Box 1334 Durban 4000 / 11 Ritson Road
Tel: 27 (0) 31 373 2611 Cell: 27 (0) 832463562
E-mail: charmak@dut.ac.za

Dr A Docrat
M. Tech: Chiropractic
Acting Head of Chiropractic Department, Durban University of Technology
P.O. Box 1334 Durban 4000 / 11 Ritson Road
Tel: 031 373 2589 or 031 202 3632
Email: AadilD@dut.ac.za

Research administrator:
Tel:031 3732900

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, ____________ (name of researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: ___________,
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

______________________	___________	_______	________________
Full Name of Participant	**Date**	**Time**	**Signature / Right Thumbprint**

I, ______________ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

___________________	___________	____________________
Full Name of Researcher	**Date**	**Signature**
___________________	___________	____________________
Full Name of Witness	**Date**	**Signature**

Appendix B: Letter of information to coaches and managers

LETTER OF INFORMATION

Dear Coach/Manager,

Welcome to my study and thank you for taking the time in reading this letter.

Title of the Research Study: An investigation into normative values for the Functional Movement Screen™ and its association to injury in female premier league hockey players in KwaZulu-Natal.
Principle Investigator: Anneke Jooste

Co-Investigator: Dr N Gomes (M. Tech: Chiropractic, M.MedSci (Sports Science))

<u>Brief Introduction and Purpose of the Study:</u>

Outline of the Procedures:
The Functional Movement Screen™ consists of seven tests that are used as a pre-participation screen to identify players who are using incorrect movement patterns to perform basic movements which can predispose the individual to injury.

The study aims to determine normative values for the FMS™ in female premier league hockey players and determine what score could be a predictor for injury.

The researcher will set up the FMS™ at the team's practice venue as arranged with you, the coach/manager. The players will be asked to perform all seven exercises that comprise of the FMS™ at a pre-season practice. A simple three to zero scoring system will be used. A score of three is given if the player is able to complete the movement perfectly, a score of two is given if the player can complete the movement but with compensatory movement, a score of one is given if the player is not able to compete the movement, and a score of zero is given if there was pain with the movement at any point. The players score per exercise will be recorded and then their total score out of 21 will be calculated and recorded.

You will be asked to complete an attendance sheet which will record attendance of each player at their practise and games during the season. This will also be collected by the researcher at the end of the season.

In the event of the player sustaining an injury during a hockey practice or during a hockey game the player will be asked to contact the researcher within 24hours to set up an appointment at the Durban University of Technology Chiropractic Day Clinic where your condition can be diagnosed by the researcher/6th year Chiropractic student and the player can receive three free treatments.
The players will be included in the study if they have signed the letter of consent and are between the ages of 18-35.

Risks or Discomforts to the Subject:
There is minimal risk involved. If the player experiences any pain during a test, the test is stopped and a score of zero is given.

Benefits:
You will benefit by learning about function movement and where your player's strengths and weaknesses lie in the functional movement tests.
Hockey players in general will benefit from the study if normative values can be established and an association between a low score on the functional movement screen and injury risk can be developed. If the study is successful then an injury prevention program can be set up for hockey players that score low on specific test or the FMS^{TM} in total. This will potentially decrease time on the reserve bench due to injury by players.
The benefit for the researcher is to produce a dissertation and publication in a peer reviewed journal.

Reason/s why the Subject May Be Withdrawn from the Study:

- The player will be withdrawn from the study if they leave the hockey club after the FMS^{TM} has been conducted.
- The player will be withdrawn if they suffer from any injury that is not sustained while playing hockey.
- The player will be withdrawn if they suffer from any illness that prevents them from playing hockey during the season.
- If you do not complete the attendance record sheet, your team could potentially be withdrawn from the study with no adverse consequences.
- The player can withdraw at any time during the study and there will be no penalty.

Remuneration:

The players or coaches/managers will not receive payment for participation in the study.

Costs of the Study:

No costs.

Confidentiality:

The players information will be kept confidential at all times and will remain anonymous in the reporting of the study. The players Injury profile and FMS^{TM} scores will not be divulged to coaches, managers or selectors.

Research-related Injury:

There are no anticipated research related injuries expected. As noted above, should a player experience pain when doing the tests, the tests will be stopped to avoid any injury.

Persons to Contact in the Event of Any Problems or Queries:

Dr .Charmaine Korporaal:
M. Tech: Chiropractic, CCFC, CCSP, ICSSD
Senior lecturer and Clinic Director: Department of Chiropractic and Somatology
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Research administrator:
Tel:031 3732900

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, ____________ (name of researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: ___________,
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

______________________ ___________ ______ ________________

Full Name of Participant **Date** **Time** **Signature / Right Thumbprint**

I, ______________ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

__________________ ___________ ____________________

Full Name of Researcher **Date** **Signature**

__________________ ___________ ____________________

Full Name of Witness **Date** **Signature**

Appendix C: Letter of information to participant

LETTER OF INFORMATION

Dear Participant,

Welcome to my study.

Title of the Research Study: An investigation into normative values for the Functional Movement Screen™ and its association to injury in female premier league hockey players in KwaZulu-Natal.

Principle Investigator/s: Anneke Jooste
Co-Investigator/s: Dr N Gomes (M. Tech: Chiropractic, M.MedSci(Sports Science))

Brief Introduction and Purpose of the Study:
Outline of the Procedures:
The Functional Movement Screen™ consists of seven tests that are used as a pre-participation screen to identify players who are using incorrect movement patterns to perform basic movements which can predispose the individual to injury.

The study aims to determine normative values for the FMS™ in female premier league hockey players and determine what score could be a predictor for injury.

The researcher will set up the FMS™ at your team's practice venue as arranged with your coach. You will be asked to perform all seven exercises that comprise of the FMS™ at a pre-season practice. A simple three to zero scoring system will be used. A score of three is given if you are able to complete the movement perfectly, a score of two is given if you can complete the movement but with compensatory movement, a score of one is given if you are not able to compete the movement, and a score of zero is given if there was pain with the movement at any point. Your score per exercise will be recorded and then your total score out of 21 will be calculated and recorded.

Each coach will be asked to complete an attendance sheet which will record attendance of each player at their practise and games during the season. This will also be collected by the researcher at the end of the season.

In the event of you sustaining an injury during a hockey practice or during a hockey game you will be asked to contact the researcher within 24hours to set up an appointment at the Durban University of Technology Chiropractic Day Clinic where your condition can be diagnosed by the researcher/6th year Chiropractic student and you can receive three free treatments.
You will be included in the study if you have signed the letter of consent and are between the ages of 18-35.

Risks or Discomforts to the Subject:
Minimal risk is involved. If you experience any pain during a test, the test is stopped and a score of zero is given.

Benefits:
You will benefit by learning about function movement and where your strengths and weaknesses lie in the functional movement tests.
Hockey players in general will benefit from the study if normative values can be established and an association between a low score on the functional movement screen and injury risk can be developed. If the study is successful then an injury prevention program can be set up for hockey players that score low on specific test or the FMS^{TM} in total.
The benefit for the researcher is to produce a dissertation and publication in a peer reviewed journal.

Reason/s why the Subject May Be Withdrawn from the Study:

- You will be withdrawn from the study if you leave the club after the FMS^{TM} has been conducted.
- You will be withdrawn if you suffer from any injury that is not sustained while playing hockey.
- You will be withdrawn if you suffer from any illness that prevents you from playing hockey during the season.
- You can withdraw at any time during the study and there will be no penalty.

Remuneration:
You will not receive payment for participation in the study.

Costs of the Study:
No costs.

Confidentiality:

Your information will be kept confidential at all times and will remain anonymous in the reporting of the study. Your Injury profile and FMS^{TM} scores will not be divulged to coaches, managers or selectors.

Research-related Injury:

There are no anticipated research related injuries that are expected. As noted above, should you experience any pain when doing the tests, the test will be stopped to avoid any injury.

Persons to Contact in the Event of Any Problems or Queries:

Dr Charmaine Korporaal:

M. Tech: Chiropractic, CCFC, CCSP, ICSSD

Senior lecturer and Clinic Director: Department of Chiropractic and Somatology

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Dr A Docrat

M. Tech: Chiropractic

Acting Head of Chiropractic Department, Durban University of Technology

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Tel:031 373 2589 or 031 202 3632

Email: AadilD@dut.ac.za

Research administrator:

Tel:031 3732900

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, ____________ (name of researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: ___________,
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

____________________ ___________ ______ _______________

Full Name of Participant **Date** **Time** **Signature / Right Thumbprint**

I, ______________ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

_________________ __________ ___________________

Full Name of Researcher **Date** **Signature**

_________________ __________ ___________________

Full Name of Witness **Date** **Signature**

Player Questionnaire:

To be complete by the player	
1. Club team:	
2. Players name:	
3. Players age:	
4. Players Position:	
5. Number of years playing hockey:	
6. Height:	
7. Weight:	
8. Previous injury: (hockey or non hockey related) E.g. • Muscle strain? • Joint sprain? • Fracture?	
9. Current injury: (hockey or non hockey related) E.g. • Muscle strain? • Joint sprain? • Fracture?	

Appendix E: Injury Profile Sheet

Injury Profile Sheet

Players name: ___________________________________

Players club team: ________________________________

To be completed by researcher or Intern	
1. Diagnosis(specify contact or non-contact injury)	
2. Severity: (mild, moderate, severe)	
3. Time lost at:	
a. Practice: (number of practices)	
b. Games: (number of games)	
c. Work: (number of days)	
4.Treatment (if any)	
5.Training: • Type: • Duration: • Distance(km) per week: • Intensity:(0-10)*	

*See table below to explain intensity.

Rating descriptor table

Rating	Descriptor
0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	-
7	Very hard
8	-
9	-
10	Maximal

(Day *et al*. 2004)

Appendix F: FMS™ Score Sheet

Team name: ___________________________________

Test	Raw Score		Final Score	Comment:
Deep Squat				
Hurdle Step	L			
	R			
In-Line Lunge	L			
	R			
Active straight leg raiser	L			
	R			
Shoulder mobility test	L			
	R			
Shoulder mobility clearing test	L			
	R			
Trunk stability Push-up				
Extension clearing test				
Quadruped Rotary stability test	L			
	R			
Flexion clearing test				
Total score:				

*For tests that are scored for both the right and left sides, the lower score is used when calculating the Functional Movement Screen™ composite score.

Appendix G: Attendance Record Sheet

Attendance Record Sheet:

Team name: ____

Coach name: ____

Players Name	Practice Week 1 Date:	Practise Week 1 Date:	Game 1 Date:	Practice Week 2 Date:	Practise Week 2 Date:	Game 2 Date:	Practice Week 3 Date:	Practise Week 3 Date:	Game 3 Date:	Practice Week 4 Date:	Practise Week 4 Date:	Game 4 Date:	Practice Week 5 Date:	Practise Week 5 Date:	Game 5 Date:
1.															
2.															
3.															
4.															
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6.															

7.															
8.															
9.															
10															
11.															
12.															
13.															
14.															
15.															

Players Name	**Practice Week 6 Date:**	**Practise Week 6 Date:**	**Game 6 Date:**	**Practice Week 7 Date:**	**Practise Week 7 Date:**	**Game 7 Date:**	**Practice Week 8 Date:**	**Practise Week 8 Date:**	**Game 8 Date:**	**Practice Week 9 Date:**	**Practise Week 9 Date:**	**Game 9 Date:**	**Practice Week 10 Date:**	**Practise Week 10 Date:**	**Game 10 Date:**
1.															
2.															
3.															
4.															
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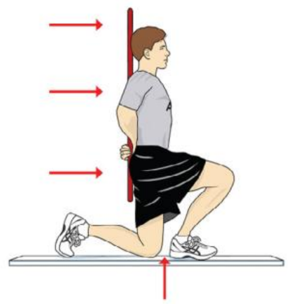
12.															
13.															
14.															
15.															

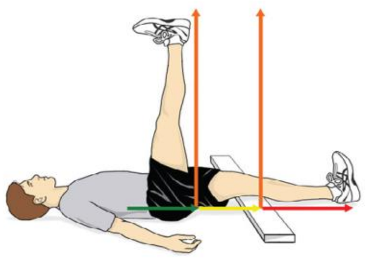
FMS^{TM} Scoring method
Functional Movement Screen^{TM}

Score	Criteria	Illustration
	Deep squat	
3	• Upper torso is parallel with tibia or toward vertical • Femur below horizontal • Knees are aligned over feet • Dowel aligned over feet	
2	• Performed with heels on 15.5cm x 147.5cm wooden board • Upper torso is parallel with tibia or toward vertical • Femur below horizontal • Knees are aligned over feet • Dowel aligned over feet	
1	• Performed with heels on 15.5cm x 147.5cm • If any of the 4 criteria are not met when the squat is performed with heels on 15.5cm x 147.5cm wooden board, the score is 1	(Holder 2014)
0	• Pain during test	
	Hurdle Step (test both right and left sides)*	
3	• Foot clears cord (does not touch) and remains dorsiflexed as leg is lifted over hurdle • Hips, knees, and ankles remain aligned in the sagittal plane • Minimal to no movement is noted in the lumbar spine • Dowel and hurdle remain parallel	
2	• Alignment is lost between hips, knees, and ankles • Movement is noted in the lumbar spine • Dowel and hurdle do not remain parallel	
1	• Contact between foot and hurdle • Loss of balance is noted	
0	• Pain during test	(Holder 2014)

(Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 2012)

In-line Lunge (test both right and left sides)*		
3	• Knee touches board behind heel • Dowel and feet remain in sagittal plane • Dowel contacts remain (head, thoracic spine, sacrum) • Dowel remains vertical, no torso movement noted	 (Holder 2014)
2	• Knee does not touch behind heel • Dowel and feet do not remain in sagittal plane • Dowel contacts do not remain • Dowel remains vertical • Movement is noted in torso	
1	• Loss of balance is noted • Inability to achieve start position • Inability to touch knee to board	
0	• Pain during test	

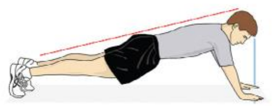
(Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 2012)

Active Straight Leg Raise (test both right and left sides)*		
3	• Malleolus of tested lower extremity located in the region between mid-thigh and anterior superior iliac spine of opposite lower extremity(green region) • Opposite hip remains neutral (hip does not externally rotate), toes remain pointing up • Opposite knee remains in contact with board	 (Holder 2014)
2	• Malleolus of tested lower extremity located in the region between mid-thigh and knee joint line of opposite lower extremity (yellow region) while other criteria are met	
1	• Malleolus of tested lower extremity located in the region below knee joint line of opposite lower extremity (red region) while other criteria are met	
0	• Pain during test	

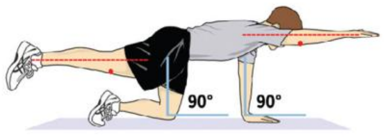
(Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 2012)

Shoulder Mobility (test both right and left sides)*		
3	• Fists are within 1 hand length	 
2	• Fists are within 1.5 hand lengths	
1	• Fists are not within 1.5 hand lengths	
0	• Pain during test <u>Shoulder mobility clearing test</u>: if pain is noted as elbow is lifted, shoulder mobility is scored as 0	(Holder 2014)

(Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 2012)

Trunk Stability Push-up		
3	• Perform 1 repetition; the thumbs are aligned with forehead for males and chin for females • Body is lifted as 1 unit (no sag in lumbar spine)	 
2	• Perform 1 repetition; the thumbs are aligned with chin for males and clavicle for females • Body is lifted as 1 unit (no sag in lumbar spine)	
1	• Unable to perform 1 repetition with thumbs aligned with chin for males and clavicle for females	
0	• Pain during test <u>Extension clearing test:</u> if pain is noted during a prone press-up, the Trunk stability Push-up is scored as 0	(Holder 2014)

(Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 201

Quadruped Rotary Stability (test both right and left sides)*		
3	• 1 unilateral repetition (lift arm and leg from same side of body) • Keep spine parallel to board • Knee and elbow touch in line over the board and then return to the start position	
2	• 1 diagonal repetition (lift arm and leg from opposite sides of body) • Keep spine parallel to board • Knee and elbow touch in line over the board and then return to the start position	
1	• Inability to perform diagonal repetition	
0	• Pain during test <u>Flexion clearing test:</u> if pain is noted during quadruped flexion, Quadruped rotary stability is scored as 0	(Holder 2014)

*For component tests that are scored for both the right and left sides, the lower score is used when calculating the Functional Movement Screen composite score. (Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 2012).

Player's Numbers

Confidential information:

Club team: ____

	Players name:
1.	
2.	
3	
4.	
5.	
6	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	
15.	

Description of FMS™ tests

The individual has three chances to perform the test bilaterally. If one repetition meets the criteria, a 3 is given.

1. Deep Squat

- Feet must be placed hip width apart
- Adjust hands on dowel to assume a 90 degree angle of elbows, with the dowel overhead
- Extend elbows and press dowel overhead
- Descend slowly into a squat position
- Heels must be on the floor
- Head and chest facing forward
- Dowel pressed maximally overhead

*If not achieved, the athlete is asked to perform the test with a block of 15.5cm x 147.5cm wooden board under their heels.

Score	Criteria	Illustration
	Deep squat	
3	• Upper torso is parallel with tibia or toward vertical • Femur below horizontal • Knees are aligned over feet • Dowel aligned over feet	 (Holder 2014)
2	• Performed with heels on 15.5cm x 147.5cm wooden board • Upper torso is parallel with tibia or toward vertical • Femur below horizontal • Knees are aligned over feet • Dowel aligned over feet	
1	• Performed with heels on 15.5cm x 147.5cm wooden board • If any of the 4 criteria are not met when the squat is performed with heels on 15.5cm x 147.5cm wooden board • , the score is 1	
0	• Pain during test	

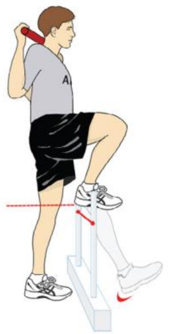
(Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 2012)

2. Hurdle Step

- Place feet together and align the toes to touch the base of the hurdle
- *Hurdle adjusted to height of tibial tuberosity of player, by the tester*
- Position dowel across shoulders below the neck
- Step over hurdle and touch the heel to the floor while maintaining the stance leg in a straightened (extended) position
- Return the moving leg to the stance position

<u>Tips</u>

– The leg stepping over the hurdle must be scored

<table>
<tr><th>Score</th><th>Criteria</th><th>Illustration</th></tr>
<tr><td colspan="3">Hurdle Step (test both right and left sides)*</td></tr>
<tr><td>3</td><td>• Foot clears cord (does not touch) and remains dorsiflexed as leg is lifted over hurdle
• Hips, knees, and ankles remain aligned in the sagittal plane
• Minimal to no movement is noted in lumbar spine
• Dowel and hurdle remain parallel</td><td rowspan="4">
(Holder 2014)</td></tr>
<tr><td>2</td><td>• Alignment is lost between hips, knees, and ankles
• Movement is noted in lumbar spine
• Dowel and hurdle do not remain parallel</td></tr>
<tr><td>1</td><td>• Contact between foot and hurdle
• Loss of balance is noted</td></tr>
<tr><td>0</td><td>• Pain during test</td></tr>
</table>

(Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 2012)

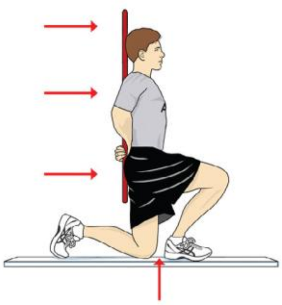
3. In-line lunge

The tester must attain the individual's tibia length (from floor to tibial tuberosity)

- Place the end of your heel on the end of the board
- *The tibia measurement is then applied from the end of the toes of the foot on the board and a mark is made*
- Place the dowel behind your back, touching your head, thoracic spine and sacrum
- The hand on the same side of the back foot should be the hand grasping the dowel at the cervical spine
- The other hand grasps the dowel at the lumbar spine
- Step out on to the board placing the heel of the opposite foot at the indicated mark
- Lower your back knee enough to touch the surface behind the heel of the front foot
- Return to starting position

<u>Tips</u>

– The front leg identifies the side being scored

Score	Criteria	Illustration
In-line Lunge (test both right and left sides)*		
3	• Knee touches board behind heel • Dowel and feet remain in sagittal plane • Dowel contacts remain (head, thoracic spine, sacrum) • Dowel remains vertical, no torso movement noted	 (Holder 2014)
2	• Knee does not touch behind the heel • Dowel and feet do not remain in sagittal plane • Dowel contacts do not remain • Dowel remains vertical • Movement is noted in torso	
1	• Loss of balance is noted • Inability to achieve start position • Inability to touch knee to board	
0	• Pain during test	

(Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 2012)

4. Active straight leg raiser

- Lie supine(on your back) with arms in the anatomical position and head flat on the floor

The tester identifies the different regions:

- *Region between mid-thigh and anterior superior iliac spine (ASIS)of opposite lower extremity(green region)*
- *Region between mid-thigh and knee joint line of opposite lower extremity (yellow region)*
- *Region below knee joint line of opposite lower extremity (red region)*

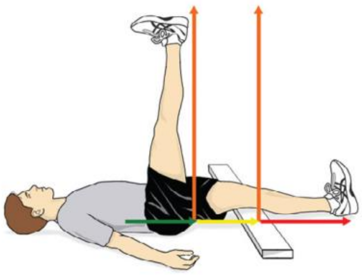
- Lift the test leg with ankle dorsiflexed (toes pointed upwards) and knee extended (leg straight).

- Make sure the opposite knee remains in contact with the ground, the toes should be pointed upwards and the hands must be flat on the floor

- *Once the end range position is achieved, the tester will identify in which zone the malleolus of the test leg is located.*

<u>Tips</u>

– The flexed hip identifies the hip being scored
– Make sure the leg on the floor does not externally rotate at the hip
– Both knees remains extended and the knee on the extended hip remains touching the ground.

Score	Criteria	Illustration
Active Straight Leg Raise (test both right and left sides)*		
3	• Malleolus of tested lower extremity located in the region between mid-thigh and anterior superior iliac spine of opposite lower extremity(green region) • Opposite hip remains neutral (hip does not externally rotate), toes remain pointing up • Opposite knee remains in contact with board	 (Holder 2014)
2	• Malleolus of tested lower extremity located in the region between mid-thigh and knee joint line of opposite lower extremity (yellow region) while other criteria are met	
1	• Malleolus of tested lower extremity located in the region below knee joint line of opposite lower extremity (red region) while other criteria are met	
0	• Pain during test	

(Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 2012)

5. Shoulder mobility

The tester first defines the hand length of the participant by measuring the distance from the distal wrist crease to the tip of the third digit in centimetres.

- Make a fist with each hand, placing the thumb inside the fist. The hands must remain in the position throughout the test.
- The test arm must reach up above your head, and you must bend your elbow and reach down your back (maximally abducted, flexed and externally rotated position with one shoulder)
- The other arm must drop down next to your body, you must bend the elbow and reach up your back (Maximally adducted, extended and internally rotated position with the shoulder)
- *The tester then measures the distance between the two closest bony prominences*

<u>Tips</u>

– The flexed shoulder identifies the side being scored
– If the hand measurement is exactly the same as the distance between the two points then score the participant low
– The clearing screen over-rides the score on the rest of the test
– Make sure the participant does not try and “walk” with their hands towards each other
–

5.1 Shoulder mobility clearing test

Simply perform the test to observe a pain response. This test is important as shoulder impingement can go undetected by shoulder mobility testing alone.

- Place your hand on the opposite shoulder
- Attempt to point your shoulder upwards

Shoulder Mobility (test both right and left sides)*		
3	• Fists are within 1 hand length	  (Holder 2014)
2	• Fists are within 1.5 hand lengths	
1	• Fists are not within 1.5 hand lengths	
0	• Pain during test <u>Shoulder mobility clearing test</u>: if pain is noted as elbow is lifted, shoulder mobility is scored as 0	

(Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 2012)

6. Trunk stability Push-up

- Lie on your stomach(prone) with feet together
- Place your hands shoulder width apart with thumbs aligned with your chin
- Fully straighten (extend) the knees and point your toes to the ground (dorsiflex ankles)
- Lift body as a unit (push-up)
- *No " lag" must occur in the lumbar spine*
- *If the individual cannot perform a push-up in this position, then thumbs must be aligned with clavicles and participant must re-attempt the push-up*

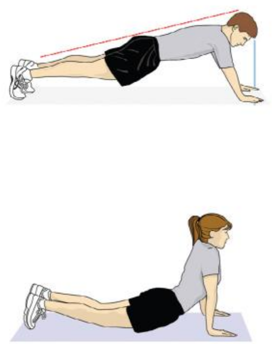
<u>Tips</u>

- Make sure hands do not slide down when they prepare to lift
- Make sure that the chest and stomach come off the floor at the same time
- The clearing screen over-rides the score on the rest of the test

6.1 Extension clearing test

Simply perform the test to observe a pain response. This test is important as back pain can go undetected during movement screens.

- Perform a press-up in a push-up position.ie. Lie on stomach and push up with arms, until elbows are straight.

Score	Criteria	Illustration
	Trunk Stability Push-up	
3	• Perform 1 repetition; the thumbs are aligned with forehead for males and chin for females • Body is lifted as 1 unit (no lag in lumbar spine)	 (Holder 2014)
2	• Perform 1 repetition; the thumbs are aligned with chin for males and clavicle for females • Body is lifted as 1 unit (no lag in lumbar spine)	
1	• Unable to perform 1 repetition with thumbs aligned with chin for males and clavicle for females	
0	• Pain during test <u>Extension clearing test:</u> if pain is noted during a prone press-up, Trunk stability Push-up is scored as 0	

(Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 2012)

7. Quadruped Rotary stability

- Start on all fours(quadruped position)with shoulders and hips at 90 degrees relative to your chest
- The knees are positioned at 90 degrees and toes point into the ground (ankles dorsiflexed)
- Lift your arm and reach out in front of you (flex the shoulder)
- Then straighten the knee on the same side as the arm that you just lifted
- The leg and hand must only be lifted approximately 15cm off the floor
- The same arm must now bend at the elbow
- The knee must be bent enough for the elbow and knee to touch

If a Three is not attained then the participant must perform a diagonal pattern using the opposite shoulder and hip in the same manner as described above.

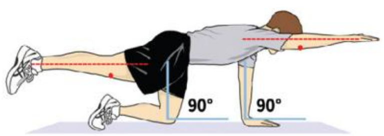
<u>Tips</u>

- The arm that moves identifies the side being tested
- Make sure the elbow and knee touch during the flexion part of the movement

7.1 Flexion clearing test

Simply perform the test to observe a pain response. This test is important as back pain can go undetected during movement screens.

- Stay in the same quadruped position as for the Quadruped Rotary stability test.
- Rock back and move your buttocks to your heels so that they are touching
- Move your chest to your thighs
- Keep your hands in front of your body, reaching out as far as possible

<table>
<tr><th colspan="3">Quadruped Rotary Stability (test both right and left sides)*</th></tr>
<tr><td>3</td><td>1 unilateral repetition (lift arm and leg from same side of body)
Keep spine parallel to board
Knee and elbow touch in line over the board and then return to the start position</td><td rowspan="4">


(Holder 2014)</td></tr>
<tr><td>2</td><td>1 diagonal repetition (lift arm and leg from opposite sides of body)
Keep spine parallel to board
Knee and elbow touch in line over the board and then return to the start position</td></tr>
<tr><td>1</td><td>Inability to perform diagonal repetition</td></tr>
<tr><td>0</td><td>Pain during test
<u>Flexion clearing test:</u> if pain is noted during quadruped flexion, Quadruped rotary stability is scored as 0</td></tr>
</table>

(Cook *et al.* 2006(a); Cook *et al.* 2006(b); Minick *et al.* 2010; Teyhen *et al.* 2012)

Appendix K: Vouchers for free treatment

Date: ______________

Durban University of Technology Chiropractic Day Clinic

VOUCHER FOR ONE FREE TREATMENT

Voucher holders name: ____

Signed by Anneke Jooste: ______________________________________

Date: ______________

Durban University of Technology Chiropractic Day Clinic

VOUCHER FOR ONE FREE TREATMENT

Voucher holders name: ____

Signed by Anneke Jooste: ______________________________________

Appendix L: Signed copy by the KZN hockey association of in principle permission to conduct the research.

Appendix 1:

Title of the Proposed Research Study: An investigation into normative values for the Functional Movement Screen™ and its association to injury in female premier league hockey players.

Principle Investigator: Anneke Jooste
Supervisor: Dr C. Korporaal

Brief Introduction and Purpose of the Study:

Outline of the Procedures:
The Functional Movement Screen™ consists of seven tests that are used as a pre-participation screen to identify players who are using incorrect movement patterns to perform basic movements which can predispose the individual to injury.
The study aims to determine normative values for the FMS™ in female premier league hockey players and determine what score could be a predictor for injury.

The researcher will set up the FMS™ at the team's practice venue as arranged with their coach. The players will be asked to perform all seven exercises that comprise of the FMS™ at a pre-season practice. A simple three to zero scoring system will be used. A score of three is given if you are able to complete the movement perfectly, a score of two is given if you can complete the movement but with compensatory movement, a score of one is given if you are not able to compete the movement, and a score of zero is given if there was pain with the movement at any point. The players score per exercise will be recorded and then their total score out of 21 will be calculated and recorded.

After completing the FMS™ the player will be given an exercise diary. The player will be asked to record the type of exercise, the duration of exercise, and the intensity of their workout for each training session everyday (from the day after completion of the FMS™ to the end of the outdoor hockey season). At the end of the season the researcher will collect their diary.

Each coach will be asked to complete an attendance record sheet which will record attendance of each player at their practise and games during the season. This will also be collected by the researcher at the end of the season.

In the event of a player sustaining an injury during a hockey practice or during a hockey game the player will be asked to contact the researcher within 24hours to set up an appointment at the Durban University of Technology Chiropractic Day Clinic where their condition can be diagnosed by the researcher and the player can receive a free treatment. The players will be included in the study if they have signed the letter of consent and are between the ages of 18-35.

Risks or Discomforts to the Subject:
There is minimal risk involved. If the player experiences any pain during a test, the test is stopped and a score of zero is given.

Benefits:

The player will benefit by learning about functional movement and where their strengths and weaknesses lie in the functional movement tests. Hockey players in general will benefit from the study if normative values can be established and an association between a low score on the functional movement screen and injury risk can be developed. If the study is successful then an injury prevention program can be set up for hockey players that score low on specific tests or the FMS™ in total. The benefit for the researcher is to produce a dissertation and publication in a peer reviewed journal.

Reason/s why the Subject May Be Withdrawn from the Study:

- The player will be withdrawn from the study if they leave the hockey club after the FMS™ has been conducted.
- The player will be withdrawn if they suffer from any injury that is not sustained while playing hockey.
- The player will be withdrawn if they suffer from any illness that prevents them from playing hockey during the season.
- If the player does not complete the exercise diary they can be withdrawn from the study with no adverse consequences.

Remuneration:

The player will not receive payment for participation in the study.

Costs of the Study:

No costs to the player or the clubs involved. No costs to the KZN Hockey Association.

Confidentiality:

The players information will be kept confidential at all times and will remain anonymous in the reporting of the study. The players Injury profile and FMS™ scores will not be divulged to coaches, managers or selectors.

Research-related Injury:

There are no anticipated research related injuries that are expected. As noted above, should a player experience pain when doing the tests, these tests will be stopped to avoid any injury.

Persons to Contact in the Event of Any Problems or Queries:

Dr C Korporaal:
M. Tech: Chiropractic, CCFC, CCSP, ICSSD
Senior lecturer and Clinic Director: Department of Chiropractic and Somatology
Durban University of Technology
P.O. Box 1334 Durban 4000 / 11 Ritson Road
Tel: 27 (0) 31 373 2611 or Cell: 27 (0) 832463562
E-mail: charmak@dut.ac.za

Dr. A Docrat
M. Tech: Chiropractic
Acting Head of Chiropractic Department, Durban University of Technology
P.O. Box 1334 Durban 4000 / 11 Ritson Road
Tel: 031 373 2589 or 031 202 3632
Email: AadilD@dut.ac.za

Research administrator:
Tel:031 3732900

I, Mr MK BOTHA (full name printed), ID number as 5510225162083, as a representative of the KZN Hockey Association, herewith grant permission to Miss Anneke Jooste to contact the clubs that fall within the jurisdiction of the KZN Hockey Association, in order that she can approach them for participation in this study.

It is our understanding that this contact with the clubs will only proceed once the research has been approved by the DUT IREC and a copy of the approved proposal and the letter of approval (copy) have been submitted to ourselves for record and reference purposes.

Signed: [redacted] Dated: 20/03/2013 Place: DURBAN

Witness (full name printed): [redacted] Signed: [redacted]

Dated: ______ Place: ______

Appendix M: ICSSD hands on Module

FEDERATION INTERNATIONALE DE CHIROPRATIQUE DU SPORT

ICSSD

International Chiropractic Sport Science Diploma

Upper and Lower Extremity Hands-on Modules

This is to certify that

Anneke Jooste

has successfully completed all of the hands-on requirements as partial satisfaction of the requirements for

Fédération Internationale de Chiropratique du Sport

Signed at Durban, South Africa this 3rd day of July, 2011

[redacted]

Sheila Wilson, DC. - Président

[redacted]

Phillip Santiago, DC. - Secretary-General

[redacted]

Timothy Stark, DC. - Chair, Ed-Committee

Certificate Number: D20110703TS

Appendix N: Permission for FMS™ illustrations

Gmail by Google

Anneke Jooste <annekejooste19@gmail.com>

RE: permissions for dissertation

1 message

Corey Parker <coreyparker@jospt.org> Fri, Apr 25, 2014 at 5:37 PM
To: Anneke Jooste <annekejooste19@gmail.com>

Dear Ms Jooste,

The illustrator has agreed to let you use her illustrations for your dissertation (see correspondence below). If you wish to contact her further, her new e-mail address is also included below.

Elizabeth Holder
elizabeth.holder.civ@mail.mil

Corey Parker
Copy Editor
Journal of Orthopaedic & Sports Physical Therapy
1033 N. Fairfax St., Suite 304
Alexandria, VA 22314
Phone: 571-970-1062
Fax: 703-836-2210
coreyparker@jospt.org

-----Original Message-----
From: Holder, Elizabeth CIV DHA HEALTH IT DIR (US) [mailto:elizabeth.holder.civ@mail.mil]
Sent: Thursday, April 24, 2014 7:29 AM
To: Deydre Teyhen; 'Corey Parker'
Subject: RE: JOSPT manuscript 04-11-3838-RR.R3 Appendix illustrations (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

Deydre and Corey,
This is cool and an honor. Definitely, you are welcome to use the illustrations.
Let me know if I can assist further.

Respectfully,
Liz

Elizabeth Holder
Visual Information Specialist, CKM, ITIL, Sec+ DoD, Defense Health Agency
2748 Worth Road
JBSA Fort Sam Houston, Texas 78234-6011

O: 210.221.7268
E-mail: elizabeth.holder.civ@mail.mil

-----Original Message-----
From: Deydre Teyhen [mailto:dteyhen@gmail.com]
Sent: Wednesday, April 23, 2014 8:29 PM
To: 'Corey Parker'; Holder, Elizabeth CIV DHA HEALTH IT DIR (US)
Subject: RE: JOSPT manuscript 04-11-3838-RR.R3 Appendix Illustrations

Corey:

Good evening. I have included Liz Holder's new email address. The Army changed all email addressed over the last year.

Liz:

Please see the message below. There is a request from South Africa regarding your illustrations you did for us for the manuscript listed below. They love you in South Africa - how cool is that!

Kindest Regards,

Deydre

From: Corey Parker [mailto:coreyparker@jospt.org]
Sent: Wednesday, April 23, 2014 3:14 PM
To: 'Deydre Teyhen'
Subject: RE: JOSPT manuscript 04-11-3838-RR.R3 Appendix Illustrations

Hi Deydre,

I was contacted today by a South African PhD student who wanted to use some of the material from your 2012 article that featured Appendix illustrations by Elizabeth Holder. I informed her that Elizabeth held the rights to the illustrations (which we were allowed to publish in JOSPT but for which I can't grant further permission to a third party), but her .mil e-mail address doesn't seem to be working anymore. Do you know how I might track her down?

Thanks,

Corey

Corey Parker

Appendix O: Permission for hockey player photograph

Gmail by Google

Anneke Jooste <annekejooste19@gmail.com>

re: Contact Request

1 message

tjackson@spts.org <tjackson@spts.org> Fri, Apr 25, 2014 at 3:54 PM
Reply-To: tjackson@spts.org
To: annekejooste19@gmail.com

You have permission. Thank you!

From: noreply@vision3creative.com
Sent: Friday, April 25, 2014 6:40 AM
To: tjackson@spts.org
Subject: Contact Request

Your Name: Anneke Jooste
Your Email: annekejooste19@gmail.com
Your Question: Hi,

I'm a Chiropractic student doing my masters at the Durban University of Technology at I would like to ask permission for the use of a picture from the following article:

Haydt, R., Pheasant, S. and Lawrence, K., 2012. The incidence of low back pain in NCAA division III Female Field hockey players. International Journal of Sports Physical Therapy, 7(3): 296–306.

It is Figure 1 in the article ans I will only use it for the purpose of my dissertation.

Please let me know if this is ok?

Kind regards,
Anneke Jooste

Appendix P: Ethical Clearance

DUT
DURBAN UNIVERSITY OF TECHNOLOGY

Institutional Research Ethics Committee
Faculty of Health Sciences
Room MS 49, Mansfield School Site
Gate 8, Ritson Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2900
Fax: 031 373 2407
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

29 August 2013

IREC Reference Number: **REC 52/13**

Ms A Jooste
116 Underwood Road
Pinetown
3610

Dear Ms Jooste

An investigation into normative values for the Functional Movement Screen™ (FMS™) and its association to injury in female premier league hockey players in KwaZulu-Natal

I am pleased to inform you that Full Approval has been granted to your proposal REC 52/13.

The Proposal has been allocated the following Ethical Clearance number IREC 069/13. Please use this number in all communication with this office.

Approval has been granted for a period of one year, before the expiry of which you are required to apply for safety monitoring and annual recertification. Please use the Safety Monitoring and Annual Recertification Report form which can be found in the Standard Operating Procedures [SOP's] of the IREC. This form must be submitted to the IREC at least 3 months before the ethics approval for the study expires.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC SOP's. In addition, you will be responsible to ensure gatekeeper permission.
Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

[redacted]

Prof J K Adam
Chairperson: IREC